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Mindfulness, mind-body exercises, and health promotion

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Guodong Zhang, Yang Cao and Zi Yan

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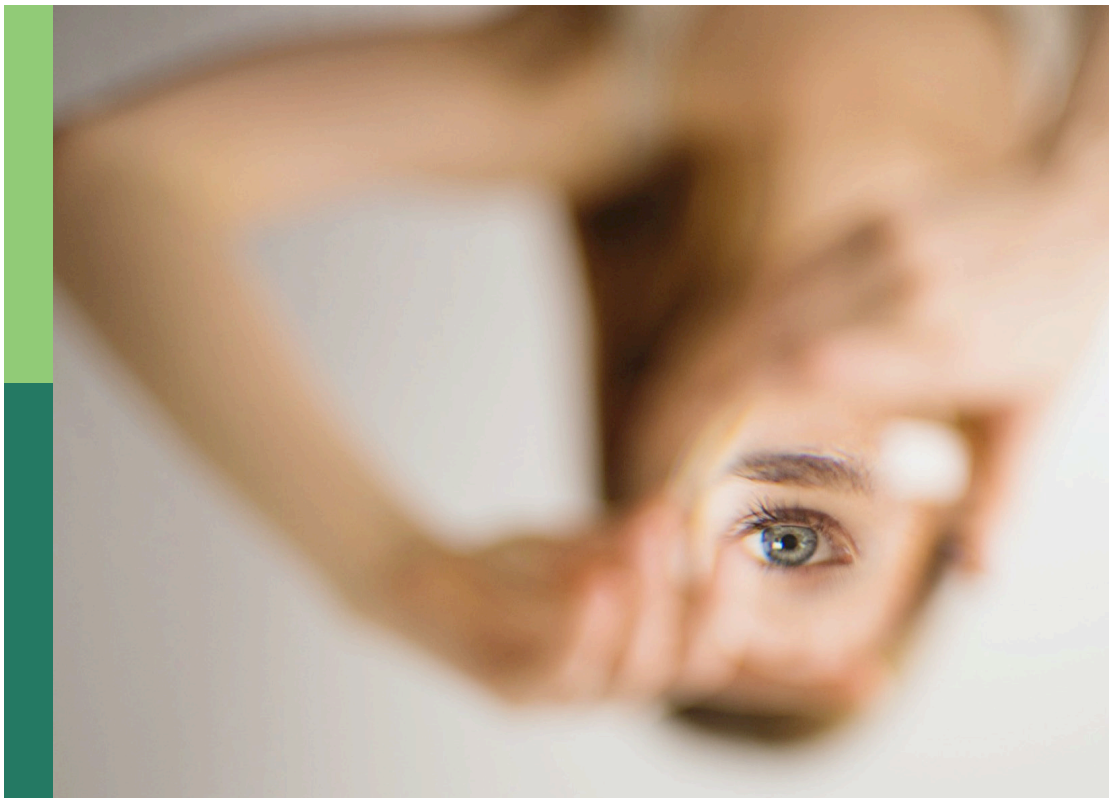

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Mindfulness, mind-body exercises, and health promotion

Topic editors
Guodong Zhang — Southwest University, China
Yang Cao — Örebro University, Sweden
Zi Yan — Merrimack College, United States

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EDITED AND REVIEWED BY
Guy Cheron,
Université Libre de Bruxelles, Belgium

*CORRESPONDENCE
Guodong Zhang
✉ lygd777@swu.edu.cn

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Editorial: Mindfulness, mind-body exercises, and health promotion

Guodong Zhang[1]*, Yang Cao[2] and Zi Yan[3]

[1]College of Physical Education, Institute of Sport Science, Southwest University, Chongqing, China, [2]Clinical Epidemiology and Biostatistics, School of Medical Sciences, Faculty of Medicine and Health, Örebro University, Örebro, Sweden, [3]School of Health Sciences, Merrimack College, North Andover, MA, United States

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Editorial on the Research Topic
Mindfulness, mind-body exercises, and health promotion

Introduction

Physical activity provides numerous benefits for both physical and mental health, such as improving physical fitness, promoting cardiovascular health, and enhancing muscle strength (Qiu et al., 2023). In particular, mind-body exercises rooted in Eastern traditional cultures, such as Tai Chi, Qigong, and Yoga, have demonstrated unique advantages in promoting mental health and physical recovery (Deuel and Seeberger, 2020; Lin et al., 2019). These practices emphasize mind-body unity and seek to achieve balance through slow and deliberate movements, deep breathing, and meditation (Kung et al., 2024). Recent studies highlight the significant advantages of mind-body exercises on physiological health, mental wellbeing, and nervous system function (Dong et al., 2024; Loewenthal et al., 2023; Tao et al., 2019). Despite this growing body of evidence, the specific mechanisms through which these exercises influence physical and mental health recovery remain unclear. This Research Topic comprises a series of articles aimed at elucidating the health benefits of mind-body exercises from the perspectives of psychological benefits, physiological effects, and emerging technologies, in order to provide a more comprehensive assessment of their impact and potential. The topic explores the health-promoting effects and mechanisms of mind-body exercises from three perspectives: psychological benefits, physiological effects, and technological approaches.

Psychological benefits

Seven studies emphasize the psychological benefits of mind-body exercises. Three cross-sectional studies, employing large-sample mediation models, confirmed the role of mind-body exercises in promoting mental health (Tang et al.; Wu et al.; Zhang et al.). Wu et al. found that practicing Tai Chi had a more pronounced impact on the mental health of elderly individuals living alone compared to Baduanjin and walking exercises, with social participation and exercise environment serving as mediating and moderating roles. Tang et al. discovered that mindfulness practice could improve state-trait anxiety and stress resilience in athletes prone to choking, with resilience and perceived stress acting as mediators. Zhang et al. found that self-compassion predicted greater emotional recovery following failure in athletes, with vagal nerve response mediating this effect.

Additionally, four studies focused on the psychological health benefits of yoga. Malipeddi et al. found that practicing Isha Yoga 3–4 times per week during the COVID-19 pandemic significantly reduced stress and mental distress while improving overall wellbeing. Chhajer and Dagar highlighted the dual benefits of yoga, noting that yoga training not only improved participants' thriving and overall health but also significantly alleviated psychological issues such as stress and anxiety. Nadholta et al. further confirmed that practicing yoga during pregnancy alleviated symptoms of stress, anxiety, and depression, while also reducing physical discomfort, fostering mind-body balance, and enhancing mother-infant relationships. Lastly, Yang et al. conducted a meta-analysis that validated the effectiveness of mindfulness-based yoga in treating depression.

These seven studies contribute significantly to the growing body of evidence supporting the mental health benefits of mind-body exercises and offer a robust theoretical foundation for refining and advancing methodologies in this field.

Physiological benefits

One of the challenges in this field is expanding the scope of research on the physiological impacts of mind-body exercises to explore a greater diversity of health outcomes. Six studies underscore the physiological benefits of mind-body exercises. Wang et al. found that 8 weeks of Tai Chi practice enhanced bed rest time, total sleep duration, and stage 2 of non-rapid eye movement sleep in elderly individuals. Van de Winckel et al. reported that Qigong practice had positive effects on the rehabilitation and quality of life of patients with spinal cord injuries, including pain reduction, improved sleep, and greater emotional stability. Thakur et al. discovered that meditation practice increased telomerase activity and telomere length while lowering cortisol levels and improving mental health, suggesting its potential as a biomarker for combating human aging. Bartenschlager and Jansen found that meditation reduced defensive responses to death-related stimuli, improved emotional regulation, lowered stress and anxiety, and enhanced overall wellbeing.

In addition, two studies emphasized the dual benefits of mind-body exercises for both physiological and psychological health. Solk et al. found that integrating mindfulness meditation with exercise reduced participants' cognitive load during physical activity, making exercise feel easier, while improving emotional regulation and mental state. This led to greater enjoyment of the exercise process and increased self-efficacy. Gu et al. similarly found that dance-based exercise games significantly boosted enjoyment among college students and positively influenced energy expenditure and self-efficacy. These studies highlight the impact and mechanisms of mind-body exercises in promoting physiological health, providing valuable evidence for developing related exercise training programs.

Technological approaches

The final area of this Research Topic explores the technological approaches, with a particular focus on Virtual Reality (VR) technology. Gao et al. provided the first comprehensive review of VR applications in meditation and teir impact on the physical and mental health of elderly individuals. The study found that VR meditation enhanced exercise quality by delivering real-time visual and auditory feedback. Additionally, the immersive VR experience made it easier for participants to engage in and enjoy meditation practice. However, the implementation of these interventions still faces challenges, such as high costs and issues like simulator sickness. Moreover, Mortlock et al. investigated how online mindfulness practices during the COVID-19 pandemic fostered trust, connection, and shared humanity within a community. Using interdependence theory, their study explored the social functions of shared mindfulness practices and proposed strategies for cultivating mindful communities, calling for further research to refine these practices across various settings.

Concluding remarks

The benefits of mind-body exercises for both physiological and psychological health have been well-established in this topic. The roles of Tai Chi, yoga, and meditation in improving sleep quality, reducing anxiety and stress, enhancing emotional regulation, and increasing overall wellbeing have been thoroughly explored. Additionally, mind-body exercises demonstrate promise in combating aging and promoting overall health through mechanisms such as reducing cognitive load during exercise, extending telomere length, and increasing telomerase activity.

Future research should continue to explore the specific mechanisms by which mind-body exercises impact health, particularly in regulating psychological and physiological processes to achieve positive health outcomes. Researchers should also focus on how various populations, age groups, and health conditions respond to mind-body exercises to design more tailored and effective training programs.

In terms of technology, VR merits further investigation, though challenges such as cost and simulator sickness must be addressed. Moreover, greater emphasis should be placed on community-based mindfulness applications to foster trust, connection, and shared humanity. Through continued research and innovation, mind-body exercises have the potential to become a vital tool for improving physical and mental health, playing a key role in promoting longevity, alleviating disease symptoms, and enhancing quality of life.

Author contributions

GZ: Writing – original draft, Writing – review & editing. YC: Writing – original draft, Writing – review & editing. ZY: Writing – original draft, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EDITED BY
Guodong Zhang,
Southwest University, China

REVIEWED BY
Xiujie Ma,
Chengdu Sport University, China
Francisco Cidral-Filho,
Universidade do Sul de Santa Catarina, Brazil

*CORRESPONDENCE
Mansee Thakur
✉ mansibiotech79@gmail.com

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Impact of Heartfulness meditation practice on anxiety, perceived stress, well-being, and telomere length

Mansee Thakur[1]*, Yogesh Patil[1], Sanjana T. Philip[1], Tahreem Hamdule[1], Jayaram Thimmapuram[2], Nishant Vyas[3] and Kapil Thakur[4]

[1]Department of Medical Biotechnology, Central Research Laboratory, Mahatma Gandhi Mission School of Biomedical Sciences, Mahatma Gandhi Mission Institute of Health Sciences, Navi Mumbai, India, [2]Department of Internal Medicine, Well Span York Hospital, York, PA, United States, [3]Logical Life Science, Pvt. Ltd., Pune, India, [4]SRCM Heartfulness Meditation Centre, Navi Mumbai, India

Objective: Exhaustion, stress, and burnout have all been found to be reduced using techniques like yoga and meditation. This study was carried out to check the effectiveness of Heartfulness practice (a form of meditation) on certain psychological and genetic variables.

Methods: A total of 100 healthy individuals (aged 18–24) were recruited and randomized into two groups-Heartfulness intervention and control group. The intervention was carried out for 03months. Participants from both groups were analysed for their cortisol levels and telomere length before and after the intervention. Psychometric measures of anxiety, perceived stress, well-being and mindfulness were carried out using Beck Anxiety Inventory (BAI), Perceived Stress Scale (PSS), WHO-Well-being Index (WHO-WBI) and Five Facet Mindfulness Questionnaire (FFMQ).

Results: The cortisol levels in the meditators group significantly decreased ($p<0.001$) after the intervention as compared to the non-meditators group, whereas, the telomere length increased in the mediators group. This increase was not significant ($p>0.05$). Anxiety and perceived stress also decreased post intervention, and well-being as well as mindfulness increased, as assessed by the questionnaire tools, although the decrease in perceived stress was statistically insignificant ($p>0.05$). A negative correlation was observed between telomere length and cortisol (stress biomarker), whereas a positive correlation was found between telomere length and well-being.

Conclusion: Our data provide evidence that Heartfulness meditation practice can improve our mental health. Additionally, telomere length is shown to be affected by cortisol levels, and this meditation practice can also help to increase telomere length, and thereby slow down cellular aging. However, future studies with larger sample size are required to confirm our observations.

KEYWORDS

anxiety, cortisol, Five Facet Mindfulness Questionnaire (FFMQ), Heartfulness meditation, RT-PCR, stress, telomere

Introduction

A growing number of people are suffering from complicated lifestyle disorders such as cardiovascular disease (CVD), infertility, diabetes, depression, and cancer. These conditions require special care and treatment to achieve optimal quality of life. These diseases have become a burden on modern society because they are significantly linked to accelerating cellular aging (Boccardi et al., 2016; Tolahunase et al., 2017). Major depressive disorder (MDD) is associated with a significantly increased risk of developing serious medical illnesses that are more commonly seen with advanced age, such as diabetes, cardiovascular disease, immune impairments, stroke, dementia and osteoporosis. A major depressive episode has been compared to "accelerated ageing," with an increased risk of aging-related disorders (Thimmapuram et al., 2017). The human body undergoes constant changes, causing changes in cells and tissues over the course of a lifetime. Some changes that occur in cells are normal processes that help keep the body healthy. Other changes can occur as a result of certain diseases or conditions, such as cancer or aging (Lipton, 2008). Certain cells in the body have specialized structures called telomeres, which are the protective caps found at the end of chromosomes that shorten with each cell division. Eventually, if the telomeres are too short, the cells cannot divide anymore and become damaged, which can lead to cell death. Cellular senescence is another consequence of shortened telomeres (Blackburn, 2000). Telomere length has an impact on total life expectancy, and telomere shortening is a sign of molecular aging (Blackburn, 2009; Beery et al., 2012; Karthik et al., 2014; Alda et al., 2016; Thimmapuram et al., 2017). Telomere shortening has been linked to cytotoxic stresses such as oxidative stress, which destroys telomeric DNA more than non-telomeric DNA, and chronic inflammation, even in non-dividing cells. Increased telomere shortening makes cells more vulnerable to apoptosis and death (Wolkowitz et al., 2011).

Cortisol is a stress hormone that is produced by the adrenal glands. Research has shown that under normal circumstances, the body maintains or regulates normal cortisol levels. However, if under higher stress conditions, the body secretes more of this hormone (Lengacher et al., 2014). Cortisol is also responsible for several stress-related changes in the body. The concentration of cortisol has also been reported to be a useful prognostic marker of stress (Álvarez-López et al., 2022).

Exhaustion, stress, weariness, and burnout have all been found to be reduced using techniques like yoga and meditation (Walsh and Shapiro, 2006; Thimmapuram et al., 2017). Yoga is also effective in treating depression (Cramer et al., 2013; Seppälä et al., 2014; De Manincor et al., 2016; Falsafi, 2016; Cramer et al., 2017; Prathikanti et al., 2017; Ramanathan et al., 2017; Streeter et al., 2017), even in the perinatal period (Cramer et al., 2013; Davis et al., 2015). The results with yoga vs. exercise and yoga vs. medication were found to be similar, as concluded by a systemic review (Cramer et al., 2017). However, results indicating yoga for the treatment of anxiety is unclear. Few studies have found that yoga is effective as compared to no treatment (Michalsen et al., 2012; Parthasarathy and Jaiganesh, 2014; Vorkapic and Rangé, 2014; Falsafi, 2016; Ramanathan et al., 2017), whereas other studies suggest no improvement in anxiety (Davis et al., 2015; De Manincor et al., 2016). Tai chi is another practice that has shown to reduce anxiety in older adults, when used as an adjunct therapy along with medications (Song et al., 2014). A small body of literature indicates mixed evidences for qi gong therapy. A qi-gong-based stress reduction program showed reduced anxiety (Hwang et al., 2013), however a meta-analysis revealed contradictory results (Wang et al., 2010). Tai chi and qi gong therapies have also shown evidence to reduce depression (Tsang et al., 2013; Yin and Dishman, 2014; Yeung et al., 2017). Apart from these strategies, meditation can also be used as an effective treatment strategy for psychiatric disorders such as depression and anxiety. For instance, Mindfulness-Based Interventions (MBIs) showed better results for reducing depression as compared to no treatment. It is also worth noting that this intervention was found to be equivalent to treatment by selective serotonin reuptake inhibitors (Goldberg et al., 2018). Anxiety and mood disorders can also be reduced using MBIs as determined by a meta-analysis (Hofmann et al., 2010). A study showed that depression in patients with a traumatic brain injury was reduced by MBI (Bédard et al., 2014). Similarly, MBI was effective in patients with PTSD and depression, although statistically significant results were not obtained for anxiety and quality of life (Hilton et al., 2017).

In recent years, there has been a growing interest in exploring the possible impacts of meditation practice on telomere dynamics, in addition to diet and physical activity (Dyrbye et al., 2008). In leukocytes, psychological stress has been linked to rapid telomere shortening, whereas meditation has been linked to increased telomere length (Blackburn, 2009; Beery et al., 2012; Karthik et al., 2014; Thimmapuram et al., 2017). Shorter telomeres are also linked with diseased conditions diseases (Zhao et al., 2013; Haycock et al., 2014; Ridout et al., 2016). A growing body of research suggests that meditation, which has been shown to support healthy biological processes, may also affect biomarkers associated with aging. The findings suggest that practicing mindful meditation may be one way to build resilience against disease through maintaining a healthy body and mind (Sudsuang et al., 1991; Pace et al., 2009; Lengacher et al., 2014; Turan et al., 2015; Alda et al., 2016; Álvarez-López et al., 2022). In fact, intensive meditation training has been linked to increased telomerase activity (Jacobs et al., 2011) and longer telomere length in blood cells, which are considered potential biomarkers of human ageing. Recent research suggests that these factors may be influenced by psychological stress, stress assessments, and well-being (Epel et al., 2004; Walvekar et al., 2015; Alda et al., 2016). Investigations have demonstrated a beneficial correlation between meditation and longer telomeres (Alda et al., 2016) in addition to an increase in telomerase (Zi and Shuai, 2013), suggesting that meditation may be crucial for disease prevention.

Heartfulness meditation is one such practice of meditation. This tradition uses three primary methods: 1) meditation, 2) cleaning, and 3) prayer. These techniques are intended to purify and broaden consciousness and awareness about oneself (Sylapan et al., 2020). Heartfulness meditation was chosen because of its characteristic yogic transmission which helps to achieve a state of Samadhi even in beginners due to the effectiveness of Pranahuti. Furthermore, the Heartfulness technique draws upon the research and practical experience of yogis, as opposed to abstract theory. They emphasize "direct perception" as the preferred method, which is considered to be a more accurate method of learning from Yoga (van't Westeinde and Patel, 2022).

Heartfulness meditation has been shown to positively influence physical and mental health outcomes, however there are relatively few studies exploring its biological mechanisms.

This study was carried out to support the idea that Heartfulness meditation is linked to longer telomeres. The second objective was to link it with decreased cortisol levels and psychological variables such as stress, anxiety, mindfulness and well-being. Only a few researchers have shown this connection (Epel et al., 2004; Zi and Shuai, 2013; Walvekar et al., 2015; Alda et al., 2016). Questionnaire tools such as PSS, BAI, WHO-WBI, and FFMQ were used to show the effect of meditation on different psychological constructs.

Methodology

Participants and setting

The study was a prospective cohort analysis carried out for 12 weeks from October 2022–December 2022. It is a single-arm randomized-controlled trial with one intervention condition (guided Heartfulness meditation) and one active-control condition (sham meditation). The design employed was a 2 (condition) × 2 (time) parallel-group design which is explanatory in nature. A convenience sampling method was chosen to recruit healthy-matched ($N = 100$) participants. The principal investigator (PI) sent emails to volunteers to assess their interest in participation. Participants were assigned randomly into two groups-the meditators (intervention) and the non-meditators (no intervention). Participants enrolled had a similar lifestyle and were matched by gender and age (±2 years). Participants in both groups were aged between 18 to 24 years. The participants did not have any experience in any of the meditation practices. According to G Power Software, a sample size of 100 participants (50 meditators and 50 non-meditators) was required for an effect size of 0.8 and 80% power for Type I error; $\alpha = 0.05$ (Faul et al., 2007). 50 participants were randomly allocated into the meditaors group and 50 into the non-meditators group. There was an exclusion from the study for participants with psychiatric disorders, those undergoing pharmacological or psychological treatment or those with medical conditions that may affect the activity of telomerase (such as cancer, lupus, rheumatoid arthritis) (Thimmapuram et al., 2017). To ensure the integrity of the study, all the selected participants were given an information sheet explaining the details about the purpose of the study, voluntary participation, duration of the study, participants' responsibilities and potential benefits of the study. Written consent was also obtained from each participant. Ethics approval for this study was granted by the Ethics Review Committee, of MGMIHS (MGM/DCH/IEC/109/22).

Intervention

A Heartfulness-certified trainer briefed the participants of the meditators group on how to practice Heartfulness meditation. These participants practiced the meditation technique once daily on all working days (online-through HeartssApp, and offline) and on their own on holidays by using Heart App software. They meditated weekly once in the Heartfulness meditation centre-located at New Panvel, Navi Mumbai, India.

Guided audio clips were also shared with the participants to follow Heartfulness core practices (meditation, rejuvenation, and bed-time relaxation and meditation) every day for 12 weeks in the following schedule:

Sr. no.	Practice	Description of practice	Duration (mins)
1.	Heartfulness meditation-morning	Participants were asked to sit comfortably and with their eyes closed, were made to focus their attention on the source of light that is present within the heart. Rather than strictly trying to visualize this, participants were asked to simply tune in to their hearts and be open to any experience that they may feel (van't Westeinde and Patel, 2022)	30
2.	Heartfulness rejuvenation/cleaning-evening	Participants were asked to imagine that stress and heaviness ('impurities and complexities') were escaping through the back of their body in the form of smoke or vapour. And, feelings of purity, lightness, and freshness replaced these impurities (van't Westeinde and Patel, 2022)	15
3.	Heartfulness bed-time relaxation and meditation before sleeping – night time	Participants were asked to recite the Heartfulness prayer, followed by 10 min of meditation in order to strengthen one's connection to the source (van't Westeinde and Patel, 2022).	15

The non-meditators group did not receive any intervention of Heartfulness meditation program during the study period. The group was requested to complete the same baseline assessments as the intervention group and were instructed to carry on with their usual daily life routine.

Participants of both groups had to go through tests of selected psychological, biological and molecular parameters before and after 3 months (ie. Pre-test and Post-test).

Procedure

Participants from both groups gave their blood samples in the morning (fasting) for measurement of telomere length and cortisol levels. They were also asked to complete sociodemographic, psychological, and health-related questionnaires. All these analyses/measurements were carried out at MGM Central Research Laboratory, MGMIHS, Navi Mumbai.

Measurements

Telomere length measurement by using qRT-PCR

The telomere length for pre and post intervention was analysed as per the protocol described by Cawthon (2002). A total of 80 samples were analysed by qRT-PCR assay. All extracted DNA samples were normalized to final concentration of 10 ng/μL. The telomere length and housekeeping gene (acidic ribosomal

phosphoprotein 36B4) specific PCR was performed by using Takara's TBGreen® Premix Ex Taq™ II PCR master mix by mixing 10 µL of TB Green Premix Ex Taq II (TliRNaseH Plus) (2X), 0.8 µL forward and reverse primers with a final concentration of 10 µM, 0.4 µL ROX Reference Dye (50X), 6 µL of molecular grade water and 2 µL template DNA samples (10 ng/µL). The prepared samples were subjected to following thermal cycling conditions, 95^{0}Cfor 5 min as an initial denaturation followed by 45 cycles of 95^0\u00B0C for 5 s and 60^0\u00B0C for 30 s. Post amplification the average CT values were calculated for all analysed samples and the T/S ratio was calculated by using the method described by Cawthon (2002). TL is expressed as t/s, the ratio of telomeric (T) to single copy (S) gene product for a particular sample. T and S values were measured in triplicate using a real-time PCR machine with a 96-tube capacity performed using Himedia Insta Q48 real-time PCR system, and the t/s ratio for a given sample was calculated.

Cortisol measurement by competitive ELISA

A total of 80 samples were analysed for quantitative estimation of serum cortisol as an indicator of stress marker by using Bioelsa Competitive ELISA method. The blood samples were collected in the morning. The serum samples were diluted 10 folds in order to get the concentrations of the unknown samples within the detection limits of the said assay, rest of the assay protocol was followed according to the standard operating procedure as prescribed by the manufacturer. The analysis of the results was done by plotting the concentration verses O. D plot of standard reference samples and the concentration of the unknown samples was calculated as per the standard graph.

Wellbeing questionnaires

Four self-reporting inventories were used in this study, namely, the Beck Anxiety Inventory (BAI), Perceived Stress Scale (PSS), WHO Well-being Index (WHO-WBI) and the Five Facet Mindfulness Questionnaire (FFMQ).

Beck anxiety inventory (BAI)

To measure anxiety among paramedical students. The BAI questionnaire; a 21-item questionnaire, has been commonly used in clinical research as a measure of generalized anxiety (physical and cognitive anxiety). It is a trademark of Pearson Education, Inc., or its affiliate(s). A four-point Likert scale ie. 0 (not at all) to 3 (severely), is used to score the responses. It consists of items that indicate how much a person has been bothered by that symptom during the past month. For example, a sample item in the scale is: "Fear of worst happening." A score of 36 and above indicates high anxiety, 22–35 moderate anxiety, and 0–21 low anxiety (Piotrowski, 1999).

Perceived stress scale (PSS)

To measure perceived stress among the students, the PSS questionnaire; a 10-item questionnaire tool was used. It evaluates the degree at which each individual perceives situations in their lives as stressful. It is widely used for young people and adults above 12 years. Here, a 5-point Likert scale ie. 0 (never) to 4 (very often) is used. A sample item is: "In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?" High levels of perceived stress is determined by scores in the range from 27 to 40, moderate perceived stress by 14–26 and low perceived stress by 0–13 scores (Lee, 2012).

WHO-well being index (WHO-WBI)

It is a short questionnaire to measure well-being over the last 2 weeks. It was used to indicate the well-being of the students. It consists of 5 items, each rated between 0 and 5 representing "At no time" and "All the time" respectively. A sample item is: "I have felt cheerful and in good spirits." Scores between 0 and 25 indicates the worst and best possible lifestyle (Topp et al., 2015).

Five facet mindfulness questionnaire (FFMQ)

It is a self-reported questionnaire to measure the tendency to be mindful in daily life. This questionnaire assessed students' mindfulness which included various parameters such as observing, describing, acting with awareness, non-judging of inner experience, and non-reactivity to inner experience. A sample item is: "I pay attention to sensations, such as the wind in my hair or sun on my face." A 5-point Likert scale ie. From 1 (never or very rarely true) to 5 (very often or always true), was used (Baer et al., 2008). All these three questionnaires were sent electronically in the form of Google Forms to all participants pre-and post-intervention, and their responses were collected.

Statistical analysis

Depending on the variable, mean, standard deviation (SD), or percentage values were used. Mann Whitney U test was performed to calculate the significance of psychological variables between the groups. Student's t test and chi-square test were performed for the sociodemographic characteristics of the samples. Pearson correlation (r) was used to study and determine the relationship between the psychological variables, telomere length, and cortisol levels. All these tests were performed at the significance level $\alpha < 0.05$ by the SPSS-25 statistical software package.

Results

Out of 100 participants enrolled in this study, a total of 18 participants were retained till the end of this study. They were randomly allocated into meditators (intervention) and non-meditators group (no intervention); 40 participants were in each group. The sociodemographic characteristics (age, age groups, and gender) of the sample are tabulated in Table 1. Both the meditators and non-meditators groups were similar in age and gender.

Telomere length measurement by using qRT-PCR

The telomere length was measured using qRT-PCR. The average telomere length in the meditators group (mean = 0.83; SD = 0.144) was found to be more ($t = 1.656$; df = 78; $p = 0.0190$) than the non-meditators group (mean = 0.77; SD = 0.114), as calculated by paired t-test (Figure 1).

Cortisol measurement by competitive ELISA

The paired t-test showed that the average cortisol level in the meditators group (mean = 32.07 ng/mL; SD = 23.583) was significantly

TABLE 1 Sociodemographic characteristics of the sample.

Characteristics	Meditators	Non-meditators	Significance
1. *Age*			$p = 0.327$[a]
Mean (SD)	20.95 (1.753)	21.35 (1.875)	
Range	18–24	18–24	
2. *Age groups-n, (%)*			
<18	0	0	
18 to <20	5 (12.5)	4 (10)	
20 to <22	24 (60)	19 (47.5)	
≥22	11 (27.5)	17 (42.5)	
3. *Gender-n, (%)*			$p = 0.576$[b]
Male	9 (22.5)	7 (17.5)	
Female	31 (77.5)	33 (82.5)	

[a]*p* values were calculated using the independent *t*-test.
[b]*p* values were calculated using the Chi-square test.

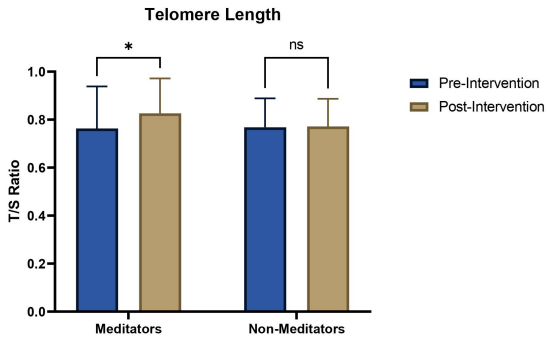

FIGURE 1
Telomere length in meditators and non-meditators at pre and post-intervention of Heartfulness meditation practice. A significant increase in telomere length was observed in meditators after the intervention period. *p<0.05.

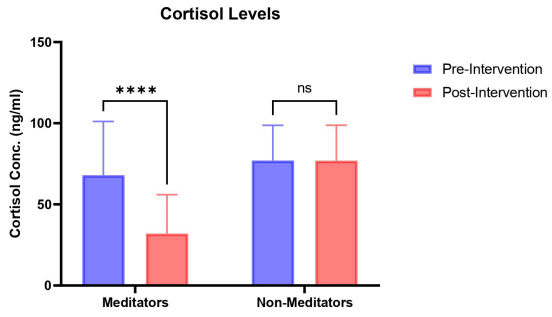

FIGURE 2
Concentration (ng/mL) of cortisol in meditators and non-meditators at pre and post-intervention of Heartfulness meditation practice. A significant decrease in cortisol was observed in meditators post-intervention. ****p<0.0001.

less ($t = 3.999$; df = 78; $p = 0.0003$) than the non-meditators group (mean = 76.975 ng/mL; SD = 21.567) (Figure 2).

Psychological variables

The psychological variables such as perceived stress, anxiety, FFMQ, and well-being were studied in meditators and non-meditators before and after the intervention. The level of anxiety and perceived stress was higher in non-meditators, as compared to meditators, after the intervention; however, the difference was significant only in the case of anxiety ($p = 0.008$). The mindfulness variables such as observing, describing, and acting with awareness significantly increased in meditators. However, there was no significant difference observed with non-judging and non-reactivity. The well-being scores also increased significantly ($p = 0.010$) after meditation (Table 2).

Telomeres and psychological variables

The correlation between telomere length and psychological variables was in the expected direction. Post-intervention, a negative correlation between perceived stress, anxiety and mindfulness was observed (Table 3); although this correlation was significant only in the case of perceived stress.

Similarly, the correlation between cortisol and psychological variables was in the expected direction. With an increase in cortisol levels, an increase in perceived stress, and anxiety was also observed (Table 4); however, this correlation was only significant in the case of anxiety. Whereas, a significant decrease in mindfulness and well-being was observed with an increase in cortisol.

The scatter plot of psychological variables with cortisol and telomere length is shown in Figure 3.

Discussion

Our study adds to the growing literature that meditation practice improves mental health. The main hypothesis of our study was that Heartfulness meditation can improve mental health by increasing telomere length. This study demonstrates that Heartfulness meditation affects cortisol levels and psychological variables such as perceived stress, anxiety, mindfulness, and well-being. It further demonstrates that Heartfulness meditation is linked to longer telomeres. All these parameters were studied in two groups; one with the intervention of Heartfulness meditation and the other with no intervention. The

TABLE 2 Psychological variables in meditators (n=40) and non-meditators (n=40).

Variable	Meditators, mean (SD)	Non-Meditators, mean (SD)	z score	p value[a]
Perceived Stress[b]	18.6 (7.489)	21.03 (7.433)	−1.003	0.316
Anxiety[c]	12.4 (9.083)	21.28 (14.793)	−2.673	0.008
FFMQ[d]	122.85 (17.876)	98.35 (31.939)	−3.457	0.001
FFMQ Observing	28.55 (6.872)	19.7 (8.582)	−4.216	0.000
FFMQ Describing	24.78 (4.44)	20.87 (6.541)	−2.455	0.014
FFMQ Acting with awareness	22.78 (4.388)	18.2 (6.513)	−3.629	0.000
FFMQ non-judging	18.47 (4.206)	20.03 (6.956)	−1.240	0.215
FFMQ non-reactivity	18.45 (5.198)	18.35 (6.912)	−0.024	0.981
Well-being[e]	12.3 (6.174)	15.73 (6.333)	−2.578	0.010

[a]p values were calculated using the Mann Whitney U test due to non-normalpaired data.
[b]As determined by the Perceived Stress Scale (PSS).
[c]As determined by the Beck Anxiety Inventory (BAI).
[d]As determined by the Five Facet Mindfulness Questionnaire (FFMQ Total).
[e]As determined by the WHO-Well Being Index (WHO-WBI).

TABLE 3 Correlation between psychological variables and telomere length.

Variable	Telomere Length (r)	p value
Perceived stress	−0.315**	0.004
Anxiety	−0.211	0.061
FFMQ	−0.056	0.624
Well-being	0.009	0.937

r = Pearson's Coefficient. **p<0.01.

TABLE 4 Correlationp between psychological variables and cortisol.

Variable	Cortisol levels (r)	p value[a]
Perceived stress	0.003	0.978
Anxiety	0.237*	0.034
FFMQ	−0.308**	0.005
Well-being	−0.221*	0.048

r = Pearson's Coefficient. *p<0.05; **p<0.01.

non-meditators group did not show any significant differences in any of these parameters. The sociodemographic characteristics of both groups were similar.

It is expected that people with anxiety and stress may have low mindfulness awareness. The same was observed in our study. The PSS and BAI questionnaire revealed that Heartfulness meditation was able to decrease perceived stress and anxiety scores in our participants, although it was not significant in the case of perceived stress. These results are similar to previous studies. For instance, a Mindfulness-based Stress Reduction (MBSR) program in cardiac patients showed statistically significant changes in depression ($p = 0.01$) and anxiety ($p = 0.04$), and a non-significant change in perceived stress (Nijjar et al., 2019). MBSR intervention in students in low-middle-income countries (LMICs) indicated an effective reduction in stress scores. Interestingly, even after 2 months of completion of the intervention, lower negative emotional states, were observed especially in the Anxiety and Depression scores (An et al., 2022). A Mindfulness-based Yoga intervention in nurses and health care professionals (HCPs) showed significant improvement in perceived stress and mindfulness, whereas, cortisol and blood pressure were not significantly improved (Hilcove et al., 2021). Our results reveal that meditators are better at labeling their experiences, such as observing, describing, and acting with awareness which significantly increased after the intervention, suggesting that Heartfulness practice is positively related to mindful awareness. However, there was no significant difference observed with the parameters of non-judging and non-reactivity. The well-being scores also increased significantly ($p = 0.010$) after meditation. These higher mindfulness levels in meditators are consistent with previous work that provides a link between Heartfulness meditation and perceived stress. Thimmapuram et al. (2017) also found that negative emotions, and burnout were reduced with the help of meditation and that further research with more participants and a more representative sample would provide significant results to this effect. The current study indicates that Heartfulness practice can help improve mental well-being and aid in the reduction of anxiety.

The majority of the studies are based on mindfulness practices. To the best of our knowledge, this is the first study to establish a direct effect of Heartfulness meditation practice on the stress hormone cortisol. A significant decrease ($p = 0.0003$) in serum cortisol levels in meditators was observed after the intervention. Previous studies involving other meditation-based interventions have shown similar results. In a study, MBSR intervention in patients with Generalized anxiety disorder (GAD) showed a larger reduction in cortisol as compared to the control group after the Trier Social Stress Test (TSST), showing resilience to stress (Hoge et al., 2018). In another study, a mindfulness retreat showed a statistically significant decrease ($p < 0.0001$) in anxiety and perceived stress (Gardi et al., 2022). This study also showed a positive significant correlation between cortisol levels and both perceived stress ($r = 0.92$, $p < 0.0001$) and anxiety ($r = 0.56$, $p < 0.0001$); as demonstrated in our study too (Gardi et al., 2022). MBSR program has also shown improved effects in

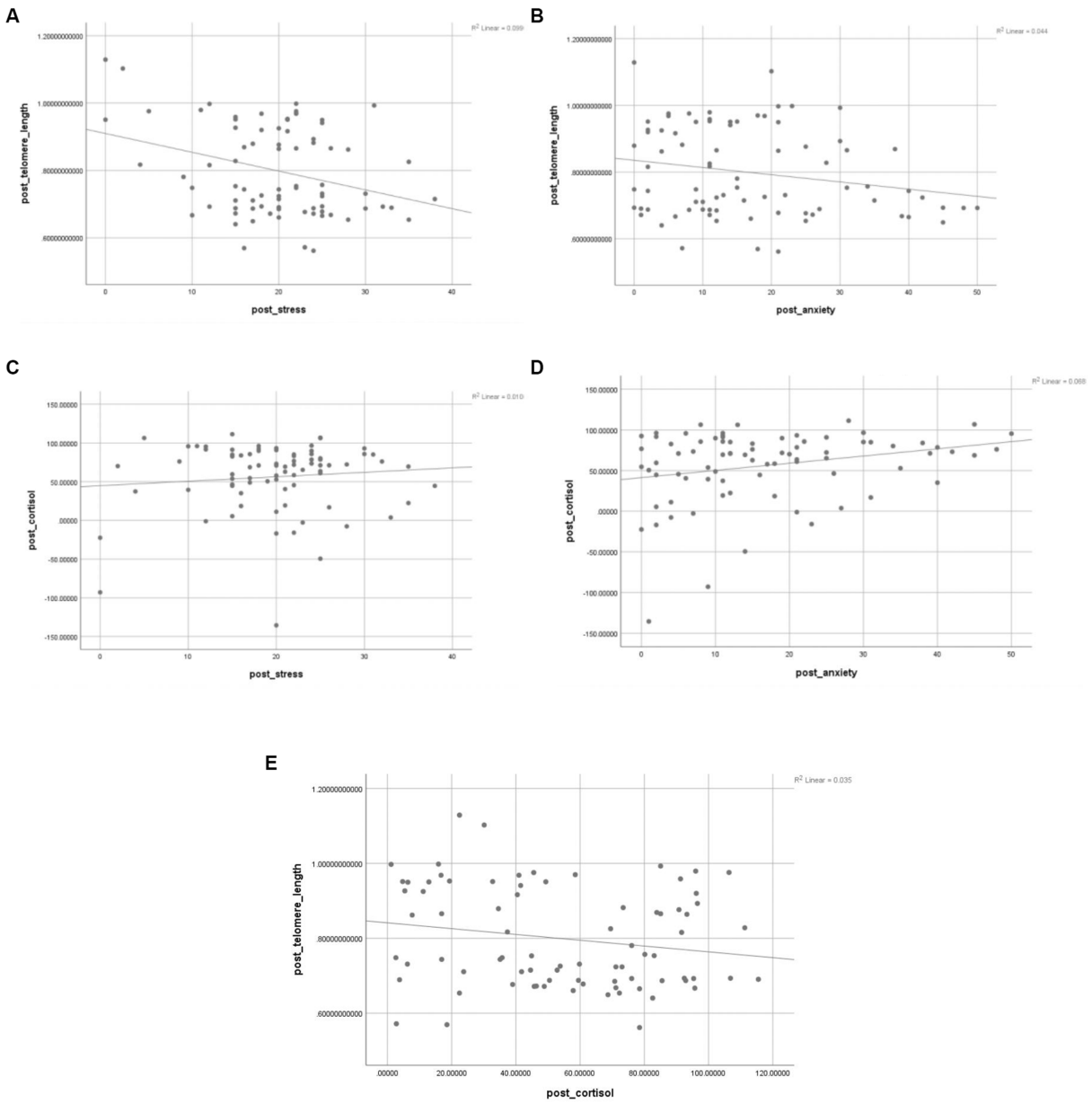

FIGURE 3
Correlation between psychological variables, telomere length, and cortisol levels. **(A)** correlation between telomere length and stress; **(B)** correlation between telomere length and anxiety; **(C)** correlation between cortisol and stress; **(D)** correlation between cortisol and anxiety; **(E)** correlation between telomere length and cortisol levels.

lowering cortisol in patients with primary open-angle glaucoma (POAG) (Dada et al., 2018). Other forms of meditation have also shown similar results. For instance, a brief Psychoneuroendocrinoimmunology-Based Meditation (PNEIMED) displayed reduced levels of cortisol levels at awakening and under acute mental stimulation in a group of healthy university students (Bottaccioli et al., 2020). Another group of researchers showed that Rajyoga meditation reduced anxiety and cortisol levels in patients undergoing coronary artery bypass surgery (Kiran et al., 2017).

In the current study, the changes in telomere length were also studied. It was observed that the average telomere length significantly increased ($p = 0.0190$) in the meditators group after the intervention. There are other studies that show longer telomeres (Schutte and Malouff, 2014; Thimmapuram et al., 2017; Tolahunase et al., 2018). Madhuri Tolahunase et al. showed that Yoga and meditation-based lifestyle intervention (YMLI) increased telomerase activity and telomere length, but it was not significant in the latter; whereas a significant decrease in cortisol levels was observed in apparently healthy individuals after YMLI (Tolahunase et al., 2017). A 12-week YMLI showed significantly increased telomerase activity and decreased cortisol levels in patients with Major Depressive Disorder (MDD) (Tolahunase et al., 2018). In a pilot trial involving African American patients suffering from stage 1 hypertension, two interventions-Transcendental Meditation technique plus health education and

extensive health education, respectively, showed an increase in gene expression of telomerase enzyme (Duraimani et al., 2015). In another pilot trial, dementia caregivers were exposed to relaxation music, which increased their telomerase activity (Lavretsky et al., 2013). Hence, our study indicates that the maintenance of longer telomeres with the help of Heartfulness meditation is possible.

Our study also focused on the correlation between psychological stress and cellular aging. We examined that non-meditator volunteers who were under stress had shorter telomeres than meditators who showed an increase in telomere length and reduction in psychological and perceived stress. Telomere shortening is a natural process; indicating cellular ageing. But this process is seen to be faster in individuals associated with psychosocial adversity (Thimmapuram et al., 2017). Defects in the DNA repair system can also lead to pathological aging (Pan et al., 2016). Our results show that telomere length is negatively linked to perceived stress and anxiety. The same has been demonstrated in other studies-for anxiety (Hoen et al., 2013) and perceived stress (Epel et al., 2004; Epel, 2009; Epel et al., 2010; Tomiyama et al., 2012; Shalev et al., 2013).

A possible connection between Heartfulness meditation and telomere length may be that individuals who practice Heartfulness experience less stress, anxiety, and depression, which leads to decrease in cortisol levels and this decrease may be associated with enhanced telomerase activity (Schutte and Malouff, 2014). Evidences show that stress-related health problems can be due to cellular ageing, resulting in shortening of telomere length (Epel et al., 2004; Shalev, 2012; Conklin et al., 2018). Therefore, it is important to maintain telomere length for a better cellular health. Healthy life style interventions can possibly increase telomere length in these individuals (Puterman et al., 2018). Findings from Marta et al. show that experienced Zen meditators had longer telomeres as compared to non-meditators (Alda et al., 2016). Similarly, Loving-Kindness meditation practice; another type of meditation showed longer relative telomere length than the control (Hoge et al., 2013).

Researchers have increasingly attributed shorter telomere length to psychosocial stress (Epel et al., 2004; O'Donovan et al., 2011; Drury et al., 2012; Puterman et al., 2016). This study also showed a negative correlation between telomere length, perceived stress and cortisol (as shown in Figures 3A,E). This indicates that the decrease in cortisol (stress) might be due to the increase in telomere length. A recent systematic review and meta-analysis found the same correlation; however, it was between cortisol reactivity in saliva to psychosocial stressors and telomere length and not basal serum cortisol levels in serum and telomere length, as seen in our study (Jiang et al., 2019). The possible mechanism behind improving mental health through Heartfulness intervention could be that the yogic transmission might have led to a state of Samadhi among the participants, leading to an overall positive impact. This involves reduction in perceived and psychological stress leading to changes in the brain via hypothalamic–pituitary–adrenal (HPA) axis (Tolahunase et al., 2017). A key component of the HPA axis is the interaction between the hypothalamus, the pituitary gland, and the adrenal glands, which secrete cortisol; an end result of feedback interactions amongst these glands (Jiang et al., 2019). The reduction in cortisol levels post intervention may have led to an increase in telomere length, which can further slowdown the process of cellular ageing. Researchers have linked this activity in the HPA axis to telomere length (Tomiyama et al., 2012; Savolainen et al., 2015; Nelson et al., 2018). Our findings further show a positive link between well-being and telomere length, hence indicating improved cellular health. These changes in cortisol and telomere length after Heartfulness intervention suggests that Heartfulness can affect our body at cellular and genetic levels and also may slowdown the progression of diseases related to cellular aging.

Limitations and future research

This study has established a relationship between Heartfulness meditation with modern scientific discipline and provided scientific validation for improving overall well-being by using a non-invasive lifestyle intervention like Heartfulness meditation. However, our study has certain limitations. First, certain parameters did not show a significant effect after the practice of Heartfulness meditation. One reason could be due to the smaller sample size studied in this research. Second, due to the short period of intervention (only 12-weeks of intervention). Third, this study was conducted with only healthy volunteers.

Future studies will include a larger sample size and a longer duration of Heartfulness meditation to strengthen our findings. Additionally, being a part of medical college and a 1,000 bedded hospital, we would like to extend this study to patients with non-communicable lifestyle disorders such as cardiovascular disorder, diabetes, etc. We would also like to study the immunomodulatory patterns resulting due to heartfulness meditation so that we can develop a process and protocol to help quantitative measurement of biological markers. In future, this intervention protocol can be used as a cost-effective and sustainable secondary prevention strategy to maintain well-being.

Conclusion

The practice of Heartfulness meditation had a positive effect on anxiety, perceived stress, mindfulness, and well-being. The biological indicators such as cortisol concentration and telomere length were also altered after the intervention; showing a reduction in the cortisol levels and an increase in the telomere length. This further indicates that long-term practice of Heartfulness meditation can further improve mental health along with a slow cellular aging process, and hence promote good well-being.

Data availability statement

The datasets presented in this article are not readily available because informed consent signed by participants stated that data were only accessible to the authors of this study. Requests to access the datasets should be directed to MT, mansibiotech79@gmail.com.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Review Committee, of MGMIHS (MGM/DCH/IEC/109/22). The patients/participants provided their written informed consent to participate in this study.

Author contributions

MT and JT designed the study. YP, SP, and TH conducted the study. SP and TH collected the research data. MT, YP, and KT supervised this work. Results interpretation was done by MT, YP, JT, and NV. SP performed the statistical analyses. SP and MT wrote the original manuscript. JT, NV, and KT reviewed the original manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

NV is employed by Logical Life Science, Pvt. Ltd., Pune, India.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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EDITED BY
Zi Yan,
Merrimack College, United States

REVIEWED BY
Gewnhi Park,
Westmont College, United States
Richard Gevirtz,
Alliant International University, United States

*CORRESPONDENCE
Jiasheng Huang
✉ huangjsh39@mail.sysu.edu.cn

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Athletes' self-compassion and emotional resilience to failure: the mediating role of vagal reactivity

Nan Zhang[1], Jiasheng Huang[2]* and Jiaxin Yao[3]

[1]School of Psychology, Beijing Sports University, Beijing, China, [2]Department of Psychology, Sun Yat-sen University, Guangzhou, China, [3]College of Education and Psychology, Tianjin University of Sport, Tianjin, China

Whether athletes' self-compassion predicts their emotional resilience to failure has yet to be empirically tested. Moreover, as an important physiological process of stress regulation, vagal reactivity is a plausible physiological mechanism for this relationship. Through a laboratory-based observational study of 90 college athletes, this research explores the influence of athletes' trait self-compassion on their emotional resilience when recalling failure, and examines whether vagal reactivity plays a mediating role. The results show that self-compassion did not significantly predict athletes' positive emotions but did significantly predict better recovery from negative emotions after recalling failure events. Furthermore, vagal reactivity was a significant mediator between self-compassion and recovery from negative emotions.

KEYWORDS

self-compassion, emotional resilience, failure, vagal reactivity, mediation

1. Introduction

In sports competitions, all athletes expect to succeed, but there is only one champion, so failure is an inevitable and frequent outcome for most participants. When an athlete fails, especially in an important game, possible consequences include depression, anger, and mental fatigue (Jones and Sheffield, 2007; Hammond et al., 2013), leading to a decline in performance. The emotional devastation of failure may even make some athletes end their sporting careers prematurely. Thus, it is important to investigate how athletes can develop emotional resilience to failure, which refers to generating positive emotions and recovering quickly from the negative emotional experiences caused by failure (Davidson, 2000).

Previous studies have shown that athletes tend to engage in severe self-criticism, self-judgment, and rumination when encountering failures (Mosewich et al., 2013; Ferguson et al., 2014). This is especially typical of Chinese athletes: they compete not only for themselves but also for their team and country. Should they fail, the voice of self-criticism and self-condemnation becomes stronger (Wang and Shi, 2012). Many athletes believe this way of relating to themselves is necessary for success in elite sports, and without it, they will become complacent and fail to reach their potential (Sutherland et al., 2014; Rodriguez and Ebbeck, 2015). However, the outcomes can be counterproductive. Research showed that self-criticism or self-punishment undermined athletes' self-regulation, emotional recovery, stress management, and performance (Powers et al., 2009; Tenenbaum et al., 2013; Ferguson et al., 2015). These harsh attitudes were also positively associated with negative emotional responses, avoidance, and fear of failure (Sagar et al., 2007; Powers et al., 2009).

By contrast, treating oneself with compassion may be a more beneficial way to respond to failure. Self-compassion entails three main components: (a) self-kindness—being kind and

understanding toward oneself in instances of pain or failure, rather than being harshly self-critical; (b) common humanity—perceiving one's experiences as part of the larger human experience, rather than seeing them as separating and isolating; and (c) mindfulness—holding painful thoughts and feelings in balanced awareness, rather than over-identifying with them (Neff, 2003). When facing difficulties, people with self-compassion have the desire to soothe themselves rather than ruminate and overidentify painful experiences and have motivation and action to pursue happiness (Neff, 2003; Allen and Leary, 2010; Barnard and Curry, 2011; Terry and Leary, 2011). Self-compassion also has particular benefits for athletes, helping them to develop adaptive thoughts, emotions, and behavioral responses to stress (Mosewich et al., 2013; Ferguson et al., 2015; Reis et al., 2015; Ceccarelli et al., 2019), as well as realizing their potential under adversities (Ferguson et al., 2014; Lizmore et al., 2017). Moreover, evidence in the general population suggests that self-compassion may facilitate emotional resilience to negative events. For example, studies have found that people with high self-compassion tend to take a more balanced approach to their negative experiences—neither avoiding nor dwelling on negative emotions—and recover more quickly (Neff and Vonk, 2009; Poots and Cassidy, 2020). Mantelou and Karakasidou (2017) also found that changes in self-compassion on the part of the intervention group could predict changes in positive affect. That means that participants who face everyday challenging situations in a more self-compassionate manner are also to gain more in terms of positive effect. However, compared with the general population, athletes face tremendous pressure over a long period; they are used to being strict with themselves and particularly worry that self-compassion could lead to complacency, mediocrity, or passivity (Ferguson et al., 2014). Thus, the contributive role of self-compassion to athletes' emotional resilience to failure remains questionable and has yet to be explored.

Vagal reactivity may be an important physiological mechanism through which self-compassion promotes better emotional resilience failure in athletes. The vagus nerve is a component of the parasympathetic branch of the autonomic nervous system (Beauchaine, 2001). It helps individuals maintain homeostasis in response to changes in the external environment by regulating organs. The Polyvagal theory posits that vagus nerve activity is an important neurophysiological basis of emotion and social behavior (Porges, 1995, 2001, 2003, 2007). When the external environment is relatively safe, the parasympathetic system plays a leading role in physiological regulation, with the vagus nerve strongly contributing to maintaining the homeostasis of the internal environment and directing appropriate emotional and behavioral responses. By contrast, when the external environment changes and the individual is in a state of stress, the sympathetic nerve plays a leading role, and the regulation of the vagus nerve on the heart will be weakened, resulting in vagal withdrawal (Porges, 2001). Vagal reactivity is the strength of responsiveness of the vagus nerve during such a withdrawal process. High vagal reactivity indicates individuals' flexibility in coping with challenges caused by environmental changes (Porges et al., 1996; Porges, 2007; Santucci et al., 2008).

In stressful situations such as failure, higher vagal reactivity may help athletes generate adaptive emotional responses, thereby facilitating their emotional resilience. Prior studies have revealed a positive association between vagal reactivity and appropriate emotional responses in other populations. For example, using discussion of anger events to induce negative emotions in participants, Cui et al. (2015) found that higher vagal reactivity was associated with better regulation of anger and sadness and more prosocial behavior in adolescents induced with negative emotions. Obradović et al. (2010) showed that children with high vagal reactivity showed more positive emotions toward social activities under low adversity conditions. Moreover, Calkins and Keane (2004) found that children with higher vagal reactivity throughout preschool years had fewer negative emotions, behavioral problems, and better social skills than those with lower vagal reactivity.

Self-compassion, as a healthy attitude toward oneself, may promote better vagal reactivity in individuals. Gilbert (2009) suggests that caring and supportive self-talk has similar effects to early attachment experiences. On this basis, self-compassion is linked to feelings of safety because one knows that failure or mistakes will not result in severe self-condemnation. According to Porges' polyvagal theory, when individuals feel safe, they tend to have higher physiological flexibility (Thayer and Lane, 2000; Porges, 2001). Thus, as an indicator of physiological flexibility, vagal reactivity should be improved by better self-compassion. Researchers have also explored the relationship between self-compassion and vagal reactivity to acute stress events, finding that self-compassion predicted athletes' vagal reactivity upon stress induction (Ceccarelli et al., 2019). A 12-week compassion intervention study also showed that improving self-compassion could enhance vagal reactivity in a distressed clinical sample (Steffen et al., 2021). However, no studies have explored the relationship between self-compassion and vagal reactivity in Chinese athletes. Based on the evidence above, it is plausible that self-compassion contributes to greater emotional resilience to failure in athletes, possibly through physiologically enhanced vagal reactivity.

1.1. Present research

In summary, self-compassion may be important for athletes to maintain emotional resilience in the face of failure, but this potential relationship needs to be empirically tested. As suggested by the polyvagal theory, self-compassion may influence emotional resilience to failure through vagal reactivity. Thus, it is important to investigate whether vagal reactivity, as a fundamental physiological process of stress regulation, is the underlying mechanism of this relationship. Accordingly, we conducted a laboratory-based observational study in a sample of college athletes to explore the influence of trait self-compassion on emotional resilience to failure and to verify whether vagal reactivity plays a mediating role (Figure 1). We specifically tested four hypotheses:

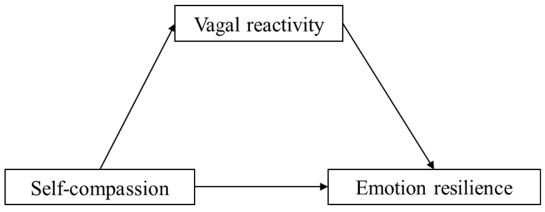

FIGURE 1
The hypothesized mediation model.

> *Hypothesis 1*: Self-compassion predicts athletes' better emotional resilience to failure (i.e., more positive emotions and better recovery from negative emotions after recalling failure events).
>
> *Hypothesis 2*: Self-compassion predicts higher vagal reactivity to recalled failure events in athletes.
>
> *Hypothesis 3*: Athletes' vagal reactivity predicts better emotional resilience to failure.
>
> *Hypothesis 4*: Vagal reactivity plays a mediating role between athletes' self-compassion and emotional resilience to failure.

2. Methods

2.1. Participants

Using G*Power to calculate the sample size, with $f^2 = 0.15$, $\alpha = 0.05$, and $power = 0.80$, we determined that at least 89 participants were required. We recruited participants from a sports university in Shandong Province, China through online advertisements. Participants were required to: (1) have experience in official competition; (2) not have physical conditions that might interfere with the measurement of HRV (e.g., concussion, sleep deprivation, and severe illness; Svendsen et al., 2016; Laborde et al., 2017); and (3) have the experience of sporting failures that they could clearly recall. 101 eligible participants were recruited, but six did not complete baseline measures, and five were unavailable for the laboratory session. Demographic information of the final sample is presented in Table 1. The sample comprised 90 college athletes (60 men, 30 women; mean age 20.79 ± 1.18 years; age range: 18–23 years). Participants competed in various fields, with handball (13.3%) and gymnastics (11.1%) most strongly represented.

TABLE 1 Demographic information of participants.

	N (%) / *M*±*SD*
Gender	
Male	60 (66.7)
Female	30 (33.3)
Age	20.79 ± 1.19
Training experience	
< 5 years	33 (36.7)
5–10 years	54 (60.0)
11–15 years	3 (3.3)
Sporting level	
International athlete	1 (1.1)
National athlete	2 (2.2)
National first-level athlete	41 (45.6)
National second-level athlete	6 (6.7)
Other	40 (44.4)
Highest competition experience	
National level	33 (36.7)
Provincial level	20 (22.2)
City level	20 (22.2)
Other	17 (18.9)

2.2. Procedures

Two days before the experiment, participants were informed not to consume any substances that may affect the stress response (such as alcohol, sedatives, and sleep aids) and to maintain a good sleep pattern (Svendsen et al., 2016; Laborde et al., 2017), aiming to ensure that their physiological data were as reliable as possible. The experiment was conducted in a laboratory without being interrupted. After giving fully informed consent, participants reported demographic information and completed the self-compassion measure. Next, the researcher helped each participant wear the physiological measurement equipment and instructed them to sit comfortably and relaxed with both of their feet flat on the floor, hands on their thighs, and palms facing up (Laborde et al., 2017) for 2 min (T1). Participants were told to remain still, as movement could interfere with the measurements. Next, physiological baseline data were recorded over a 5-min resting period (T2), with participants given the same instructions as during T1 and then asked participants to recall past sport failures (Ceccarelli et al., 2019) for 2 min (T3), again following the same instructions as those given at T1. Throughout the 2 min, the researcher read aloud cues prompting participants to recall their past failures. The prompts were adapted from the research of Ceccarelli et al. (2019). Each prompt was followed by a brief pause to give participants time to visualize the recalled failures. The prompts were as follows:

> Please recall a sport failure that happened in the past…Maybe you made a costly mistake, failed to meet an important goal, or experienced a setback in your sport progress?…Really try to take yourself back to this experience…What happened then?…Who was there?…And what about the surrounding environment?… How did you feel when this happened?… Maybe disappointment, anger, frustration, hopelessness?… Try to recall these feelings in as much detail as possible… Allow yourself to feel them… Recall the feelings of your body… tension, anxiousness, uneasiness… Imagine the scene in as much detail as possible…Try to bring yourself back to the feelings and emotions you are experiencing, as if back in that moment of failure… Now, please take a deep breath and gently open your eyes.

The recalling period (T3) was followed by a 5-min recovery period (T4), in which participants were asked to close their eyes but given no other prompts. Their emotional state was measured immediately after T3 and at the end of every minute during T4, with six measurements in total. Finally, participants rated the emotional difficulty and visual clarity of the event.

2.3. Measures

2.3.1. Demographics

Each participant reported age, gender, grade, specialist sport, training experience, sporting level, and highest competition experience.

2.3.2. Self-compassion

Participants completed the Self-Compassion Scale compiled by Neff (2003), comprising 26 items across six subscales that assess the three dimensions of self-compassion and their opposites: mindfulness (overidentification), self-kindness (self-criticism), and universal humanity (isolation). All items are scored on a five-point scale, ranging from 1 (*almost never*) to 5 (*almost always*). Higher scores on this scale indicate higher levels of self-compassion. In this study, the Self-Compassion Scale had good reliability ($\alpha = 0.87$).

2.3.3. Emotional resilience

It is suggested that emotional resilience can be indicated by individuals' ability to generate positive emotions and recover from negative emotions after adverse events (Davidson, 2000). Therefore, this study used the mean levels and the changes of positive and negative emotions after recalling failure events to measure athletes' emotional resilience to failure. Positive and negative emotional states are measured on different visual analog scales (Wolpe, 1990). For positive emotional state, 0 represents very calm, and 100 represents the most positive/pleasant emotional state, while for negative emotional state, 0 represents very calm, and 100 represents the most negative/unpleasant emotional state. Two indices were generated to assess positive emotion: the mean positive emotion and the rate of change in positive emotion during the recovery period (T4). Mean positive emotion was the average of the six repeated measures of positive emotion throughout T4. Meanwhile, the rate of change in positive emotion is measured by the slope obtained by regressing measurement time points (1–6) on the rated scores of positive emotion throughout T4. The larger the value of these two indicators, the better emotional resilience in terms of positive emotions. Mean negative emotion and the rate of change in negative emotion during the recovery period were generated in the same way. The smaller the value of the two indicators, the better emotional resilience in terms of recovery from negative emotions.

2.3.4. Vagal reactivity

Participants' HRV was measured using a Polar H10 chest strap (Rockliff et al., 2008; Arch et al., 2014). This device collects and processes HRV measurements by detecting electrical signals from the heart. The device was connected to the Elite HRV app on an iPad via Bluetooth 4.0. After data collection, the original R-R interval data in Elite HRV were downloaded to a Windows 10 laptop as a text file. They were imported to Kubios HRV software (version 3.1.0, Biosignal Analysis and Medical Imaging Group, University of Kupio, Finland, MATLAB).

Vagal reactivity can be reflected by the inhibitory effects of vagus on sinus node, which can be quantified by heart rate variability (Thayer and Sternberg, 2006). Therefore, as many previous studies did, our study used heart rate variability to measure vagal reactivity (Muhtadie et al., 2015; Stellar et al., 2015; Luo et al., 2018; Di Bello et al., 2020). There are two methods for measuring heart rate variability, time-domain and frequency-domain indicators. Studies using these two indicators showed relatively consistent findings regarding the relation between HRV and emotional response, as well as self-compassion (Eisenberg et al., 1996; Geisler et al., 2010; Kirby et al., 2017; Lischke et al., 2019; Di Bello et al., 2020). However, research suggested that while time-domain indicators such as RMSSD could be influenced by sympathetic input, frequency-domain indicators such as HF-HRV might better reflect cardiac vagal activity (Berntson et al., 1993, 2005). Moreover, prior studies also showed that HF-HRV was applicable in measuring the vagal activity of athletes (Davydov et al., 2015; Laborde et al., 2015; Ceccarelli et al., 2019). Therefore, this study used HF-HRV to measure vagal reactivity. Kubios was used to calculate HF-HRV (0.15–0.4 Hz, absolute units). HF-HRV values were log-transformed to better approximate a normal distribution in order to conform to parametric assumptions. In our study, we chose threshold-based correction to correct artifacts and ectopic beats. The number of corrected beats was controlled at a level of less than 5%. Drawing on the approach of Muhtadie et al. (2015), we calculated the baseline HF-HRV using HRV records throughout the last minute of T2, then calculated HF-HRV reactivity by subtracting the baseline HF-HRV (T2) from HF-HRV during the first minute of T3 (Stellar et al., 2015). For ease of interpretation, we multiplied HF-HRV reactivity by −1 so that the more significant number of HF-HRV reactivity denoted greater vagal reactivity (Muhtadie et al., 2015).

2.3.5. Validity of recall

We used two items to assess the validity of recall by reference to previous studies investigating athletes' responses to hypothetical and recalled scenarios of adverse events (Reis et al., 2015; Ceccarelli et al., 2019). Participants rated the emotional difficulty they experienced when recalling the failure event, using a six-point scale ranging from 1 (not at all) to 6 (extremely). They are also asked to report the visual clarity of the recalled sport failure, using a seven-point scale ranging from 1 (very blurred) to 7 (very clear).

2.4. Data analysis

SPSS 27.0 was used in this study to conduct descriptive statistics and regression analysis. Descriptive statistics were used to analyze the scores of the three variables and failure-induced manipulation tests. The macro program PROCESS of SPSS developed by Hayes (2013) was used to examine the mediating role of vagal reactivity between self-compassion and emotional resilience. First, a simple mediation analysis was performed. The analysis of the simple mediation effect model is to implement the following linear regression equation:

$$Y = cX + \varepsilon_1 \tag{1}$$

$$M = aX + \varepsilon_2 \tag{2}$$

$$Y = c'X + bM + \varepsilon_3 \tag{3}$$

where the regression coefficient c of equation (1) is the effect of independent variable X on dependent variable Y; the regression

TABLE 2 Mediation analyses of vagal reactivity between self-compassion and emotional resilience.

Path	*B*	*SE*	*p*	95%CI
SC → VR	0.37	0.17	0.03	[0.035, 0.697]
VR → Negative emotion change rate	−0.06	0.02	0.008	[−0.098, −0.015]
SC → VR → Negative emotion change rate	0.02	0.01	–	[−0.052, −0.003]
VR → Mean negative emotion	−0.24	0.10	0.02	[−0.428, −0.046]
SC → VR → Mean negative emotion	−0.09	0.05	–	[−0.221, −0.010]
VR → Positive emotion change rate	0.01	0.03	0.66	[−0.070, 0.044]
SC → VR → Positive emotion change rate	0.004	0.01	–	[−0.020, 0.029]
VR → Mean positive emotion	−0.10	0.12	0.45	[−0.350, 0.158]
SC → VR → Mean positive emotion	0.03	0.05	–	[−0.071, 0.152]

SC, self-compassion; VR, vagal reactivity; and CI, confidence intervals.

TABLE 3 HF-HRV values of different periods.

Variables	*M*	*SD*
T1-2 min HF-HRV	51.87	20.48
T2-1 min baseline HF-HRV	49.56	21.64
T3-1 min recall failures	54.99	20.80

coefficient a of equation (2) is the effect of independent variable X on mediator variable M; the regression coefficient b of equation (3) is the effect of M on Y after controlling the effect of X; the coefficient c' is the effect of X on Y after controlling the effect of M; ε_1, ε_2, and ε_3 represent residuals, assuming that the residuals follow a normal distribution and are independent of each other. Substituting (2) into (3), we get

$$Y = (c' + ab)X + \varepsilon_2 b + \varepsilon_3 \quad (4)$$

ab in equation (4) is the mediation effect of the independent variable X on the dependent variable Y; c' is the direct effect of X on Y, and $c' + ab$ is the total effect of X on Y (total effect), that is $c = c' + ab$. The mediation effects were tested with the Bootstrap method, in which the sample was repeatedly sampled 5,000 times (Preacher and Hayes, 2008). The confidence intervals (CI) of 95% were generated based on the bootstrapped results, and a 95% CI that did not include 0 indicated a significant mediation effect.

3. Results

The scores of emotional difficulty ($M = 3.86/6$, $SD = 1.09$) and visual clarity ($M = 4.70/7$, $SD = 1.17$) of the recalled sport failure were both above the mid-point of the corresponding scales (i.e., 3.5 and 4, respectively). Results indicated that the failure events were generally validly and effectively recalled (Ceccarelli et al., 2019).

The results of mediation analyses are presented in Table 2. Controlling for age and gender, results showed that higher self-compassion significantly predicted both a smaller rate of change in negative emotion ($c = -0.08$, $SE = 0.03$, $p = 0.01$) and lower mean negative emotion ($c = -0.35$, $SE = 0.15$, $p = 0.03$). However, self-compassion failed to significantly predict the rate of change in positive emotion ($c = 0.01$, $SE = 0.04$, $p = 0.86$) and mean positive emotion ($c = -0.04$, $SE = 0.20$, $p = 0.85$). Thus, higher self-compassion significantly predicted better recovery from negative emotions, but not more positive emotions, after recalling a sport failure, which partially supported Hypothesis 3.

Table 3 is the HF-HRV values of different periods. As shown in Table 2, higher self-compassion significantly predicted higher vagal reactivity when recalling a sport failure ($a = 0.37$, $SE = 0.17$, $p = 0.03$), thus supporting Hypothesis 2.

Higher vagal reactivity significantly predicted both smaller rate of change in negative emotion ($b = -0.06$, $SE = 0.02$, $p = 0.008$) and lower mean negative emotion ($b = -0.24$, $SE = 0.10$, $p = 0.02$). However, vagal reactivity significantly predicted neither the rate of change in positive emotion ($b = 0.01$, $SE = 0.03$, $p = 0.66$) nor mean positive emotion ($b = -0.10$, $SE = 0.12$, $p = 0.45$). These results showed that higher vagal reactivity significantly predicted better recovery from negative emotions, but not more positive emotions, after recalling a sport failure, which partially supported Hypothesis 3.

Vagal reactivity was found to have significant mediating effects between self-compassion and, respectively, the rate of change in negative emotion ($ab = 0.02$, $SE = 0.01$, 95% CI [−0.052, −0.003]) and mean negative emotion ($ab = -0.09$, $SE = 0.05$, 95% CI [−0.221, −0.010]). These indirect effects are 0.099 and 0.023, respectively, accounting for 25 and 24% of the total effects. Vagal reactivity did not significantly mediate self-compassion and, respectively, the rate of change in positive emotion ($ab = 0.004$, $SE = 0.012$, 95% CI [−0.020, 0.029]) and mean positive emotion ($ab = 0.03$, $SE = 0.054$, 95% CI [−0.071, 0.152]). The results partially supported Hypothesis 4. Self-compassion significantly predicted neither the rate of change in negative emotion ($c' = 0.06$, $SE = 0.03$, $p = 0.06$) nor mean negative emotion ($c' = -0.26$, $SE = 0.15$, $p = 0.09$) after controlling for the effects of vagal reactivity.

Self-compassion was not significantly associated with rate of change in negative affect ($c' = 0.06$, SE = 0.03, $p = 0.06$) and mean negative affect ($c' = -0.26$, SE = 0.15, $p = 0.09$; Figure 2).

4. Discussion

The primary objective of this study was to examine the effect of athletes' self-compassion on their emotional resilience to failure (i.e., positive emotions and recovery from negative emotions), as well as the potential mediating role of vagal reactivity. Results showed that self-compassion did not significantly predict athletes' positive emotions, but higher self-compassion did significantly predict better recovery from negative emotions after recalling failure events. Furthermore, vagal reactivity when recalling failure events significantly mediates self-compassion and recovery from negative emotions.

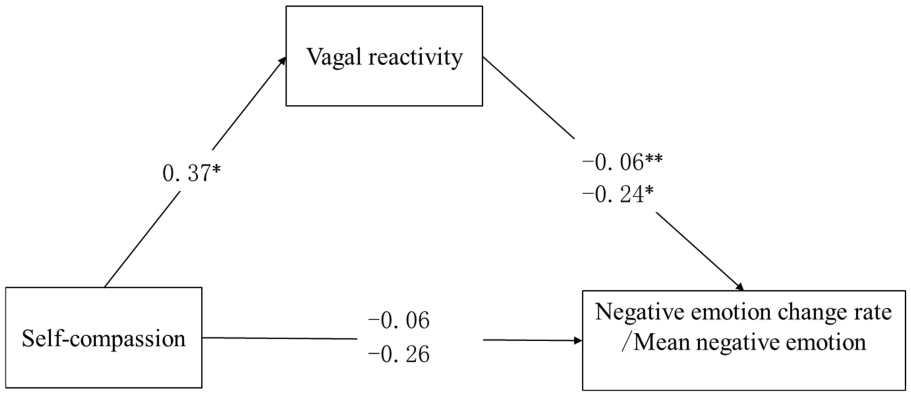

FIGURE 2
Results of the mediation model. *p<0.05 and **p<0.01. The upper coefficient is the standardized regression coefficient when the outcome variable is negative emotion change rate. The lower coefficient is the standardized regression coefficient when the outcome variable is mean negative emotion.

4.1. Self-compassion and athletes' emotional resilience to failure

Our results demonstrated that higher self-compassion could significantly predict better emotional resilience in terms of recovery from negative emotions: athletes with higher self-compassion demonstrated less negative emotion and a faster recovery rate of negative emotion after recalling a failure event. This is consistent with previous results in the general population (Neff and Vonk, 2009; Poots and Cassidy, 2020), which have shown that people with high self-compassion tend to engage less in excessive thinking and thought inhibition (Neff, 2003; Neff and Knox, 2016) and typically take a more balanced approach toward their emotional experience, neither avoiding nor dwelling on negative emotions (Neff and Vonk, 2009; Poots and Cassidy, 2020). Consequently, individuals with high self-compassion can recover faster from negative emotions. Athletes are more accustomed to treating themselves harshly than the general population and worry that self-compassion will hinder their progress (Ferguson et al., 2014). However, our findings showed a positive connection between self-compassion and recovery from negative emotions after recalling a failure in an athlete sample. When failures or setbacks occur, it is important for athletes to recover quickly from negative emotions. Because negative emotions could narrow people's momentary thought–action repertoire (Fredrickson, 2001) and lead to energy depletion (Ekman, 1999; Lundqvist and Kenttä, 2010), which might substantively impair athletes' performance, therefore failure to rapidly recover after a negative event can increase vulnerability to emotional disorders, particularly for an individual frequently exposed to negative events (Davidson, 2000). So developing emotional resilience can help athletes recover quickly from setbacks in training or competition and, ultimately, positively impact their performance, long-term health and well-being. While failures are inevitable and frequent in athletes' careers, our findings highlight the possible role of self-compassion in athlete development because this positive psychological trait might help build up athletes' ability to better recover from negative emotions caused by failure.

However, this study did not find significant associations between athletes' self-compassion and positive emotional experiences after recalling sport failure. This finding is inconsistent with the results for Western populations (Mantelou and Karakasidou, 2017). However, prior studies have shown that mindfulness interventions could effectively improve positive emotions in Western people (Anderson et al., 2007; Schroevers and Brandsma, 2010) but not in Chinese populations (Liu et al., 2013). Researchers have suggested that Chinese culture may explain this difference, which emphasizes the state of tranquility—contrasting with the hedonism and self-realization view of happiness in Western culture (Gao et al., 2010). Thus, Chinese people may place higher values on safe or content positive affect (e.g., safe) and relaxed positive affect (e.g., calm) than activated positive affect (e.g., excited; Gilbert et al., 2008). Thus, the influence of self-compassion on positive emotional experience after failure may be more manifested as the effect on safe/content/calm affect in the Chinese population. This study used a single item to broadly measure participants' positive emotional state, and so may not have captured the impact of self-compassion on athletes' experience in terms of safe/content/calm positive affect. Therefore, future research should specifically measure safe/content/calm positive affect, for instance, by using the Affect Balance Scale or the Activation and Safe/Content Affect Scale (Gilbert et al., 2008).

4.2. The mediating role of vagal reactivity

More importantly, we found that vagal reactivity mediated the relationship between self-compassion and athletes' emotional resilience to failure. To the best of our knowledge, this is the first study exploring the mechanism by which self-compassion affects emotional resilience in athletes. Specifically, our findings showed that athletes with higher self-compassion had higher vagal reactivity when recalling a failure event, thereby demonstrating better recovery from negative emotions after recalling the failure.

Our findings showed that higher self-compassion predicted higher vagal reactivity to failure. This is consistent with previous results in Western groups (Ceccarelli et al., 2019; Steffen et al., 2021). Our study replicates prior findings in a sample of Chinese athletes. This association suggests that self-compassion may benefit athletes' physiological flexibility in times of stress. According to the Cognitive Activation Theory of Stress (Ursin and Eriksen, 2004),

cognitive processes may extend the duration of physiological stress responses. Thus, when an athlete is unable to regulate negative thoughts about the stressful situation, the stress response would not be "switched off," and the psychophysiological activation would remain high, which can undermine the functioning of physiological systems (Gilbert, 2009). While people with higher self-compassion tend to have a better ability to accept and tolerate negative experiences (Neff et al., 2005; Diedrich et al., 2014) and use less maladaptive regulation strategies such as avoidance, thought suppression, and rumination (Neff et al., 2005, 2007; Barnard and Curry, 2011), they may thereby be equipped with better physiological resources to stress.

While higher self-compassionate athletes possessed higher vagal reactivity in the face of failure, they could thereby recover better from negative emotions after the event. Such findings are consistent with the polyvagal theory, which argues that vagal reactivity is the basis for flexible adaptation (Porges, 1995, 2001, 2003, 2007). On this basis, athletes with higher vagal reactivity are more likely to respond effectively to changes in the environment. When negative emotions occur due to undesirable stimuli such as failure, these athletes may show more adaptive emotional responses and faster recovery from negative emotions. This is crucial in highly competitive sports, in which athletes' performance is substantively affected by their momentary mental and physical state: rapid and adaptive physiological and emotional responses to incidental failures may be critical determinants of ultimate victory and long-term progress.

The positive role of self-compassion in athletes' vagal reactivity and emotional resilience to a failure we found in this study further emphasizes the importance of self-compassion for athletes. Previous studies have also shown that self-compassion positively influences athletes' adaptive thoughts, behaviors, and potential personal development (Ferguson et al., 2014; Lizmore et al., 2017; Ceccarelli et al., 2019). Worth noted, self-compassion has been found intervenable via different types of well-established clinical programs (e.g., Mindful self-compassion program; Neff and Germer, 2013 and compassion-focused therapy; Gilbert, 2009). In the sporting domain, Mosewich et al. (2013) also developed a 7-day self-compassion intervention for athletes. Evidence from a randomized control trial showed that female athletes receiving this intervention demonstrated enhanced self-compassion, as well as decreased self-criticism and rumination, and these improvements were maintained 1 month later. These findings, together with ours, implicate the practical utility of training self-compassion to facilitate athletes' career development. Future studies may further develop intervention programs of self-compassion and test their efficacy in a broader sample of athletes.

Finally, our study has several limitations. First, this study relied on recalled rather than actual failure stimuli, which may bias athletes' physiological and emotional responses. Future research could examine the relationship between self-compassion and emotional resilience and the mediating role of vagal reactivity under standardized laboratory stressor conditions or in real-life failure scenarios in training or competition. Second, as mentioned above, our measure of positive emotion did not differentiate the types of positive affect, which may have neglected the culture-specific emphasis on safe/content positive affect or relaxed positive affect in the Chinese population. We recommend future research to add measures of safe/content/calm positive affect to further examine the influences of self-compassion on athletes' positive feelings of safety or contentment after failure. Third, we assessed vagal reactivity using a 1-min HF-HRV mean. Although measurements over such a short period can be considered reliable (Esco and Flatt, 2014; Laborde et al., 2017), future research should test the robustness of our findings by measuring HF-HRV over a longer time period. Fourth, our findings do not allow inferences of causality because this study did not involve manipulations of self-compassion or vagal reactivity. Future studies could employ appropriate experimental designs to examine the causal relationship between self-compassion and emotional resilience to failure and the mediating role of vagal reactivity.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by College of psychology, Beijing Sports University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

NZ, JH, and JY: conceptualization and writing—review and editing. NZ and JH: data curation. NZ: investigation and writing—original draft. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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EDITED BY
Zi Yan,
Merrimack College, United States

REVIEWED BY
Charles Huang,
Wayland Baptist University, United States
Lucas Murrins Marques,
University of São Paulo, Brazil

*CORRESPONDENCE
Xianxiong Li
✉ lixianxiong@hunnu.edu.cn
Zan Gao
✉ zangao@utk.edu

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Acute effects of exergaming on young adults' energy expenditure, enjoyment, and self-efficacy

Dandong Gu[1], Chenling Gu[2], John Oginni[3], Suryeon Ryu[4], Wenxi Liu[5], Xianxiong Li[6]* and Zan Gao[3]*

[1]School of Physical Education, Hengyang Normal University, Hengyang, China, [2]Central South University of Forestry and Technology, Changsha, China, [3]Department of Kinesiology, Recreation, and Sports Studies, University of Tennessee, Knoxville, TN, United States, [4]School of Kinesiology, University of Minnesota–Twin Cities, Minneapolis, MN, United States, [5]Department of Physical Education, Shanghai Jiao Tong University, Shanghai, China, [6]School of Physical Education, Hunan Normal University, Changsha, China

This study investigated the effects of a dance-based exergaming on Chinese college students' energy expenditure, self-efficacy, and enjoyment in comparison with the traditional aerobic dance exercise. Forty young adults (33 females; Mage = 21.55 years, SD = 2.06) completed two separate 20 min exercise sessions with 10 min intervals on the same day: (1) Xbox 360 Kinect Just Dance exergaming session; and (2) a traditional instructor-led aerobic dance exercise session. Participants' energy expenditure (Kcal/session) was measured by the ActiGraph GT9X Link accelerometers, and their perceived self-efficacy and enjoyment were assessed via validated surveys following each session. Dependent t-test indicated significant differences in participants' enjoyment ($t = -1.83$, $p = 0.04$). Specifically, participants in the dance-based exergaming session reported a higher level of enjoyment (M = 3.96, SD = 0.65) as compared to the aerobic dance session (M = 3.61, SD = 0.54). However, there was no significant difference in energy expenditure and self-efficacy between the two sessions. Findings suggest that college students had comparable energy expenditure as the traditional aerobic dance session while experiencing more fun and enjoyment. This suggests that exergaming can be a fun exercise alternative for promoting physical activity among young adults.

KEYWORDS

accelerometers, college students, Just Dance, exergaming, perceived enjoyment, physical activity, self-efficacy

1. Introduction

Physical inactivity and sedentary behavior can have a severe negative impact on adults. It can increase the risk for heart disease, stroke, high blood pressure, Type 2 diabetes, and certain types of cancer (Santos-Lozano et al., 2021; Sheng et al., 2021; Xiao and Rosenzweig, 2021; Zhu, 2022). It can also lead to mental health issues such as depression, anxiety, and low self-esteem (Gao and Lee, 2022). Furthermore, physical inactivity and sedentary behavior can also lead to weight gain, joint pain, poor balance and coordination, and weak muscles (Pellegrini et al., 2016; Lee et al., 2019). Therefore, it is essential to make physical activity and a healthy lifestyle a priority to maintain overall health and well-being in young adults, including college students. As known, regular physical activity helps to maintain a healthy weight and lowers blood pressure, which reduces the risk of developing type 2 diabetes, heart disease, and other chronic

diseases (Jennings et al., 1989; Chen et al., 2022; Gao and Lee, 2022). By staying active, college students can improve their overall physical fitness and reduce their risk of developing chronic diseases (Vainshelboim et al., 2019). Regular physical activity can also help reduce stress, improve mood, and increase energy levels (Jennings et al., 1989; Chen et al., 2022; Gao and Lee, 2022). College students can engage in physical activities such as running, jogging, and cycling to help them stay fit and healthy.

Physical activity engagement among college students has been on a downward trend in recent years. Studies have found that only a small percentage of college students are meeting the recommended amount of physical activity and that most are not engaging in any physical activity at all (Douglas et al., 1997; Ferreira Silva et al., 2022). For example, recent studies have shown that physical activity engagement in Chinese college students is declining (Yuan et al., 2018; Wang, 2019; Bao et al., 2020). With the growing prevalence of digital devices and the development of technology, physical activity has been increasingly replaced by sedentary activities. This has resulted in the decrease of physical activities among Chinese college students (Yuan et al., 2018; Xu et al., 2021). Additionally, due to the high academic pressure and the lack of leisure time, students are not motivated to exercise, leading to an overall decrease in physical activity (Li et al., 2022). Although there are some efforts to encourage physical activity, such as the launch of various sports activities and the construction of sports facilities on campuses, the current physical activity engagement level among college students in China is still too low. As a result, college campuses should now make an effort to create more accessible and engaging opportunities for physical activity, such as intramural sports, outdoor recreation, and exergaming activities and events.

In the past decade, exergaming has proven to be an effective way to promote physical activity and health in individuals (Douris et al., 2012; Gao et al., 2012; Gao and Xiang, 2014; Benzing and Schmidt, 2018; Ye et al., 2019; Gonçalves et al., 2021; Baysden et al., 2022; Pasco and Roure, 2022; Sadeghi and Jehu, 2022; Sousa et al., 2022). Exergaming combines video gaming with physical activity, which helps to make exercise more enjoyable and accessible. It provides an alternative to traditional physical activity, making it more appealing and accessible to college students (Siegel et al., 2009; McDonough et al., 2018, 2020). Research has shown that exergaming can be an effective way to encourage individuals to become more physically active in college students (McDonough et al., 2018). Research has found that exergaming can increase energy expenditure among players (Gao et al., 2019; O'Loughlin et al., 2020; Mohd et al., 2021). This can be especially helpful for college students who may not have the time or resources to fit in regular exercise and can benefit from a fun and engaging activity.

Studies have shown that exergaming can lead to increased motivation, self-efficacy, and enjoyment in college students (Siegel et al., 2009; Liu et al., 2019; McDonough et al., 2020; Pasco and Roure, 2022; Sousa et al., 2022). It has been found that college students who regularly engage in exergaming have higher levels of self-efficacy and an improved sense of enjoyment in physical activity (McDonough et al., 2018, 2020). Additionally, the interactive and social components of exergaming can help create a sense of camaraderie among participating students. Furthermore, exergaming can provide an engaging and fun way to meet the recommended levels of physical activity in college students. Overall, exergaming is an effective tool for promoting self-efficacy and enjoyment in college students.

Recent studies have compared outcome variables of various exergaming modalities (e.g., virtual reality, and Xbox) to traditional exercise (e.g., cycling) (Zeng et al., 2017; McDonough et al., 2018; Liu et al., 2019; McDonough et al., 2020; Zeng et al., 2022). Taking into consideration the literature reviews and the limitations noted in earlier studies, we understand that different physical activity modalities may have varying effects on individuals' physiological and psychological outcomes. However, few studies compare the effects of exergaming aerobic dance and traditional aerobic dance among college students (Gao et al., 2013). This study aims to compare the effects of exergaming aerobic dance to traditional aerobic dance on the physiological and psychological outcomes of young adults. We hypothesize that energy expenditure will be similar, but that self-efficacy and enjoyment will be higher when using exergaming aerobic dance. The results of this study could provide health professionals, physical educators, and young adults with a greater range of activities to promote physical activity and help to identify which exergaming programs are most effective in promoting self-efficacy and enjoyment while sustaining energy expenditure.

2. Materials and methods

2.1. Participants and the research setting

In the summer of 2018, forty young adults (33 females, 7 males) were recruited from a Southcentral Chinese University. The inclusion criteria were that participants must be enrolled at the university, aged between 18 and 25 years, in good health (i.e., no physical or mental diseases/conditions preventing PA participation), and had provided their informed consent. University research ethics approval and participant written consent forms had been obtained prior to data collection.

During the scheduled time slots at the campus fitness gym, those who agreed to participate completed two separate 20 min dance sessions: (1) non-stop exergaming aerobic dance (Xbox 360 Kinect Just Dance – Just Sweat around the World); and (2) traditional aerobic dance led by an experienced instructor. Specifically, Xbox 360 Kinect Just Dance is an interactive gaming experience that combines the technology of the Xbox 360 Kinect sensor with the popular rhythm-based game Just Dance. The Xbox 360 Kinect sensor allows players to control the game through their body movements, eliminating the need for traditional controllers. This innovative technology creates a more immersive and engaging gameplay experience, as players can dance, jump, and move in time with the on-screen characters. With a range of popular songs and dance routines to choose from, players can showcase their skills and compete against friends and family in a variety of game modes. Whether the player is a seasoned dancer or a complete beginner, Xbox 360 Kinect Just Dance offers a fun and accessible way to get moving and improve an individual's coordination. In the present study, Just Dance – Just Sweat around the World was selected, as it was the perfect game for those young adults who loved to dance and wanted to incorporate a fun and challenging workout into their routines. Developed by Ubisoft, this specific game features a range of high-energy dance routines set to popular songs from around the world. With the Just Sweat mode, players can track their calories burned and set personalized fitness goals, making it a great way to stay motivated and improve overall fitness. The game can

be played alone or with friends, and with a variety of difficulty levels and dance styles. In this study, participants were paired up to play the exergaming dance (See Figure 1). On the other hand, in the present study, the traditional aerobic dance session was led by an experienced instructor in the fitness gym. As known, traditional aerobic dance is a popular form of exercise that has been enjoyed by adult fitness enthusiasts for decades. With its high energy music, choreographed routines, and enthusiastic instruction, aerobic dance offers an engaging and effective way to improve cardiovascular health, burn calories, and increase muscle strength and endurance. The aerobic dance workout involved a series of choreographed dance routines that incorporate a range of movements such as jumping jacks, grapevines, and side-to-side shuffles. The instructor demonstrated the moves, provided verbal cues and encouragement, and adjusted the intensity of the workout to suit the needs of the participants. In this study, two participants were paired up to engage in aerobic dance activities led by the experienced instructor (See Figure 2).

To ensure that the results of this study were not influenced by the order in which participants were tested, we employed a counterbalancing technique. All study procedures were conducted following the ethical standards set out in the 1964 Helsinki Declaration and its later amendments (World Medical Association, 2013) and were approved by the Institutional Review Board at the University. Written informed consent was obtained from each participant before data collection.

2.2. Procedures

Before beginning the dance sessions, trained research assistants collected participants' demographic and anthropometric information. Participants were randomized split into two groups and completed a 20 min exergaming dance session and a 20 min instructor-led aerobic dance sessions (See Figures 1, 2) in a counterbalanced order. To avoid potential carry-over effects between sessions, participants had a 10 min break to allow their blood pressure and heart rate to return to baseline levels. They also wore accelerometers on their hips before the exercise sessions and responded to a questionnaire evaluating their perceived self-efficacy and enjoyment following each dance session during the breaks.

FIGURE 1
Exergaming dance.

The exergaming session took place at a console station set up on one side of the fitness gym and utilized Xbox 360 Kinect Just Dance — Just Sweat Around the World, including 4–5 moderate intensity dance exercise in a row. Participants followed the actual dance moves of the dancer that appeared in the game, with no transition time between dances as set by the game console. The aerobic dance session was conducted on the other side of the fitness lab, with a well-trained instructor guiding participants through a series of aerobic dances. The instructor led the dance exercise at the moderate intensity which was the same or similar level of Just Dance.

2.3. Measures

2.3.1. Demographic and anthropometric data

On a demographic questionnaire, participants provided their date of birth, sex, college classification, and race/ethnicity. Height was determined to the closest 0.1 cm with the aid of a Seca stadiometer (Seca, Hamburg, Germany), while weight and body fat percentage were measured using the InBody 230 Body Composition Analyzer (Biospace, Seoul, Korea). Subsequently, BMI was computed as weight [kg]/height [m2] (Centers for Disease Control and Prevention, n.d.). Participants were also asked to report their prior experience with playing exergaming.

2.3.2. Energy expenditure

In this research, the participants wore an ActiGraph Link GT9X accelerometer (ActiGraph, Pensacola, FL, United States) on the right hip to measure energy expenditure. The ActiGraph Link GT9X accelerometer is a small wearable device used to measure physical activity and movement patterns. It is commonly used in research studies to assess physical activity levels and sedentary behavior in pediatric and adult populations. The device is compact and light-weight, weighing only 16 grams, and can be worn on the wrist, hip, or ankle. It uses triaxial accelerometry, which measures movement in three dimensions, to capture detailed information about physical activity patterns, including intensity, frequency, and duration. The device is equipped with a range of features, including a customizable sampling rate, activity classification algorithms, and the ability to measure sedentary behavior, sleep quality, and energy expenditure. It also includes a built-in triaxial gyroscope and magnetometer, allowing for more precise movement tracking. Overall, the ActiGraph Link GT9X accelerometer is a valid and reliable tool for measuring physical activity and energy expenditure, making it a valuable tool for researchers, clinicians, and healthcare professionals in a wide range of settings (McDonough et al., 2018; Zeng et al., 2022). In the present study, activity intensity can be classified into different categories based on established cut points, as the sum of activity counts in an epoch shows a linear relationship with activity intensity.

Given the short duration of the exercise session and the aims of this study, activity counts were measured in 1-s epoch, and physical activity levels were quantified as average activity counts per 1 s for

FIGURE 2
Traditional aerobic dance.

TABLE 1 Demographic Characteristics of Participants ($N = 40$).

Characteristics	N	% of total sample
Previous just dance experience (n some: n none)	1:39	
Gender		
Male	7	17.5
Female	33	82.5
Ethnicity		
Han	39	97.5%
Dong	1	2.5%
College Classification		
Sophomore	16	40%
Junior	5	12.5%
Senior	9	22.5%
Graduate students	10	25%
	Mean	*SD*
Age (years)	21.55	2.06
Height (cm)	162.68	6.71
Weight (kg)	55.61	9.77
BMI (kg/m^2)	20.86	2.06

BMI, body mass index.

activity intensities. Cut points established by Freedson adult VM3 (1998) were applied to the data. In detail, for the ActiGraph accelerometer, the cut points are 100 counts per minute (cpm) for sedentary behavior, 100–1951 cpm for light activity, 1952–5,724 cpm for moderate activity, and above 5,725 cpm for vigorous activity. These cut points have been widely used in research studies and are useful for comparing physical activity levels across adult populations and settings. Similarly, the METs cut points from Freedson adult (1998) were adopted in this study. Participants' percentage of time spent in different intensities of physical activity was recorded, and their total kilocalories taken over each 20-min session were calculated as energy expenditure. ActiLife software version 6.13.3 (Actigraph, United States) was used to set up the GT3X+ and to analyze these data.

2.3.3. Self-efficacy and enjoyment

After each exercise session, participants responded to a 3-item self-efficacy survey and a 5-item enjoyment survey, both using a 5-point Likert-type scale (1: strongly disagree to 5: strongly agree) (Zeng et al., 2017). The self-efficacy survey items asked participants with the stem question "With regard to the [traditional aerobic dance or exergaming dance], I have confidence in…" and then rated their confidence in their ability to do well in the activity, learn skills, and perform in it. The enjoyment survey items asked participants to rate their fun doing the activity, preference to do it over other things, wanting to play it more, preferring to watch rather than play (reverse-coded) and overall likes for the activity. Item means were calculated from the answers on both surveys and used as measures of participants' self-efficacy and enjoyment of the two types of exercise.

2.4. Data analysis

The research assistant entered the data electronically into SPSS while ensuring accuracy and proper documentation. Additionally, the data was kept confidential, password protected and was organized and cleaned to facilitate analysis. Furthermore, the data was stored electronically in a format that allows for exportation to statistical packages. Descriptive statistics were first calculated, followed by the dependent t-test to analyze the mean difference in energy expenditure between the two dance sessions. Subsequently, two dependent t-tests were executed to assess the difference in self-efficacy and enjoyment between the sessions. All statistical analyses were conducted in SPSS 28.0 (SPSS Inc., Chicago, IL, USA) with the significance level set at 0.05. Effect sizes (partial eta squared; η^2) were reported for each comparison, with values of 0.01, 0.06, and 0.14 or higher interpreted as small, medium, and large, respectively (Richardson, 2011).

3. Results

Full demographic and baseline anthropometric information for all participants is provided in Table 1. The final sample comprised 40 young adults (Female = 33; mean age = 21.55 years, SD = 2.06). In the final sample, the majority ethnicity of participants was Han Chinese (n = 39, 97.5%) compared to the other ethnicity Dong (2.5%). In terms of college classification, 40% were sophomores, followed by graduate students (25%), seniors (22.5%), and juniors (12.5%). Additionally, only 5% of participants played an exergaming dance before participating in this study.

Data screening was conducted prior to the main analysis. The result yielded that all study variables were normally distributed, meaning no outliers existed in the present study. In general, the Chinese college students displayed relatively moderate to high self-efficacy and perceived enjoyment toward both dance activities, as mean scores for their self-efficacy and perceived enjoyment were above the midpoint (i.e., 3 for self-efficacy and perceived enjoyment). The participants yielded over 100 kilocalories in both dance activities in the 20 min sessions. Interestingly, these Chinese college students

showed large variability in the percentage of time spent in moderate-to-vigorous physical activity, ranging from 17.50 to 69.17% for the traditional dance class, and from 10.83 to 80.00% for the exergaming dance class. They also displayed large variability in the percentage of time spent in light physical activity, ranging from 19.17 to 67.50% for the traditional dance class, and from 16.67 to 76.67% for the exergaming dance class. Additionally, the participants demonstrated large variability in the percentage of time spent in sedentary behavior, ranging from 1.60 to 41.05% for the traditional dance class, and from 3.33 to 41.09% for the exergaming dance class.

When comparing participants' energy expenditure between exergaming aerobic dance and traditional aerobic dance (see Table 2), participants had similar kilocalories in traditional aerobic dance as they did in exergaming dance ($p > 0.05$) during the 20 min sessions. Also, no significant difference was observed for self-efficacy across both groups ($p > 0.05$). The results, however, indicate a significant main effect reported between two sessions for perceived enjoyment. In detail, traditional aerobic dance showed significantly lower enjoyment ($t = -1.83$; $p < 0.05$) compared to exergaming aerobic dance with a large effect being found.

4. Discussion

In this study, the energy expenditure, self-efficacy, and enjoyment of Chinese young adults were compared while they practiced exergaming dance and traditional aerobic dance. The results indicate that Chinese college students used the same energy while doing either exergaming dance or traditional aerobic dance, and the self-efficacy was similar in both activities. Notably, participants enjoyed exergaming dance significantly more than traditional aerobic dance.

In terms of energy expenditure, our data illustrated that college students' energy expenditure in exergaming dance did not differ significantly from that of traditional dance. It is essential to investigate if this game-like exercise produces a similar physiological response to traditional aerobic dance, since increased energy expenditure during physical activity is essential for burning calories (Gao et al., 2013; Malone et al., 2019). This examination would build a body of evidence to determine if this form of exergaming can be used to promote health in young adults. Energy expenditure in exergaming is often compared to traditional aerobic exercise because it can provide many of the same benefits with some additional advantages (Hwang et al., 2019; Çakir-Atabek et al., 2020; Park et al., 2020; Ferreira et al., 2022). Exergaming typically requires the user to physically engage with the game (e.g., by hopping or jumping) just like traditional aerobic exercise does (McDonough et al., 2018; Oppici et al., 2022; Pasco and Roure, 2022; Sousa et al., 2022). This physical engagement can be seen as a form of exercise and has been shown to increase energy expenditure in some cases.

TABLE 2 Descriptive statistics for outcome variables ($N = 40$).

	Traditional dance		Exergaming dance		p	η^2
	Mean	*SD*	*Mean*	*SD*		
Energy expenditure	106.76	35.63	104.14	28.87	0.65	0.01
Self-efficacy	4.05	0.61	3.95	0.80	0.30	0.03
Enjoyment	3.61[a]	0.54	3.96	0.65	0.04	0.30

[a]significantly less than exergaming dance ($p < 0.05$).
SD, standard deviation.

We found that young adults demonstrated similar self-efficacy in exergaming dance as they did in traditional aerobic dance. The finding fails to provide support for the second hypothesis and is inconsistent with the findings in the pediatric population (Gao et al., 2013). Adults' self-efficacy of exergaming is similar to traditional aerobic exercise because both activities require the same physical and mental effort to be successful. The physical exertion necessary for exergaming is similar to that of traditional aerobic exercise, as both activities involve intense physical movement and require a great deal of endurance (McDonough et al., 2018; Liu et al., 2019; McDonough et al., 2020). Mental effort is also similar, as both activities require focus and concentration to reach desired results (McDonough et al., 2020; da Silva et al., 2022; Meulenberg et al., 2022). Additionally, both activities can improve physical health, as they both promote increased heart rate, improved cardiovascular health, and increased muscular strength and endurance. Ultimately, adults' self-efficacy of exergaming dance and traditional aerobic exercise are similar because they both require physical and mental effort to be successful.

The finding is in line with our hypothesis, as exergaming might be more attractive and enjoyable than traditional aerobic exercise. It is congruent with previous research literature comparing aerobic exercise modalities in pediatric and adult populations (Gao, 2012; Gao et al., 2013, 2014). Adults often find exergaming more enjoyable than traditional aerobic exercise because it adds an element of fun and competition (McDonough et al., 2018; Morais et al., 2022). Exergaming combines the physical activity of traditional aerobic exercise with the engagement and interactivity of video games, making it an enjoyable and immersive experience. Exergaming also encourages exploration and encourages players to try new activities, as there is a wide variety of exergames to choose from. Because of the fun and engagement of exergaming, adults are more likely to commit to their fitness goals and enjoy the process of working out (McDonough et al., 2018; Seo et al., 2023). In addition, exergaming often includes features that may increase motivation to play, such as attractive visuals or rewards for reaching certain goals. This can make exergaming more enjoyable than traditional aerobic exercise and can lead to longer, more consistent exercise sessions (McDonough et al., 2018; Liu et al., 2019). Overall, exergaming can offer similar benefits to traditional aerobic exercise while providing additional features to increase motivation and enjoyment.

Overall, exergaming dance has become an increasingly popular form of exercise for young adults. This type of exercise combines physical activity with interactive gaming elements to create a fun and engaging workout experience. Compared to traditional aerobic exercise, exergaming dance offers similar energy expenditure and self-efficacy, but higher enjoyment and increased motivation for physical activity. Additionally, exergaming dance is a novel way to exercise, providing a refreshing break from the monotony of ordinary workouts. Ultimately, exergaming dance is a great way for young adults to get active, stay fit, and have fun. This study is unique in that it measures the effects of two different types of dances (exergaming dance and traditional aerobic dance) on energy expenditure, self-efficacy, and enjoyment in Chinese college students. However, several limitations should be noted. These include not examining differences

between male and female students, unbalanced sample size between male and female participants, not collecting information on physical activity and diet history, and the fact that this is only a one group pre-test and post-test experiment, meaning cause and effect relationships cannot be established. The dominance of one gender in the study might affect generalization. In addition, we did not conduct the power calculation to determine the sample size in this preliminary study, and thus the sample size may have compromised the results. Also, although we screened and sorted the data, we did not perform the absence of outliers testing and there is a chance for us to omit a few outliers in this study. To gain a better understanding of the effects of exergaming dance, further research using true experimental designs and decent sample is needed.

5. Conclusion

This study suggests that exergaming aerobic dance can have a beneficial effect on the enjoyment of Chinese young adults. Specifically, energy expenditure in exergaming is comparable to traditional aerobic exercise in Chinese young adults. Exergaming is an effective form of exercise because it encourages the user to exert energy and physical effort to achieve a desired outcome. In addition to burning calories, exergaming can be an enjoyable and motivating form of exercise for those who prefer to stay active without the monotony of traditional aerobic exercise. Exergaming can also provide a more immersive experience than traditional aerobic exercise, as users can interact with the game, which can lead to increased engagement and motivation while exercising (McDonough et al., 2018; Liu et al., 2019). The results suggest that young adults could be more inclined to take part in gaming-based exercise if they expend the same amount of energy as they would in traditional aerobic exercise. Further research is needed to determine which type of exergaming is most beneficial to young adults' health and well-being when engaging in physical activities.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics review committees at Hunan Normal University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

The author would like to thank the co-authors for their help to complete this study. During the construction of this study, DG and CG played a role in data sorting and writing the article. WL and XL played a role in data collection and paper editing. JO and SR played a role in helping write the article. ZG played a role in developing the research ideas, overseeing data collection and analysis, and revising the article. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EDITED BY
Guodong Zhang,
Southwest University, China

REVIEWED BY
Xiang Cai,
Guilin University of Electronic Technology, China
Wenfeng Liu,
Hunan Normal University, China
Zi Yan,
Merrimack College, United States

*CORRESPONDENCE
Huilin Wang
✉ 1150141@hnust.edu.cn

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Association of mindfulness on state-trait anxiety in choking-susceptible athletes: mediating roles of resilience and perceived stress

Yiwei Tang[1], Longjun Jing[1], Yang Liu[2] and Huilin Wang[2]*

[1]School of Physical Education, Hunan University of Science and Technology, Xiangtan, China, [2]School of Business, Hunan University of Science and Technology, Xiangtan, China

Introduction: It is a well-documented psychological phenomenon for athletes to experience abnormal performance on the field, often called choking. Negative emotions such as perceived stress and state-trait anxiety have been linked to this phenomenon. In an effort to delve into the intricate relationship between mindfulness and state-trait anxiety among athletes susceptible to choking, this study was conducted in Central China during the period from October to November 2022.

Methods: The sample selection process employed a combination of cluster sampling and random sampling, resulting in a total of 377 viable samples encompassing choking-susceptible athletes who frequently grapple with state-trait anxiety and demonstrate performance deviations. The data analysis was executed utilizing AMOS v.26.

Results: The results indicate a negative association between mindfulness and perceived stress (standardized coefficient = −0.224, $p < 0.001$), resilience and perceived stress (standardized coefficient = −0.237, $p < 0.001$), as well as perceived stress and state-trait anxiety (standardized coefficient = 0.510, $p < 0.001$). The positive impact of mindfulness on state-trait anxiety is mediated by resilience and perceived stress (standardized indirect effect = 0.237, $p < 0.001$). The explanatory power of this study is $R^2 = 0.35$.

Discussion: Drawing from these substantial findings, a key recommendation is to implement mindfulness training programs for athletes prone to choking. This proactive measure, facilitated by sports departments, clubs, and coaches, could potentially alleviate state-trait anxiety, enhancing athletes' mental well-being and optimizing their performance outcomes during competitions.

KEYWORDS

choking-susceptible athletes, mindfulness, resilience, perceived stress, state-trait anxiety

1. Introduction

In high-stakes sports competitions, athletes are expected to perform at their best under pressure. However, some athletes may experience a phenomenon called choking, which leads to abnormal performance and can result in a loss. Many sports psychology scholars have defined choking as the result of athletes trying too hard to win the championship (Baumeister, 1984; Hill et al., 2010). Pressure is believed to destroy habitual exercise methods, leading to a decline in

performance and reflecting the participation of effort (Baumeister and Showers, 1986). Although factors such as pre-match preparations, physical conditions, and injuries can also contribute to poor performance, choking is common among high-level athletes, especially during critical stages of the game. Research has shown that, even with high motivation and subjective efforts to perform well, athletes who perceive pressure often exhibit lower than expected or usual performance, making choking a cognitive to execution process (Papathomas, 2007). It is primarily influenced by the combined effects of stable factors, such as self-awareness and anxiety characteristics, and unstable factors, such as internal and external incentives (Krane et al., 1995; Anshel, 2011). In addition, some scholars believe stress can cause athletes to lose control and negatively affect their performance (Wang et al., 2004). The choking phenomenon illustrates that success in high-level competitions requires a high level of physical ability, technique, tactics, and sound psychological qualities.

Athletes commonly experience sports anxiety, which can hurt their performance, causing them to underperform in critical moments. State-trait anxiety refers to a temporary emotional state of restlessness, including tension and fear, which perceives the movement situation as a threat. It comprises three components: state self-confidence, cognitive anxiety, and physical anxiety (Wilson et al., 2009). According to Spielberger (1983), state-trait anxiety is a short-term emotional state triggered by the perception of dangerous stimuli, such as personal tension, worry, anxiety, distress, and overexcitement of the autonomic nervous system. The leading control theory of exercise suggests that stress-induced anxiety is associated with cognitive bias (Eysenck and Wilson, 2016). Research has demonstrated that anxious individuals are more inclined to focus on threatening stimuli and interpret stress as an unfavorable factor for performance (Bar-Haim et al., 2007). Additionally, the study found that cognitive bias is crucial in whether anxiety occurs under pressure. Athletes who interpret stress or competitive situations as threatening are more likely to develop anxiety, affecting sports performance (Eysenck and Wilson, 2016). In light of these insights, the choice to target state-trait anxiety as the focal outcome variable in this study attains a heightened level of specificity, effectively honing in on the performance dynamics of athletes vulnerable to choking in high-stakes competitive environments.

Simultaneously, in athletes, personal and environmental factors influence their emotions before and after competitions, leading to psychological changes, with perceived stress and trait anxiety being common emotional issues. Given the positive correlation between perceived stress and psychological and health-related problems, there is a causal relationship between perceived stress and trait anxiety. Many scholars have verified the relationship between perceived stress and trait anxiety. For example, Ghorbani et al. (2008) found that individuals with high levels of perceived stress often experience higher levels of anxiety and depression, regardless of their race and cultural characteristics. Similarly, Bedini et al. (2011) reported a negative correlation between perceived stress and indicators of quality of life. Perceived stress can impact an individual's life and potentially lead to depression and anxiety. For athletes, those with higher levels of perceived stress often exhibit poorer emotional and subjective performance during competitions, leading to anxiety (Nicholls et al., 2012). The above-mentioned research demonstrates the direct or indirect effects of perceived stress on anxiety. Secondly, resilience, as a positive coping behavior, has been shown in the literature to help individuals effectively cope with stress (Aspinwall and Taylor, 1997). For example, Lehrer et al. (2020) found that individuals with resilience are unlikely to experience negative emotions as they are more proactive in managing the associated psychological stress. Similarly, if individuals are facing various mental health problems such as loneliness, anxiety, depression, or insomnia, those with lower resilience are expected to experience higher levels of stress, making them more prone to anxiety (Tudose, 2021). Thirdly, existing literature indicates that mindfulness and resilience significantly and directly affect individuals' perceived stress, indirectly explaining lower levels of trait anxiety. Lemay et al. (2021) found a negative correlation between mindfulness and stress and anxiety levels. Therefore, in many previous studies, mindfulness directly influenced resilience, perceived stress, and anxiety, or mediated anxiety through variables such as fatigue and self-efficacy. Given the correlation between resilience and perceived stress and the impact of mindfulness on trait anxiety, it is reasonable to hypothesize a relationship among these factors. This study attempts to explore an important and indirect pathway from mindfulness to trait anxiety, examining how resilience and perceived stress influence trait anxiety.

Since the 1980s, researchers in sports psychology have been interested in athletes' abnormal performance during competitions, known as choking (Hill et al., 2010). Considerable progress has been made in understanding the mechanism underlying this phenomenon. Researchers have explored various perspectives, including interference theory and self-monitoring theory, to explain how attention shifting can lead to choking. Wang (2002) proposed a comprehensive choking process theory that considers task characteristics, skill levels, coping strategies, and the impact of individual factors on choking. However, the relationship between the different factors that induce athletes' choking needs further study. Stress is a critical factor that can induce abnormal performance in athletes, and individuals with solid self-awareness may be more vulnerable to external stimuli (Geukes, 2013). The ultimate goal of this research is to develop effective interventions to prevent choking in athletes. Current interventions, such as mindfulness training, dual-task intervention (Wulf, 2013), and music therapy (Mesagno et al., 2009), have shown some promise in preventing choking by activating different brain areas. Nevertheless, the existing body of research concerning mindfulness interventions specifically targeting athletes facing choking episodes remains somewhat scant, necessitating additional validation of their efficacy. Given these prevailing limitations, the present study seeks to address a comprehensive set of objectives: (1) to understand the association among various psychological factors that induce athletes' choking; (2) to examine the impact of mindfulness on athletes' state-trait anxiety and validate its effectiveness; (3) to investigate the relationship among athletes' mindfulness, resilience, perceived stress, and state-trait anxiety; (4) to provide recommendations for preventing athletes' choking phenomenon.

Numerous studies have demonstrated the benefits of mindfulness (Kiken et al., 2017), particularly in reducing stress and anxiety in individuals (Lindsay and Elsie, 2016; Tang et al., 2022). While mindfulness has been explored extensively in psychology literature (Sharma et al., 2014), it has also been applied in organizational research as a trait that helps employees improve job performance and mental health (Charoensukmongkol, 2014). However, its role in abnormal performance in athletes has yet to be extensively studied. This study aims to investigate the association of mindfulness on athletes' state-trait anxiety, perceived stress, and choking, as these factors are crucial contributors to athletes' choking phenomenon.

However, it remains unclear whether mindfulness can influence athletes' resilience, perceived stress, and subsequently their state-trait anxiety. This study makes the following contributions: Firstly, this study focuses on choking-susceptible athletes' stress and trait anxiety intervention, using mindfulness interventions to enhance mental resilience and reduce perceived stress and trait anxiety. This expands the research on the mechanisms through which mindfulness affects athletes' state-trait anxiety. Additionally, the study explores the mediating effects of resilience and perceived stress on the relationship between mindfulness and trait anxiety to prevent choking in athletes. The results suggest that mindfulness interventions lead to improved resilience and reduced perceived stress and trait anxiety, thereby reducing the incidence of choking in athletes. It highlights the positive resilience developed by choking-susceptible athletes through mindfulness training, enabling them to establish more adaptive perceptions of stress and state anxiety. Moreover, the study extends the research on the micro-level mechanisms of resilience. While previous studies typically treat resilience as the outcome variable, in this study, it serves as a mediating variable. Therefore, this study analyzes the association of mindfulness on choking-susceptible athletes' perceived and trait anxiety, improves resilience, and reduces blocking when athletes participate in significant competitions. These findings provide effective intervention methods and mean to prevent choking in athletes. In conclusion, this study contributes to a better understanding of choking in athletes, supports previous research, and provides a reference for future research.

The remaining sections of this study are organized as follows: Section 2 provides a comprehensive literature review, which includes relevant theories and hypotheses proposed in this study. Additionally, a conceptual model is presented. Section 3 introduces the data collection, questionnaire composition, and analysis methods. The results of the data analysis and hypothesis testing are presented in Section 4. Section 5 discusses the results and shows the theoretical and practical implications of the study. In Section 6, the limitations of the study are acknowledged and discussed, providing insights into areas for improvement and further research. Finally, Section 7 summarizes the study's central ideas and suggestions for future research.

2. Hypotheses development

2.1. Mindfulness, resilience, perceived stress, and state-trait anxiety

As the study of mindfulness has progressed, its definition has gained greater precision. Brown and Ryan (2003) characterize mindfulness as "paying attention to and being aware of what is happening in the present." The application of mindfulness across diverse domains has also undergone extensive examination (Chiesa and Serretti, 2010). Numerous investigations have underscored the affirmative outcomes of mindfulness in mitigating individuals' psychological stress and bolstering their physical well-being. Firstly, within many professional contexts, individuals who integrate mindfulness into their routine exhibit enhanced competence in managing external stressors. Illustratively, mindfulness training has proven effective in mitigating work-related stress and ameliorating the overall quality of life for healthcare practitioners (Burton et al., 2017). Secondly, mindfulness empowers individuals to adeptly navigate unwelcome emotional states by preventing excessive attachment or detachment from their emotional experiences (Feldman et al., 2007; Baer et al., 2008). Furthermore, the study by Gal et al. (2021) sought to ascertain the impact of mindfulness interventions on individuals' well-being and mental health. The study's findings indicate that such interventions can significantly diminish individuals' perceived stress, anxiety, and depression.

According to previous research, Cohen et al. (1983) posited stress as a universally recognized perception. Among the most prevalent emotions linked to stress are depression, tension, and anxiety, with perceived stress often manifesting a positive correlation with psychological and health-related challenges. For instance, Kulsoom and Afsar (2015) assessed the psychological well-being of medical students and discerned an association between elevated stress levels and heightened anxiety. Similarly, Lebares et al. (2018) identified a correlation between elevated burnout levels, intense stress, and adverse impacts such as depression and anxiety among surgical residents in the United States. Their study also revealed that mindfulness training and bolstering resilience among medical professionals can mitigate negative emotional states. When individuals across diverse vocations encounter stress, they deploy various psychological interventions to sustain a positive mindset and continue their professional endeavors. Mindfulness stands out as a pivotal intervention method. A plethora of researchers have concurred that mindfulness constitutes a pivotal factor in advancing individuals' psychological well-being, augmenting cognitive and other capabilities, and mitigating the influence of perceived stress on mental health. Consequently, individuals characterized by heightened levels of mindfulness often exhibit diminished negative emotional responses and reduced stress levels.

Empirical research underscores resilience as a psychological construct encapsulating an individual's adeptness in adapting to adversity, trauma, or stress (White et al., 2008). This intricate psychological framework encompasses personality attributes such as self-assurance, concentration, emotional regulation, positive cognitive patterns, tenacity, and the capacity for psychological recovery post-trauma (Butt et al., 2010). Furthermore, heightened levels of resilience correlate with amplified positive emotions and enhanced emotional intelligence, facilitating more effective management of perceived stress (Wu et al., 2022).

On one facet, stress is not a static phenomenon but rather an evolving process. While a commonplace experience in daily life, poorly managed stress can precipitate negative emotional states, including depression and anxiety (Ystgaard et al., 1999). Research findings highlight the critical importance of resilience for choking-susceptible athletes. Jones et al. (2002) assert that resilience consistently emerges as a linchpin in the accomplishments of athletes in studies pertaining to high-achieving athletes. Moreover, Jones et al. (2002) posit that resilience, whether an innate genetic predisposition or an acquired psychological advantage, equips athletes to navigate competitions, training regimens, and life's stressors more effectively than their counterparts. In a similar vein, Madigan and Nicholls (2017) posit that mentally resilient athletes exhibit positive perceptions of external stimuli under pressure, skillful emotional regulation, and optimistic attitudes toward achieving their goals. Consequently, heightened resilience empowers individuals to deftly marshal resources and confront diverse stressors, indicative of its multifaceted nature (Gucciardi et al., 2009). As a protective factor, resilience serves to mitigate the detrimental impact of perceived stress (Thurston et al.,

2018), implying that individuals with elevated resilience often experience diminished levels of perceived stress.

Conversely, state-trait anxiety encapsulates emotional responses like unease, restlessness, and apprehension when individuals perceive a challenge in completing tasks. Recent investigations by Trigueros et al. (2020) delve into the interplay of motivation, resilience, and anxiety within volleyball players, revealing a negative correlation between resilience and anxiety to some extent. Similarly, in a case study involving 200 postdoctoral researchers, Gloria and Steinhardt (2016) establish that resilience serves to curtail the likelihood of encountering anxiety or depressive symptoms during postdoctoral training. Furthermore, Scelzo et al. (2018) employ qualitative and quantitative methodologies on older participants, uncovering a positive link between resilience and mental health, while revealing a negative correlation with anxiety. This underscores the dual influence of resilience, not only positively affecting perceived stress but also exerting a favorable impact on anxiety.

The literature converges to demonstrate the interrelation and reciprocal influence between anxiety and stress. Wathelet et al. (2020) investigate the mental well-being of French university students amid the COVID-19 pandemic, unearthing widespread elevated levels of perceived stress, correlating with mental health disorders including severe depression and heightened anxiety. Moreover, research identifies a correlation between athletes' perceived stress and trait anxiety in the context of paralympic competitions (Belinchon-deMiguel et al., 2019), thus reasonably inferring that athletes' elevated perceived stress during competitions can precipitate state-trait anxiety. Based on these findings, this study proposes the following four hypotheses.

The hypothesized model is shown in Figure 1:

Hypothesis 1 (H1). Mindfulness is negatively related to perceived stress.

Hypothesis 2 (H2). Resilience is negatively related to perceived stress.

Hypothesis 3 (H3). Resilience is negatively related to state-trait anxiety.

Hypothesis 4 (H4). Perceived stress is positively related to state-trait anxiety.

2.2. The mediating effects

According to Brown and Ryan (2003), mindfulness is being aware and paying attention to the present moment, being able to maintain a positive state of mind. At the same time, resilience is a positive psychological trait that allows individuals to recover from adversity, uncertainty, conflict, and failure, leading to positive changes, progress, and increased sense of responsibility (Luthans, 2002). Consequently, both mindfulness and resilience hold the potential to positively shape individuals' emotional responses and facilitate their capacity to confront and adapt to challenging circumstances (Hao et al., 2015). Substantiation for this notion emerges from scholarly research. For instance, Mitchell (2021) underscores that nurturing mindfulness via acceptance and focused attention plays a pivotal role in enhancing the adaptability of nurses during their training. In a similar vein, Masrour et al. (2017) demonstrate that engaging in mindfulness practices can fortify the resilience of couples facing infertility, concurrently ameliorating symptoms of depression, anxiety, and stress. Notably, mindfulness-based intervention initiatives have demonstrated efficacy in alleviating the burdens faced by family caregivers, thereby enhancing their adaptability. This underpins a positive correlation between mindfulness and resilience.

Furthermore, precedent studies have highlighted the potential of mindfulness to ameliorate stress and anxiety (Burton et al., 2017). Some investigations have suggested that resilience may modulate the impact of mindfulness on perceived stress. Consequently, the central focus of this study resides in probing the potential significant interconnections between mindfulness, resilience, perceived stress, and state-trait anxiety, prompting the need for a comprehensive exploration.

In conclusion, previous studies have demonstrated a positive effect of mindfulness on perceived stress in individuals. Additionally, a significant relationship between resilience and perceived stress has been reported. Therefore, it is plausible that resilience partially mediates the effect of mindfulness on perceived stress. Furthermore, perceived stress is significantly related to state-trait anxiety. Therefore, considering the interrelationship between mindfulness, resilience, perceived stress, and state-trait anxiety, it is worth exploring whether mindfulness can mediate it through resilience and perceived stress. Based on this, this study proposes the following two hypotheses:

Hypothesis 5 (H5). Resilience mediates the relationship between mindfulness and perceived stress.

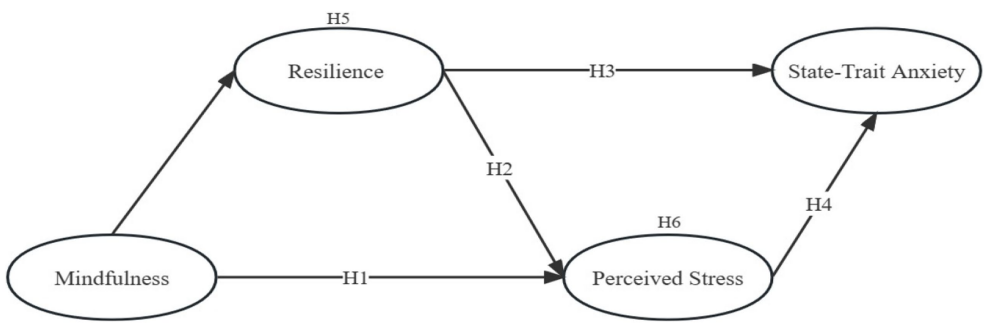

FIGURE 1
The hypothesized model.

> *Hypothesis 6 (H6)*. Resilience and perceived stress mediate the relationship between mindfulness and state-trait anxiety.

3. Methodology

3.1. Participants and procedure

This study employed cluster and random sampling methods to select participants from among choking-susceptible athletes competing in the provincial games in a province in central China. Participants all self-reported themselves as choking-susceptible athletes due to various reasons. Before the survey, the ethics committee at the first author's institution approved the research protocol. Then, from October to November 2022, the researchers administered a survey to the participating athletes, who were fully informed about the survey's objectives and provided informed consent before completing the questionnaire. A total of 400 questionnaires were distributed, out of which 377 valid questionnaires were collected, yielding an effective questionnaire recovery rate of 94.25%.

Table 1 displays the demographic characteristics of the 377 participating athletes who completed the survey. The results indicate that: (1) approximately half of the respondents were aged 18 to 25; (2) slightly more male athletes (54.6%) than female athletes (45.4%) took part in the study; (3) over half of the athletes (57.6%) were college students; (4) regarding sports level, nearly half of the athletes (50.1%) reached the athlete level, while only a tiny proportion (4.5%) achieved the national master level; (5) the sports disciplines included ball sports, track and field, and other types of sports. Among them, ball sports, including basketball, soccer, volleyball, badminton, table tennis, and tennis, accounted for the largest portion with 178 individuals, representing 47.2% of the sample. Meanwhile, track and field events, encompassing sprinting, middle-distance running, long-distance running, relay races, hurdles, long jump, and high jump, accounted for 107 participants, or 28.4% of the total. Other sports, such as cheerleading, swimming, taekwondo, and martial arts, constituted the third category, representing 92 individuals or 24.4% of the cohort. Notably, ball sports dominated the majority of the sample's engagement.

The survey questionnaire used in this study was composed of five parts, totaling 23 items. The first part of the questionnaire aimed to gather demographic information from the participants, including age, gender, education level, athletic level, and sport. The second part used the five items from the mindfulness scale developed by Carlson and Brown (2005). An example item from the sample included: "It seems I am 'running on automatic', without much awareness of what I am doing." The third part collected data on resilience, measured using the six items from the mental toughness scale developed by Connor and Davidson (2003). An example item from the sample included: "When things look hopeless, I do not give up." The fourth part gathered data on perceived stress, calculated using the six items from the perceived stress scale developed by Cohen et al. (1983). An example item from the sample included: "In the last month, how often have you felt nervous and stressed?" Finally, the fifth part collected data on state-trait anxiety using the six items from the scale developed by Spielberger (1983). An example item from the sample included: "Cannot get thoughts out of mind." All four scales were measured using a five-point Likert scale, ranging from 1 (strongly disagree, never) to 5 (strongly agree, always).

TABLE 1 Participant profile ($N = 377$).

Profiles	Survey (%)
Age	
18–25	216 (57.3%)
26–35	140 (37.1%)
35≤	21 (5.6%)
Gender	
Male	206 (54.6%)
Female	171 (45.4%)
Education level	
Below high school	28 (7.4%)
High school/vocational school	132 (35%)
College and above	217 (57.6%)
Sport level	
No sports grade certificate[a]	188 (49.9%)
Second-level athlete[b]	122 (32.4%)
Tier 1 athlete[c]	50 (13.2%)
National athlete level[d]	17 (4.5%)
Sports items	
Ball sports	178 (47.2%)
Track and field	107 (28.4%)
Other sports	92 (24.4%)

[a]Refers to individuals who did not meet the established performance criteria in the previously mentioned competitions.
[b]Pertains to participants who successfully meet the performance criteria in championships or championship matches that are co-organized by provincial, regional, or municipal sports administrative departments and education administrative departments.
[c]Denotes those who satisfy the performance criteria in national sports competitions and encompassing comprehensive sports events, as well as championships or championship matches orchestrated by provincial, regional, or municipal sports administrative departments.
[d]Signifies participants who fulfill the performance criteria in national-level sports competitions, which include the National Games, National Youth Games, National Championships, National Youth Championships, National Junior Championships, National Indoor Championships, National Grand Prix, National Individual Events, National Team Events, in addition to the National Student Games and National Middle/High School Championships.

The researchers modified some items in the original scales to ensure that the scales used in the study were appropriate for the Chinese cultural context and research field. A pilot test was then conducted on a sample of high-level collegiate athletes in Changsha, China, to ensure the reliability of the revised scales (Fornell and Larcker, 1981). The pilot test received 75 valid responses, and the results showed that the Cronbach coefficients for all the scales were higher than 0.9, which justified the researchers' modifications to the scales.

3.2. Data analysis

In this study, a structural equation model (SEM) was constructed using AMOS v.26 to examine how choking-susceptible athletes can

alleviate state-trait anxiety through mindfulness, with the parameters of the model estimated using a maximum likelihood (ML) estimation method. A two-step modeling approach was employed to evaluate the measurement and structural models (Anderson and Gerbing, 1988). Specifically, the reliability and validity of the model were first comprehensively assessed, followed by an examination of the fit and path coefficients of the hypothesized models, as well as testing for the presence of mediating effects.

We conducted two tests to address common method variance (CMV) issues. First, we performed Harman's univariate test, which showed that the percentage of variance extracted from the univariate test was 44.01%, below the classical threshold of 50%. This suggests that CMV was not a significant issue in this study (Podsakoff et al., 2012). Second, we adopted the CFA single-factor and two-factor comparison methods proposed by Mossholder et al. (1998). The chi-square value for the univariate model was 5190.6 with 230 degrees of freedom, while the chi-square value for the multivariate model was 239.7 with 224 degrees of freedom. The ratio of the difference in chi-square values to the difference in degrees of freedom for the two models is 825.2, indicating a significant difference between the two models and further supporting the absence of CMV. Hence, we concluded that the impact of CMV on this study is minimal and does not require correction.

4. Results

4.1. Assessment of the measurement model reliability and validity

This study assessed the reliability and discriminant validity by calculating Cronbach's α and composite reliability (CR) coefficients for the latent variables (Fornell and Larcker, 1981). All variables had Cronbach's α coefficients ranging from 0.937 to 0.957. Concurrently, the CR values for each variable demonstrated high reliability, falling within the range of 0.938 to 0.957, surpassing the recommended threshold of 0.9, thus affirming the strong reliability of the measurement model. In addition to this, the average variance extraction (AVE) values exhibited noteworthy results, ranging from 0.715 to 0.814 for all variables. These findings solidify the convergent validity of the study's measurements, reinforcing the coherence of the underlying constructs. Furthermore, Table 2 shows that all correlation coefficients were smaller than the square root of AVE.

4.2. Hypotheses testing results

Several tests were conducted to assess the validity and reliability of the structural equation model used in this study. First, the error and residual terms did not show negative values, indicating that the model's estimates were not violated. Second, the goodness of fit was high ($\chi^2/df = 1.104$, GFI = 0.947, AGFI = 0.934, NFI = 0.972, CFI = 0.997, TLI = 0.997, RMSEA = 0.017), indicating that the model fit the data well. Third, the Pearson correlation results in Table 3 showed significant correlations among the independent, mediator, and dependent variables, supporting the hypotheses. Fourth, the results of the structural pathway model in Figure 2 indicated that mindfulness and perceived stress had a significant negative association ($\beta = -0.224$, $p < 0.001$), supporting H1; resilience and perceived stress had a significant negative association ($\beta = -0.237$, $p < 0.001$), supporting H2; resilience and state-trait anxiety had a significant negative association ($\beta = -0.174$, $p < 0.001$), supporting H3; and perceived stress and state-trait anxiety had a significant positive association ($\beta = 0.510$, $p < 0.001$), supporting H4.

The study hypothesized that mindfulness affects motor state-trait anxiety through two mediators: resilience and perceived stress. To test for mediating effects, the researchers used the bootstrap method (Bollen and Stine, 1990). The results of the 95% confidence intervals of the 5,000 bootstrap samples are shown in Table 3. The absolute values of all Z values are significant (greater than 1.96), and the 95% confidence intervals do not include zero. The study found a significant indirect effect between mindfulness and state-trait anxiety via resilience (standardized indirect effect = −0.096, $p < 0.001$), supporting H5. Additionally, resilience and perceived stress significantly mediated the relationship between mindfulness and state-trait anxiety (standardized indirect effect = −0.229, $p < 0.001$), supporting H6.

TABLE 2 Discriminant validity test.

Construct	MIN	RE	PS	STA
MIN	**(0.902)**			
RE	0.475**	**(0.888)**		
PS	−0.341**	−0.332**	**(0.845)**	
STA	−0.355**	−0.335**	0.541**	**(0.872)**

The square root of the average variance extracted (AVE) is in the diagonals (bold); off diagonals is a Pearson's correlation of contracts. **$p < 0.01$, the following significance standard is the same.

TABLE 3 Indirect effects.

	Point estimate	Product of coefficients		Bootstrapping				
				Percentile 95% CI		Bias-corrected 95% CI		Two-tailed significance
		SE	Z	Lower	Upper	Lower	Upper	
MIN → PS	−0.096	0.027	−3.556	−0.174	−0.067	−0.178	−0.071	0.000 (***)
MIN → STA	−0.229	0.034	−6.735	−0.329	−0.197	−0.328	−0.196	0.000 (***)

Standardized estimations of 5,000 bootstrap samples.

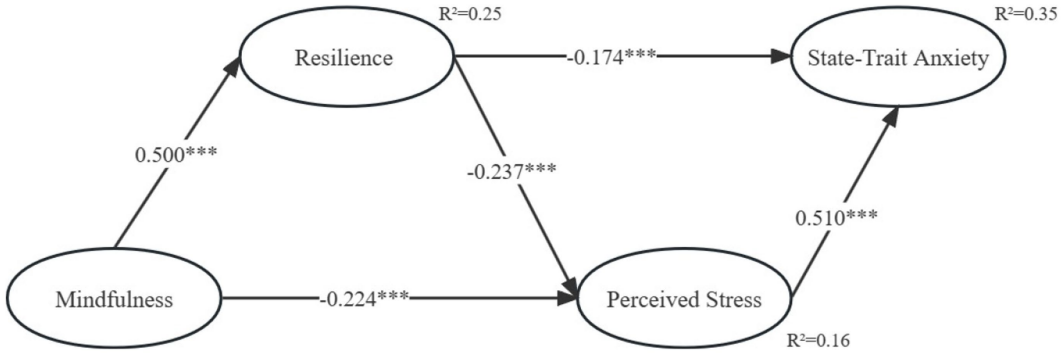

FIGURE 2
Structural path model. ***$p < 0.001$. Standardized coefficients are reported.

These findings suggest that mindful and resilient athletes are likely to experience lower levels of perceived stress and state-trait anxiety.

5. Discussion

5.1. Theoretical contribution

This study significantly contributes to the comprehension of the psychological determinants that exert influence on the state-trait anxiety experienced by athletes susceptible to choking. Its primary thrust is to unravel the impact of mindfulness on the state-trait anxiety of these athletes, while concurrently introducing the pivotal roles of resilience and perceived stress as mediating agents. The existing body of research has predominantly focused on the mechanics and catalysts behind choking incidents, yet a dearth of exploration exists regarding the intricate interplay of internal and external factors in conjunction with the psychological underpinnings that culminate in performance anomalies among athletes prone to choking. In this context, the study's meticulous scrutiny of stress and anxiety, which precipitate choking tendencies, aligns with targeted precision and contributes to the enrichment of pertinent theories. By unraveling the intricate mechanics of athlete choking, this study aspires to pave the way for future research endeavors, enabling the exploration of efficacious intervention modalities. The holistic understanding of choking mechanisms aims to empower athletes and coaches alike with a comprehensive grasp of choking phenomena and avenues for resolution (Beilock and Gray, 2007; Hill et al., 2010).

Extensive investigations have previously established that athletes' anxiety linked to choking emanates from their perception of external pressures. These external pressures act as catalysts for triggering psychological stress responses, thereby inducing choking occurrences (Wilson et al., 2009). Given the compelling nexus between anxiety, stress, and athletes' propensity to choke, with heightened state-trait anxiety often translating into suboptimal performance during competitions, this study delves into the imperative of influencing athletes' perceived stress and state-trait anxiety through mindfulness and resilience interventions. The proposition is substantiated by evidence suggesting that mindfulness, as a potent psychological asset, can mitigate athletes' anxiety levels, thus ameliorating anomalous performances during competitions (Murray and Janelle, 2003). In consonance, the findings of Medina (2016) which highlight the efficacy of anxiety control in averting athlete choking, align with the present study's orientation. Consequently, the attenuation of state-trait anxiety could conceivably engender a favorable impact on athletes' performance, equipping them to attain superior outcomes. Furthermore, this investigation expounds on the correlation between mindfulness and perceived stress, along with the mediating role played by resilience in their dynamic interplay. This insightful exploration adds depth to the understanding of choking-susceptible athletes' perceived stress, bolstering previous findings put forth by Lemay et al. (2021) and Gal et al. (2021).

In terms of outcomes, the study's results spotlight mindfulness as the most substantial influencer, with the greatest sway on resilience, followed by perceived stress. Notably, resilience and perceived stress operate as key mediators within the connection linking mindfulness and state-trait anxiety, elucidating a noteworthy 35% of the variance observed in state-trait anxiety, as depicted in Figure 2. The study's revelations thereby furnish invaluable insights into the intricate dynamic between mindfulness and state-trait anxiety, with a distinct emphasis on the resilience facet among athletes susceptible to choking. By accentuating the pivotal role of resilience, this study proffers a promising avenue for influencing athletes' state-trait anxiety through mindfulness-based interventions, thereby contributing significantly to both empirical understanding and potential interventions in this domain.

5.2. Practical implications

Research has shown that mindfulness can significantly impact the perceived stress and state-trait anxiety of suffocating athletes. The results of this study confirmed the negative correlation between mindfulness and perceived stress, as well as the negative correlation between mindfulness and state-trait anxiety. Moreover, the study also found that psychological resilience and perceived stress mediate the relationship between mindfulness and state-trait anxiety. Considering the various personal and external factors that may cause emotional fluctuations in athletes during competitions, the occurrence of "choking" is prevalent among many athletes. Therefore, the potential adverse effects of mindfulness on athlete performance and mental health are essential considerations.

In light of these insights, it is strongly recommended that coaches and sports organizations prioritize the integration of mindfulness training for athletes susceptible to choking. Such initiatives aim to nurture and enhance athletes' mindfulness quality. Incorporating mindfulness practices, including meditation, into athletes' training regimens during periods of rest or prior to and after competitions, holds the potential to facilitate relaxation and efficacious management of performance-related pressures. This proactive approach to mindfulness training can be of immense benefit to all athletes, particularly those prone to choking incidents, given their heightened vulnerability to the influence of performance stress and anxiety. To this end, coaches might consider implementing mandatory mindfulness training as a preemptive measure to curb the likelihood of anxiety manifesting during competitive scenarios, especially for athletes who exhibit heightened emotional susceptibilities.

The importance of mindfulness training is supported by previous research, including Tang et al. (2022), who found a negative correlation between athletes' mindfulness during competitions and state-trait anxiety, along with its positive impact on athletes' emotional regulation self-efficacy. Additionally, the views of Lindsay and Elsie (2016) receive further reinforcement. However, despite the proven benefits of mindfulness training, the present landscape of mindfulness initiatives for athletes in domestic settings is less than optimal. This disparity can be attributed to multiple factors, including athletes' limited awareness of the advantages associated with mindfulness training, coupled with the scarcity of accessible, professionally guided mindfulness programs. This encompasses inadequate infrastructure and a shortage of qualified mental health practitioners well-versed in mindfulness training.

In light of these prevailing challenges, a series of actionable recommendations is put forth. To heighten athletes' awareness about the pivotal significance of mindfulness training, governmental bodies and sports governing authorities are urged to undertake comprehensive promotional campaigns that spotlight the benefits, techniques, and guidelines underpinning mindfulness practice. Concurrently, sports management entities and coaches should play an active role in motivating athletes to embrace consistent mindfulness training. This necessitates the provision of suitable facilities and a dedicated investment in cultivating a cadre of mental health professionals proficient in mindfulness-based interventions. Through this multifaceted approach, athletes can be empowered with effective coping strategies to curtail state-trait anxiety during competitive engagements, ultimately fostering their holistic well-being and optimized performance outcomes.

6. Limitations

This study, while making valuable contributions, is not without its limitations, which warrant careful consideration. Firstly, the study relied on cross-sectional data, which limits the ability to infer causal relationships among the examined variables. Future research should employ longitudinal designs and experimental control groups to provide a more in-depth and comprehensive understanding of these relationships. Secondly, the research model did not consider other moderating variables that may influence the relationships between mindfulness, perceived stress, resilience, and state-trait anxiety. Future studies should take these factors into account to enhance the accuracy and predictive power of the model. Lastly, the study sample targeted choking-susceptible athletes, including a relatively small proportion of national athlete level participants (4.5%), which may limit the generalizability of the findings. Future research should involve a larger number of high-level athletes to validate the results of this study and provide a more comprehensive understanding of the relationship between mindfulness and athletic performance.

7. Conclusion

Current cross-sectional survey research indicates that mindfulness has a positive impact on choking-susceptible athletes' state-trait anxiety. Specifically, this influence of mindfulness on state-trait anxiety is mediated by two variables: resilience and perceived stress. The study findings shed light on the mechanisms through which mindfulness affects choking-susceptible athletes' state-trait anxiety and contribute to the theoretical understanding of choking-susceptible athletes' psychological response during times of state-trait anxiety. Considering that choking-susceptible athletes often experience heightened psychological pressure when facing competitive events, it is crucial to encourage coaches to provide psychological training to enhance choking-susceptible athletes' emotional abilities, ultimately improving their performance in sports.

Furthermore, it is recommended that the National Sports Administration establish relevant training institutions focusing on athletes' psychological well-being. These institutions can assist athletes representing the country in competitions in addressing psychological pressure and anxiety issues. This will ensure that athletes perform consistently during competitions and reduce the occurrence of choking phenomena.

By incorporating mindfulness-based training and psychological support into athletes' preparation, athletes can effectively manage their emotions, reduce anxiety, and perform at their best during crucial moments. Establishing such psychological training institutions can be a valuable investment in enhancing athletes' mental resilience and optimizing their overall athletic performance.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of the School of Physical Education of Hunan University of Science and Technology (No. ECSPEHUST 2022/0014). The patients/participants provided their written informed consent to participate in this study.

Author contributions

YT and HW contributed to the conception, design of the study, and organized the database. YT and YL performed the statistical analysis and wrote the first draft of the manuscript. LJ and HW wrote sections of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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EDITED BY
Guodong Zhang,
Southwest University, China

REVIEWED BY
Huilin Wang,
Hunan University of Science and Technology, China
Yang Cao,
Örebro University, Sweden

*CORRESPONDENCE
Ann Van de Winckel,
avandewi@umn.edu

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Feasibility of using remotely delivered Spring Forest Qigong to reduce neuropathic pain in adults with spinal cord injury: a pilot study

Ann Van de Winckel [1]*, Sydney T. Carpentier[2], Wei Deng[2], Lin Zhang[3], Angela Philippus[4], Ricardo Battaglino[4] and Leslie R. Morse[4]

[1]Division of Physical Therapy, Division of Rehabilitation Science, Department of Rehabilitation Medicine, Medical School, University of Minnesota, Minneapolis, MN, United States, [2]Division of Rehabilitation Science, Department of Rehabilitation Medicine, Medical School, University of Minnesota, Minneapolis, MN, United States, [3]Division of Biostatistics, School of Public Health, University of Minnesota, Minneapolis, MN, United States, [4]Department of Rehabilitation Medicine, Medical School, University of Minnesota, Minneapolis, MN, United States

Introduction: Approximately 69% of 299,000 Americans with spinal cord injury (SCI) suffer debilitating chronic neuropathic pain, which is intractable to treatment. The aim of this study is to determine feasibility, as the primary objective, and estimates of efficacy of a remotely delivered Qigong intervention in adults with SCI-related neuropathic pain, as the secondary objective.

Methods: We recruited adults with SCI-related neuropathic pain, with SCI ≥3 months, with complete or incomplete SCI, and highest neuropathic pain level of >3 on the Numeric Pain Rating Scale (NPRS), using nationwide volunteer sampling. Using a non-randomized controlled trial design, participants practiced Spring Forest Qigong's "Five Element Qigong Healing Movements" (online video) by combining movement to the best of their ability with kinesthetic imagery, at least 3x/week for 12 weeks. Adherence was automatically tracked through the Spring Forest Qigong website. Outcomes of neuropathic pain intensity (NPRS) were assessed weekly, and SCI-related symptoms were assessed at baseline, 6, and 12 weeks of Qigong practice and at 6-week and 1-year follow-ups.

Results: We recruited 23 adults with chronic SCI (7/2021–2/2023). In total, 18 participants started the study and completed all study components, including the 6-week follow-up. Twelve participants completed the 1-year follow-up assessment. Feasibility was demonstrated through participants' willingness to participate, adherence, and acceptability of the study. Mean age of the 18 participants was 60 ± 12 years, and they were 15 ± 11 years post-SCI with the highest baseline *neuropathic pain* of 7.94 ± 2.33, which was reduced to 4.17 ± 3.07 after 12 weeks of Qigong practice (Cohen's d = 1.75). This pain relief remained

Abbreviations: FA, Functionality Appreciation Scale; IRB, Institutional Review Board; NINDS-CDE, Neurological Disorders-Common Data Elements; NPRS, Numeric Pain Rating Scale; PHQ-9, Patient Health Questionnaire-9; PSFS, Patient-Specific Functional Scale; SCI, spinal cord injury; SCI/FI, Spinal Cord Injury Functional Index; WHOQOL-BREF, World Health Organization Quality of Life Instruments.

at 6-week and 1-year follow-ups. Participants reported reduced spasm frequency (change score 1.17 ± 1.20, d = 0.98) and severity (0.72 ± 1.02, d = 0.71), reduced interference of neuropathic pain on mood (3.44 ± 2.53, d = 1.36), sleep (3.39 ± 2.40, d = 1.41), daily activities (3.17 ± 2.77, d = 1.14), greater ability to perform functional activities (6.68 ± 3.07, d = 2.18), and improved mood (2.33 ± 3.31, d = 0.70) after Qigong.

Discussion: Remote Spring Forest Qigong's "Five Element Qigong Healing Movements" practice is feasible in adults with SCI-related neuropathic pain, with promising prolonged results of neuropathic pain relief and improvement in SCI-related symptoms after Qigong practice.

Clinical trial registration: https://www.clinicaltrials.gov/ct2/show/NCT04917107, identifier NCT04917107

KEYWORDS

spinal cord injury, neuropathic pain, body awareness, autonomic function, Qigong, spasm, mood

1 Introduction

Chronic neuropathic pain is described as sharp, shooting, stabbing, electric, or burning, and sometimes excruciating pain. The mechanisms underlying neuropathic pain are not completely understood but are commonly reported as being related to damage to the somatosensory system in the peripheral or central nervous system (Raja et al., 2020; Ghazisaeidi et al., 2023). Due to this damage, changes occur at all levels of somatosensory circuitry (i.e., the spinal cord, brainstem, and brain), altering the sensorial communication between the brain and the body, resulting in the development of various degrees of sensory and motor impairment and aberrant pain sensations above, below, or at the level of the lesion (Chambel, Tavares, and Cruz, 2020; Forte et al., 2022). Furthermore, changes in brain function may contribute to neuropathic pain (Hawasli et al., 2018; Huynh et al., 2019; Black et al., 2021).

Chronic neuropathic pain occurring in approximately 69% of the 299,000 Americans with spinal cord injury (SCI) is debilitating and persistent, and it is the most intractable type of chronic pain (Guy et al., 2016; Hatch et al., 2018; Raja et al., 2020; Leitzelar and Koltyn, 2021). Accessible treatment options (exercise and medication) have limited success in reducing pain (Kramer et al., 2017; Hatch et al., 2018; Kim et al., 2020; Felix et al., 2022; National Spinal Cord Injury Statistical Center, 2022). For instance, pain medications result in <50% pain reduction for only approximately 1/3 of the people trying them and some with notable adverse events. Studies conducted with SCI stakeholders confirm that accessible treatments are limited; that pain medications insufficiently relieve pain but carry high risks for addiction and adverse effects; and that improved patient access to non-pharmacological approaches for neuropathic pain is urgently needed (Guy et al., 2016; Hatch et al., 2018; Leitzelar and Koltyn, 2021).

Concurrently with reduced or absent sensation after SCI, accumulating evidence shows that adults with SCI experience body awareness deficits (Lenggenhager et al., 2012; Scandola et al., 2017; Kaur et al., 2019; Leemhuis et al., 2019; Osinski et al., 2020; De Martino et al., 2021; Leemhuis et al., 2021; Moro et al., 2021; Vázquez-Fariñas and Rodríguez-Martin, 2021; Leemhuis et al., 2022; Maggio et al., 2022; Moro et al., 2022; Vastano, Costantini, and Widerstrom-Noga, 2022; Vastano and Widerstrom-Noga, 2023), which is thought to contribute to the production and maintenance of chronic neuropathic pain (Lenggenhager et al., 2012; Leemhuis et al., 2019; Leemhuis et al., 2022; Vastano et al., 2022). Body awareness refers to an attentional focus on and awareness of internal body sensations, including awareness of how the body/body parts are positioned and move in space (Mehling et al., 2011).

Mind and body approaches improve body awareness and thus could be a viable approach to treating neuropathic pain (Impett et al., 2006; Mehling et al., 2011; Naranjo and Schmidt, 2012; Schmalzl et al., 2014; Jong et al., 2016; Mehling et al., 2018). However, research demonstrating the effectiveness of mind and body approaches for reducing pain in SCI is limited to seven studies among which only two (yoga and Tai Chi) (Shem et al., 2016; Curtis et al., 2017; Chalageri et al., 2021) reported pain reduction but without mentioning the type of pain (Tsang et al., 2015; Shem et al., 2016; Curtis et al., 2017; Qi et al., 2018; Madhusmita and Ebnezar, 2019; Hearn and Cross, 2020; Chalageri et al., 2021). Mind and body research in SCI is recent, and often movement modifications are needed to allow participation by adults with SCI. Chalageri et al. (2021) reported pain reduction after yoga meditation combined with conventional rehabilitation, mostly benefitting adults with acute SCI and paraplegia (Chalageri et al., 2021). Curtis et al. (2017) reported greater improvements in depressive symptoms and self-compassion, but not pain, in adults with SCI practiced adaptive yoga vs. waitlist group (Curtis et al., 2017). A seated Tai Chi program was well tolerated in adults with SCI with benefits in pain, emotional sense, and physical sense of wellbeing after each session, but the weekly in-person classes had a dropout rate of 60% (Shem et al., 2016). Tsang et al. (2015) reported greater improved dynamic sitting balance and grip strength after 12 weeks of sitting Tai Chi in 11 adults with SCI vs. eight controls (Tsang et al., 2015). With the exception of Chalageri et al.'s study (n = 91), sample sizes were small (n = 23, n = 26, and n = 19), and only Tsang et al. (2015) included adults with

incomplete tetraplegia; all others recruited adults with paraplegia only. Thus, studies with accessible interventions for adults with tetraplegia are needed. Of the mind and body approaches, Qigong seems the most accessible approach for adults with SCI due to the simple, gentle movements, combined with a focus on breathing and body awareness. Remote Qigong delivery provides a feasible approach for adults with SCI as it eliminates reported in-person intervention barriers of transportation and scheduling difficulties (Huberty et al., 2017).

Therefore, our primary objective was to determine the feasibility of a 12-week Qigong practice with a remotely delivered Spring Forest Qigong "Five Element Healing Movements" video in adults with SCI-related neuropathic pain. Qigong could be practiced in standing, sitting, or lying positions. Our Qigong practice combined actively moving to the participant's ability level with kinesthetic imagery, i.e., focusing on the feeling of moving the whole body *as if* in an upright position, because imagery may be an additional way to improve body awareness and reduce pain (Scandola et al., 2017; Kaur et al., 2019). Therefore, adults with high-level tetraplegia after SCI could practice Qigong in their power wheelchair or lying down. In contrast, in other studies, the requirement of minimum active muscle strength to perform the exercises often excludes them. Our secondary objective was to calculate estimates of the efficacy of Qigong practice in adults with SCI-related neuropathic pain to inform future efficacy clinical trials.

2 Materials and methods

2.1 Study design and recruitment

Full detail of the protocol can be found in Van de Winckel et al. (2023a). We used nationwide volunteer sampling through fliers and announcements on relevant websites, in the community, through the M Health/Fairview healthcare recruitment system, and in locations within the Minnesota Regional Spinal Cord Injury Model System (MN SCIMS). More specifically, we recruited from all clinical site partners within the MN SCIMS, which include hospitals, clinics, and rehabilitation centers in the *Twin Cities* and Mayo Clinic in Rochester. We have ongoing collaborations within the Twin Cities with the UMN Medical Center, M Health/Fairview; MN SCI associations; Regions Hospital; Courage Kenny Rehabilitation Institute; Get Up Stand Up to Cure Paralysis; Unite2Ffight Paralysis, and Fit4Recovery. Healthcare providers provided enrollment information and materials to potential participants and posted fliers in their locations. M Health/Fairview had a recruitment system in place where approximately 1,000 letters were sent from the electronic medical record system directly to patients with SCI and neuropathic pain. Patients who were interested in participating contacted the researchers. This was a very successful method of recruitment. Furthermore, we received calls and emails from potential participants from all over the United States when they saw study information from professional websites displaying information on the studies (through fliers or interview) or when they found the study through ClinTrial.gov.

2.2 Participants

We recruited adults with complete or incomplete SCI ≥3 months, medically stable, and with the highest neuropathic pain level of >3/10 on the Numeric Pain Rating Scale (NPRS) (Hanley et al., 2006) who were willing to participate in a 12-week Remote Qigong practice (mind-body approach), fluent in English, and had access to the internet and a computer/iPad or smartphone.

The study was conducted in accordance with the Declaration of Helsinki principles (2013) (WMA Declaration of Helsinki–Ethical Principles for Medical Research Involving Human Subjects, 2021). The study was approved by the Institutional Review Board (IRB) of the University of Minnesota (IRB# STUDY00011997). The CONSORT reporting guidelines were followed (Moher et al., 2010; Boutron et al., 2017). After signing HIPAA/informed eConsent, study staff members acquired demographic information, general health, medical history, screened for cognitive impairments (Mini-Mental State Examination-short version, cutoff score <13/16) (Folstein, Folstein, and McHugh, 1975; Cummings, 1993), and for kinesthetic motor imagery ability (Kinesthetic and Visual Imagery Questionnaire, cutoff score <15/25 points) (Malouin et al., 2007). Data were collected on REDCap, which uses a MySQL database via a secure web interface.

2.3 Intervention

We used the Spring Forest Qigong's "Five Element Healing Movements" video (41 min), in which Grand Master Lin demonstrates five gentle horizontal and vertical arm and leg movements in specific postures in the standing position. A Qigong Master (Spring Forest Qigong Center, Minnesota) taught the 6-h introductory class over Zoom. Participants accessed the video with a study number and password and were asked to practice at least 3x/week for 12 weeks in any location of their choice with an internet connection. Figure 1 shows the five Qigong movements. More details are available in Van de Winckel et al. (2023a). Participants were instructed to actively move along with the video however much they comfortably could and to perform kinesthetic imagery at the same time. The first author developed specific kinesthetic imagery instructions to allow participants with all levels of mobility to participate maximally in the Qigong practice: participants were asked to focus on the feeling of the body as if they were standing up (regardless of whether they were actually standing, sitting, or lying down) and to imagine the *feeling* of the soles of their feet being in contact with the floor and the *feeling* of the flow while imagining performing the whole-body movements, rather than to "visualize" the whole-body movement. If reproducing this feeling was difficult, participants were asked to associate positive memories from before their SCI with this imagined standing posture, i.e., the feeling of warm sand under the soles of their feet when walking on the beach.

During the 6-week follow-up, participants were not practicing Qigong, but afterward, participants could restart their Qigong practice at the frequency of their choice so we could evaluate behavioral changes, neuropathic pain, and function at 1-year follow-up.

FIGURE 1
Spring Forest Qigong's "Five Element Qigong Healing Movements". The five movements are presented in clockwise order. Movement 1: moving of Yin and Yang; movement 2: breathing of the universe; movement 3: connecting with the heaven and Earth; movement 4: connecting with your body's energy; and movement 5: connecting with your heart's energy. Details of how the different movements are performed are presented in Van de Winckel et al. (2023a).

2.4 Outcome measures

2.4.1 Primary outcome

Based on prior literature (Rounsaville, Carroll, and Onken, 2001; Czajkowski et al., 2015; Winckers et al., 2015; Greenberg et al., 2020; 2019; Carl et al., 2020), we assessed the following *a priori* feasibility indicators for our primary objective: recruitment estimate of 40% of adults with complete SCI and 60% of adults with incomplete SCI; Qigong adherence of minimum 70% of participants practicing at least 2x/week; maximum 30% attrition; none of the questionnaires fully missing in >25% of the participants; mild study-related adverse events in maximum 10% of participants; and ≥70% participants satisfied with the program. Quotes from participants were used to identify satisfaction with the Qigong practice and the study. Video access (day, time, and duration) was automatically tracked via the Spring Forest Qigong website, and the logs were provided to the first author. The first author, a certified Spring Forest Qigong practice group leader, level 5 of 5 in the Spring Forest Qigong with Qigong practice experience, organized weekly 1:1 check-ins to address questions, perceptions, effects, and satisfaction with the Qigong practice, demonstrate movements if needed, and monitor adverse events. Given the slow, gentle movements, kinesthetic imagery, and weekly check-ins, we considered Qigong practice *risks* minimal and limited to mild transient discomfort. Participants continued with regular healthcare appointments and neuropathic pain medication if needed, but other health appointments for neuropathic pain (e.g., osteopathy) were not permitted during the study to avoid concomitant effects.

2.4.2 Secondary outcomes

As estimate of efficacy outcomes for larger future randomized controlled trials, graduate students called participants weekly to monitor the highest, average, and lowest *neuropathic pain* intensity ratings (NPRS) (Hanley et al., 2006). Distinctions between types of pain were made using the National Institute of Neurological Disorders-Common Data Elements (NINDS-CDE) International SCI Pain Basic Data Set Version 2.0 (Widerström-Noga et al., 2014). The graduate students noted neuropathic pain medication dosage taken that week, recent illnesses, and healthcare utilization, including recent hospitalizations.

Other outcome measures were collected by graduate students over Zoom at five time points: baseline, 6 weeks (mid-Qigong practice), 12 weeks (end of Qigong practice), 6-week follow-up, and 1-year follow-up.

The NINDS-CDE International SCI Pain Basic Data Set Version 2.0 (Widerström-Noga et al., 2014) also assessed pain dimensions (e.g., pain location) and how intense pain interferes with mood, activity, and sleep. We evaluated the frequency of spasms and spasm severity (Penn Spasm Frequency Scale) (Mills et al., 2018); mood (Patient Health Questionnaire-9, PHQ-9) (Kroenke, Spitzer, and Williams, 2001; Bombardier et al., 2004; Krause et al., 2009; Krause, Reed, and McArdle, 2010; Fann et al., 2011); anxiety (Spielberger State-Trait Anxiety Inventory) (Spielberger et al., 1983); body appreciation (Functionality Appreciation Scale, FAS) (Alleva, Tylka, and Kroon Van Diest, 2017); and quality of life (World Health Organization Quality of Life Instruments, WHOQOL-BREF) (Jang et al., 2004). Participants self-reported on whether

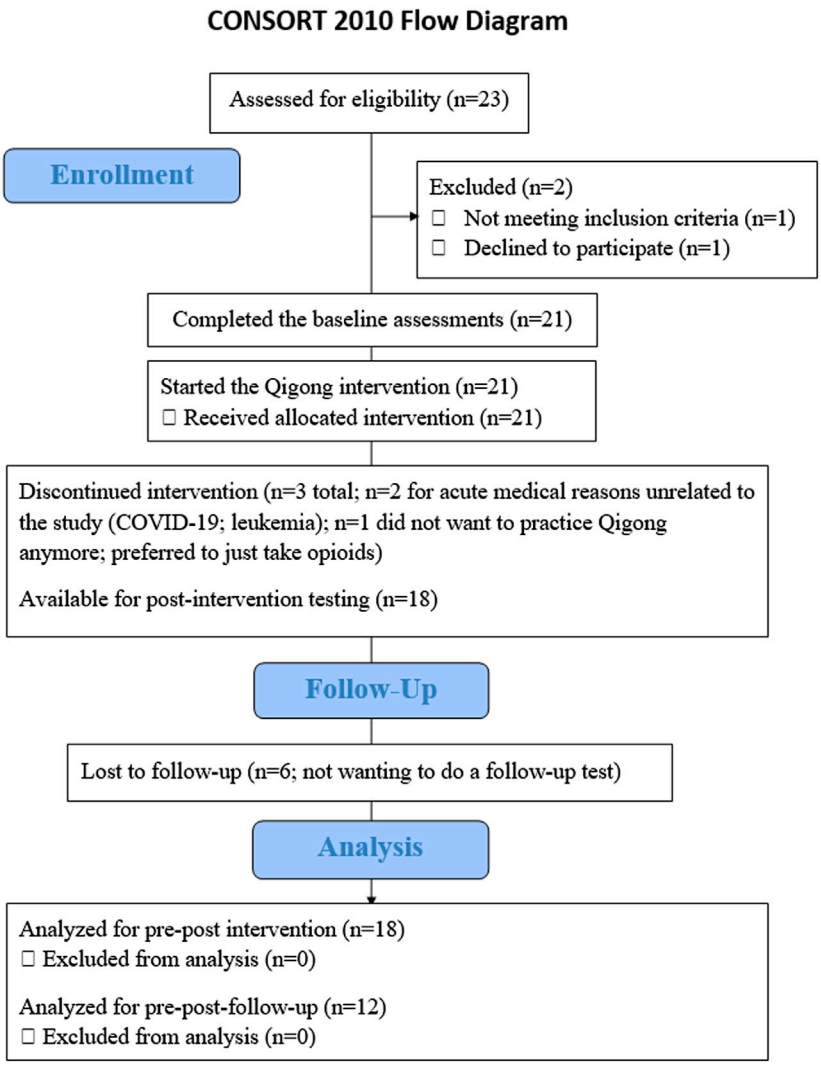

FIGURE 2
CONSORT flow diagram showing flow of participants throughout the study.

cardiovascular, bladder, bowel, and sexual functions were normal, abnormal, or absent (Autonomic Standards Assessment Form) (Krassioukov et al., 2012). Functional performance was assessed with the Spinal Cord Injury Functional Index (SCI/FI) (Slavin et al., 2016), across four domains: basic mobility, self-care, fine motor function, and ambulation (Keeney et al., 2018). Participants self-identified goals related to important daily life activities that were currently difficult to perform because of neuropathic pain (Patient-Specific Functional Scale, PSFS) (Westaway, Stratford, and Binkley, 1998).

2.5 Statistical analysis

2.5.1 Sample size

Power and sample size calculations were made based on estimates from another body awareness therapy (i.e., cognitive multisensory rehabilitation) in adults with SCI (Van de Winckel et al., 2023b). Assuming the same SD estimate, n = 18 participants have >98% power to detect the same pain reduction of 2.31 points on the NPRS (d = 1.12) with a two-sided significance level of 0.05 using a paired t-test, and 80% power to detect a pain reduction of 1.46 points (d = 0.72). A 30% attrition rate would result in 80% power to detect a pain reduction of 1.85 points (d = 0.89).

2.5.2 Statistical analysis

Per-protocol analyses were conducted for all outcomes for our secondary objective. We have added intent-to-treat analyses for the ANOVA tests and longitudinal modeling of the pain outcomes. We imputed the data with multiple imputations using the "mice" package in R, conducted the ANOVA test, Tukey's *post hoc* comparisons, and the longitudinal modeling using linear mixed models for each imputed dataset, and averaged the results across all datasets.

The present data provide an estimate of key trial elements to determine whether to proceed to a larger randomized controlled trial. Quantitative variables are summarized using descriptive statistics at each time point. We used standard statistical software R version 4.2.1. Data from the first 12 weeks were analyzed using a

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TABLE 1 Demographic and clinical characteristics of adults with spinal cord injury and neuropathic pain.

	Adults with SCI and neuropathic pain (n = 18)
Age, years mean ± SD (range)	59.61 ± 11.54 (30–76)
Sex, n (%)	
Male	12 (66.67)
Female	6 (33.33)
Gender identity, n (%)	
Male	12 (66.67)
Female	6 (33.33)
Others	0 (0.00)
Ethnicity, n (%)	
Hispanic	0 (0.00)
Non-Hispanic	18 (100.00)
Race, n (%)	
White	18 (100.00)
Asian	0 (0.00)
African-American/Black	0 (0.00)
Multi-racial	0 (0.00)
Hawaiian or other Pacific Islander	0 (0.00)
Others	0 (0.00)
Veterans, n (%)	3 (16.67)
Yes/no	15 (83.33)
Location of residence, n (%)	
Rural	6 (33.33)
City or suburb	12 (66.67)
Financial situation, n (%)	
Socioeconomic distress	12 (66.67)
Below the poverty threshold	3 (16.67)
Baseline neuropathic pain intensity level, mean ± SD	
High	7.94 ± 2.15
Average	4.78 ± 2.69
Low	3.06 ± 2.24
Time since spinal cord injury, years, mean ± SD, range (years)	15.17 ± 11.16 (1–40)
Etiology of spinal cord injury, n (%)	
Traumatic	13 (72.22)
Non-traumatic	5 (27.78)
Spinal cord injury lesion level, n (%)	
Cervical	8 (44.44)
Thoracal	7 (38.89)
Lumbar	3 (16.67)

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TABLE 1 (*Continued*) Demographic and clinical characteristics of adults with spinal cord injury and neuropathic pain.

	Adults with SCI and neuropathic pain (n = 18)
Sacral	0 (0.00)
AIS level, n (%)	
A	6 (33.33)
B	1 (5.56)
C	6 (33.33)
D	5 (27.78)
Level of impairment, n (%)	
Paraplegia (complete; incomplete)	4 (22.22); 6 (33.33)
Tetraplegia (complete; incomplete)	2 (11.11); 6 (33.33)
Ambulation, n (%)	3 (16.67)
Walking without assistance	1 (5.56)
Combined use of walking with and without assistance	0 (0.00)
Walking with assistance	3 (16.67)
Manual wheelchair	2 (11.11)
Combined use of manual and motorized wheelchairs	1 (5.56)
Combined use of motorized wheelchair and walking with assistance	1 (5.56)
Combined use of manual wheelchair and walking with assistance	7 (38.89)
Motorized wheelchair	0 (0.00)
Ambulation, mean percent time (SD)	
Walking	21.11 (±40.85)
Walking with assistance	2.5 (±6.47)
Manual wheelchair	30 (±44.95)
Motorized wheelchair	46.39 (±48.62)
Neuropathic pain medication at baseline, n (%)	
Advil	1 (5.55)
Aspirin	1 (5.55)
Belbuca	1 (5.55)
Duloxetine	8 (44.44)
Gabapentin	1 (5.55)
Ibuprofen	1 (5.55)
Lamictal	1 (5.55)
Lidocaine patch	1 (5.55)
Lyrica	4 (22.22)
Naproxen	1 (5.55)
Oxycodone	1 (5.55)
Tegretol	1 (5.55)
Tylenol	1 (5.55)
Mini-Mental State Examination-short version (cutoff score <13/16), mean ± SD	15.06 ± 1.21
Kinesthetic and Visual Imagery Questionnaire (cutoff score <15/25 points), mean ± SD	23.44 ± 2.01

AIS level, International Standards for Neurological Classification of SCI American Spinal Cord Injury Association Impairment Scale (ISNCSCI-AIS) exam.

TABLE 2 Primary and secondary outcome measures in adults with SCI-related neuropathic pain at five time points.

Outcome measure	Baseline (mean ± SD)	6-week Qigong (mean ± SD)	12-week Qigong (mean ± SD)	6-week follow-up (mean ± SD)	1-year follow-up (mean ± SD)	Repeated-measures ANOVA (baseline–6wFU)	Significant Tukey's *post hoc* pairs	Paired *t*-tests (6wFU–1YFU)
n	(*n* = 18)	(*n* = 18)	(*n* = 18)	(*n* = 18)	(*n* = 12)			
Highest NPRS	7.94 ± 2.15	5.94 ± 2.48	4.17 ± 3.07	4.39 ± 3.05	4.92 ± 3.03	F (3.15) = 19.70 p < 0.0001*	B–6wQ	t = 2.24 p = 0.05
							B–12wQ	
							B–6wFU	
							6wQ–12wQ	
							6wQ–6wFU	
Average NPRS	4.78 ± 2.69	3.92 ± 2.57	2.72 ± 2.54	2.94 ± 2.58	2.75 ± 2.01	F (3.15) = 7.65 p = 0.003*	B–12wQ	t = 1.74 p = 0.11
							B–6wFU	
							6wQ–12wQ	
Lowest NPRS	3.06 ± 2.24	2.00 ± 2.28	1.67 ± 2.45	1.61 ± 2.40	1.08 ± 2.19	F (3.15) = 8.24 p = 0.002*	B–6wQ	t = 2.25 p = 0.81
							B–12wQ	
							B–6wFU	
Interference on - Activity	5.39 ± 3.55	3.61 ± 2.38	1.94 ± 2.29	2.11 ± 2.37	2.67 ± 2.84	F (3.15) = 10.09 p = 0.0007*	B–6wQ	t = 1.91 p = 0.82
							B–12wQ	
							B–6wFU	
							6wQ–12wQ	
							6wQ–6wFU	
- Mood	5.00 ± 3.50	3.56 ± 2.23	1.61 ± 2.59	1.67 ± 2.22	1.92 ± 2.35	F (3.15) = 10.95 p = 0.0005*	B–6wQ	t = 2.24 p = 0.05
							B–12wQ	
							B–6wFU	
							6wQ–12wQ	
							6wQ–6wFU	
- Sleep	5.44 ± 3.57	3.94 ± 3.44	2.28 ± 3.04	2.44 ± 3.38	2.83 ± 3.95	F (3.15) = 8.55 p = 0.002*	B–12wQ	t = 1.43 p = 0.18
							B–6wFU	
							6wQ–12wQ	
Spasm - Frequency	1.67 ± 1.37	1.22 ± 1.35	0.50 ± 0.71	0.39 ± 0.61	0.50 ± 0.90	F (1.83, 31, 12) = 12.71 p = 0.0001*	B–12wQ	t = 1 p = 0.34
							B–6wFU	
							6wQ–12wQ	
							6wQ–6wFU	
- Severity	1.39 ± 1.14	1.06 ± 1.16	0.67 ± 0.84	0.33 ± 0.49	0.42 ± 0.67	F (3.15) = 7.59 p = 0.003*	B–12wQ	t = 1 p = 0.34
							B–6wFU	
							6wQ–12wQ	
PHQ-9	6.94 ± 5.54	5.22 ± 4.58	4.61 ± 4.82	4.39 ± 4.78	NA	F (3.15) = 3.48 p = 0.04*	B–12wQ	NA
							B–6wFU	
PSFS	1.07 ± 1.46	4.04 ± 2.59	7.76 ± 2.85	7.93 ± 2.91	7.64 ± 3.19	F (1.96, 33.35) = 53.18 p = 0.0001*	B–6wQ	t = −0.74 p = 0.47
							B–12wQ	
							B–6wFU	

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TABLE 2 (*Continued*) Primary and secondary outcome measures in adults with SCI-related neuropathic pain at five time points.

Outcome measure	Baseline (mean ± SD)	6-week Qigong (mean ± SD)	12-week Qigong (mean ± SD)	6-week follow-up (mean ± SD)	1-year follow-up (mean ± SD)	Repeated-measures ANOVA (baseline–6wFU)	Significant Tukey's *post hoc* pairs	Paired *t*-tests (6wFU–1YFU)
							6wQ–12wQ	
							6wQ–6wFU	
State anxiety	35.00 ± 10.95	30.11 ± 9.79	29.67 ± 11.88	27.94 ± 7.61	NA	F (3.51) = 3.93 p = 0.013*	B–6wFU	NA
Trait anxiety	40.11 ± 10.71	35.78 ± 10.05	35.28 ± 11.60	34.39 ± 10.07	NA	F (3.51) = 5.79 p = 0.0017*	B–6wQ	NA
							B–12wQ	
							B–6wFU	
FAS	3.12 ± 0.58	3.13 ± 0.60	3.41 ± 0.60	3.52 ± 0.51	NA	F (3.15) = 5.81 p = 0.008*	B–12wQ	NA
							B–6wFU	
							6wQ–12wQ	
							6wQ–6wFU	
WHOQOL - Physical health	51.33 ± 19.57	58.44 ± 18.68	59.28 ± 17.40	61.28 ± 17.76	NA	F (3.51) = 4.69 p = 0.006*	B–12wQ	NA
							B–6wFU	
- Psychological health	64.61 ± 17.20	64.72 ± 18.20	69.61 ± 19.21	67.78 ± 18.13	NA	F (3.51) = 2.68 p = 0.057		NA
- Social relationships	53.17 ± 20.60	53.50 ± 21.16	59.72 ± 17.67	61.56 ± 17.76	NA	F (3.51) = 3.66 p = 0.018*		NA
- Environment	77.56 ± 16.76	79.56 ± 15.87	79.33 ± 19.78	81.67 ± 16.49	NA	F (3.51) = 0.84 p = 0.48		NA
Autonomic Function - General function	21.72 ± 3.18	21.72 ± 3.18	22.78 ± 1.83	23.00 ± 1.57	23.17 ± 1.53	F (3.51) = 5.137 p = 0.004*	B–6wFU	Same value
							6wQ–6wFU	
- Bladder function	1.94 ± 2.44	1.94 ± 2.44	2.22 ± 2.32	2.22 ± 2.32	2.83 ± 2.29	F (3.51) = 2.457 p = 0.07	NA	t = 1.60
								p = 0.14
- Bowel function	2.89 ± 2.45	2.89 ± 2.45	3.22 ± 2.46	3.22 ± 2.46	3.83 ± 2.17	F (3.51) = 2.83 p = 0.05	NA	t = 1
								p = 0.34
- Sexual function	2.28 ± 2.61	2.28 ± 2.61	2.50 ± 2.83	2.61 ± 2.85	3.33 ± 3.20	F (3,51) = 3.40 p = 0.03*	NA	Same value
SCI-FI para	(n = 10)	(n = 10)	(n = 10)	(n = 10)	(n = 9)			
- Basic mobility	26.40 ± 9.45	26.80 ± 9.81	31.40 ± 5.32	32.80 ± 4.05	31.22 ± 6.26	F (1.13, 10.14) = 10.54 p = 0.007*	B–12wQ	t = −1.20 p = 0.26
							B–6wFU	
							6wQ–12wQ	
							6wQ–6wFU	
- Self-care	26.80 ± 10.34	27.70 ± 9.09	30.20 ± 7.51	32.10 ± 5.28	29.78 ± 8.61	F (1.57, 14.10) = 8.87 p = 0.005*	B–12wQ	t = −1.07
							B–6wFU	p = 0.32
- Fine motor function	28.20 ± 4.02	28.90 ± 2.92	30.50 ± 1.90	31.40 ± 1.07	31.11 ± 2.03	F (1.76, 15.85) = 7.86 p = 0.005*	B–12wQ	t = −1
							B–6wFU	p = 0.35
- Ambulation	5.60 ± 6.93	6.30 ± 7.29	6.80 ± 7.51	7.30 ± 7.82	5.33 ± 7.71	F (1.79, 16.09) = 3.87 p = 0.05	NA	t = −1.79
								p = 0.11

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TABLE 2 (*Continued*) Primary and secondary outcome measures in adults with SCI-related neuropathic pain at five time points.

Outcome measure	Baseline (mean ± SD)	6-week Qigong (mean ± SD)	12-week Qigong (mean ± SD)	6-week follow-up (mean ± SD)	1-year follow-up (mean ± SD)	Repeated-measures ANOVA (baseline–6wFU)	Significant Tukey's *post hoc* pairs	Paired *t*-tests (6wFU–1YFU)
SCI-FI quad	(n = 8)	(n = 8)	(n = 8)	(n = 8)	(n = 3)			
- Basic mobility	12.00 ± 11.26	13.63 ± 12.19	15.00 ± 12.82	15.50 ± 12.60	17.67 ± 15.04	F (3.5) = 4.03 p = 0.08	NA	Same value
- Self-care	14.00 ± 13.15	14.25 ± 12.71	17.38 ± 13.00	18.00 ± 13.02	22.67 ± 10.60	F (1.35, 9.44) = 7.03 p = 0.02*	B–12wQ	t = −2
							B–6wFU	p = 0.18
- Fine motor function	16.63 ± 10.34	17.25 ± 10.91	18.00 ± 10.80	18.25 ± 10.87	25.67 ± 5.03	F (3,5) = 2.30 p = 0.19	NA	t = −1
								p = 0.42
- Ambulation	4.00 ± 6.30	4.50 ± 6.89	4.63 ± 6.93	4.75 ± 7.19	4.33 ± 7.51	F (1.34, 9.37) = 1.63 p = 0.24	NA	Same value

12wQ, 12 weeks of Qigong practice; 6wQ, 6 weeks of Qigong practice; 6wFU, 6-week follow-up; B, baseline; NPRS, Numeric Pain Rating Scale (used here to assess neuropathic pain intensity in the prior week); average NPRS, pain experienced most of the time in the past week; PHQ-9, Patient Health Questionnaire-9; PSFS, Patient-Specific Functional Scale; FAS, Functional Appreciation Scale; SCI/FI, Spinal Cord Injury Functional Index; WHOQOL, World Health Organization quality-of-life scale. Significant p-values ($p < 0.05$) are indicated with an *.

repeated-measures ANOVA, with Tukey's *post hoc* tests to evaluate changes between every pair of time points. The data at 1-year follow-up with missingness were compared to each of the time points during the 12-week main study using the paired t-tests with Bonferroni correction of the p-values.

3 Results

3.1 Demographic and behavioral data and feasibility measures

Figure 2 shows the CONSORT study flow chart of this non-randomized clinical trial. We recruited 23 adults with SCI between 1 July 2021 and 2 February 2023. We exceeded the *a priori* set feasibility benchmarks by retaining 18 participants (i.e., 82% retention) who completed the study, with 100% adherence to all study components, including the 6-week follow-up. Reconsenting (n = 12) at 1-year follow-up assessment was completed on 2 February 2023.

Table 1 displays the demographic and behavioral data of the participants. Among the 18 adults, six were women, 10 had paraplegia, and eight had tetraplegia; 33% of adults had a complete SCI (i.e., slightly below our estimated 40% recruitment). Mean age was 59.61 ± 11.54 years (range 30-76 years), and they were 15.17 ± 11.16 years post-SCI (1–40 years). The sex ratio of new SCI cases of men to women is approximately 4:1 (i.e., 78%). We enrolled a representative sample of women with SCI (33.33%), adults, 65+ years of age (38.89%), adults living in rural areas (33.33%), and veterans (16.67%). Despite recruiting nationally, all participants were non-Hispanic White people, pointing to the need for more diverse recruitment strategies. Approximately 67% of the participants had socioeconomic distress and were dependent on Medicare/Medicaid. Almost 17% of the participants were below the poverty threshold (Federal Poverty Guidelines - ProJusticeMN, 2023).

3.2 Outcome measures

For our primary objective, we exceeded our *a priori* benchmark of a minimum 70% of participants practicing at least 2x/week: group average was 169.72 min or 137.98% of the required Qigong practice intensity (3x/week). There were no study-related adverse events.

Participants almost unanimously reported that they could not wait to get back to the Qigong practice after the 6-week follow-up because they benefitted so much from it. At 1-year follow-up, one person was still performing Qigong every day. Five participants used Qigong when needed as a tool to bring their pain down. Two participants developed their own methods of breathing and mindfulness, based on what they learned in the program. Four participants had not performed Qigong since the end of the intervention period.

In total, 17 out of 18 participants (94.44%) were satisfied with the program (exceeding the 70% benchmark). One person [59-year-old man] was neutral and expressed: "I feel neutral about the Qigong exercises and weekly calls. I am pain-free now, and my goals (PSFS) were all achieved at week 6 and were still achieved at week 12."

For our secondary objectives, all means and standard deviations of the outcome measures are listed in Table 2. The main findings are reported in the following paragraphs.

The results with repeated-measures ANOVA (Table 2) showed a significant reduction in the highest, average, and lowest neuropathic pain levels from baseline to 12 weeks of Qigong, which was maintained at the 6-week (n = 18) and 1-year follow-ups (n = 12). Some participants had urinary tract infections or underwent surgeries at 1-year follow-up, causing a temporary increase in the highest neuropathic pain levels. The highest, average, and lowest pain all showed a significant reduction over time for both intent-to-treat and per-protocol analyses. The ANOVA and Tukey's *post hoc* comparisons showed a significant reduction in pain pre–post Qigong practice, and no significant changes were observed between post-Qigong and 6-week follow-up.

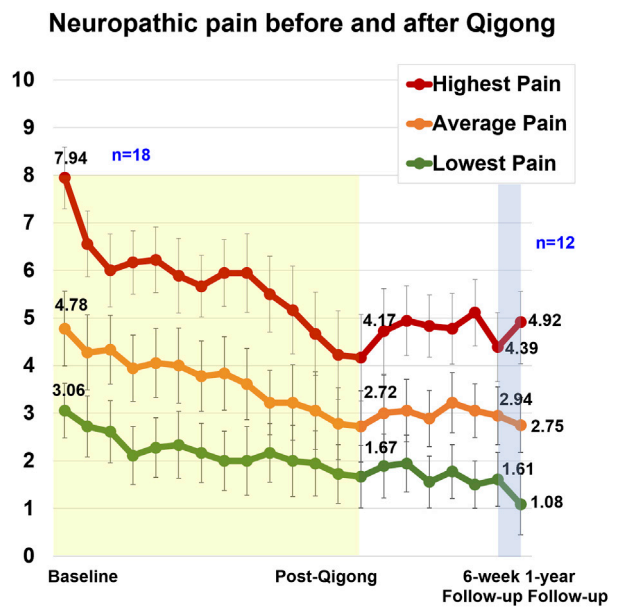

FIGURE 3
Weekly neuropathic pain levels for highest, average, and lowest pain in 18 adults with SCI. The 12-week Qigong training is highlighted in yellow. During the 6-week follow-up (n = 18), participants did not practice Qigong but implemented body awareness in daily life. Between the 6-week and 1-year follow-ups, participants could restart the Qigong practice at the frequency of their choice (n = 12).

The weekly highest, average, and lowest neuropathic pain intensity ratings (NPRS) (Hanley et al., 2006) are shown in Figure 3. The highest *neuropathic pain level* at baseline was 7.94 ± 2.33. After 12 weeks of Qigong, there was a reduction of 3.78 points (large effect size, Cohen's d = 1.75), 2.06 points (d = 1.12), and 1.39 points (d = 1.08) for highest, average, and lowest neuropathic pain levels, respectively, exceeding a minimal clinically important difference for the highest and average neuropathic pain levels (>1.80 points) (Williamson and Hoggart, 2005; Hanley et al., 2006; Galhardoni et al., 2019; Kim et al., 2020). After 12 weeks of Qigong, four participants were pain-free, and nine participants scored 0 on their lowest neuropathic pain. Pain reduction was maintained over the 6-week follow-up period (three were completely pain-free, and nine participants scored 0 on the lowest neuropathic pain). The person who was pain-free after 12 weeks of Qigong but not at the 6-week follow-up reported that the increased pain was due to the ongoing bladder issues and that his highest pain occurred infrequently. In total, 15 out of 18 participants reported significant pain reduction. Those that did not report any pain reduction shared that they enjoyed "listening" or "watching" the video but did not perform the kinesthetic imagery or did not apply the kinesthetic imagery tools in daily life or had significant pressure ulcers. Pressure ulcers or urinary tract infections during the study could cause temporary increases in neuropathic pain. However, even those three participants reported that they enjoyed watching the video and moving; they had fewer spasms, better sleep, and it was relaxing and calming.

After 12 weeks of Qigong, participants also reported reduced spasm frequency (change score 1.17 ± 1.20, d = 0.98) and severity (0.72 ± 1.02, d = 0.71), and reduced interference of neuropathic pain on activity (3.44 ± 2.53, d = 1.36), mood (3.39 ± 2.40, d = 1.41), and sleep (3.17 ± 2.77, d = 1.14, Figure 4 1). Participants performed better on functional activities (PSFS, 6.68 ± 3.07, d = 2.18, Figure 5), had reduced anxiety (state anxiety, −5.33 ± 11.84, d = 0.45; trait anxiety, −4.83 ± 6.19, d = 0.78), improved mood (2.33 ± 3.31, d = 0.70), body appreciation (−0.29 ± 0.48, d = 0.60), and quality of life (physical health, 7.94 ± 10.59, d = 0.75; psychological health, 5.00 ± 9.13, d = 0.55; social relationships, 6.56 ± 11.27, d = 0.58; and environment, 1.78 ± 7.06, d = 0.25). Overall, participants reported more intense daily activity (e.g., reorganizing furniture). One person could play the piano again after 3 years for 30 min/day, which is his favorite hobby. These significant improvements were maintained at follow-ups.

The results from the *post hoc* tests showed that cardiovascular function improved between baseline and 6-week follow-up and was maintained at 1-year follow-up, and participants' reports confirmed that this was related to improved temperature regulation. Four participants could better feel the need for bowel movements (greater interoception); they had improved sphincter control and were better at avoiding leakage. Four other participants could feel and enjoy sexual activity more, which was reflected by improvements in sexual function on the Autonomic Standards Assessment Form. Two participants reported increased awareness of the need to urinate or feeling urine passing through the catheter. Several participants became more aware when something was "off" in their bodies, and thus they could address urinary tract infections or uncomfortable seating positions quicker.

Finally, participants with paraplegia reported improved balance, which was reflected in improved scores in basic mobility, self-care, and fine motor function on the SCI/FI assessment. An example of improved fine motor function was that they did not need to use their hands anymore for balance and, thus, could do fine motor activities while sitting in the wheelchair. Participants with tetraplegia improved in self-care.

4 Discussion

The results of this pilot non-randomized controlled trial demonstrate feasibility and adherence to a remote Qigong intervention and study protocol. Qigong practice was well tolerated with no study-related adverse events. The vast majority of participants enjoyed Qigong practice and continued practicing as needed afterward, pointing to a change in behavior that helped them gain control over an otherwise debilitating symptom. The feedback from some of the participants after the Spring Forest Qigong practice can be found in the following paragraphs:

[65-year-old woman] "It got me back in touch with meditating that I felt I was missing in my life. At times, I have more body awareness which can further increase over time. I have much less pain. I am grateful and glad that I was able to do it."

[68-year-old man] "The fact that the pain is reduced makes life more pleasurable, especially with social contacts (family gatherings)."

[53-year-old man] "Qigong is relaxing and calming. That relaxed and calm feeling carries over into the day."

[76-year-old man] "Two thumbs up. I can't say enough good about it, how many good things it is doing for me. I am practicing

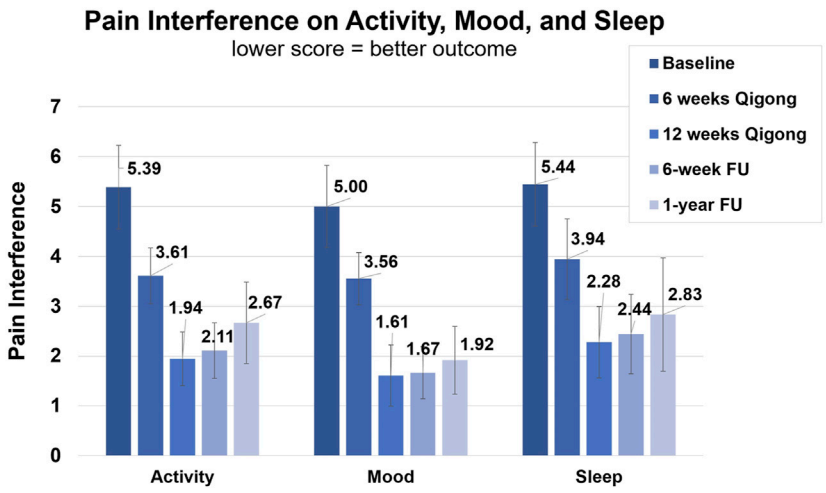

FIGURE 4
Clinical assessments of the NINDS-CDE International SCI Pain Basic Data Set Version 2.0.1. Average score of interference of neuropathic pain with activity, mood, and sleep. Assessments were taken at baseline, 6-week Qigong practice, 12-week Qigong practice, 6-week follow-up, and 1-year follow-up.

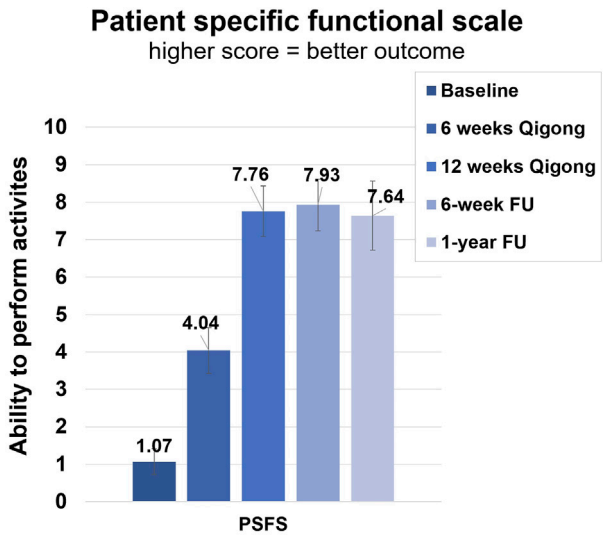

FIGURE 5
Clinical assessments of the Patient-Specific Functional Scale (PSFS). Average score of ability to perform three functional activities. Assessments were taken at baseline, 6 weeks of Qigong practice, 12 weeks of Qigong practice, 6-week follow-up, and 1-year follow-up.

almost every day. Before the study, I was ready to jump from a building ("ready to get out of this body") and now I do not have these feelings anymore. The underlying results are excellent: pain-free, no spasms, sleep is good now, calmer, can handle things better. I can play the piano again after 3 years. Before the study, I was antsy after about 15 min at the computer, and I had to take a nap on the bed. Now I can sit at the computer for 3–4 h, and it feels good. At night, I used to be cold and needed a sweatshirt to sleep. Now I stay comfortably warm, and I do not need the sweatshirt anymore. In the last 2 weeks, I also regained sensation of the catheter. I feel when urine is passing through which I could not feel before."

[46-year-old woman] "It was really helpful to get more in tune with my body. My pain is down, and I am sleeping better. I knew that if I signed up for the study I would do it because of outside accountability. There was curiosity involved. The Qigong was relaxing and soothing. It was helpful for my children as well. The plantar fasciitis is better. It is healing faster. The tingling in the feet is better, and the pain is down so I am sleeping better. I am more social; I have more energy and organize things easier. I have more control over life. It is easier now for me to make decisions and to undertake a big thing like a move."

[58-year-old man] "I am over the moon! I never thought that it would go this well. Before the study, I was spending much time in the shower to deal with the pain and now, I have had no need at all anymore for that. My feeling has been that it was absolutely wonderful! I am so happy for the opportunity to be part of this study because it made so much difference. I do not need to lay in the shower anymore to reduce the pain, and I was able to sit for a whole day inspiring students and researchers by sharing my journey, telling them: And here is this study . . . what a difference it is making in people's lives. The idea that there is something out there that could help me, considering how long ago I had the SCI (29 years of dealing with this pain!). . . and here in only 8 weeks it makes a profound difference in my life. It gives people hope. Prior to the study, I would not have been able to sit here and talk to you for so long. This is another proof of how profound the difference is that this study has made."

[60-year-old woman] "What you practice grows stronger. It stayed with me. The positivity part has been more prominent there for me. My life is changing a lot. I have been able to realize that those five emotions from the Five Element Qigong Healing Movements are what I want for my life. There are changes in friendship. I have stopped taking calls from negative people and spent more time with positive people. As simple as those points are, they are profound.

Years ago, a therapist told me that you can decide in the morning how you want to use your energy. That makes sense now. I have been using energy now to bring joy and contentment. I have been a lot more active, I do not have to lay down anymore during the day."

Specific exercises that participants preferred were the bouncing (at the beginning of the video), the focus on positive emotions, and movements 2 and 5. Some participants liked the second movement because of the focus on the vertical alignment and flow in the body (head to toe) while gently moving the arms in an elliptical movement up and down and the fifth movement for the connection with the gratitude feeling and heart's energy. They also reported that the kinesthetic imagery, e.g., imagining the feeling of how the foot would leave imprints in the sand or being aware/imagining the weight shift in the pelvis during transfers and at other moments (e.g., during sitting in the wheelchair) helped with reducing the pain.

Twelve weeks of Qigong practice appears to be the best duration for sustained neuropathic pain reduction (Table 2). The participants reported that the video was easy to follow and understand. The Qigong practice frequency is feasible given that the majority of participants practiced more often than the requested 3x/week. The adaptation to the Qigong practice for adults with SCI by combining active movements to their ability level with kinesthetic imagery seemed particularly an effective and worth pursuing further in a larger study.

In addition to pain reduction and improvements in mood and function, participants reported a change in *mindset* in how they approached their pain. At baseline, participants distracted themselves from pain or ignored pain, and as a result, the pain worsened often. After Qigong practice, many participants shared that they learned how to connect with their body, developed the ability to listen to their bodies, and understood when their bodies gave signals of an uncomfortable position or situation (e.g., bowel or bladder issue). Participants felt they reacted quicker to these signals, and the uncomfortable feeling did not develop into pain. Examples include that participants more quickly repositioned themselves in the chair to avoid pressure sores, or participants were able to identify quicker when they had a urinary tract infection or that "something was off" in the body, prompting them to get medical help and treatment (e.g., detecting iron deficiency and receiving iron supplements). Events like urinary tract infections could cause short neuropathic pain flare-ups. However, given that chronic neuropathic pain is persistent and refractory to medications, the observed long-standing pain reduction all through the study is very likely related to the Qigong practice. Additionally, we observed in another study on adults with spinal cord injury that chronic neuropathic pain does not change when only medication (treatment-as-usual) is given (Van de Winckel et al., 2023b). Yet, our results need to be investigated in a future randomized controlled trial with a greater sample size.

There are different concepts around mindset. One concept distinguishes a growth mindset [i.e., believing that qualities can be cultivated and expanded through personal investment (Thames and Webster, 2015)] from a fixed mindset (i.e., believing that change is a threat). Another concept distinguished "stress-is-enhancing" mindset (i.e., stress leads to better performance, productivity, health, wellbeing, learning, and growth). which is also related to the ability to positively reframe a situation, greater wellbeing, and fewer depressive symptoms, from "stress-is-debilitating" mindset (Grünenwald et al., 2023). The latter (stress is debilitating) has been reported more frequently in adults with chronic pain vs. those without chronic pain. Similarly, views of coping with the pandemic (it is an opportunity vs. it is manageable vs. it is a catastrophe), where the first two groups (i.e., opportunity and manageable) reported greater wellbeing than those who viewed COVID-19 as a catastrophe (Zion et al., 2022).

While we did not specifically evaluate the type of mindset through questionnaires, the fact that the study used volunteer sampling might have attracted adults who were willing to try something new. Most of our participants had not heard of Qigong prior to entering the study, and some were skeptical about the ability of Qigong being able to help reduce pain, but they were willing to invest their time and explore the effects, given the debilitating situation of the neuropathic pain. Their skepticism often evaporated and their enthusiasm grew after the first effects of pain reduction were perceived, and they experienced an increased feeling of control over their body and confidence about being able to successfully do something to relieve the pain.

The increased body awareness and ability to listen to body cues, as well as being calmer, having better mood, better sleep, and being able to deal with things better were consistently reported among the participants. They also reported having more in control over their life, having more energy, and more confidence knowing that they now had tools to deal with the pain if the pain would come up again. They reported having a calmer mind and a calm body, feeling more peace and restful, more connectedness/in tune with the body. They figured out more quickly when something was not right. They experienced more happiness, and were ready to interact socially again, changing the circle of friends if needed by seeking out those with a positive outlook on life, or they reported taking on life goals or bigger house tasks such as rearranging furniture, or bidding on a house, or moving. One person reported it is easier now to make decisions and undertake big things, like a move. They reported that also other types of pain (e.g., plantar fasciitis or elbow tendonitis) got better. One participant reported her children enjoyed doing the Qigong with her. They also felt that the positive emotions and gratitude practiced during Qigong carried over into daily life.

There are some limitations to this study. The volunteer sampling may have led to selection bias of those that chose to invest in a 12-week program and thus may limit generalization. This non-randomized pilot clinical trial was conducted in a small sample, and thus validation in a larger sample with a randomized clinical trial design is needed. Even though we did not have a control group in this study, we know from our other studies with a control group of adults with spinal cord injury with similar intensity levels of neuropathic pain (n = 14) that 6 weeks of standard of care only (i.e., neuropathic pain medication) did not change their neuropathic pain levels or any other SCI-related measures (Van de Winckel et al., 2023b). We are therefore confident that the proposed results are due to Qigong and not due to the placebo. Moreover, neuropathic pain is known to be resistant to pharmacological and non-pharmacological interventions such as surgery, neurostimulation (Forte et al., 2022), and physical and psychological therapy, and therefore the large effect size results seen with Qigong are very encouraging. Furthermore, while we recruited participants living in remote

areas and/or in financial distress, diversity in terms of race and ethnicity was missing. For example, adults of the Hispanic background account for 17.4% of the US population, or 55.4 million, (Velasco-Mondragon et al., 2016), and represent 8.3% of all SCI since 2005 (Spinal Cord Medicine, 2011; Spinal Cord Injury Statistics, 2016). Yet, they are underrepresented in SCI rehabilitation studies (National Spinal Cord Injury Statistical Center, 2022).

In conclusion, our pilot data demonstrate the feasibility and acceptability of practicing Qigong in adults with SCI-related neuropathic pain, generating promising results in terms of neuropathic pain and SCI-related symptoms. The data from the present work will inform the design of future randomized controlled trials. The remote delivery of Qigong offers multiple applications for use in the home or community. Further studies in adults with SCI of different races and ethnicity and Qigong delivery in other languages are needed.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at the Dryad repository: doi: 10.5061/dryad.6t1g1jx43.

Ethics statement

The studies involving humans were approved by the Institutional Review Board of the University of Minnesota. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

Specific contributions include conception or design of the work: AVdW. Recruitment: AVdW and LM. Data acquisition: AVdW, SC, and WD. Data curation: AVdW, SC, and WD. Data analysis, visualization, and interpretation of the evidence: AVdW, LZ, SC, WD, AP, RB, and LM. Writing of the original draft: AVdW. Writing, review, and editing: AVdW, LZ, SC, WD, AP, RB, and LM. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EDITED BY
Guodong Zhang,
Southwest University, China

REVIEWED BY
Afsaneh Bakhtiari,
Babol University of Medical Sciences, Iran
Fatemeh Nasiri Amiri,
Babol University of Medical Sciences, Iran

*CORRESPONDENCE
Krishan Kumar
✉ keshusony@rediffmail.com
Akshay Anand
✉ akshay1anand@rediffmail.com

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Mind-body practice as a primer to maintain psychological health among pregnant women–YOGESTA–a randomized controlled trial

Pooja Nadholta[1], Krishan Kumar[2]*, Pradip Kumar Saha[3], Vanita Suri[3], Amit Singh[4] and Akshay Anand[1,5]*

[1]Department of Neurology, Postgraduate Institute of Medical Education and Research, Chandigarh, India, [2]Department of Psychiatry, Postgraduate Institute of Medical Education and Research, Chandigarh, India, [3]Department of Obstetrics and Gynecology, Postgraduate Institute of Medical Education and Research, Chandigarh, India, [4]Division of Yoga and Life Science, Swami Vivekananda Yoga Anusandhana Samsthana, Bengaluru, India, [5]CCRYN-Collaborative Centre for Mind Body Intervention, PGIMER, Chandigarh, India

Objective: The objective of this study was to investigate the impact of Gestational Yoga-YOGESTA (Gestational Yoga), on the neuropsychology, quality of life, and personality of pregnant women.

Design: Open label, randomized controlled trial, used allocation concealment to allocate the treatment.

Setting: Department of Obstetrics and Gynecology and Neuroscience Research Lab, Department of Neurology, Post Graduate Institute of Medical Education and Research, Chandigarh, India.

Participants: We recruited a total of 100 pregnant women visiting the Outpatient Department of Obstetrics and Gynecology. Participants were aged between 18 and 35 with uncomplicated pregnancies and they were randomly assigned to either the Yoga group (YG) or the usual care group (UCG). A total of 77 pregnant women completed both the pre- and post-survey, with 34 participants in the Yoga group and 43 in the Usual care group.

Intervention: Pregnant women in their second and third trimesters were provided with a 16-week online Prenatal Yoga intervention. The intervention began after enrollment in the 2nd trimester, specifically between the 16th and 20th week, and was conducted 5 days a week until delivery, with an average intervention period of 47.18 $\pm$ 2.031 (mean $\pm$ SEM) days.

Chief outcome measures: We measured Perceived stress, Depression, Anxiety, Stress, and quality of life by using standard questionnaires.

Results: A total of 77 participants were included in the analysis, with 34 assigned to the Yoga group and 43 assigned to the control group. Most of the measured parameters demonstrated significant changes. The Yoga group exhibited a noteworthy decrease in perceived stress, depression, anxiety, and psychological stress, as well as an improvement in the psychological and environmental domains of QOL-BREF. Conversely, the control group demonstrated a significant increase in perceived stress, depression, anxiety, and psychological stress, along with a reduction in the physical, psychological, and social domains of QOL-BREF at the follow-up stage. Although the two groups were similar at baseline, the Yoga group showed substantial enhancements in perceived stress, depression, anxiety,

physiological stress, and overall quality of life when compared to the control group at follow-up.

Conclusion: The study's findings indicate that stress, anxiety, and depression are more likely to occur as gestational age progresses during pregnancy. Nevertheless, practicing Prenatal Yoga can effectively manage these changes and enhance the quality of life for expectant mothers.

Clinical trial registration: Clinical Trials Registry-India, Identifier CTRI/2021/01/030827.

KEYWORDS

pregnancy, Yoga, mind body intervention, neuropsychologial assessment, stress, prenatal Yoga, YOGESTA

Introduction

Pregnancy is marked by continuous physiological, metabolic, and mental challenges that can be difficult to adapt to. A woman's neuropsychology and ability to manage these challenges effectively can play a crucial role in her adaptation to the physical and physiological demands of pregnancy. Stress, anxiety, and depression are common sources of distress during pregnancy that can have negative impacts on both maternal and fetal health (1). To ensure the smooth progression of pregnancy and fetal development, it is important to consider both biological and psychological factors such as anxiety, and physical and psychological stress, which may contribute to pregnancy-related complications (2). During the prenatal and postpartum periods, women experience significant changes in their psychological health, physiological function, and social interactions, all of which can have a significant impact on their lives. Stress, anxiety, and depression are the most common factors that affect neuropsychology during pregnancy and can contribute to various complications that arise during pregnancy (3). A study conducted in Sweden on a population of 1,734 pregnant women revealed that psychiatric disorders were prevalent in 14.1% of pregnant women, with 3.3% exhibiting signs of major depression, 6.9% showing signs of minor depression, and 6.6% displaying signs of anxiety during pregnancy (4). Studies have shown that women in late pregnancy experience poorer sleep quality, worse physical health, and higher rates of depression compared to women in early pregnancy (4). The physical and psychological changes brought on by pregnancy also impact the different aspects of quality of life (QOL). Additionally, poor quality of life has been linked to an increased risk of pregnancy complications such as premature birth and low birth weight. Therefore, healthcare providers should be aware of the psychological changes that occur during pregnancy and provide additional support to pregnant women (5). The effects of prolonged psychological stress on pregnant women include premature births, abnormal fetal development at birth, and attention disorders or reduced performance of new-born with regard to executive function in later life (6). It is important to manage stress levels in pregnant women and implement interventions that are designed to reduce psychological distress. However, it should be noted that psychopharmacological stress management may not be suitable for pregnant women due to concerns about the adverse effects of some commonly used pharmaceuticals (7). It is crucial to manage psychological distress during pregnancy for the well-being of both the mother and the fetus. Early detection and non-pharmacological management through techniques such as psychological counseling, stress management, lifestyle modifications (including light physical activity and a balanced diet), and social support can significantly improve the psychological health and quality of life of pregnant women (8). Incorporating non-pharmacological interventions, such as exercise and Yoga, has been shown to be effective in managing psychological problems during pregnancy. These interventions provide a proactive approach for pregnant women to promote their wellness during this critical time.

Existing research indicates that psychological distress can have a negative effect on the ability to participate in physical activity (9). Physical inactivity is a prevalent issue during pregnancy, with approximately 60% of pregnant women being sedentary. This is often due to a lack of awareness about the advantages of exercising during pregnancy, which may lead to hesitation among women. However, exercise during pregnancy is of utmost importance in terms of maternal and fetal health, as it effectively reduces common pregnancy issues such as depression, insomnia, anxiety, fatigue, and excessive weight gain in the mother (10, 11). With growing evidence and awareness of their benefits, exercise and Yoga have become more widely embraced and practiced by pregnant women (12). In general, exercise has a significant effect on the improvement of neuropsychology in adults as well as in older adults (13, 14). Given the limited feasibility of engaging in intense physical activities during pregnancy, gentle exercise practices such as Yoga may be a preferred option for pregnant women. Yoga can provide a combination of physical and mental wellness benefits that are well-suited to the needs of pregnant women.

Yoga is usually a mix of physical exercise, mental exercises, meditation, different types of deep breathing, stretching, and relaxation. The meditation component of Yoga promotes deep relaxation, which helps to calm the senses and improve the focus of the mind, thereby enhancing mental health. Practicing Yoga during pregnancy is known to promote a holistic connection between the mind, body, and fetus of expectant mothers (15). Previous research has shown promising results regarding the benefits of Yoga during pregnancy (16). Studies have demonstrated that practicing Yoga can

reduce stress, anxiety, and depression, improve mood, and enhance overall well-being (17, 18). However, there is a need for further research to confirm and extend these findings.

Moreover, it is important to note that there is limited awareness about mental health issues during pregnancy, and routine screening for such problems is not common practice, thereby neglecting their significance as high-risk factors in pregnancy (19). However, it is crucial to acknowledge that psychological imbalances, including stress, anxiety, and psychosocial factors, have been associated with adverse outcomes such as preterm birth, low birth weight, and complications during both antepartum and intrapartum periods (19, 20). The generality ofthe need to carry out a counter-stress randomized controlled trial (RCT) in this region is imperative. It is worth mentioning that the labor room unpublished statistics of the hospital where our study was conducted revealed that out of a total of 5,202 deliveries in 2022, approximately 20.8% were preterm deliveries without a known cause. Psychological distress during pregnancy remains relatively understudied and often goes unnoticed as it is not routinely assessed during prenatal checkups. Hence the rationale of this study owes its origin to the need to investigate the incidence of psychological distress in pregnant women. We aimed to study the potential impact of Yoga on distress and its relationship to quality of life in healthy pregnant women. Our hypothesis is that regular practice of Yoga may enhance psychological resilience and lead to improved quality of life during pregnancy, thereby reducing the incidence of psychological distress. This study provides a rigorous and detailed investigation into the potential benefits of an online Yoga intervention for psychological distress and quality of life among uncomplicated pregnant women, and the randomized controlled design adds to the robustness of the study and the outcomes. By examining these variables in uncomplicated pregnant population, we hope to provide insights into the incidents of psychological distress during pregnancy, its progression throughout the period, and the potential role of Yoga as a preventive intervention for psychological distress during pregnancy. Further, this investigation might provide preliminary data about the incidents of psychological distress among pregnant women which can further be used to identify the mental health problem, its associated risks for maternal and fetal complications, and the need for psychological counseling during antenatal checkups.

Through our examination of these variables in women with uncomplicated pregnancies, our aim is to shed light on the occurrence and progression of psychological distress during pregnancy. Additionally, we seek to explore the potential role of Yoga as a preventive intervention for managing psychological distress during this critical period. Furthermore, this investigation may yield preliminary data regarding the incidence of psychological distress among pregnant women, which can contribute to identifying mental health issues, associated risks for maternal and fetal complications, and the need for psychological counseling during antenatal checkups.

Materials and methods

Study design and setting

The YOGESTA (Gestational Yoga) trial was carried out at the Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh, India after taking approval from the institutional ethics committee PGIMER.

This was an Open label, Parallel randomized controlled trial of online Yoga intervention among uncomplicated pregnant women. We recruited the participants in the 16th to 20th week of pregnancy and randomized them into Yoga and Usual care groups (UCG). Yoga group participants attended online morning Yoga classes from the time of recruitment until delivery, with daily attendance records and screenshots/videos of Yoga classes taken to ensure compliance with the intervention. UCG participants did not practice any Yoga or exercise during the study period. Assessment was done at two time points, baseline and follow-up. Baseline measurements were collected at the time of recruitment, i.e., between the 16th and the 20th week of pregnancy, and follow-up measurements were taken after 32 gestational weeks, using questionnaires to assess perceived stress (PSS); depression, anxiety, and stress (DASS); and quality of life (WHO-QOL BREF). The study design is both a between-subjects variable (comparing the Yoga group to the usual care group) and a within-subjects variable (comparing pre and post-intervention). The study was registered prospectively in the Clinical Trials Registry-India.

Participants

From November 2021 to January 2023, pregnant women who visited or tele-consulted with the Department of Obstetrics and Gynecology at PGIMER were recruited for the study by the first author, based on defined inclusion criteria, which included uncomplicated normal pregnancy aged between 18 and 35 years in the 16th to 20th week with a BMI < 30 and no associated anomalies such as hypertension or gestational diabetes. Pregnancies with any associated comorbidities like hypertension, gestational diabetes mellitus, small cervical length, low-lying placenta, and high-risk pregnancies were excluded from the study. The sample size was estimated based on the mean and standard deviation from published research which had delivered Yoga interventions to the pregnant population, using the formula $n = t2s2/r2m2$ where t is the value of t statistic for 95% confidence, s is the standard deviation, r is the relative precision, taken as 0.05 in this case and m is the mean. The maximum sample size was then taken to ensure the estimation and testing of the hypothesis for the variable having maximum variance. The participants were invited by telephone or directly approached during antenatal clinic checkups, 100 agreed and provided written consent. The first author then randomly allocated the participants into the Yoga group ($n = 50$) and usual care group ($n = 50$) by using specific codes (A = Yoga group, B = Usual Care Group) concealed in sealed envelopes. The allocation ratio of randomization of the control to the Yoga group was 1:1. Whole process of recruitment and randomization was done by the first author. Blinding was not possible for this study due to the nature of the intervention, which involved participants actively engaging in Yoga sessions. As the participants were aware of their group assignment and actively participated in the Yoga intervention, it was not feasible to blind them or the researchers conducting the study to the treatment allocation. The protocol was reviewed and approved by the institutional ethical committee before the recruitment of participants. The final analysis included 77 participants (34 in the Yoga group and 43 in the usual care group) with a power level of 95% and an effect size of 0.5. The participants' flow from baseline to

follow-up is shown in Supplementary Table S1, as per the CONSORT flow chart. The participants' age, BMI, and height did not differ between the two groups. The socioeconomic status [LIG- Low-Income group (5,000–16,000/month), MIG-1- Middle-Income group-1 (17,000–40,000/month), MIG-II- Middle Income group-II (41,000–85,000/month), HIG- High-Income group (85,000 and above)], demographics, and other parameters are reported as frequency and presented in Table 1.

Prenatal Yoga protocol

To cater to the changing physiological needs of pregnant women, our study aimed to implement gestational Yoga which we abbreviated as YOGESTA among uncomplicated pregnant women. YOGESTA consists of two distinct Yoga protocols for the 2nd and 3rd trimesters. The protocols incorporated a range of practices including stretching, breathing, relaxation, and meditation (details presented in Supplementary Table S2). The Yoga protocol was adapted from the book "Yoga for Pregnancy" by *HR Nagarathna*, with necessary modifications made by the Institute Ethical Committee, in consultation with an obstetrician. The modifications were made keeping in mind the safety and comfort of pregnant women, given the online nature of the intervention. The protocol was designed as 60 min for the second trimester and 40 min for the third trimester. The intervention was delivered by certified Yoga experts via the Google Meet interface 5 days a week from the time of recruitment until delivery. All the sessions were delivered online by instructors who observed and corrected the postures of individual participants. Daily attendance was recorded for every participant throughout the period of intervention. Participants in the Yoga group attended Yoga sessions for an average of 47.18 ± 2.03 (Mean ± SEM) days. The UCG participants were contacted via telephone follow-up to ensure that they were not involved in any physical activity except normal walking.

Briefly, the protocol comprised of asana (physical postures), pranayama (breathing practices), kriya (tratak), meditation, and relaxation practices.

Instrumentation

Multiple scales were used in this research study, including the PSS-10, DASS-42, and WHO-QOL-26, to comprehensively assess psychological distress in pregnant women and evaluate the impact of Yoga on these parameters, ensuring a comprehensive and multi-dimensional assessment of psychological well-being and quality of life.

Perceived stress scale

The Perceived Stress Scale (PSS-10) is a 10-item stress assessment instrument originally, scale was developed in *1983* by *Cohen*, *Kamarck*, *and Mermelstein* (21). (PSS-10) was used to measure the perceived stress levels among pregnant women. It is a widely recognized and validated scale that assesses how various situations and events impact an individual's thoughts and feelings, providing valuable insights into the specific stressors experienced during pregnancy. The scale asks questions related to negative events like how often you have been upset because of something that happened unexpectedly, how you felt you were unable to control important things in your life, and how often your felt nervous and stressed. Some questions are related to positive events which are revered during scoring, these are how often you felt confident about your ability to handle personal problems, how often you were able to control irritation, and how often you felt on top of things. Reliability, Validity, and scalability of PSS-10 during pregnancy have already been established by previous studies (22, 23) which show PSS-10 to be an appropriate scale to measure the perceived stress among pregnant women. The PSS measures an individual's perceived stress, with scores ranging from 0 to 40. A score of 0–13 is considered low, 14–26 is moderate, and 27–40 is high.

Depression anxiety stress scale

The Depression Anxiety Stress Scale (DASS-42) is a self-report measure that assesses the severity of negative emotions. The scale consists of three subscales, namely depression, anxiety, and stress, which are measured separately. Scores on each subscale can range from normal to extremely severe, depending on the severity of the symptoms reported by the individual. The severity levels are categorized as normal, mild, moderate, severe, and extremely severe (24). The scale contains 14 questions related to dysphoric moods such as sadness and unworthiness, measuring depression; 14 questions related to panic attacks and fears, measuring Anxiety, and the remaining 14 questions relate to tensions and irritability, measuring stress. Validation of DASS reliability during pregnancy has been done by previous studies (25, 26). (DASS-42) was employed to evaluate the severity of negative emotions, including depression, anxiety, and stress. By utilizing this comprehensive scale, we were able to capture a broad spectrum of psychological distress symptoms commonly experienced by pregnant women.

Who- quality of life- BREF scale

Quality of life was measured using the WHO-QOL-BREF questionnaire which contains 26 original items, among which 2 items measure overall perception of quality of life and 24 items examines 4 domains (D1- Physical, D2- Psychological, D3- Social, and D4- Environmental) (27). This is also a reliable scale to be used during pregnancy (28). This questionnaire depicts score from 0 to 100 and a higher score signifies better QOL. This questionnaire was used to assess the overall quality of life of pregnant women across multiple domains, including physical, psychological, social, and environmental aspects. This scale provides a holistic understanding of the impact of pregnancy on various aspects of life.

Results

In total, 100 participants gave their consent to participate and were randomized into Yoga ($n = 50$) and control or usual care groups ($n = 50$). During the course of the study, in the Yoga group, 16 participants dropped out for various reasons. Five of these individuals were not willing to participate in the Yoga intervention, eight started but discontinued the intervention, one participant experienced a

miscarriage, and two did not complete the required neuropsychological assessments. In the Usual care group, five discontinued the trial, and two experienced miscarriages. When accounting for miscarriages, the attrition rate was found to be 23%. However, if miscarriages are not included, the attrition rate for the study is 20%. Finally, 77 participants who completed the neuropsychological assessment at both time points were included in the data analysis including 34 and 43 in YG and UCG groups, respectively.

The two groups were found to be similar in terms of age, height, weight, BMI, occupation, education level, parity distribution, diet, socio-economic status, pregnancy method, and complications, indicating no significant differences between them in these demographic and lifestyle factors (Table 1).

All results are reported as Mean ± SEM and frequencies in %. Frequency percentage was reported as low, moderate, and high for PSS and normal, mild, moderate, severe, and extremely severe for DASS as per the standard questionnaire classification using descriptive statistics (Table 3). Within-group changes and between-group changes of Yoga and control groups are reported as Mean ± SEM in Table 2 along with the effect size of each parameter and considering $p \leq 0.05$ as a significant change. The effect size was calculated by dividing the difference of mean value between two groups by pooled standard deviation and is reported as a value of Cohen's d where $d = 0.2$ is small, $d = 0.5$ is medium and $d = 0.8$ is considered as large based on the benchmark suggested by Cohen (29).

Perceived stress

When the average scores were compared, both groups reported the same level of stress at baseline (UCG: 16.79 ± 0.763, Yoga: 17.38 ± 0.943) without any significant differences ($p = 0.623$). However, within-group analysis after follow-up showed a significant increase in perceived stress from 16.79 ± 0.763 to 20.84 ± 0.927 ($p = 0.000$) in the UCG (average change: −4.047) and a significant decrease in perceived stress from 17.38 ± 0.943 to 13.41 ± 0.943 ($p = 0.000$) in the YG (average change: 3.971).

Between-group analysis at follow-up demonstrated a highly significant reduction in perceived stress in the Yoga group, with an average change of −7.425 ($p = 0.000$) compared to the UCG.

At baseline, the UCG reported a low level of perceived stress at 20.9%, while the remaining 79.1% reported a moderate level. These levels changed at follow-up, with only 11.6% reporting low stress, 67.4% reporting moderate stress, and 20.9% reporting high stress. However, the YG reported 26.5% low stress, 70.6% moderate stress, and 2.9% high stress at baseline, which changed to 55.9% low stress and 44.1% moderate stress after the intervention.

Depression, anxiety, and stress

At baseline average score of the two groups did not differ for depression, anxiety, and stress. UCG reported a significant increase in depression from 7.33 ± 0.938 to 10.35 ± 1.191 ($p = 0.016$), anxiety from 7.44 ± 0.818 to 9.93 ± 1.044 ($p = 0.016$), and stress from 11.70 ± 1.090 to 16.93 ± 1.342 ($p = 0.000$) at follow-up. However the opposite trend was seen in YG with a significant decrease in depression from 8.71 ± 1.441 to 4.41 ± 0.998 ($p = 0.000$), anxiety from 9.09 ± 0.946 to 6.35 ± 0.774 ($p = 0.011$) and stress from 12.38 ± 1.346 to 7.35 ± 1.010 ($p = 0.000$) after intervention.

In the UCG group, at baseline, 72.16% were in the normal category of depression which decreased to 48.8% at follow-up. However, in mild, moderate, severe, and extremely severe categories percentages increased from 14.0, 11.6, 0, and 2.9%, to 23.3, 20.9, 4.7, and 2.3%, respectively. Similarly, the percentage of anxiety and stress in the normal range decreased from 58.1 and 81.4% to 48.8 and 41.9%, respectively. However, incidents of anxiety in the mild, moderate, severe, and extremely severe ranges increased from 4.7, 27.9, 9.3, and 0% to 11.6, 14.0, 11.6, and 14.0%, respectively. There were only 16.3% mild and 2.3% moderate incidents of stress while at follow-up only 9.3% were in the mild range, the moderate range increased to 27.9 and 20.9% were in the severe range.

In the YG group, the baseline there were 70.6% in the normal range of depression which increased to 91.2% after intervention, while the mild, moderate, and extremely severe range decreased to 2.9% only from 11.8 and 5.9%. Incidents in the normal range of anxiety and stress also increased after intervention from 47.1 and 70.6% to 70.7 and 88.2%, respectively. However, the mild and extremely severe ranges of anxiety remained the same at 8.8 and 2.9%, while the moderate and severe ranges decreased from 29.4 and 11.8% to 14.7 and 2.9%. Incidents of stress in the mild category decreased from 11.8 to 5.9%, remaining the same (i.e., 5.9%) in the moderate category and there were no incidents in the severe and extremely severe categories of stress after intervention which were 8.8 and 2.9% at baseline.

Quality of life

Initially, no significant differences in the quality of life (QOL) were observed between the two groups. However, during the follow-up period, the group that received usual care (UCG) showed a significant decline in physical, psychological, and social domains, with scores decreasing from 68.21 ± 1.672 to 59.28 ± 2.190 ($p = 0.001$), 69.07 ± 1.924 to 62.07 ± 2.229 ($p = 0.001$), and 76.77 ± 3.140 to 67.5 ± 3.269 ($p = 0.002$), respectively, indicating a reduced quality of life with the progression of gestation. In contrast, the Yoga group reported a significant increase in psychological and environmental domains, with scores increasing from 64.76 ± 2.732 to 74.68 ± 2.789 ($p = 0.001$) and 66.15 ± 2.913 to 75.18 ± 2.358 ($p = 0.002$), respectively, indicating improved quality of life after Yoga.

Comparison of only follow-up data from both groups, the Yoga group demonstrated improved QOL, as evidenced by a significant average change of 8.486 (0.007), 12.607 ($p = 0.001$), 9.277 (0.050), and 11.269 ($p = 0.002$) in the physical, psychological, social and environmental domains, respectively, when compared to the UCG.

Discussion

Our study underscores the impact of advancing gestational age on the neuropsychology of pregnant women, which can increase their vulnerability to symptoms of stress, anxiety, and depression. The findings emphasize the significance of prioritizing the psychological well-being of expectant mothers, particularly through Yoga, which can enhance their psychological resilience, as evidenced by the positive outcomes reported by the Yoga group. While the study findings

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TABLE 1 Characteristics and demographic details of participants.

Variables	Yoga group ($n = 34$)		Control group ($n = 43$)		
	n	%	*n*	%	*p*-value
Age distribution					
18–25	4	11.8	3	7.0	
26–30	18	52.9	23	53.5	0.752
31–35	12	35.3	17	39.5	
Occupation					
Housewives	26	76.5	26	60.5	0.151
Job	8	23.5	17	39.5	
Education level					
12th	7	20.6	11	23.6	0.248
Graduate	14	41.2	23	53.5	
Post graduate	13	38.2	9	20.9	
Occupation of husband					
Unemployed	0	0	0	0	
Employed	34	100	43	100	
Smoke/alcohol					
No	21	61.8	25	58.1	0.817
Yes	13	38.2	18	41.9	
Parity distribution					
Nulliparous	30	88.2	31	72.1	0.098
Multiparous	4	11.8	12	27.9	
History of miscarriage					
Yes	5	14.7	4	9.3	0.497
No	29	85.3	39	90.7	
Year of marriage					
2010–2014	1	2.9	6	14.0	0.126
2015–2020	33	97.1	37	86.0	
Diet					
Vegetarian	23	67.6	27	62.8	0.810
Non-vegetarian	11	32.4	16	37.2	
Religion					
Hindu	27	79.4	41	95.3	0.159
Sikh	5	14.7	2	4.7	
Jaat	1	2.9	0	0	
Jain	1	2.9	0	0	
Socio-economic status					
LIG	5	14.7	–	–	0.336
MIG-I	10	29.4	14	32.6	
MIG-II	9	26.5	14	32.6	
HIG	10	29.4	15	34.9	
Average Age Mean ± SEM	29.31 ± 3.415		29.71 ± 3.00		0.116
Average Height Mean ± SEM	1.58 ± 0.3293		1.59 ± 0.5269		0.412
BMI Mean ± SEM (in 2nd trimester)	22.32 ± 0.435		22.32 ± 0.378		0.413
BMI Mean ± SEM (in 3rd trimester)	26.09 ± 0.519		25.85 ± 0.401		0.414

Characteristics and demographics of participants in Yoga group ($n = 34$) and Usual care group ($n = 43$). Descriptive statistics was done to derive the frequency of variables and chi-square was done to obtain significance level of differences. LIG, Low-income group; MIG, Middle-income group; HIG, High-income group; BMI, Basal metabolic Rate; SEM, Standard Error Mean. Significance was observed at $p \leq 0.05$.

TABLE 2 Neuropsychological scoring within and between two groups.

Scale	Study group	Baseline Mean (SEM)	Follow-up Mean (SEM)	Average change Mean (SEM)	Effect size baseline vs. follow-up	Baseline vs. follow-up (*p* value)	Yoga vs. control *at baseline #at follow-up (*p* value)	95% confidence interval of the difference (* baseline # followup)	
								Lower	Upper
Perceived stress scale	YG	17.38 (0.941)	13.41 (0.943)	3.971 (0.963)	0.658	**0.0001**	0.623*	−1.796	2.979
	UCG	16.79 (0.763)	20.84 (0.927)	−4.047 (0.898)	−0.73	**0.0001**	**0.0001**#	−10.091	−4.76
Depression	YG	8.71 (1.441)	4.41 (0.998)	4.294 (0.992)	0.57	**0.0001**	0.408*	−1.923	4.684
	UCG	7.33 (0.938)	10.35 (1.191)	−3.023 (1.204)	−0.43	**0.016**	**0.0001**#	−9.14	−2.734
Anxiety	YG	9.09 (0.946)	6.35 (0.774)	2.735 (1.011)	0.38	**0.011**	0.191*	−0.837	4.13
	UCG	7.44 (0.818)	9.93 (1.044)	−2.488 (0.992)	−0.41	**0.016**	**0.010**#	−6.29	−0.865
Stress	YG	12.38 (1.346)	7.35 (1.010)	5.029 (0.981)	0.7	**0.0001**	0.691*	−2.728	4.097
	UCG	11.70 (1.090)	16.93 (1.342)	−5.233 (1.339)	−0.66	**0.0001**	**0.0001**#	−13.078	−6.076
Physical domain	YG	64.71 (2.188)	67.76 (2.006)	−3.059(2.634)	0.18	0.254	0.199*	−8.892	1.885
	UCG	68.21 (1.672)	59.28 (2.190)	8.930 (2.393)	0.71	**0.001**	**0.007**#	2.425	14.546
Psychological domain	YG	64.76 (2.732)	74.68 (2.789)	−9.912 (2.787)	0.67	**0.001**	0.19*	−10.784	2.173
	UCG	69.07 (1.924)	62.07 (2.229)	7.000 (1.928)	0.51	**0.001**	**0.001**#	5.584	19.63
Social domain	YG	78.00 (3.336)	76.32 (3.218)	1.676 (2.884)	0.07	0.565	0.79*	−7.955	10.42
	UCG	76.77 (3.140)	67.05 (3.269)	9.721 (2.403)	0.46	**0.002**	**0.050**#	−0.005	18.559
Environmental domain	YG	66.15 (2.913)	75.18 (2.358)	−9.029 (2.640)	0.64	**0.002**	0.597*	−9.252	5.36
	UCG	68.09 (2.310)	63.91 (2.572)	4.186 (2.269)	0.26	0.072	**0.002**#	4.151	18.388

Baseline and follow-up changes in neuropsychology were compared between the Yoga group ($n = 34$) and usual care group ($n = 43$) at baseline and at follow-up using independent *t*-test and with the group using paired *t*-test. Significance was observed at $p \leq 0.05$.

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TABLE 3 Descriptive of PSS and DASS as per the severity.

	Yoga group (*N* = 34)		Usual care group (*N* = 43)	
Variables	Baseline *N* (%)	Followup *N* (%)	Baseline *N* (%)	Followup *N* (%)
PSS				
Low	9 (26.5%)	19 (55.9%)	9 (20.9%)	5 (11.6%)
Moderate	24 (70.6%)	15 (44.1%)	34 (79.1%)	29 (67.4%)
High	1 (2.9%)	–	–	9 (20.9%)
Depression				
Normal	24 (70.6%)	31(91.2%)	31 (72.16%)	21 (48.8%)
Mild	4 (11.8%)	1 (2.9%)	6 (14.0%)	10 (23.3%)
Moderate	4 (11.8%)	1 (2.9%)	5(11.6%)	9 (20.9%)
Severe	–	–	–	2 (4.7%)
Extremely severe	2 (5.9%)	1 (2.9%)	1 (2.9%)	1 (2.3%)
Anxiety				
Normal	16 (47.1%)	24 (70.6%)	25 (58.1%)	21 (48.8%)
Mild	3 (8.8%)	3 (8.8%)	2 (4.7%)	5 (11.6%)
Moderate	10 (29.4%)	5 (14.7%)	12 (27.9%)	6 (14.0%)
Severe	4 (11.8%)	1 (2.9%)	4 (9.3%)	5 (11.6%)
Extremely Severe	1 (2.9%)	1 (2.9%)	–	6 (14.0%)
Stress				
Normal	24 (70.6%)	30 (88.2%)	35 (81.4%)	18 (41.9%)
Mild	4 (11.8%)	2 (5.9%)	7 (16.3%)	4 (9.3%)
Moderate	2 (5.9%)	2 (5.9%)	1 (2.3%)	12 (27.9%)
Severe	3 (8.8%)	–	–	9 (20.9%)
Extremely severe	1 (2.9%)	–	–	–

Percentage of PSS (perceived stress scale) and DASS (depression anxiety stress scale) as per the severity at baseline and at follow-up in Yoga group ($n = 34$) and usual care group ($n = 43$).

suggest that Yoga can enhance psychological resilience in pregnant women, it is crucial to acknowledge the challenges associated with engaging a large population in such interventions. Despite offering the intervention at no cost and making it convenient to attend from home, with flexible scheduling options, a considerable number of eligible participants declined to participate and a few dropouts also occurred. This may indicate a need for healthcare providers to increase awareness among the pregnant population about the potential benefits of such interventions. Nonetheless, for those who are willing and able to engage in such programs, Yoga can provide significant benefits in terms of building psychological resilience and improving overall wellbeing. The intervention of prenatal Yoga demonstrated significant improvement in the psychological health of pregnant women, as reflected by reduced levels of perceived stress, depression, anxiety, and psychological stress. Furthermore, the intervention contributed to an overall enhancement of the quality of life. The effect size for the differences observed in the Yoga group was moderate to large, with a Cohen's d value of 0.5 or greater. These findings suggest that the prenatal Yoga intervention had a substantial impact on the psychological well-being of pregnant women. In this study, we used a prenatal Yoga protocol that incorporated safe and gentle practices such as stretching, mild bending, meditation, breathing exercises, and relaxation techniques. These practices are considered to be beneficial to pregnant women and have been widely used for the general maintenance of their health. However, scientific evidence to support these claims has been limited until now. This study aimed to bridge this gap by designing a Yoga intervention that specifically focused on improving the attention and mental wellness of pregnant women. The results of our study suggest that this approach was effective in improving the psychological resilience and mental well-being of pregnant women, thereby highlighting the potential benefits of non-pharmacological interventions for this population. It should be noted that the practices used in the Yoga protocol were safe and adapted to the unique needs of pregnant women. Our study findings are in line with a previous study conducted by Abbas Rakhshani et al., which also reported improvement in psychological, social, and environmental domains of quality of life (QOL) through integrated Yoga practice during pregnancy (30). Our research further reinforces these findings by highlighting the positive impact of prenatal Yoga on the psychological and environmental domains of QOL, indicating a better outlook of pregnant women toward pregnancy after practicing Yoga. On the other hand, the usual care group reported a decrease in QOL domains of physical, psychological, and social health, indicating that physiological and psychological changes during pregnancy may have a greater impact on expectant mothers as pregnancy progresses, affecting their QOL and ultimately pregnancy outcomes. These changes can be better adapted by pregnant women if they integrate Yoga as a lifestyle during pregnancy, as our results show.

Kusuka et al. (17) have shown decreased salivary cortisol after each Yoga session in pregnant women. A negative indicator of mood

such as anxiety, depression fatigue, and confusion, it was decreased after Yoga practice (17). We also find that perceived stress, anxiety, psychological stress, anxiety, and depression were significantly decreased in YG, whereas we found a significant increase shift in perceived stress and anxiety in UCG. Mindfulness Yoga was also effective in reducing depression symptoms and increasing maternal-fetal attachment and mindfulness among psychiatrically high-risk women (31), in addition to those in healthy pregnancies.

According to a study conducted by Field et al. (16), Yoga has advantages for pregnant women, including reducing stress, anxiety, and physical complaints throughout pregnancy, reducing discomfort, minimizing birthing pain, and speeding up the opening of the birth canal during birth. Yoga during pregnancy is thought to promote nervous system control and physiological system function (immunity, endocrine, neurotransmitter, and cardiovascular) as well as improve mental health to achieve a balance between the body and mind (16).

When compared to a waitlist control group, an RCT by Vieten et al. (32) evaluated a psychosocial mindfulness-based intervention administered in the second half of pregnancy reporting a reduction in anxiety and negative mood, indicating mindfulness-based interventions are a possible mental health approach to managing pregnancy stressors (32). Women who underwent mindfulness Yoga courses grew more comfortable with their position as mothers and valued their interactions with the fetus, according to a study by Muzik et al. (31), and they concluded that the supporting environment given in prenatal Yoga promotes the transition to safe motherhood. Prenatal Yoga encourages pregnant women to envisage and speak with their unborn child, which may explain why women who participated in Yoga courses had higher maternal-fetal attachment scores (31). Telephonic survey with the study participants after delivery revealed that participants of YG felt more connectedness with the fetus, more willpower, confidence to deal with stress and situations, relaxation, calmness, and positive attitude, incidents of which were much less in UCG as compared to YG.

Quality of life during pregnancy affects the pregnancy outcomes and impacts both the mother and the developing fetus. Depression and anxiety are independently associated with poor quality of life and vice versa which implies the need for healthcare professionals to give attention to the quality of life of women visiting prenatal clinics. Mild muscle relaxation exercise combined with music therapy has been shown to significantly improve quality of life parameters in pregnant women with low back pain (33). Likewise, mindfulness helps in bringing more coping strategies and management toward negative psychological emotions of mood and anxiety, and improves the quality of life which can ultimately improve pregnancy outcomes. Mindfulness Yoga intervention significantly reduced psychological distress symptoms and improve quality of life as reported by previous studies (34).

PSS measures the degree to which an individual perceives life to be unpredictable, uncontrollable, and overloaded for the previous month which can impact the psychological state of the individual. To predict specifically the role of Yoga in changing the perception toward their situation we individually compared the questions in the PSS scale, which depicts that after Yoga practice women were able to control their emotions in challenging situations, handle anger, and face difficulties with a more positive attitude, as suggested by the results. The present study specifically examines the effects of Yoga on both psychological distress and quality of life during pregnancy. By focusing on both outcomes, our study provides a comprehensive assessment of the potential benefits of Yoga during pregnancy. Additionally, it adds to the limited body of research on this topic, which will help inform healthcare providers and pregnant women about the potential benefits of incorporating Yoga into their prenatal care.

Based on the findings, Yoga may be used as a primer to reduce or prevent stress, anxiety, and depression-like symptoms, and improve QOL during pregnancy. One of the limitations of the study is the small sample size. We suggest that similar kinds of studies can be done using similar Yoga protocols to evaluate the impact on psychological parameters, quality of life, and other pregnancy outcomes on a bigger sample size and using molecular markers of the same parameters assessed in the study. To gain a deeper understanding of the impact of prenatal Yoga on pregnant women, future studies may consider exploring the molecular-level changes by analyzing Umbilical Cord Blood. Various biological components like cells, serum plasma from Yoga practitioners can be transplanted into animals to see the changes driven by Yoga at cellular and molecular level.

Conclusion

Our study shows that the prenatal Yoga protocol used in this study was associated with reduced stress, anxiety, and depression among pregnant women. Therefore, this protocol can be used by pregnant women as a preventive as well as a therapeutic complementary measure for reducing pregnancy-induced stress, anxiety, and other psychological imbalances. Yoga appears to maintain good psychological health even in unhelpful emotional and mental states. Apart from psychological changes, our prenatal Yoga protocol was found to be helpful in alleviating overall quality of life by improving the quality of psychological and environmental health and balancing social and physical domains throughout the pregnancy.

Statistical analysis

Within-group analysis was done using paired *t*-test while between-group analysis was done using an independent *t*-test. Statistical significance was considered a two-tailed value of $p < 0.05$. The frequency of the PSS and DAS scales was analyzed using descriptive statistics. All analyses were performed using IBM SPSS Statistics 21 software.

Limitations of the study

Interpretation of our study outcome is made with caution given the number of limitations to our study design.

Lack of blinding

Blinding of participants and researchers was not possible in this study due to the nature of the intervention. This may introduce bias in the assessment of outcomes and influence the results.

Self-report measures

The study relied on self-report measures, which are subjective and can be influenced by participants' interpretation and response bias, which may potentially affect the validity of the results.

Sample characteristics

The study included only uncomplicated pregnant women aged between 18 and 35 years with a BMI < 30 and no associated anomalies. These narrow inclusion criteria may limit the generalizability of the findings to a broader population of pregnant women with different characteristics or complications.

Compliance and adherence

The study aimed to ensure compliance with the intervention through daily attendance records and submission of screenshots/videos of Yoga classes. However, the accuracy and completeness of self-reported compliance data may be influenced by participants' motivation, memory recall, and social desirability bias.

Online intervention

The Yoga intervention was delivered online via Google Meet, which may have limitations compared to in-person classes. Factors such as internet connectivity, video and audio quality, and participants' familiarity with technology could impact the effectiveness and engagement with the intervention.

Strengths of the study

Randomized controlled trial design

The study utilized a randomized controlled trial design, which is considered reliable for evaluating the effectiveness of interventions. Random allocation of participants into the Yoga group and usual care group helps minimize selection bias and increases the internal validity of the study.

Prospective registration

The study was prospectively registered in the Clinical Trials Registry-India, which promotes transparency and helps prevent selective reporting of outcomes. This enhances the credibility and reliability of the study findings.

Well-defined protocols

The study implemented two different Yoga protocols for the second and third trimesters of pregnancy, adapted from established sources and reviewed by an obstetrician and an institutional ethical committee. This standardized approach ensures consistency in the intervention delivery and allows for the reproducibility of the study in future research.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Institutional Ethical Committee-Post Graduate Institute of Medical Education and Research (PGIMER). The patients/participants provided their written informed consent to participate in this study.

Author contributions

AA conceptualized the whole study, edited the manuscript, and provided resources to complete the study. PN collected and sorted data, wrote the manuscript, and analyzed data. KK guided in doing neuropsychology of participants and reviewed and validated data and manuscripts. PS and VS provided the participants and assisted in the recruitment of participants. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1201371/full#supplementary-material

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Guodong Zhang,
Southwest University, China

REVIEWED BY
Huilin Wang,
Hunan University of Science and Technology, China
Shuge Zhang (CPsychol),
University of Derby, United Kingdom

*CORRESPONDENCE
Siobhan M. Phillips
✉ smphillips@northwestern.edu

†These authors have contributed equally to this work and share first authorship

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Effects of mindful physical activity on perceived exercise exertion and other physiological and psychological responses: results from a within-subjects, counter-balanced study

Payton Solk[1†], Lisa A. Auster-Gussman[1†], Emily Torre[1], Whitney A. Welch[1], Karly Murphy[2], Julia Starikovsky[1], Jean M. Reading[1], David E. Victorson[2] and Siobhan M. Phillips[1*]

[1]Department of Preventive Medicine, Northwestern University Feinberg School of Medicine, Chicago, IL, United States, [2]Department of Medical Social Sciences, Northwestern University Feinberg School of Medicine, Chicago, IL, United States

Background: Most adults are insufficiently active. Mindfulness training may increase moderate to vigorous physical activity (MVPA) adoption and adherence. However, physiological and psychological factors underlying these effects are not well understood. This study examined the effects of an acute bout of MVPA, mindfulness training, and combined MVPA and mindfulness training on physiological and psychological outcomes.

Methods: Healthy adults ($N = 29$, $M_{age} = 28.6$) completed 20-min counterbalanced conditions: (a) mindfulness training (MIND); (b) moderate intensity walking (PA), and (c) moderate intensity walking while listening to MVPA-specific guided mindfulness training (PAMIND). Heart rate (HR), Rating of Perceived Exertion (RPE), Feeling Scale (FS) and Blood Pressure (BP) were measured at rest, at regular intervals during each condition, and post-condition. Mindfulness, state anxiety, and self-efficacy were assessed pre- and post-condition.

Results: Average and peak HR, systolic BP (SBP), and RPE were significantly higher, and average and peak FS were significantly lower during the PA and PAMIND conditions compared to MIND ($p < 0.001$). Average RPE was significantly higher for PA compared to PAMIND ($p < 0.001$). Heart rate, feeling scale, body and mental events mindfulness, and self-efficacy for walking increased from pre to post (all p's < 0.001) for all conditions. Time by condition interactions were significant for change in heart rate, mental events mindfulness, and state anxiety from pre- to post-condition.

Conclusion: The physiological response to MVPA and PAMIND were similar. However, RPE was rated lower in the PAMIND condition, which could have implications for MVPA adoption and maintenance. Future work should further explore RPE combining MVPA and mindfulness training.

KEYWORDS

moderate to vigorous physical activity, guided meditation, perceived exertion, health behavior, mindful physical activity

1. Introduction

Moderate to vigorous physical activity (MVPA) is associated with reduced risk of numerous chronic conditions [i.e., diabetes, cardiovascular disease and certain cancers (Warburton et al., 2006; U.S. Department of Health and Human Services, 2018), depression, stress, and anxiety (Ensari et al., 2015; Mikkelsen et al., 2017)]. Moderate intensity activity (e.g., walking briskly, dancing, doubles tennis, slow swimming) is typically defined as any activity that requires three to six times as much energy per minute as being at rest [i.e., 3.0–6.0 metabolic equivalents (METS)] or elevates heart rate to 40 to 60% of heart rate reserve or 65%–76% of maximum heart rate (MacIntosh et al., 2021). Vigorous intensity activities (e.g., jogging, running, strenuous fitness class, fast swimming) burn more than 6 METs or elevates the heart rate to 60%–84% of heart rate reserve or 77%–93% of maximum heart rate (MacIntosh et al., 2021). Despite the benefits of MVPA, physical inactivity is prevalent globally, and less than half of the global adult population meet the World Health Organization (WHO) physical activity guidelines of 150 min of MVPA per week (World Health Organization, 2019; Bull et al., 2020; Cunningham et al., 2020). Physical activity research has been conducted widely and has focused on various key areas including health benefits of physical activity (Penedo and Dahn, 2005; Warburton et al., 2006), sedentary behavior reduction (Rezende et al., 2014; Park et al., 2020), feasibility, acceptability and efficacy of physical activity interventions (Howlett et al., 2018), technology and physical activity (Hakala et al., 2017; Brickwood et al., 2019), motivation and behavior change factors of physical activity participation (Teixeira et al., 2012; French et al., 2014; Young et al., 2014), and environmental and policy factors associated with physical activity (Humpel et al., 2002; Smith et al., 2017). Despite the evidence supporting MVPA participation and large scale public health physical activity promotion efforts, there has been little change to the rate of adherence to aerobic physical activity recommendations (Ding, 2018). Given the lack of MVPA uptake, it is essential to identify novel and effective strategies to promote MVPA adoption and maintenance.

Although various factors might contribute to low adherence to MVPA guidelines, one potential modifiable, low cost, and scalable target for remediation is promoting mindfulness practice (Schneider et al., 2019; Yang and Conroy, 2020). Mindfulness is characterized by paying attention to one's present moment experiences with curiosity, openness, and awareness of thoughts, feelings, and physical sensations (Bishop et al., 2004; Schneider et al., 2019). Mindfulness-based interventions are ubiquitous in healthcare and have demonstrated effectiveness in improving emotion regulation and decreasing symptoms of depression, anxiety, and a host of physical symptoms and side effects associated with chronic disease and its treatment (Victorson et al., 2015). Emerging data indicate mindfulness training that occurs independently from physical activity may increase adoption and maintenance of MVPA participation (Ulmer et al., 2010; Loucks et al., 2015; Ruffault et al., 2017; Meyer et al., 2018). A recent meta-analysis found moderate effects for increasing physical activity following mindfulness training in adults with overweight/obesity (Ruffault et al., 2017). Further, increased mindfulness is associated with higher likelihood to follow through on MVPA intentions (Chatzisarantis and Hagger, 2007) and maintain an exercise program (Ulmer et al., 2010). Thus, engagement in mindfulness training may be an effective, scalable strategy for increasing MVPA.

Although existing literature supports the association between mindfulness and MVPA participation, less is known about factors that explain this relation. Many physiological and psychological factors have been hypothesized to explain the underlying potential relationship between mindfulness training and physical activity. Firstly, mindfulness may enhance MVPA participation through mitigation of uncomfortable physiological reactions, downregulation of negative affect [e.g., displeasure, discomfort (Lind et al., 2009; Cox et al., 2018)], increased positive experiences during MVPA and enhancement of behavioral and psychological factors [e.g., self-regulation, motivation, habit (Schneider et al., 2019)]. Further, physiological stress, associated discomfort, and perceived exertion may contribute to negative affective associations with MVPA, (Lind et al., 2009) which have been associated with reduced MVPA participation (Cox et al., 2018). Mindfulness is associated with decreased physiological stress markers including slower respiratory rate, decreased heart rate, and decreased systolic and diastolic blood pressure (Ditto et al., 2006; Kingston et al., 2007; Delgado et al., 2010; Pascoe et al., 2017; Gamaiunova et al., 2022). Mindful awareness may enhance regulation of physiological and affective responses and lessen the reactivity to discomfort experienced during MVPA (Kabat-Zinn, 1982; Arch and Craske, 2006; Chambers et al., 2009; Schneider et al., 2019). Mindfulness has also been associated with improved positive affective responses to MVPA, leading to increased enjoyment and satisfaction and lower perceived exertion (Hardy and Rejeski, 1989) which have been associated with increased physical activity uptake and adherence (Williams et al., 2008; Tsafou et al., 2016). Changes in psychological factors such as habit, intention, motivation, self-efficacy and tolerance of discomfort are also associated with increases in mindfulness-related facets including attentional awareness, acceptance, and openness, suggesting these could, in part, contribute to both short-term increases in MVPA and readiness for longer-term behavior change (Schneider et al., 2019). In summary, existing literature has hypothesized many different factors that could explain the effects of mindfulness on MVPA including enhanced self-regulation abilities (e.g., attentional focus, behavioral flexibility, emotional relation) (Schneider et al., 2019), increased acceptance of uncomfortable thoughts and sensations (Arch and Craske, 2006), and changes in the stress response [i.e., changes in the hypothalamic–pituitary–adrenal (HPA) axis and autonomic nervous system] (Gamaiunova et al., 2022) that occur as an outcome of mindfulness practice.

Most studies examining the relation between MVPA and mindfulness targeted the two behaviors separately and demonstrated both increased mindfulness and increased physical activity adherence (Blair Kennedy and Resnick, 2015; Edwards and Loprinzi, 2018). To the best of our knowledge, only two studies have examined the effects of MVPA coupled with mindfulness training *during* an acute bout of activity [i.e., single period of activity (Basso and Suzuki, 2017)]. The first study used a within-subject design, and found listening to a mindfulness training video while engaging in an acute 10-min bout of moderate treadmill walking resulted in more positive affective valence, mindfulness and lower ratings of perceived exertion compared to walking alone (Cox et al., 2018). The second study was a between-groups randomized controlled trial in which participants randomized to 30-min of moderate intensity treadmill exercise while listening to a mindfulness recording for 7 days had higher self-reported MVPA and accelerometer MVPA as compared to the heart

rate monitor only control group, and the combined activity and mindfulness intervention was feasible and acceptable (Sala et al., 2021). Although promising, these studies did not investigate objective exertion levels using physiological measures [i.e., blood pressure (BP), heart rate (HR)] to determine whether mindfulness training during physical activity alters the physiological response to exercise.

Thus, the purpose of this study was to examine the effects of an acute bout of MVPA (PA), mindfulness training (MIND), and combined MVPA and mindfulness training (PAMIND) on physiological and affective parameters. We hypothesized the MIND condition would result in the lowest physiological measure values and highest affective scores as compared to the other two conditions (PA and PAMIND). Further, we hypothesized that the PAMIND condition would result in lower perceived exertion ratings, HR response, and systolic blood pressure, and increased feeling ratings as compared to the PA condition.

2. Materials and methods

2.1. Study design

This study utilized a within-subjects, counter-balanced design. All participants were randomized 1:1 in a counterbalanced order to complete all three conditions: mindfulness only (MIND), physical activity only (PA), and physical activity while listening to a mindfulness audio recording (PAMIND). The within-subjects design allows for increased statistical power with a lower sample size, and controls for individual participant variables. Counterbalancing (i.e., randomizing the order in which a participant completes the study conditions) improves internal validity by controlling for sequence (e.g., practice) and order effects that may occur when participants repeatedly complete study conditions (Corriero, 2017).

2.2. Study procedures

Participants were recruited through self-referral using the Northwestern University Department of Psychology's list of Paid Research Studies. Information about the present study was e-mailed to all individuals subscribed to the Paid Participant Registry. Individuals who were interested in participating were instructed to contact the study team via e-mail or phone after which they were emailed a link to the online screening survey to determine eligibility. Inclusion criteria were: (a) age 18–65 years old, (b) able to read, write, and speak in English, (c) able and willing to attend three in-person study visits, (d) access to a computer with Internet, (e) no self-reported respiratory, joint, or cardiovascular problems precluding physical activity, and (f) not pregnant or planning to become pregnant during the duration of the study. Eligible and interested participants completed an online informed consent. Participants were required to pass the Physical Activity Readiness Questionnaire (PAR-Q) (Adams, 1999) or obtain physician consent to participate. Within 48 h of passing screening, potential participants were emailed a copy of the study informed consent and a study overview document. Between 24 h to 5 business days after this email was sent, participants were called by study staff to confirm interest and eligibility. During this call, participants had the opportunity to ask questions about the study and informed consent. All eligible and interested individuals were emailed a secure, individualized link to complete the online informed consent. After informed consent completion, participants were emailed an individualized, secure link to the baseline assessment questionnaires. Upon completion of the baseline questionnaire, participants were randomized to the order of conditions and scheduled for their three study visits. All study procedures were approved by the institutional review board.

All study procedures occurred during three separate, individual in-person lab study visits separated by at least 48 h to ensure adequate recovery from physical activity. All participants were instructed to refrain from physical activity and caffeine consumption 6 h prior to each study visit to mitigate outside influence on HR or BP responses. Participants were fitted with a Polar H10 HR monitor (Polar Electro Oy, Kempele, Finland) (Gilgen-Ammann et al., 2019). Participants remained seated for a 5-min resting period during which measures of pre-condition Rating of Perceived Exertion (RPE) (Williams, 2017) and Feeling Scale (FS) (Hardy and Rejeski, 1989) were collected. At the end of the 5-min resting period, resting HR (two HR measurements from the Polar H10 monitor were recorded 1 min apart) and BP were measured.

Following the resting period, pre-condition questionnaires were completed and followed by the 36-min experimental condition (i.e., MIND only, PA only, or PAMIND) to which they were assigned for that visit. RPE, FS, HR, and BP measurements were recorded once during the warm-up period and once during the cool down period. In addition, RPE, FS, and HR were recorded every minute during the 20-min active period, and BP was measured manually and recorded every 4 min. To prevent potential confounding of social interaction between the participant and study staff, talking was kept to a minimum at every visit. Upon completion of each experimental condition, participants engaged in seated rest for 5 min during which post-condition RPE, FS, HR and BP were measured. Finally, participants completed the post-condition questionnaires. Study visit procedures are demonstrated in Figure 1.

2.2.1. MIND condition

Participants listened to a pre-recorded, 36-min, guided mindfulness meditation. The guided meditation instructed participants to lie on their back on a padded exam table, with the option to close their eyes at various points during the recording. The meditation emphasized bringing awareness to bodily sensations. The recording was structured as follows: (a) 10-min "warm-up," (b) 20-min "active" mindfulness meditation, and (c) 6-min "cool down" period to match the PA and PAMIND protocols.

2.2.2. PA condition

Prior to starting the condition, participants were familiarized with the treadmill controls and how to properly walk on a treadmill. The PA condition consisted of a: (a) 10-min warm-up (5 min of full body stretching and 5 min of easy walking), (b) 20-min brisk walk, and (c) 6-min cool down (3 min of light walking and 3 min of stretching). During the 20-min brisk walk, participants selected a speed and incline with the assistance of study staff to reach a moderate to vigorous intensity. The speed of the treadmill never increased to a point that required participants to jog. Rather, the incline was increased so that participants could maintain a walking pace and reach a moderate to vigorous intensity level of activity defined as

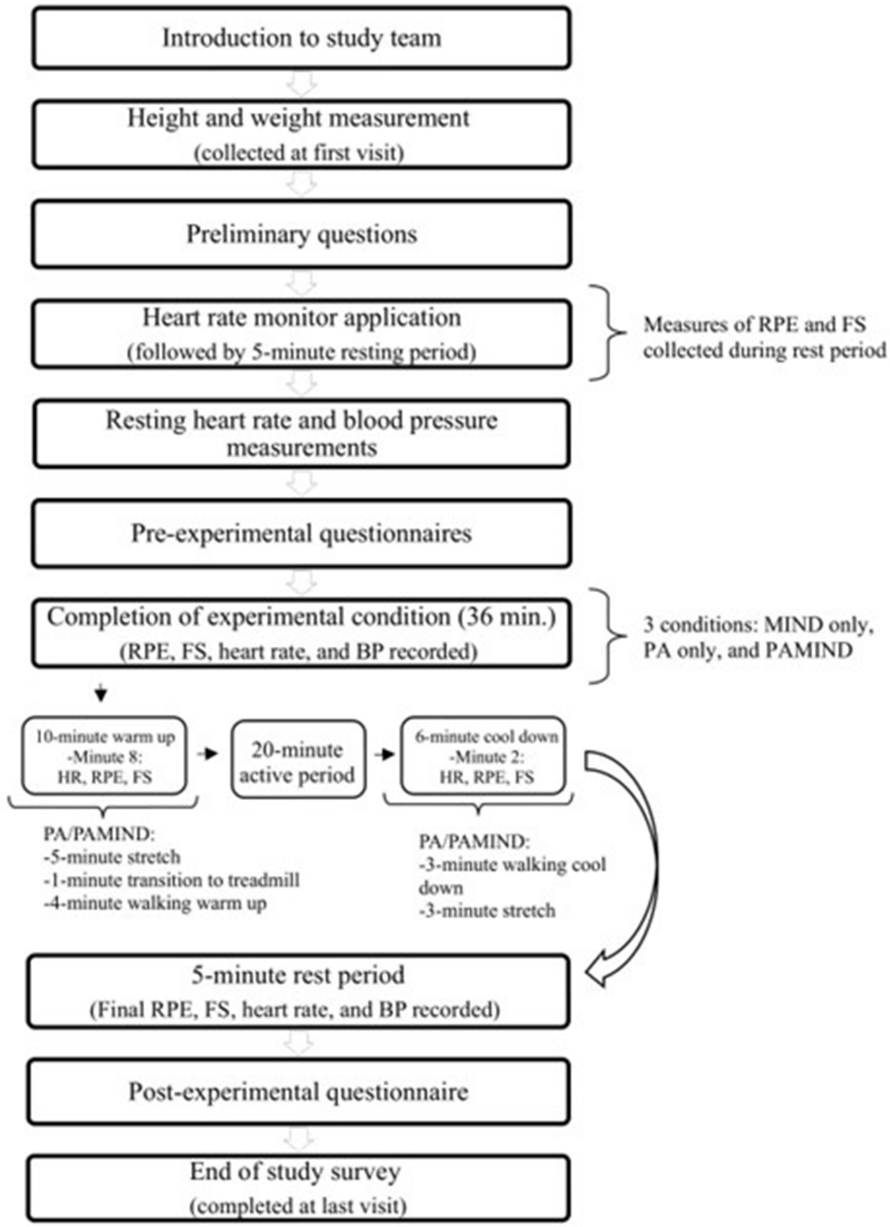

FIGURE 1
Participant flow through the study.

65%–85% of their maximum HR calculated by the Karvonen formula which takes into account resting heart rate and uses heart rate reserve (220-age) to estimate maximum HR (Karvonen et al., 1957). Study staff monitored participants' heart rate in real-time to confirm participants were working at this moderate to vigorous intensity throughout the duration of the experimental condition.

2.2.3. PAMIND condition

During this condition, participants walked on the treadmill following the exact same protocol as described above except they listened to a pre-recorded, 36-min, "Walking with Awareness" guided walking meditation during the warm-up, 20-min brisk walk, and the cool-down. Speed and incline were kept the same for each participant for the PA only and PAMIND condition to ensure consistency in intensity across conditions. A description of how this condition was developed is described below:

2.2.3.1. Development of the PAMIND condition

The "walking with awareness" PAMIND component used in this study was led by co-author DV, who has significant experience teaching and conducting research in mindfulness and developing mindfulness-based clinical research interventions. Prior to writing and recording the script, several study team members participated in an audio recorded "think aloud" walking exercise on the treadmill, where they were asked to verbalize out loud everything they were noticing, observing, and experiencing across the five senses, thoughts, and emotions. This was done to gather rich, descriptive details of their walking experience that could be integrated into the recording and to

pace the delivery of these details in line with the timeframe in which they were mentioned. This pre-testing activity was implemented by co-author WW.

During the 2-minute pre-walk stretch, participants made statements about noticing the environment they were in (e.g., cold floor, quietness, others watching them) while they stretched. They also commented on noticing muscle sensations of relaxation or tightness in the body. During the three-minute warm up on the treadmill, common observations included how this exercise differed from their usual workout routines (e.g., walking on a treadmill with no music while others watch). They also took notice of how their bodies felt as they warmed up, especially their legs. Another observation included how they focused on time due to no other distractions during the walk.

During the 20-min walk, observations were noted at each minute, which included:

- *Minutes 1–5*: Feeling bored without music and how their mind wandered to future activities; noticing the speed/sounds of the treadmill and breathing rate increasing following the warmup. Feeling their bodies awakening as they walked; beginning to think about their hunger and lunch plans; searching for something to look at in the room to distract themselves while they walked; being curious about the buttons on the treadmill; noticing the sounds of the treadmill while they scuffed their feet; checking in on their bodies including elevated heart rates, and unevenness of their gait.
- *Minutes 5–10*: Noticing skin warmth and being on the verge of breaking a sweat in their hands and other parts of their body; noticing other bodily sensations, such as their breathing increasing, goosebumps, or feeling their bodies loosening up; more comments about boredom and noticing the feeling of their arms swinging back and forth.
- *Minutes 10–15*: Describing tightness in legs; comments about wishing for a distraction such as music, and awkwardness of others in the room; noticing the pace they were walking, the body continuing to warm up, and the mind beginning to wander and think about what they planned to do later in the day; noting they would rather be outside than walking on a treadmill inside, as a poster inside of the room showed a picture of nature; one person reported feeling their body finally receiving the message that they were exercising and felt his body change not only movement-wise, but also temperature-wise; observations about physical state including dry mouth, muscles feelings more "awake" and feeling as though they were in a better mood.
- *Minutes 15–20*: Remarks of boredom and feeling uncomfortable making observations out loud while exercising; noticing breathing becoming heavier and how this exercise is atypical because they do not normally check in with how their bodies feel while working out, as they typically have external distractions such as listening to music/wearing a heart rate monitor; noticing breathing patterns and feelings in muscles that were working; feelings of breathing becoming heavier in comparison than the beginning of the exercise; noting the need to breathe through the mouth instead of the nose; realizing the walk is almost over and beginning to think about tasks they need to get done in the near future; noting it was mentally challenging to walk for such a long period of time on a treadmill without a change of scenery as exercising outside is motivating; remarking about being at peak physical exertion since the start of the exercise.

During the three-minute cool down on the treadmill, participants reported feeling that the pace was a drastic change from the speed they were previously walking at, as the cool down felt significantly slower. They noticed their heart rate and breathing slow down, their warmed-up bodies, and the feeling in the legs as the treadmill slowed. One person reported feeling accomplished about finishing the walk, and they were looking forward to being done and having a break. During the 2-min post walk stretch, participants reflected on enjoying the stretch and cool down and noticed how they felt looser now than at the start. They commented on the feeling of their bodies relaxing, and a comment was made about feeling more awake (mentally and physically).

Using descriptive statements from the "think aloud" exercises, a guided "walking with awareness" script was written that would lead participants through an 8-min warm up of stretching and warm up walking, 20-min of active treadmill walking, and 8-min of cool down (cool down walking and post-walk stretching). Photos of the intervention environment were taken to be able to visually describe the setting, which included the color of the walls, descriptions of photos and paintings, furniture, and room fixtures. A purposeful attempt was made to write and record these awareness-eliciting statements in a normal pace and vocal tone, so as not to induce a relaxation response, but rather seamlessly invite participants to notice and observe their multisensory experiences, thoughts, and feelings during the walking exercise. The final script was reviewed by the study team, and an audio recording was created by DV. Please see Appendix for the PAMIND script.

2.3. Measures

Table 1 details the measurement schedule for data collected during the study visits.

2.3.1. Physiological measures

2.3.1.1. Height and weight

These measures were assessed during the first study visit prior to the start of the condition. Height and weight were measured objectively using a stadiometer for height (rounded to nearest 0.5 cm) and a body scale for weight (rounded to nearest 0.1 kg).

2.3.1.2. Heart rate

HR was measured using a Polar H10 HR monitor (Polar Electro Oy, Kempele, Finland) (Gilgen-Ammann et al., 2019). Participants wore the Polar strap around the chest under their shirt, against their skin. The monitor was secured at the base of the sternum, just below the chest muscles, at the center of the chest. HR was measured twice during the pre-condition rest period (averaged to calculate pre-condition HR value), once during the walking phase of the warm-up, during each minute of the experimental condition, during the final minute of the cool-down, and twice during the post-condition rest period with the first reading occurring immediately following the cool down and the second reading 1 min later. HR measured via polar HR monitors worn around the chest is highly

TABLE 1 Measurement schedule.

	Pre-condition	Post-condition	Warm-up	Cool-down	Every minute of condition	Every 4 min of condition
Heart rate	X*	X*	X	X	X	
Blood pressure	X	X	X	X		X
Feeling scale (FS)	X	X	X	X	X	
Rating of perceived exertion (RPE)	X	X	X	X	X	
State mindfulness scale (SMS)	X	X				
State trait anxiety inventory-state (STAI-S)	X	X				
Self-efficacy for walking duration (SEWD)	X	X				
Overall RPE		X				
Overall FS		X				
Overall enjoyment		X				

Values with * indicate a measure was recorded twice at a given time point.

reliable and valid compared to electrocardiography (ECG) during rest and exercise (Plews et al., 2017; Gilgen-Ammann et al., 2019). Average and peak HR were calculated from the 20 readings taken during the 20-min active period during each condition.

2.3.1.3. Blood pressure

BP was measured by staff manually with a sphygmomanometer and stethoscope once at rest pre-condition, once during the warm-up and cool down periods at the same time as HR, and once immediately post cool down at the same time as HR. It was also measured every 4 min during the experimental condition. BP was measured following standard procedures (Beevers et al., 2001) for rest and standard procedures for obtaining an exercising BP (Myers et al., 2009). The average BP from the 6 readings taken during the 20-min active portion of each condition, and peak BP were calculated.

2.3.2. Psychological measures

2.3.2.1. Pre-, during and post-condition measures

These measures were taken immediately pre-condition, once during the warm-up, at each minute during the active condition, once during the cool down and 5 min, and after the cool down period ended (i.e., post-condition). Average ratings were calculated for each measure using the 20 readings taken during each 20-min active portion of each condition. Peak ratings were the highest value reported (RPE, FS) or collected (HR, BP) at any of the 20 during-test readings.

Feeling scale (FS). The FS measures affective valence at the present moment with one item "How do you feel right now?" on an 11-point scale from −5 (Very bad) to +5 (Very good) (Hardy and Rejeski, 1989). The FS is a valid and reliable measure of affective valance and is shown to correlate with other measures of affect (Hall et al., 2002). It has been widely used to measure affective valence in physical activity studies (Ekkekakis, 2003).

Rating of Perceived Exertion (RPE). RPE measures subjective physical activity intensity. The Borg RPE scale consists of numerical values from 6–20 to represent the effort at which an individual perceives they are exerting themselves from rest (6) to extreme exertion (20). Participants are asked "How hard does it feel like you are working"? They are instructed that their rating should reflect their total amount of exertion and fatigue and to not focus on any one factor such as leg fatigue or shortness of breath. The design of the RPE scale is to mirror that of the average human HR range: 60 bpm to 200 bpm (Williams, 2017). RPE has shown to be a valid and reliable estimation measure of perceived exertion during rest and exercise in adults (Chen et al., 2002).

2.3.2.2. Pre- and post-condition measures

Mindfulness. The 21-item State Mindfulness Scale (SMS) was used to retrospectively measure various qualities of mindful awareness during each experimental condition. Participants indicated how well each statement describes their recent experience (e.g., awareness of emotions, physical sensations, thoughts, and surroundings) on a scale from 1 (not at all) to 5 (very well). The SMS was used because it has two subscales, (1) mindfulness of bodily sensations (6 items) and (2) mindfulness of mental events (15 items) that can provide insight into components of mindfulness that are pertinent to physical activity. Items are summed and averaged to obtain subscale scores ranging from 1 to 5, with higher scores indicating higher levels of state mindfulness. This scale is valid, stable across time and context and is sensitive to change (Tanay and Bernstein, 2013) and has been used in prior studies examining the effect of incorporating mindfulness into acute bouts of physical activity (Cox et al., 2018).

State anxiety. The 20-item State Trait Anxiety Inventory-State (STAI-S), a valid and reliable measure of current anxiety (Metzger, 1976; Spielberger, 1989), assessed how participants felt right now at this moment based on various statements (i.e., "I feel calm" or "I feel nervous and restless") on a scale from 1 (Not at all) to 4 (Very much so). Item values were summed to obtain total STAI-S scores ranging from 20 to 80, with higher scores indicating higher levels of state anxiety.

Self-efficacy. The Self-Efficacy of Walking for Duration (SEW-D) scale is a 10-item scale that asks participants to rate how confident they feel that they could complete incremental 5-min intervals (5–50 min). Participants rate confidence levels to execute the behavior on a 100-point percentage scale comprised of 10-point increments, ranging from 0% (not at all confident) to 100% (highly confident). Total self-efficacy is calculated by summing each item response and dividing by the total number of items in the scale ranging from 0 to 100. The SEWD is a valid and reliable measure of walking self-efficacy for duration (McAuley et al., 2000).

2.3.3. Post-condition overall measures

Participants were asked to indicate their overall RPE, FS, and enjoyment of the specific condition completed at the conclusion of each condition by answering a one-item question about each construct. The RPE scale and FS measure question phrasing was edited to instruct participants to provide overall estimation of RPE and FS from the completed session, rather than measuring these constructs within the current moment. For overall enjoyment, participants were asked to rate their overall enjoyment of the completed condition on a scale from 1 (I enjoy it) to 7 (I hate it).

2.4. Statistical analysis

An *a priori* power analysis was conducted for sample size estimation. The required sample size to achieve 80% power for detecting a small to medium effect size ($\eta^2 \geq 0.04$) from pre- to post-session between the three conditions was $N = 24$. Descriptive analyses were conducted using SPSS Version 25 (IBM Corp, Armonk, NY, United States). Means and standard deviations of each variable were calculated for each condition. A one-factor repeated-measures ANOVA was used to examine the differences by condition on average and peak HR, BP, FS and RPE. A three (condition) by two (time) within-subjects repeated measures ANOVA was used to examine the effects of each of the three conditions on differences within and across conditions for the pre- and post-condition measures of HR, BP, FS, RPE, SMS, STAI-S and self-efficacy and post-condition only measures of RPE, FS and enjoyment. Time and condition were included as within-subjects factors to allow each subject to serve as their own "control." Bonferroni corrections were used to correct for the multiple tests conducted.

3. Results

3.1. Participants

All three conditions were completed by 29 individuals who are included in analyses. Participant demographic characteristics are presented in Table 2. Participants were on average 28.59 years old, 55% underrepresented race/ethnicity, with an average BMI of 26.67. Most participants were female (65.5%), had a college degree (72.4%), and rated their overall health status as excellent/very good (58.6%). Participant recruitment and retention is detailed elsewhere (Torre et al., 2023). Briefly, screening surveys were sent to 180 individuals and 60% ($n = 108$) were eligible to receive a recruitment call. In total, 59 recruitment calls were attempted and 72.9% ($n = 43$) were completed, resulting in 39 participants signing the informed consent form and being randomized. Of those randomized, 79.5% ($n = 31$) completed their first study visit, and 93.5% ($n = 29$) of these participants were retained through all three study visits.

TABLE 2 Participant characteristics [*n* (%) for categorial variables and mean (SD) for continuous variables].

Full sample ($N = 29$)	
Age (*M*[SD])	28.59 [9.0]
BMI (*M*[SD])	26.67 [6.1]
Exercise self-efficacy (*M*[SD])	8.59 [2.53]
Gender	
Female	19 (65.5)
Male	10 (34.5)
Race	
White	13 (44.8)
African American	6 (20.7)
Asian/Pacific Islander	8 (27.6)
Other	2 (6.8)
Hispanic or Latino	4 (13.8)
≥College degree	21 (72.4)
Working at least part-time	24 (82.8)
Annual Household Income	
< $60,001	18 (62.1)
Prefer not to answer	3 (10.3)
Overall Health Status	
Excellent /very good	17 (58.6)
Good	11 (37.9)
Fair/poor	1 (3.4)

3.2. Physiological measures

All within-subject differences between average and peak physiological measures collected during the experimental conditions (i.e., BP, HR) are demonstrated in Table 3. All within-subject differences between pre- and post-condition measures are shown in Table 4.

3.2.1. Blood pressure

Compared to the MIND condition, average and peak SBP were significantly higher during the PA and PAMIND conditions (p's ≤ 0.001), independently. There were no differences between the PA and PAMIND conditions for average or peak SBP. Average and peak DBP did not differ by condition. There were no significant main effects of condition or time or time by condition interaction effects for SBP. For DBP, there was a significant effect of time [$F(1, 27) = 5.89$, $p = 0.02$, partial $\eta^2 = 0.18$] such that diastolic blood pressure increased across all conditions from pre-to post-condition.

3.2.2. Heart rate

Average and peak HR were significantly higher during the PA and PAMIND conditions, independently, compared to the MIND condition (p's ≤ 0.001). There were no differences between the PA and PAMIND conditions for average or peak HR. There was a statistically significant main effect of time [$F(1, 27) = 23.90$, $p < 0.001$, partial $\eta^2 = 0.47$] and condition [$F(2, 26) = 17.57$, $p < 0.001$, partial $\eta^2 = 0.39$], and a statistically significant time by condition interaction [$F(2, 26) = 30.86$, $p < 0.001$, partial $\eta^2 = 0.53$] for HR (p's < 0.001). In the PA and PAMIND conditions, HR significantly increased pre- to post-condition ($p < 0.001$) while HR significantly decreased pre- to post- for MIND ($p < 0.01$).

TABLE 3 Within-subject differences between average and peak physiological and affective measures by experimental condition.

Measure	Condition			*p*-value
	MIND *M*(SD) (a)	PA *M*(SD) (b)	PA/MIND *M*(SD) (c)	
Systolic blood pressure				
Average	113.0 (10.3)[b,c]	120.4 (10.7)[a]	120.9 (11.3)[a]	<0.001
Peak	115.1 (10.7)[b,c]	124.9 (11.6)[a]	127.5 (12.2)[a]	<0.001
Diastolic blood pressure				
Average	70.9 (11.2)	67.2 (9.0)	69.6 (9.3)	0.07
Peak	72.6 (11.7)	69.1 (9.3)	72.3 (13.2)	0.15
Heart rate				
Average	64.5 (8.7)[b,c]	132.9 (10.5)[a]	128.9 (16.9)[a]	<0.001
Peak	69.7 (9.7)[b,c]	145.7 (10.1)[a]	142.4 (15.3)[a]	<0.001
Rating of perceived exertion				
Average	6.2 (0.4)[b,c]	12.4 (2.3)[a,c]	11.2 (2.0)[a,b]	<0.001
Peak	6.4 (0.8)[b,c]	13.6 (2.6)[a]	13.3 (2.2)[a]	<0.001
Overall	6.4 (0.7) [b,c]	12.2 (2.4)[a]	12.1 (2.3)[a]	<0.001
Feeling scale				
Average	3.6 (1.0)[b,c]	2.3 (1.4)[a]	2.3 (1.3)[a]	<0.001
Peak	4.1 (0.99)[b,c]	3.1 (1.3)[a]	3.1 (1.1)[a]	<0.001
Overall	3.9 (1.3)[b,c]	1.7 (1.9)[a]	2.0 (2.4)[a]	0.008
Enjoyment				
Overall	2.07 (1.2)[b,c]	2.9 (1.4)[a]	2.9 (1.7)[a]	0.009

[a,b,c] Indicate significant between condition differences at $p < 0.05$ where a = MIND, b = PA, and c = PAMIND.

TABLE 4 Average and difference of pre/post condition scores.

Measure	MIND *M* (SD)		PA *M* (SD)		PAMIND *M* (SD)		*p*-value (effect size, η^2)		
	Pre	Post	Pre	Post	Pre	Post	Condition	Time	Condition × time
Systolic BP	115.86* (2.14)	112.57* (2.03)	113.71 (10.83)	112.68 (11.20)	111.43 (11.35)	111.86 (12.41)	0.31 (0.04)	0.11 (0.09)	0.12 (0.08)
Diastolic BP	69.86 (10.98)	71.43 (10.94)	67.43 (9.06)	68.82 (9.09)	69.96 (9.23)	70.71 (9.21)	0.25 (0.50)	**0.02 (0.18)**	0.77 (0.01)
HR	78.30* (2.34)	74.07* (1.87)	79.75* (2.64)	89.45* (2.67)	81.27* (2.76)	87.31* (2.55)	**<0.001 (0.39)**	**<0.001 (0.47)**	**<0.001 (0.53)**
Rating of perceived exertion	6.07 (0.05)	6.10 (0.06)	6.24 (0.15)	6.31 (0.10)	6.28 (0.16)	6.38 (0.16)	**0.04 (0.11)**	0.39 (0.03)	0.80 (0.01)
Feeling scale	2.90* (0.25)	3.62* (0.21)	2.79* (0.30)	3.28* (0.25)	2.69* (0.26)	3.14* (0.26)	0.19 (0.06)	**<0.001 (0.38)**	0.54 (0.02)
Mindfulness (Body)	2.20* (0.91)	3.57* (0.82)	2.12* (1.03)	3.19* (0.99)	2.02* (0.92)	3.41* (1.20)	0.24 (0.05)	**<0.001 (0.71)**	0.39 (0.04)
Mindfulness (mental event)	2.80* (0.86)	3.48* (0.72)	2.72 (0.92)	2.93 (0.85)	2.71* (0.84)	3.21* (0.96)	0.09 (0.09)	**0.001 (0.37)**	**0.03 (0.13)**
State anxiety	35.37* (0.23)	31.70* (8.91)	33.22 (9.23)	33.33 (9.09)	34.48 (8.61)	34.37 (11.35)	0.53 (0.02)	0.25 (0.05)	**0.01 (0.15)**
Self-efficacy for walking	9.49 (1.74)	9.78 (1.66)	9.47 (1.64)	9.71 (1.47)	9.33 (2.00)	9.74 (1.47)	0.91 (0.00)	**0.04 (0.15)**	0.86 (0.01)

Bold indicates $p \leq 0.05$. * indicates a significant difference between pre- and post-condition.

3.3. Psychological measures

All within-subject differences between average and peak psychological measures collected during the experimental conditions (i.e., RPE, FS) are demonstrated in Table 3. All within-subject differences between pre- and post-condition measures are shown in Table 4.

3.3.1. Rating of perceived exertion

There was a statistically significant main effect of condition [$F(2, 26) = 3.32$, $p = 0.04$, partial $\eta^2 = 0.11$] on RPE. Average and peak RPE were significantly higher during the PA and PAMIND conditions, independently, compared to the MIND condition (p's < 0.001). Average RPE was significantly lower during PAMIND compared to PA ($p < 0.001$). There were no differences between the PA and PAMIND conditions for peak RPE.

3.3.2. Feeling scale

Average and peak FS were significantly lower during both the PA and PAMIND conditions, independently, compared to the MIND condition (p's < 0.001). There were no differences between the PA and PAMIND conditions on FS measures. There was a statistically significant main effect of time [$F(1, 27) = 16.78$, $p < 0.001$, partial $\eta^2 = 0.38$], demonstrating FS scores increased significantly pre- to post-condition across all conditions, demonstrating more positive affective valence.

3.3.3. Mindfulness

There was a significant increase in mindfulness of bodily sensations [$F(1, 27) = 64.74$, $p < 0.001$, partial $\eta^2 = 0.71$] and mindfulness of mental events [$F(1, 27) = 15.18$, $p = 0.001$, partial $\eta^2 = 0.37$] from pre- to post-condition across all conditions. There was also a statistically significant time by condition interaction effect for mindfulness of mental events [$F(2, 26) = 3.92$, $p = 0.03$, partial $\eta^2 = 0.13$]. Such that mindfulness for mental events increased more in the PAMIND condition than the PA condition.

3.3.4. State anxiety

There was a statistically significant time by condition interaction effect for state anxiety [$F(2, 26) = 4.73$, $p = 0.01$, partial $\eta^2 = 0.15$] such that anxiety decreased more for the MIND condition than the PA or PAMIND condition.

3.3.5. Self-efficacy

There was a statistically significant effect of time on self-efficacy for walking [$F(1, 27) = 4.71$, $p = 0.04$, partial $\eta = 0.15$].The main effect of condition and the time by condition interaction were not significant.

3.4. Post-condition overall measures

Overall post-condition ratings of session RPE, FS and enjoyment were significantly different between MIND only and PA only conditions and MIND only and PAMIND conditions. Overall ratings for RPE ($p < 0.001$) and enjoyment ($p < 0.05$) were significantly lower for the MIND only condition and overall FS ratings ($p < 0.05$) were significantly higher for MIND only condition as compared to the PA only and the PAMIND conditions. This indicates that, on average, participants reported significantly lower levels of perceived exertion, more positive affective valence, and higher ratings of enjoyment, overall, during the MIND condition as compared to PA and PAMIND conditions. Post-condition overall ratings of RPE, FS, and enjoyment were not significantly different between PA only and PAMIND conditions.

4. Discussion

The primary goal of this study was to examine the effects of guided mindfulness meditation during MVPA on physiological and psychological parameters by comparing three conditions: mindfulness only, physical activity only, and combined physical activity and mindfulness. The PAMIND condition resulted in lower perceived exertion ratings (but not physiological parameters or feeling scale ratings) compared to the PA condition, which had equivalent intensity and duration. Additionally, mindfulness of mental events increased pre- to post-condition for the MIND and PAMIND conditions, but not in the PA condition. Overall, these findings suggest mindfulness during MVPA could provide benefits via effects on RPE and mindfulness of mental events.

4.1. Theoretical contributions

We observed no significant differences between the PA only condition and the PAMIND condition in HR or BP. Although mindfulness training has been shown to have beneficial effects on physiological markers of stress, including HR and BP (Ditto et al., 2006; Kingston et al., 2007; Delgado et al., 2010; Pascoe et al., 2017; Gamaiunova et al., 2022) the pairing of guided mindfulness with an acute bout of MVPA did not influence immediate physiological responses. It is likely that the acute effects of MVPA for stimulating HR and BP outweighed the acute blunting effect of mindfulness on these physiological responses. Indeed, reduced physiological response as a function of engaging in mindfulness during MVPA may not be expected or desirable. Rather, it will be important for future studies to explore whether there are long-term effects of practicing mindfulness while engaging in MVPA on BP and HR.

Interestingly, even though physiological parameters did not differ, average RPE did differ when participants completed the same PA with and without accompanying mindfulness. In that, participants perceived the exercise to be less strenuous, on average, when mindfulness was combined with PA than when they did PA alone. Existing literature states that perceived exertion is an outcome of both psychological and physiological components (Rejeski, 1981). Our findings support that, in a controlled setting, psychological intervention (i.e., mindfulness) can influence perceived exertion when the physiological response to activity is unchanged. Practicing mindfulness simultaneously with MVPA may increase distress tolerance during PA and attenuate how hard one feels that they are working. This could be a result of individuals more accurately interpreting their physiological response to MVPA, resulting in lower perceptions of exertion (Cox et al., 2018; Meggs and Chen, 2021). Notably, it is possible that the underlying factors explaining lower RPE ratings might be distraction offered by listening to the guided audio tape while walking on the treadmill during the PAMIND condition. Prior studies support that attentional distraction and sensory deprivation while exercising (e.g., listening to music) is associated with lower RPE as compared to control groups (Boutcher and Trenske, 1990; Yamashita et al., 2006; Gillman and Bryan, 2019). Therefore, future studies might consider controlling for distraction by comparing PAMIND to a condition in which participants listen to another type of audio (e.g., music, audiobook, podcast) while walking on a treadmill.

Our findings regarding psychological variables were mixed. The feeling scale, body and mental event mindfulness and self-efficacy all improved pre- to post-test regardless of condition suggesting all three conditions have positive acute effects on psychological outcomes. There was a significant time by condition interaction such that state anxiety decreased more for the MIND condition than the PA or PAMIND condition, although it was decreased across all conditions. Additionally, there was a significant time by condition interaction for mindfulness of mental events such that mindfulness of mental events increased more in the PAMIND condition than the PA condition. These findings suggest there could be differential acute effects of the three conditions on psychological outcomes favoring the MIND or PAMIND conditions.

Overall, our study addresses gaps in the literature by investigating the physiological and psychological outcomes of practicing mindfulness during an acute bout of MVPA. Our findings are similar to Cox and colleagues' (Cox et al., 2018) study that combined listening to a mindfulness recording while walking on the treadmill regarding decreased RPE, and increased mindfulness but did not replicate results concerning positive affect or enjoyment. The discrepancy in

results might be explained by the fact that Cox and colleagues recruited individuals who were, on average, younger and reported low intrinsic motivation to exercise. The present study did not include inclusion criteria related to exercise motivation or enjoyment, and therefore, might have enrolled participants who self-reported high baseline levels of exercise enjoyment and more positive affect associated with PA. Therefore, there could be a ceiling effect for affect and enjoyment, as participants in the present study might not have had much room for improvement in these measures.

4.2. Practical implications

Findings from this study have practical implications that may guide future development of MVPA promotion interventions or policy. Firstly, the finding that RPE significantly differed between the PA and PAMIND conditions without changes in physiologic responses to activity has potential implications for exercise initiation and maintenance. High perceived exertion can be a barrier to PA participation (Lind et al., 2009). The potential for mindfulness to reduce perceived exertion for the same intensity activity, even when physiological responses are the same, could make exercise more tolerable resulting in enhanced physical activity initiation and maintenance and increased engagement in a higher dose (duration, intensity, or frequency) of MVPA. Second, this study demonstrated a significantly greater increase in mindfulness of mental events in the PAMIND condition as compared to the PA only condition. Practically, given that mindful awareness facilitates enhanced emotion regulation (Roemer et al., 2015), promoting mindfulness during physical activity could enhance MVPA participation by reducing negative and increasing positive emotional responses. Ultimately, integrating mindfulness and MVPA has potential to improve adherence to MVPA guidelines resulting in improved health outcomes and reducing disease risk. Mindfulness is growing in global popularity (Misitzis, 2020), and increased evidence of its health benefits are emerging (e.g., stress reduction, improved mental health, lowered BP, etc.) (Donald et al., 2016; Hofmann and Gómez, 2017; Pascoe et al., 2017; Gamaiunova et al., 2022). Although there are no official public health guidelines for mindfulness practice, it is possible such guidelines will be developed as research continues to support mindfulness practice as a feasible, low cost, and efficacious health behavior. As guidelines and policies are developed, considering the potential effect of mindfulness on MVPA engagement offers potential for combined recommendations that could promote MVPA adherence and compound health benefits. Future studies are warranted to further examine the acute and long-term effects of combining physical activity and mindfulness and potential biopsychosocial mechanisms by which mindfulness could enhance MVPA participation.

4.3. Limitations

This study is not without limitations. First, this research was conducted with young, healthy adults who already engage in various levels of physical activity. Future studies should examine whether these results are replicable in other populations including older adults, individuals with chronic conditions, varying activity levels, and an aversion to, or difficulty with, increased exercise. Next, this study only examined one type of physical activity that is likely familiar to participants (treadmill walking) for one 20-min session in a controlled, laboratory setting. Future work should explore whether findings differ based on different activity characteristics, including, but not limited to type (e.g., bike, running), intensity, duration, and familiarity. Additionally, it is important to examine these relationships in various contexts (e.g., indoor v. outdoors) and in participants' natural environments to better understand whether these factors differentially influence how mindfulness may influence physiological and psychological parameters and MVPA participation. More research is also needed to examine whether decreased RPE during a single bout of mindful PA increases motivation or engagement in future MVPA, or what dose of intervention is necessary to increase overall MVPA engagement and adherence. Lastly, although objective data was included in this study (i.e., HR, BP), many variables were collected via self-report measures (i.e., RPE, FS, enjoyment, mindfulness, state anxiety, self-efficacy) and reported in real-time to study staff. These data collection procedures can potentially create bias in self-reported data. Incorporating additional objective measurements (e.g., heart rate variability, lactate levels, VO2 max) in future studies may strengthen reliability and provide additional insight into potential differences in physiological responses during exercise.

5. Conclusion

Despite these limitations, this is the first study to test the acute effects of combined mindfulness and PA training on psychological and physiological outcomes. Additional strengths include the within-person randomized-controlled trial design and the inclusion of both mindfulness-only and physical activity-only conditions. Our findings are promising in terms of both the promotion of physical activity and the efficacy of combining mindfulness with acute bouts of MVPA. Future research is needed to determine if our findings can be replicated to examine the underlying factors by which combining mindfulness and PA may decrease ratings of perceived exertion, even without differences in physiological responses compared to PA only. Ultimately, these findings provide initial support to justify further exploration of the effects of combining mindfulness and MVPA as a strategy to promote PA. Given that limited equipment is required, and mindfulness can be done anywhere, mindfulness combined with PA may represent a low-cost, highly disseminable physical activity promotion strategy that could substantially impact public health.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Northwestern University Institutional Review Board (IRB). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

PS: Writing – original draft, Writing – review & editing, Formal analysis, Investigation, Project administration. LA-G: Data curation, Formal analysis, Writing – original draft, Writing – review & editing. ET: Investigation, Writing – review & editing, Project administration. WW: Formal analysis, Writing – review & editing, Data curation, Methodology, Project administration. KM: Writing – review & editing. JS: Writing – review & editing. JR: Writing – review & editing. DV: Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing. SP: Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing, Resources, Validation, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1285315/full#supplementary-material

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EDITED BY
Guodong Zhang,
Southwest University, China

REVIEWED BY
Francisco Manuel Morales,
University of Granada, Spain
Claudia Savia Guerrera,
University of Catania, Italy

*CORRESPONDENCE
Dawei Cao
✉ caodw@chnu.edu.cn
Teng Lyu
✉ lyuteng@chnu.edu.cn

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Meta-analysis of a mindfulness yoga exercise intervention on depression – based on intervention studies in China

Yuehang Yang[1], Dawei Cao[1]*, Teng Lyu[2]* and Wei Gao[1,3]

[1]College of Physical Education, Huaibei Normal University, Huaibei, China, [2]College of Literature, Huaibei Normal University, Huaibei, China, [3]Sports Department, Huaibei Institute of Technology Sports Department, Huaibei, China

Background: Using statistical methods to analyze and summarize the research data of the inclusion criteria, to provide a quantitative average effect size to interpret the influence of mindfulness yoga exercise on patients with different depressive symptoms, explain the therapeutic effect of mindfulness yoga therapy on depression and its possible mechanism of action, and provide new ideas for the clinical treatment of patients with depression.

Method: Review Manage 5.4 software was used to comprehensively evaluate the effect of yoga exercise on depression interventions to provide a reference for improving mental health. CNKI, PubMed, Web of science, EBSCO were searched for all case–control research articles on yoga for depression from 2000 to 2022. After screening, data extraction and quality evaluation of randomized controlled trials (RCTs) by inclusion and exclusion criteria, a total of 22 studies with 2,216 patients were included, including 1,101 in the yoga intervention group and 1,115 in the control group.

Results: The results showed a large heterogeneity in the literature on the effect of yoga exercise on depression, with a combined total effect size [$SMD = -1.53$, 95%CI (−1.96, −1.10), $p < 0.00001$].

Conclusion: Mindfulness yoga exercise is effective in preventing and treating depression and improving mental health, and may be considered as a non-medical, low-cost intervention as an adjunct to pharmacological treatment.

KEYWORDS

anxiety, depression, meta-analysis, mindfulness thinking, yoga exercises

1 Introduction

With the acceleration of the social development process, the phenomenon of sub-health is frequent, and while the public is concerned about the physical health of the whole population, mental health has become an urgent problem. The National Depression Blue Book 2022 China Mental Health Survey shows that there are currently 95 million people suffering from depression in China, and about 280,000 people commit suicide every year, 40% of whom suffer from depression (China Education and Research Network, 2022). According to the World Health Organization (WHO), an estimated 3.8% of the population experience depression, including 5% of adults (4% among men and 6% among women), and 5.7% of adults older than 60 years. Approximately 280

million people in the world have depression. Depression is about 50% more common among women than among men. Worldwide, more than 10% of pregnant women and women who have just given birth experience depression. More than 700,000 people die due to suicide every year (World Health Organization, 2023). The global burden of mental disorders has increased after the Newcastle pneumonia epidemic, with cases of major depression and anxiety disorders increasing by 28 and 26%, respectively, and a surge of 53 million people with depression, an increase of 27.6% (Santomauro et al., 2021). A recent WHO report shows that in the first year of the new pandemic, the global incidence of anxiety and depression increased significantly by 25 percent. Nearly 1/3 of the residents who were isolated at home experienced varying degrees of depression, anxiety, insomnia and acute stress, and more than 10% of them failed to fully recover after the pandemic.

When diagnosed with anxiety- or sleep-related depression, patients take medications such as antidepressants and benzodiazepines; the risk of recurrence is about 50%. This pathology and its chemotherapy can affect individual health and life balance, such as cognitive impairment, family and work. In addition, side effects may produce dependence, inability to concentrate or drive, to inhibit suicide attempts (Kuyken et al., 2015).

Compared with previous studies, the causes of depression are multidimensional, including psychological factors (personal history, loss, trauma), biological factors (genetic susceptibility, neurochemical disorders, bacteria) and environment (stress, social interaction, family environment, physical environment). Different degrees of depression will show different characteristics. In mild depression: appearance as usual, inner pain experience, sadness, distress, depression. Moderate depression can have low mood, sad face, sigh, low self-esteem and other states, some patients are often accompanied by neurosis symptoms, such as: inattention, memory loss, slow response, insomnia and dreaminess and other symptoms. With severe depression, there will be pessimism, despair, self-blame, delusion, loss of appetite, weight loss, dysfunction, and severe suicide attempts, and even suicidal behavior (Xu, 2021). It poses a serious threat to health, so we must attach great importance to it and treat it in time. As a long-term continuous state, depression can be treated by psychological counseling combined with physical exercise, and its positive effect is more lasting and safe. Exercise can secrete endorphins and dopamine in the brain, thus effectively relieving stress. After the patient releases the pressure and relieves the mood, it is more conducive to continuing clinical treatment, improving the body's immunity and improving the therapeutic effect.

The yoga of mindfulness is a combination of "mindfulness practice" and "hatha yoga," which teaches patients to practice "hatha yoga" while looking at the phenomena of the body and mind in the present moment (Yao et al., 2023). In recent years, some scholars have found that the combination of mindfulness and yoga exercises has a releasing effect on non-severe depression patients. The aim of this study is to systematically evaluate and apply meta-analysis to determine the effect of yoga treatment on depressed patients, in order to draw objective and accurate conclusions and provide a theoretical reference for the future application of yoga in mental health treatment and to promote the integration of somatic medicine.

1.1 Mindfulness yoga features and benefits

Mindfulness-based stress reduction (MBSR) is a systematic meditation training method based on positive thinking, which commonly includes positive meditation, body scanning and positive movement training (positive walking, positive yoga) (You, 2020). Among them, mindfulness yoga is derived from the asanas of hatha yoga, which incorporates the skill of truthfulness in positive thinking into yoga postures, focusing on the integration of present moment awareness with the body, observing the reality of mind and body in the present moment, and accepting it as it is (Miao et al., 2023a). Gentle and soothing, the long-term practice of positive yoga can improve one's physical, mental, emotional and spiritual abilities, and is a form of exercise that achieves harmony and unity between body, mind and spirit. As awareness continues to increase, tolerance increases and acceptance and tolerance strength will slowly increase (Sun and Wang, 2020). In addition, positive yoga has multiple benefits such as improved blood sugar, improved cardio-respiratory and muscle strength, and improved quality of life, and no adverse effects such as acute injuries have been observed.

Studies have shown that in Major depressive disorder, positive yoga exercise is as effective as antidepressant medication and is associated with reduced severity of depressive symptoms and increased treatment remission (Guerrera et al., 2020). Xu et al. (2023) confirmed that in patients with mild to moderate Parkinson's disease, a positive yoga program was associated with improving motor dysfunction and mobility, reducing anxiety and depressive symptoms, and improving mental health and quality of life, the intervention was superior to stretching and resistance training programs. James-Palmer reviewed 27 studies involving youth with different health conditions and found that overall 70% of studies showed significant improvement; 58% of studies assessing anxiety and depression of the studies showed a reduction in both symptoms, and 25% showed a reduction in anxiety only. In addition, 70% of the studies assessing anxiety alone showed improvement in anxiety with positive yoga, and 40% of the studies assessing depression only showed positive intervention effects for depression.

2 Method

2.1 Search strategy

Literature search with "depression" OR "depressive disorder" OR "neurosis, depressive" OR "depressive symptoms" OR "major depressive disorder" AND positive yoga ("yoga" OR "yoga therapy" OR "yoga exercise" OR "yoga") OR "yoga therapy" OR "yoga exercise" OR "yoga practice" OR "yoga intervention" OR "mindfulness yoga" in PubMed, Web of Science, CNKI database, and other databases to complete the search. The search period was from database creation to November 2022. The original results from the search were literature-weighted and screened, and relevant studies were supplemented with references from the included studies when necessary.

2.2 Selection criteria

Case-randomized controlled study and own-control study. Patients with depression diagnosed by HAMD, SDS or EPDS or other diagnoses were included. The experimental group was given positive yoga treatment (breathing, movement, meditation), and the control group was given conventional intervention. The severity of depression was assessed by HAMD (Hamilton Depression Scale), SDS

(Self-Rating Depression Scale) or EPDS (Edinburgh Postnatal Depression Scale) or other types of depression measurement scales.

2.3 Data extraction

Regarding various types of data, such as patient (age, gender, diagnosis) method (randomized, blinded) intervention (type, duration, frequency of yoga) control group intervention (type, frequency, duration) outcome indicators, etc., will be done by two evaluators, and in case of dispute a third evaluator will be involved in the discussion to reach consensus.

2.4 Quality assessment

The risk of bias assessment tool of Review Manager 5.4 was used to evaluate the included studies in the following six aspects: ① generation of random assignment scheme; ② concealment of assignment scheme; ③ implementation of blinding method; ④ completeness of outcome data; ⑤ no selective reporting of results; ⑥ other sources of bias. "Low risk" indicates low risk of bias, "high risk" indicates high risk of bias, and "Unclear risk" indicates that the literature does not provide enough or uncertain information for bias assessment. To ensure the objectivity and scientific validity of the meta-analysis, the quality scores of the literature were conducted independently by two investigators, and the scores were compared with each other after completion.

2.5 Data analysis

Meta-analysis and heterogeneity tests were performed using Review Manage 5.4 software for the final screened literature using the random effects model (Random effects, *RE*), and the combined effect sizes of continuous variables were expressed as standardized mean difference (*SMD*). For continuous data, weighted mean difference (*MD*) was used for analysis if the differences in mean values of outcome indicators were small or if the same measurement tools were used; if different measurement tools were used for the same variables or if the differences in mean values of outcome indicators were large, standardized mean difference (*SMD*) was used for analysis, and 95% confidence intervals were calculated for all analyses. When heterogeneity existed among the literature for meta-analysis, the sources of heterogeneity were analyzed using subgroup analysis, and finally, funnel plots and forest plots were used for publication bias detection, with $p < 0.05$ being considered a statistically significant difference. Heterogeneity was tested by Q test and I^2 test, and publication bias analysis was performed by Egger test. If $p > 0.01$ and $I^2 < 50\%$, a small heterogeneity was considered, a fixed-effects model (*FE*) was used; if $p < 0.10$ and $I^2 > 50\%$, a large heterogeneity was considered, a random-effects model (*RE*) was used, and further sensitivity analysis and Meta regression analysis were used. Subgroup analysis was used to compare the differences in performance of the positive yoga exercise program on different depressed subjects.

A total of 401 relevant papers were obtained by database search, including 293 in English and 108 in Chinese (Figure 1). After reading the titles and/or abstracts to exclude those that obviously did not meet the inclusion criteria, 241 papers that were repeatedly published, crossed over, and did not meet the inclusion criteria were excluded, 160 papers were screened, and 84 papers were assessed to be eligible, and then after finding reading the full text and quality evaluation, 62 of them were excluded due to: ① non-high quality randomized controlled studies (RCT) ② not using test scales ③ missing experimental results. Therefore, they were removed, and 22 qualified papers were finally included.

3 Results

3.1 Characteristics and quality of the included studies

A total of 2,216 patients, including 1,101 in the yoga intervention group and 1,115 in the control group. Nine studies were interventions for postpartum depression, 10 studies were mindfulness yoga interventions for patients with common depression, and 3 studies were interventions for patients with other diseases and symptoms of depression. Six studies used the Edinburgh postnatal depression scale (EPDS), nine studies used the Self Rating Depression Scale (SDS), and five studies used the Hamilton Depression Scale (HAMD). Other outcome measures included the Hospital Anxiety and Depression Scale (HADS). The general situation and baseline characteristics of the included studies are detailed in Table 1.

3.2 Sensitivity analysis

In this study, the sensitivity analysis was performed by excluding the literature one by one. After the meta-analysis was performed again, the results were compared with the previous data. It was found that the change of the combined effect results of each literature was not obvious, indicating that the results of the meta-analysis were credible. Only one paper intersected with the vertical line, indicating that the results of this study were stable. The results showed that the distribution of each study was uniform, suggesting that the possibility of publication bias was small, and the sample size was large, and the standard error was small, as shown in Figure 2.

3.3 Risk of bias evaluation of included studies

According to the bias risk assessment method recommended by the Cochrane assistance network. The baselines of the 22 studies included were comparable, but all had different levels of bias (Figure 3). Two of the 22 studies did not mention that randomization was rated as high risk (Yang, 2007; Shu et al., 2019). Nine studies reported that the sampling method was cluster sampling and allocation, and were therefore rated as low risk. Eight studies assigned exercise programs according to preferences or gender when grouping interventions, making it possible for subjects or researchers to predict allocation results, making it difficult to achieve allocation concealment, and thus being rated as high risk. In terms of blinding of subjects and staff, 22 studies were rated as high-risk because the intervention methods of the experimental group and the control group were

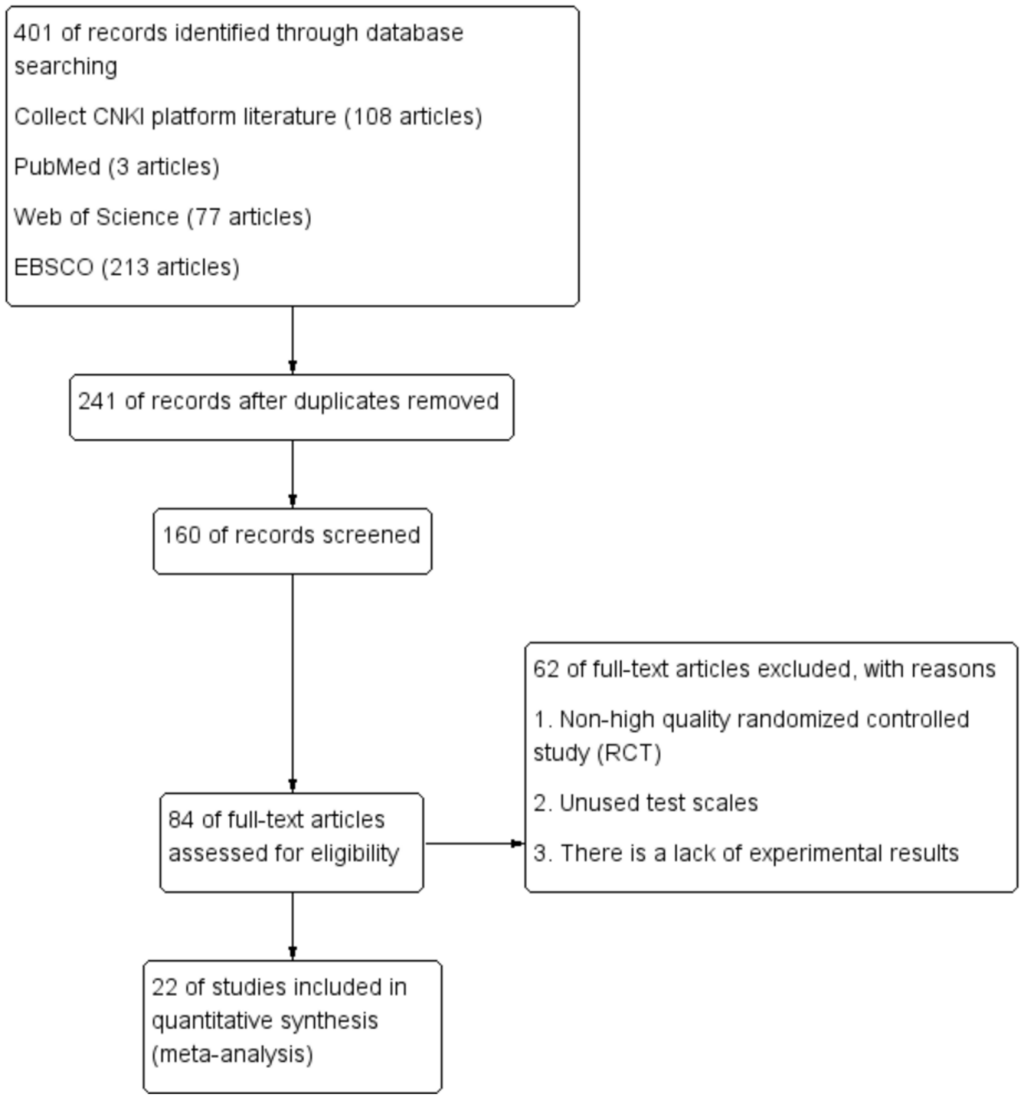

FIGURE 1
Literature screening flow chart.

completely different, and the control group had no intervention measures. Therefore, it could not comply with the double-blind principle, resulting in selection and implementation bias, and the outcome might be affected by the lack of blinding. Therefore, all studies assessed the risk of bias in incomplete outcome data as low risk. One study was rated as high risk because it difficult to obtain or replicate (Li et al., 2021). Finally, the three studies described the limitations at the end, and were therefore rated as high-risk (Lin et al., 2010; Li et al., 2020; Zhang et al., 2021). The remaining studies were unclear about other shifts due to insufficient information judgment.

3.4 Meta-analysis of the effect of yoga exercise on depression level

In the 22 literatures on the effect of mindfulness yoga intervention on depression level, the heterogeneity test showed that (Figure 4): heterogeneity coefficient ($p < 0.00001$, $I^2 = 94\%$), indicating that there was a strong heterogeneity between the control experiments included in the meta-analysis, and the measurement tools of each study were different. Therefore, *SMD* was selected as the combined statistic, and the random effect model (*RE*) was used to combine the effect quantity. The overall effect size $SMD = -1.53$, 95%*CI* was [−1.96, −1.10], and the combined effect size test $Z = 7.03$, $p < 0.00001$. According to Cohen's research explanation, 0.8 or more is a large effect size, and $p < 0.05$, indicating that the combined effect size of multiple sets of data is statistically significant. The data showed that the level of depression in the mindfulness yoga intervention group was significantly lower than that in the control group, which could reduce the standard deviation by 1.53 times. That is, the use of mindfulness yoga could better improve the effect of depressive symptoms in patients, which was statistically significant. However, due to the substantial heterogeneity between the studies, sensitivity analysis was performed, and the included studies were excluded one by one. However, due to the substantial heterogeneity between the studies, sensitivity analysis was performed, and the included studies were excluded one by one. When the study of Bao et al. (2015) or Liang et al. (2021) was deleted, the heterogeneity was significantly increased ($I^2 = 95\%$, $p < 0.00001$). When you's research report is deleted, the heterogeneity is significantly reduced ($I^2 = 93\%$, $p < 0.00001$).

TABLE 1 Basic characteristics of included literature.

References	Age	*N*		Intervention programs		Outcome indicators
		EG	CG	EG	CG	
Yang (2007)	19 ~ 23	30	30	MY		SDS
Lin et al. (2010)	18 ~ 45	30	30	MY	CC	SDS
Wang et al. (2014)	EG:23 ~ 29 CG:21 ~ 32	20	20	MY	CC	SDS
Bao et al. (2015)	19 ~ 24	24	24	MY	CC	SDS
Qiu et al. (2017)	19 ~ 43	95	105	MY	CC	EPDS
Niu and Guo (2017)	19 ~ 43	40	40	MY	CC	HAMD
Shu et al. (2019)	20 ~ 45	43	43	MY	CC	EPDS
Li and Lin (2019)	18 ~ 35	50	50	MY	CC	EPDS
Li et al. (2020)	20 ~ 40	41	41	MY	CC	EPDS
Gui (2020)	EG:21 ~ 39 CG:22 ~ 38	47	47	MY	CC	SDS
Gao et al. (2020)	22 ~ 40	42	42	MY	Venlafaxine	HAMD
You (2020)	EG:30 ~ 68 CG:31 ~ 70	189	189	MY	CC	HADS
Chen and Ye (2020)	EG:28 ~ 53 CG:25 ~ 52	26	30	MY	CC	HAMD
Li et al. (2021)	18 ~ 65	32	32	MY	CC	HAMD
Zhao and Xu (2021)	EG:28 ~ 55 CG:26 ~ 55	59	59	MY	CC	HAMD
Liang et al. (2021)	13 ~ 18	35	35	MY	CC	SDS
Liu and Zhang (2022)	EG:22 ~ 52 CG:22 ~ 51	45	45	MY	CC	SDS
Zhang et al. (2021)	29 ~ 57	38	38	MY	CC	HADS
Yang et al. (2021)	EG:21 ~ 34 CG:22 ~ 35	60	60	MY	Yoga Nidra	EPDS
Liu and Zhang (2022)	22 ~ 40	43	43	MY	CC	EPDS
Sun and Zheng (2022)	19 ~ 45	49	49	MY	CC	SDS
Wang et al. (2022)	EG:29 ~ 45 CG:31 ~ 46	63	63	MY	CC	SDS

MY, Mindfulness Yoga; CC, Conventional Care.

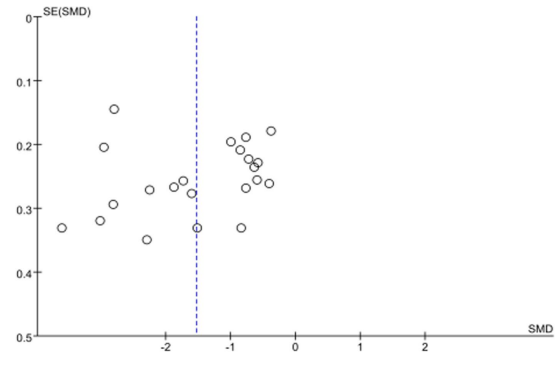

FIGURE 2
Publication bias funnel plot.

3.5 Subgroup analysis of moderating variables

According to the heterogeneity of the overall effect size test, further subgroup analysis of the regulatory variables is needed to explore the source of heterogeneity. In this study, four adjustment variables, including outcome measurement index, weekly intervention frequency, intervention duration and experimental subject (prevalence of disease) were set up and tested in subgroups (Table 2).

3.5.1 Outcome indicators

The 22 articles were divided into four groups: SDS, EPDS, HAMD and HADS according to different scales. *MD* was selected as the statistic. According to the results, the effect size of *RE* was combined. The effect size of the four groups had high heterogeneity ($I^2 = 95\%$), indicating that the measurement of different outcome indicators had a certain impact on the relationship between exercise intervention and depressive symptoms. Among them, SDS had the greatest effect on the results of depressive symptoms $d = -5.80$ ($p < 0.00001$), 95%*CI*: [−7.72, −3.89]; the second is the EPDS measurement index, the effect size $d = -3.13$ ($p < 0.00001$), 95%*CI*: [−4.42, −1.85]. Among them, the effect size of HADS was $d = -2.79$, 95% *CI*: [−4.29, −1.29] ($p < 0.00001$); the effect size of HAMD was the smallest, $d = -2.47$, 95% *CI*: [−3.54, −1.37] ($p < 0.00001$).

3.5.2 Weekly intervention frequency

The study was divided into four groups according to the frequency of weekly exercise intervention, and *SMD* was selected as the statistic. According to the results, the combined effect of RE was used. The effect size of the four groups had moderate heterogeneity ($I^2 = 74.6\%$), indicating that different weekly intervention frequencies had a certain effect on depressive symptoms. Among them, the 3–4 times per week

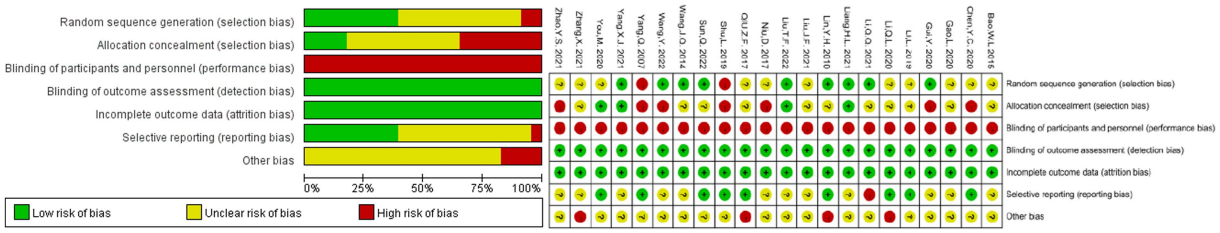

FIGURE 3
Bias risk assessment of included studies.

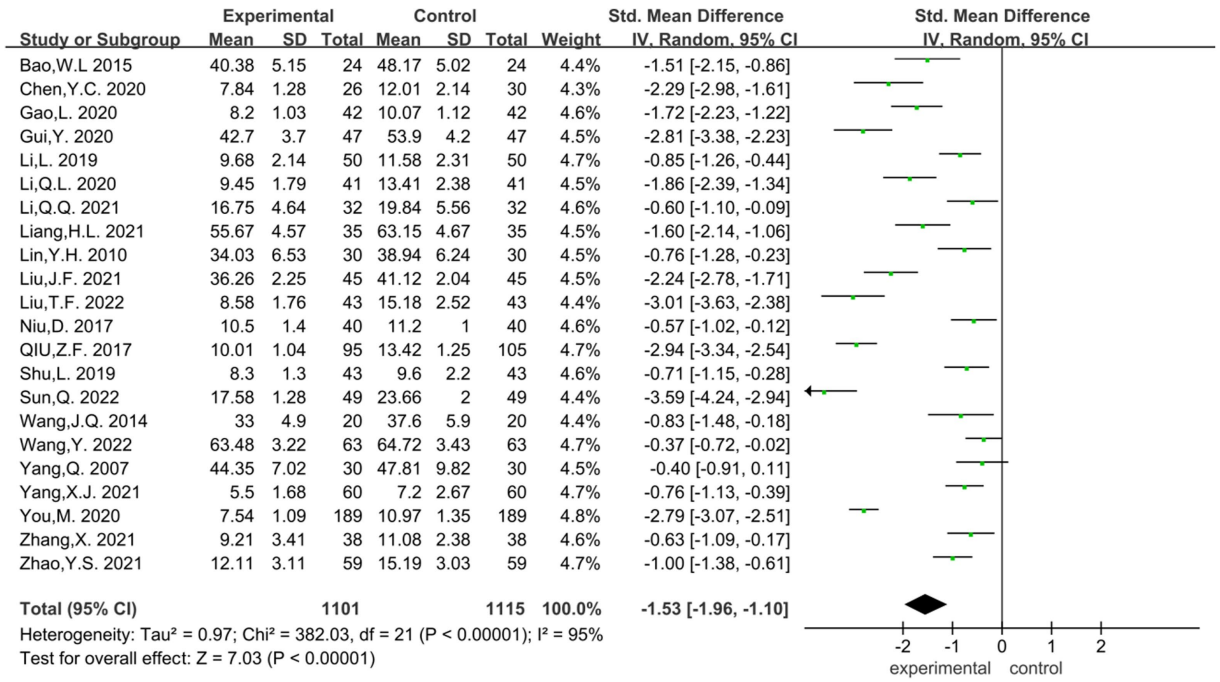

FIGURE 4
Meta-analysis forest plot of the effect of yoga exercise on depression level.

intervention produced the largest effect size of $d = -1.53$ ($p < 0.00001$), 95%*CI*: [−2.01, −1.05] for depressive symptom outcomes; followed by the 5 times per week exercise intervention with an effect size of $d = -1.20$ ($p = 0.0005$), 95%*CI*: [−1.87, −0.53]; in addition, the 2 times per week intervention had an effect size was $d = -0.93$ ($p = 0.001$), 95%*CI*: [−1.75, −0.12]; in addition, the effect size for the 2 times per week intervention was $d = -0.93$ ($p = 0.001$), 95%*CI*: [−1.75, −0.12]. The smallest effect size was for the once-weekly exercise intervention, $d = -0.33$, 95%*CI*: [−0.84, 0.18], which was not significant because $p = 0.21 > 0.05$.

3.5.3 Exercise intervention duration

The 22 studies were divided into 4 groups based on the exercise intervention period, and *SMD* was selected as the statistic, and the effect size was combined using RE based on the results, with a high degree of heterogeneity ($I^2 = 83.1\%$) across the 4 groups, indicating that there was an effect of different weekly intervention periods on depressive symptoms. Among them, the 12-week intervention produced the largest effect size of $d = -1.69$ ($p < 0.00001$), 95%*CI*: [−2.31, −1.07] in improving depressive symptoms outcomes; followed by the 16-week intervention group with an effect size of $d = -1.33$ ($p = 0.0007$), 95%*CI*: [−2.09, −0.56]; in addition, the 8-week intervention group had an effect size of $d = -1.01$ ($p = 0.001$), 95%*CI*: [−1.62, −0.38]. Finally, the smallest effect size was in the 9-10-week intervention group with $d = -0.26$, 95%*CI*: [−0.64, 0.12], which was not significant because $p = 0.18 > 0.05$.

3.5.4 Experimental subject

Due to the heterogeneity between the studies, the depressive symptoms were analyzed according to the subgroup of the experimental subjects. The results were as follows: on the index of the experimental subjects, the scores of postpartum depression patients in the intervention group were lower than those in the control group (*SMD* = −1.68, 95%*CI* = [−2.34, −1.02], $p < 0.00001$). The depression tendency of patients with other diseases in the intervention group score was lower than that in the control group (*SMD* = −1.89, 95%*CI* = [−3.23, −0.56], $p = 0.005$); according to the general depression patients, the intervention group scores were lower than the control

TABLE 2 The results of the effect of moderating variables on depressive symptoms in mindfulness yoga programs.

Regulated variable	Heterogeneity test			Subgroup	Number of studies	95% CI	Two-tailed test	
	χ^2	P	I^2				Z	P
Outcome indicators	59.87	<0.00001	95%	SDS	9	−5.80 [−7.72, −3.89]	5.94	<0.00001
				EPDS	6	−3.13 [−4.42, −1.85]	4.77	<0.00001
				HAMD	5	−2.47 [−3.54, −1.37]	4.35	<0.00001
				HADS	2	−2.79 [−4.29, −1.29]	3.64	0.0003
Freq. (times/week)	11.8	0.008	74.6%	1	1	−0.33 [−0.84, 0.18]	1.26	0.21
				2	5	−0.93 [−1.49, −0.37]	3.26	0.001
				3–4	10	−1.53 [−2.01, −1.05]	6.12	<0.00001
				5	6	−1.20 [−1.87, −0.53]	3.49	0.0005
Duration (weeks)	17.8	0.0005	83.1%	8	5	−1.01 [−1.62, −0.38]	3.21	0.001
				9–10	4	−0.26 [−0.64, 0.12]	1.35	0.18
				12	8	−1.69 [−2.31, −1.07]	5.36	<0.00001
				16	5	−1.33 [−2.09, −0.56]	3.38	0.0007
Experimental subject	1.61	0.45	0%	With other diseases	3	−1.89 [−3.23, −0.56]	2.78	0.005
				Ordinary depression	10	−1.21 [−1.71, −0.71]	4.73	<0.00001
				Postpartum depression	9	−1.68 [−2.34, −1.02]	4.96	<0.00001

group ($SMD = -1.21$, 95%$CI = [-1.71, -0.71]$, $p < 0.00001$). However, the p value in Heterogeneity Test was not significant, indicating that experimental subject was not the source of heterogeneity.

4 Discussion

With the acceleration of the pace of life in today's society, people's pressure on learning, employment and other aspects has increased dramatically, which has caused a greater impact on mental health. Depression is a common mental illness in clinic, which is characterized by continuous low mood, high incidence and disability rate, causing serious economic burden to patients (Zhang, 2017). It may occur at all ages, posing a serious threat to the public's mental health, and the cost of treatment is high (Wu, 2020). The disease has a long course of disease and is prone to recurrence. It is easy to produce other negative emotions. Negative emotions continue to accumulate, seriously affecting work and life, leading to decreased social function, resulting in a vicious circle (Guo et al., 2021). It is expected that 2030 will become the first cause of suicide (Friedrich, 2017).

A nationwide epidemiological survey (Huang et al., 2019) showed that the lifetime prevalence of depression in China was 3.4%. The main treatment of the disease is drug therapy, but only the application of drug therapy is limited (Kang and Sheng, 2020). European Psychiatric Association recommends the combination of drug therapy and psychotherapy (Probst et al., 2020). "Mindfulness" originated from the Eastern Buddhist culture and has developed from meditation and meditation to a systematic psychotherapy (Williams et al., 2020). This paper systematically analyzes the effect of mindfulness therapy on depression, anxiety symptoms and sleep quality in patients with depression. Mindfulness therapy is a common method for the treatment of mental disorders. It has formed a relatively mature system and has a significant effect in the treatment of mental disorders such as depression, anxiety and personality disorders (Spinhoven et al., 2017). As a non-drug therapy for mental health intervention, applying mindfulness therapy to patients with depression can help alleviate their anxiety and depressive symptoms, reduce the occurrence of rumination, reduce suicidal willingness, improve mindfulness skills, and promote disease recovery (Xia, 2020).

Of the 22 RCTs selected in this study, one was self-controlled and the rest were randomized controlled studies. Compared with the non-yoga treatment group, the score of depression was significantly lower in the yoga treatment group. Compared with simple meditation, meditation, and complete yoga (exercise, breathing, meditation) combined with mindfulness, the improvement of depression was more significant. Yoga posture exercise promotes blood circulation and effectively improves sleep. Respiratory regulation can stabilize autonomic nerves, relieve stress and eliminate mental tension. Mindfulness meditation practice can make patients with depression calm, reduce depression and anxiety, and concentrate. There are still some deficiencies in the literature included in this study. The level of depression in the experiment is not strictly controlled, and some depressed patients have physical diseases (Hua et al., 2018), which may seriously interfere with patients' yoga practice, especially cancer and bone and joint diseases. There are also many differences in the types of depression. The depression assessment scale may not truly reflect the degree of depression in patients due to different cultures. In this study, a meta-analysis method was used to quantitatively evaluate the improvement of yoga exercise on mental health.

4.1 The intervention mechanism of mindfulness yoga on mental health

According to scientific experiments, when people enter the state of meditation, the activity of the brain will show regular brain waves. At this time, the role of the neocortex of the brain that governs intellectual and rational thinking will be inhibited, while the autonomic nerves that dominate animal instincts and self-will and cannot be controlled, as well as the role of the brainstem and the lower part of the thalamus that are responsible for adjusting hormones, will become active (Qi et al., 2020). When entering the yoga meditation state, the practitioner must slow down the muscles, cells and blood circulation of the whole body, and finally make the meditator obtain inner peace and tranquility.

Yoga uses complete breathing, that is, the combination of abdominal breathing and chest breathing. This breathing method is analyzed from a physiological point of view. More oxygen is taken in when inhaling, and more carbon dioxide and toxic substances are discharged when exhaling, which can make each cell of the body work better and more fully. With each breath, the diaphragm will also fluctuate regularly, and it can also play the role of massage and reconciling internal organs (Smith et al., 2023). From a psychological point of view, because attention is focused on breathing, it can make the practitioner calm and mentally stable. At the same time, more oxygen is delivered to the brain, which also increases the attention of the practitioner and enhances the brain's ability to coordinate bodily functions (Xiong and Li, 2014).

4.2 The effect of mindfulness yoga on depressive symptoms in patients with depression

The results of meta-analysis showed that mindfulness therapy was helpful to improve depressive symptoms in patients with depression. However, there is a large heterogeneity in depression indicators. Subgroup analysis was performed on the included studies according to the research objects and evaluation scales. Among the subjects, the depressive symptoms were relieved after the intervention of mindfulness therapy, but the heterogeneity was large, which may be related to the inclusion of patients with depression in different diagnostic grades. Because only individual studies described detailed diagnostic grades, it was impossible to further analyze the application of mindfulness therapy to patients with depression in different diagnostic grades. In terms of evaluation scales, after combining the effect values of SDS, EPDS and HAMD, it was found that the heterogeneity was reduced, and the EPDS score was significantly reduced, suggesting that the inconsistency of the evaluation scales used among the studies may be the source of heterogeneity. The unity of the evaluation methods of outcome indicators can be the focus of future research. Due to the different evaluation time used in each study and the small number of literatures included, the evaluation time was not combined and analyzed. All studies compared the efficacy within 3 weeks after the intervention, and the results showed that mindfulness therapy helped to alleviate depressive symptoms in patients with depression ($p < 0.00001$). Some studies were followed up for more than 6 weeks, and the results showed that the long-term effect of mindfulness therapy on relieving depressive symptoms was not obvious ($p = 0.52$). To this end, Segal et al. (2020) proposed that future research should pay more attention to the duration of intervention time, and evaluate the medium and long-term intervention effects of mindfulness therapy by prolonging the intervention time.

4.3 The intervention effect of mindfulness yoga on improving mental health at home and abroad

Foreign studies have shown that in the field of physiology and psychology, researchers have been able to perform various physiological tests such as electromyography, electroencephalogram and respiratory status before and after yoga training, and demonstrate that yoga training can reduce cortisol content in the body (Amitani et al., 2022), relieve psychological pressure (Schmalzl and Kerr, 2016), and improve people's mental health (Wang et al., 2020). Foreign scholar (Daley et al., 2015) believes that yoga practice can make individuals feel happy and satisfied (Kuyken et al., 2015), which is conducive to physical health. Prenatal yoga exercise has the most significant effect on preventing maternal stress and anxiety (Niu and Guo, 2017; Gui, 2020; Miao et al., 2023b), and has a positive effect on emotional improvement (Zhou et al., 2021). Domestic scholars believe that each action to complete yoga needs to be based on mindfulness meditation and listening to achieve the realm of physical and mental integration (Shu et al., 2018; Wu and Feng, 2023). After practicing yoga, practitioners can feel physical and mental pleasure. Long-term practice can cultivate a natural state of mind (Chen and Ye, 2020), which is of great help to alleviate the release of negative emotions such as psychological anxiety and depression. Liu and Zhang (2022) selected 86 cases of second-child pregnant women as the research object, and randomly divided them into two groups. The patients in the control group were given routine psychological nursing, and the patients in the study group were given mindfulness yoga training based on the control group. The study found that mindfulness yoga can effectively alleviate the generation and accumulation of depression

during pregnancy in second-child pregnant women, shorten the labor process of pregnant women, and have a significant effect on PPD prevention and depression reduction. Du and Zhang (2005) and Shan et al. (2017), etc. have selected people with depression as experimental subjects for yoga practice. The results show that there are very significant differences in anxiety and depression factors before and after practice. It is concluded that yoga practice can alleviate depression.

5 Conclusion

Limitations: (1) Only original studies in Chinese and English were included in this meta-analysis, which increased the risk of incomplete literature inclusion. (2) The evaluation time of the included literature was different, and there was a problem of short evaluation time. Because only 22 original studies were included, some factors affecting the severity of depression, such as the diagnosis and classification of depression and the use of depression drugs, could not be further explored. (3) The specific measures of mindfulness intervention adopted in each study are not the same, and the interpretation of the results needs to be cautious.

In summary, mindfulness meditation training combined with group yoga intervention for patients with depression can effectively improve the depression and anxiety status of patients, improve the cognitive level of patients with depression, and improve the quality of life, which is worthy of clinical application. Colleges, enterprises and obstetrics and gynecology hospitals should popularize mindfulness yoga and configure corresponding instructors or teachers to help improve the physical quality of the sick group and reduce the level of depression and anxiety. To a certain extent, it can also alleviate and prevent depression.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

YY: Conceptualization, Data curation, Formal analysis, Investigation, Software, Visualization, Writing – original draft. DC: Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing – review & editing. TL: Methodology, Project administration, Supervision, Writing – review & editing. WG: Investigation, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EDITED BY
Guodong Zhang,
Southwest University, China

REVIEWED BY
Xing Zhang,
Chengdu Sport University, China
Huilin Wang,
Hunan University of Science and Technology, China

*CORRESPONDENCE
Petra Jansen
petra.jansen@ur.de

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Subliminal mortality salience does not increase physical strength output in double-blind randomized controlled trial

Christopher T. J. Bartenschlager and Petra Jansen*

Faculty of Human Sciences, University of Regensburg, Regensburg, Germany

Introduction: Using the morality salience paradigm, this research tested whether subliminal death stimuli lead to increased physical strength. Moreover, it was investigated if mindfulness and self-esteem instability influence terror management.

Methods: In total, data from 160 undergraduate sports students were analyzed. Participants completed a word decision task in which they were presented with either the word death or pain for 28.5 ms. Before and after the task, their grip strength was measured using a hand dynamometer.

Results: Linear mixed models could neither confirm the effect of the mortality salience hypothesis on strength nor an influence of mindfulness and self-esteem.

Discussion: The results raise the question of a potential influence of subliminal mortality salience on athletic performance and how mindfulness and self-esteem instability affect terror management.

KEYWORDS

terror management theory, subliminal mortality salience, mindfulness, self-esteem instability, physical strength

1 Introduction

Humans differ in their reaction to death. Terror Management Theory (TMT; Greenberg et al., 1986) addresses this impact from a social psychological perspective and has been applied in various areas, like the investigation of physical and psychological health and the relation of TMT to close relationships, religion, and politics (Arrowood and Cox, 2020). Here, it will be investigated under which condition the reactions to death are related to a specific motor performance. TMT assumes that death awareness fuels a potentially ever-present danger that must be handled (Greenberg et al., 1986, 1990). According to TMT, this is done through cultural belief systems, the associated worldviews and self-esteem. Simply put, self-esteem and cultural worldviews have the role of an anxiety buffer. However, individual differences in self-esteem (Harmon-Jones et al., 1997) and mindfulness (Niemiec et al., 2010) shape our responses to thoughts of mortality. One objective of this study is to investigate these constructs following mortality salience (MS), which is the experimental confrontation with death-related thoughts (Burke et al., 2010).

1.1 Subliminal mortality salience manipulation

The Dual Process Model of TMT was introduced by Pyszczynski et al. (1999) and described the processes occurring when confronted with death-related stimuli. Following that, distal defenses emerge after MS manipulation, either after a delay or immediately, and when death-related thoughts are at the threshold of consciousness, i.e., highly available but still unconscious (Cox et al., 2019). Distal defenses involve upholding one's worldview and pursuit of self-esteem, leading to the decline of death-thought accessibility, and an anxiety-buffering effect emerges (Greenberg et al., 1990). In approximately 80% of studies, explicit (supraliminal) death primes are used, which typically consist of answers from participants to questions regarding their emotions concerning their own death (Burke et al., 2010). By contrast, subliminal death primes were investigated less frequently and could have higher ecological validity. For example, Arndt et al. (2001) presented the word *death* under the perception threshold for 28.5 ms in a word-relation task. This led to a more negative evaluation of an author who had written an anti-U.S. essay among Americans. Regarding the underlying mechanisms of the model, there is convincing evidence that subliminal primes lead to increased death-thought accessibility (Hayes et al., 2010; Steinman and Updegraff, 2015). In summary, the effects of subliminal MS are comparable to typically used explicit methods, albeit with some advantages like concealment of manipulation and better stimulus control. Since most studies have used the more easily implementable explicit manipulation, the current study uses a subliminal one.

1.2 Mindfulness and terror management

Mindfulness can be seen as the ability to be present in the moment in a non-judgmental way (Kabat-Zinn, 1994). According to Bishop et al. (2004), mindfulness is a construct consisting of two components: The first involves self-regulation of attention to immediate mental experiences. The second is a specific orientation characterized by curiosity, acceptance, and openness to the present moment. A basic assumption is that mindful individuals engage intensively with death-related thoughts after a MS, and therefore no need for defense mechanisms emerges. This hypothesis was supported by Niemiec et al. (2010), who demonstrated fewer defensive reactions in more mindful individuals. Since then, few studies have been published investigating mindfulness following MS. In studies by Kashdan et al. (2011) and Grevenstein and Bluemke (2016), neither the typical MS effect nor an interaction effect was observed. However, both studies probably implemented a too short delay between MS and the dependent variable, as only a 20-item questionnaire (Grevenstein and Bluemke, 2016) and an unspecified mood assessment (Kashdan et al., 2011) served as a filler. Park and Pyszczynski (2017) found evidence consistent with Niemiec et al. (2010) in three studies. Both quasi-experimental procedures and fully randomized experiments showed no worldview defense following MS in meditating individuals and meditating and non-meditating Buddhists. This is important due to positive associations between meditation experience and scores on trait mindfulness (Lykins and Baer, 2009). Lastly, Chittaro et al. (2017) addressed facets of mindfulness and MS. For the subscales of the Five Facet Mindfulness Questionnaire (Baer et al., 2006), a marginally significant interaction between MS and acting with awareness emerged. So far, the findings indicate that mindfulness could make defensiveness redundant, or that mindful individuals process mortality-related stimuli non-reactively. This is in line with findings linking mindfulness with higher emotion regulation and lower emotional reactivity. In this sense, Heppner et al. (2015) argue that decentering mitigates reactions to self-threatening stimuli. Mindfulness is also associated with self-regulation, which is associated with less automatism (Brown and Ryan, 2003).

1.3 Self-esteem and terror management

Like mindfulness, studies have shown that self-esteem, which is an overall assessment of the value of one's self, influences the effect of MS on defenses. Harmon-Jones et al. (1997) demonstrated that induced and dispositional high self-esteem was associated with an absence of worldview defense. Moreover, low implicit combined with high explicit self-esteem were found to produce high defensiveness (Schmeichel et al., 2009). Of particular interest is the research of Peters et al. (2005), who showed that MS increased physical strength of the hand. Though, this applied to individuals for whom weightlifting was perceived as important and therefore derive self-esteem from this domain. This effect was not observed for individuals who had indicated that lifting weights was not important. This is consistent with TMT, since following MS subjects strive to meet the standards on which their self-worth is based (Pyszczynski et al., 2015). Interestingly, this effect was also seen in individuals who do not generate self-esteem from strength and has been investigated by Kawakami et al. (2018). They implemented a co-activation of death-related and self-related thoughts for subjects with low muscular self-esteem. However, low muscular self-esteem individuals receiving self- and death-related words showed higher muscle strength at post-measurement than before.

Moreover, improved performance of basketball players following MS underpins the role of task-related self-esteem (Zestcott et al., 2016). Further, following MS, individuals with high body-related self-esteem have been shown to identify more with their bodies and display greater appeal in sex (Goldenberg et al., 2000) and will express environmental concern if their self-esteem is built on it (Vess and Arndt, 2008).

Even self-esteem is central for terror management, specific facets like implicit self-esteem were not investigated yet. Because research has shown that measures of implicit self-esteem have limitations (Buhrmester et al., 2011) self-esteem instability, defined as the stability or instability of self-esteem over time (Zeigler-Hill, 2006), might be a relevant construct to investigate and clarify the inconsistent results of trait self-esteem. Accordingly, a person's self-worth can change, and a higher variability is therefore associated with a greater instability of self-esteem. For instance, the combination of high instability and high explicit self-esteem is referred to as fragile high self-esteem and "reflects positive feelings of self-worth that are vulnerable to threat, as they require continual bolstering, protection, and validation through various self-protective or self-enhancement strategies" (Kernis, 2005, p. 1590). Consequently, considering the instability component of self-esteem seems vital in the light of MS effects.

1.4 Goal of this study

The present study investigates the influence of the stability of self-esteem and dispositional mindfulness following exposure to subliminal MS-cues with the dependent variable grip strength. Self-esteem as well as dispositional mindfulness are chosen because both variables are assumed to lead to a less defense behavior also about death related thoughts. For the first hypothesis, we expect MS to increase handgrip force in a posttest (vs. pretest) compared to the control group. Hypothesis two expands the latter and states that lower mindfulness scores will be associated with a greater increase compared to higher ones following MS. Third it is hypothesized that high instability of self-esteem is associated with stronger handgrip force in a posttest compared to low instability. However, all hypotheses are only expected to be valid provided that strength-self-esteem is essential to the participants.

2 Method

2.1 Participants

The required sample size was calculated using G*Power (Faul et al., 2007) for a linear model. We were guided by the small to medium effects of relevant research (Peters et al., 2005; Niemiec et al., 2010; Kawakami et al., 2018). Consequently, an effect of $f^2 = 0.1$ with $\alpha = 0.05$, $(1-\beta) = 0.8$, and eight predictors (condition, time, strength self-esteem, mindfulness and self-esteem instability, interactions for three hypotheses) provided a sample size of 159 individuals. Given that linear mixed models have higher power, the number of subjects should be adequate (Hilbert et al., 2019). To account for potential drop-out in measuring self-esteem stability, we collected data from 165 participants between 19 and 32 years. Recruitment of participants was carried out through internal email newsletters and faculty homepage announcements. In appreciation for their participation, course credit was granted to the participants. All participants met the minimum age requirement of 18 years. Of the 165 participants, 163 were enrolled in the Applied Movement Science program, and three did not complete the daily life assessment, resulting in a sample of 160 participants (52.5% female, mean age = 22.3, SD age = 2.11). Inclusion criteria were the ability to exert grip strength (no injuries) and owning a smartphone. No exclusion criteria were applied. The Ethics Committee of the University of Regensburg approved the study (22-2840-101).

2.2 Materials and procedure

Participants were randomly assigned to one of two conditions. Embedded in a simple word decision task on the computer, they were subliminally presented with either the German word for death (Tod) or pain (Schmerz). The words were shown on a 17-inch screen with 60 Hz in black font on a light gray background using OpenSesame (Mathôt et al., 2012). The task was adopted from previous research (Arndt et al., 1997, 2001; Koole and Van den Berg, 2005). Three words were presented consecutively per trial, and the participants had to decide whether the first and third words, visible for 356 ms, were related or not (e.g., rose and tulip vs. vase and plaster). The first and third words always consisted of two syllables. The second word was presented for 28.5 ms and used for manipulation. Subjects indicated their decision by clicking the mouse buttons. There were 40 trials in total, with the second word in the first 10 trials being neutral, the next 20 trials being either death or pain, and the last 10 being senseless. For the neutral trials, words were chosen from the Berlin Affective Word List Reloaded with an emotional valence close to or equal to zero (Võ et al., 2009). Furthermore, the order of all word pairs was randomized.

Before and after the task, the maximum grip strength was measured twice using the Baseline BIMS Digital Grip Dynamometer (Fabrication Enterprises, n.d.). From both attempts the mean was calculated and used for the measurement of maximum grip strength. Subjects sat in an upright position with their elbows open at 90 degrees. The experimenter then counted from one to three, with the participants increasing the force and holding the same for one second at three (Kluttig et al., 2020). Participants have not been verbally motivated but informed about their maximum grip strength at the end. Following the central part of the study, questionnaires were assessed.

2.2.1 Mindfulness

The Comprehensive Inventory of Mindfulness Experiences (CHIME; Bergomi et al., 2014) is a validated questionnaire in German Language and measures trait mindfulness with 37 items (e.g., "When I have pain, I try to avoid this perception as much as possible.") and eight subscales: accepting nonjudgemental attitude, acting with awareness, nonreactive decentering, openness to experience, awareness of thoughts' relativity, awareness of internal experiences, awareness of external experiences and insightful understanding. Answers were given on a 6-point scale ranging from *almost never* to *almost always*, whereas higher scores represent higher mindfulness. The internal consistency in this study was good ($\alpha = 0.86$).

2.2.2 Instability of self-esteem

Instability of self-esteem was measured in daily life twice on each of five consecutive days (Kernis, 2005) using the German version of the Rosenberg Self-Esteem Scale (von Collani and Herzberg, 2003), which comprises 10 items (e.g., "I have found a positive attitude toward myself.") on a 4-point scale (0 = *strongly disagree*, 3 = *strongly agree*). The questionnaire was adapted to refer to the present moment rather than how people generally feel about themselves. Data was collected with the PIEL survey platform developed for smartphone devices (Jessup et al., 2012). Participants were prompted to complete the questionnaire at 9 a.m. and 7 p.m., for which they were given 1 h. If the questionnaire was not completed at the notification, three reminders appeared throughout the hour (after 3, 30, and 45 min). We calculated the individual standard deviation of self-esteem to obtain a measure of self-esteem instability, with higher values representing higher instability (Webster et al., 2017). A 10-point scale was used for this purpose (Kernis et al., 2008). Subjects were excluded if they completed less than 7 out of 10 assessments.

2.2.3 Positive and negative affect

We used the German Version of the Positive and Negative Affect Schedule (Watson et al., 1988; Breyer and Bluemke, 2016) right before and after the central part to investigate the potential effects of the subliminal induction. The instruction aimed to provide information

about the present moment. Responses were provided on a 5-point scale (1 = *not at all*, 5 = *fully*). Separate means for positive and negative effects were computed.

2.2.4 Strength self-esteem

Subjects responded to three items based on the research of Peters et al. (2005) and Zestcott et al. (2016). Specifically, we asked: "How important is physical strength to you?," "To what degree does your physical strength influence your self-esteem or how good you feel about yourself?" and "How important are strength training exercises to you?." A 9-point scale ranged from *not at all (important)* to *fully (important)* and a higher score from the calculated mean reflects increased self-esteem, which depends on physical strength. The internal consistency was good ($\alpha = 0.83$).

2.2.5 Awareness check

To investigate whether the subliminal words were consciously perceived, we assessed three questions at the end of the study. Subjects were instructed to report how many words they saw in the word task per trial. If they said they saw more than two words, they had to name the word. Then they were to say which of the following five words it could have been. In randomized order, the German words for death, suffering, pain, failure, and shame were offered for choosing.

2.3 Design and statistical analysis

The design is 2 (condition: death vs. pain) × 2 (grip strength: pre vs. post) mixed-factorial, with the first factor being between- and the latter within-subject. Statistical analyses were performed in R (version 4.0.3; R Core Team, 2020) using lme4 package for the linear models (version 1.1.28; Bates et al., 2014). However, in a first step we analyzed repeated measures ANOVAs to investigate the dependent variables of positive and negative affect, separately. Next, we tested whether our manipulation was not consciously processed with a Pearson chi-square test, which investigates the frequencies of the five words depending on the condition. Data for the main hypotheses were analyzed with linear mixed models building on Matuschek et al. (2017) with maximum likelihood estimation and the optimx package (version 2022-4.30; Nash et al., 2022), for the exact description see supplementary material.

3 Results

3.1 Awareness check

A Pearson chi-square test revealed no different frequencies in naming the words between the conditions, $\chi^2(4) = 1.62$, $p = 0.805$. Therefore, we conclude that there was no conscious awareness of the subliminal words.

3.2 Positive and negative affect

To test the possible effects of our manipulation on positive (PA) and negative (NA) affect, we conducted two 2 (condition: pain, death) × 2 (time: pre, post) mixed ANOVAs. For PA, a main effect of condition emerged, $F(1, 158) = 5.23$, $p = 0.024$, $\eta^2_p = 0.32$. PA was significantly lower for the death condition, independently from the time factor, $F(1, 158) = 3.02$, $p = 0.084$, $\eta^2_p = 0.02$. For NA, again a significant main effect of condition was observed, $F(1, 158) = 5.76$, $p = 0.018$, $\eta^2_p = 0.04$. The pain condition was associated with higher NA values. Moreover, the main effect of time was significant, $F(1, 158) = 71.16$, $p < 0.001$, $\eta^2_p = 0.31$. This indicates that both groups were lower on NA after the manipulation. There were no significant interactions condition x time for PA and NA. Consequently, the manipulation did not lead to an increase in either positive or negative affect.

3.3 Main results

Linear mixed effects models were calculated for the dependent variable strength, which was averaged for both measurements before and after the manipulation. Descriptively, the grip strength in the death condition was $M = 38.04$ (SD = 11.25) at the first and $M = 37.55$ (SD = 11.47) at the second time point – in the pain condition, $M = 36.75$ (SD = 10.42) at the first and $M = 36.14$ (SD = 10.94) at the second time point. The predictors were entered in the mixed model: time (pre vs. post), condition (pain vs. death), strength self-esteem, self-esteem instability, mindfulness, as well as their associated interactions. In the first step, the LR-test led to removal of the by-subject random slope for time, $\chi^2(2) = 2.41$, $p = 0.299$, resulting in an intercept only model. This final model was used for the evaluation of significant fixed effects of interest (Table 1). The next model tested the four-way interaction of mindfulness × time × condition × strength self-esteem, which investigates the hypothesis that less mindful individuals show a strength increase following MS. However, the result of the LR-test was not significant, $\chi^2(1) = 0.18$, $p = 0.673$. Next, we compared the basis model with one without the four-way interaction of self-esteem instability x time x condition x strength self-esteem, which examines whether a higher self-esteem instability leads to a higher grip strength after MS. Again, the LR-test showed no significant result, $\chi^2(1) = 0.51$, $p = 0.477$. Lastly, a model comparison without the three-way interaction of strength self-esteem x condition x time, analyzing the profound effect from previous studies, also resulted in a zero effect of the same, $\chi^2(1) = 0.151$, $p = 0.698$. In summary, the hypotheses were rejected. As can be seen in Table 1, strength self-esteem, mindfulness, their interaction, as well as the interaction of mindfulness and self-esteem instability reached significance when predicting grip strength with all other fixed effects in the final model. However, these results are no preregistered object of investigation and unrelated to the MS-hypothesis. Finally, the low marginal R^2 (0.368) compared to the high conditional R^2 (0.971) suggests that variation in grip strength is largely explained by individual differences.

4 Discussion

The study aimed to investigate whether subliminal presentation of the word death influences athletic performance. Based on a TMT-framework, we hypothesized that MS leads to an increase in muscle strength compared to a control condition for participants rating their physical strength as important for their self-worth. However, the relevant interaction did not reach significance. In

TABLE 1 Final linear mixed effect model for the dependent variable grip strength.

	Grip strength			
	Estimate	*SE*	*t*	*p*
Fixed effects				
Intercept	−275.90	107.52	−2.57	**0.011**
Condition	−114.61	214.75	−0.53	0.594
Time	−11.18	33.86	−0.33	0.742
SSE	46.96	15.49	3.03	**0.003**
Mindfulness	79.56	26.61	2.99	**0.003**
SEI	130.84	70.82	1.85	0.066
2-way-interactions				
Condition*time	27.92	67.73	0.41	0.680
Condition*SSE	32.29	30.68	1.05	0.294
SSE*time	3.40	4.94	0.69	0.491
Condition*mindfulness	−1.11	53.43	−0.02	0.983
Time*mindfulness	2.95	8.45	0.35	0.727
SSE*mindfulness	−11.60	3.81	−3.05	**0.003**
Condition*SEI	80.93	141.03	0.57	0.567
Time*SEI	0.76	21.95	0.04	0.972
SSE*SEI	−19.88	10.52	−1.89	0.060
Mindfulness*SEI	−34.88	17.70	−1.97	**0.050**
3-way interactions				
Condition*time*SSE	−3.84	9.87	−0.39	0.698
Condition*time*mindfulness	−7.32	16.89	−0.43	0.665
Condition*SSE*mindfulness	−2.93	7.60	−0.39	0.701
Time*SSE*mindfulness	−0.90	1.22	−0.74	0.461
Condition*time*SEI	−32.44	43.89	−0.74	0.460
Condition*SSE*SEI	−22.76	20.83	−1.09	0.275
Time*SSE*SEI	−0.84	3.28	−0.26	0.798
Conditon*mindfulness*SEI	−8.53	35.33	−0.24	0.809
Time*mindfulness*SEI	−0.39	5.50	−0.07	0.944
SSE*mindfulness*SEI	5.03	2.63	1.91	0.057
4- and 5-way interactions				
Condition*time*SSE*mindfulness	1.04	2.44	0.43	0.670
Condition*time*SSE*SEI	4.67	6.56	0.71	0.477
Condition*time*mindfulness*SEI	8.66	10.99	0.79	0.432
Condition*SSE*mindfulness*SEI	3.66	5.22	0.70	0.484
Time*SSE*mindfulness*SEI	0.25	0.82	0.30	0.764
Condition*time*SSE*mindfulness*SEI	−1.27	1.64	−0.77	0.440
Random effects				
σ^2	7.62			
$\tau_{00\ participants}$	159.45			
ICC	0.95			
Observations	320			
Marginal R^2/Conditional R^2	0.368/0.971			

SSE = strength self-esteem, SEI = self-esteem instability, time = pre- vs. post-manipulation, condition = death vs. pain, mindfulness = global mindfulness score. Significant results are printed in bold.

addition, two variables were investigated that potentially influence this effect: mindfulness and self-esteem instability. It was stated that lower mindfulness and higher self-esteem instability would be associated with higher strength following reminders of death. Again, none of the hypotheses was confirmed.

4.1 Theoretical implications

These results seem to contradict numerous studies that reliably demonstrated TMT effects over many years (Burke et al., 2010; Cox et al., 2019). Our results could provide insights on the boundary conditions and robustness of MS effect. They hint that the MS effect might appear only under specific conditions. Furthermore, the results align with the evidence that the impact may be smaller and not as universal as assumed (Klein et al., 2019; Schindler et al., 2021).

The question arises why other studies demonstrate effects of MS in motor behavior. Several reasons could be carved out: One difference to the study of Peters et al. (2005) was implementation of a subliminal instead of supraliminal manipulation and a different population. It is plausible that lifting weights was more important to weightlifting individuals than sports students. However, Kawakami et al. (2018) showed that an ordinary subliminal MS was insufficient to induce increased grip strength in undergraduates. Unfortunately, the authors did not measure task-related self-esteem. Lastly, the effects vary in the different cultures of the studies and Americans react stronger to MS induction than Europeans (Burke et al., 2010). A compatible explanation would be that the participants showed lower levels of death anxiety than typical samples participating in TMT studies. However, those possible cultural differences in diverse reaction to levels of death anxiety must be investigated in more depth.

Moreover, the manipulation was conducted under the threshold of conscious awareness. The presentation of the stimuli and the procedure of the masked priming were very similar to what had been used in previous studies (e.g., Koole and Van den Berg, 2005). One modification is the presentation of 20 trials with the word death or pain and 20 trials with distractor items. Other studies used, for example, 10 death and 30 distractor trials (Arndt et al., 2001), only 10 death trials (Arndt et al., 1997) or 25 death and 25 distractor trials (Kawakami et al., 2018). This gives no reason to believe the alteration is a factor contributing to the zero effect results and is also supported by the fact that far less standardized MS inductions have resulted in distal responses (Zestcott et al., 2016). In addition, there is evidence in a meta-analysis on masked priming that the number of trials can influence the priming effect – with a higher number being associated with larger effect sizes for lexical decision and naming tasks (van den Bussche et al., 2009). To check whether the induction indeed led to increased death though accessibility, a rather complicated measurement of the same would have been necessary.

The present study is the first to investigate mindfulness and self-esteem instability following subliminal death reminders. The absence of an effect for mindfulness is essential considering the findings of Niemiec et al. (2010). To our knowledge, their research was the only one to show significant buffering effects using the Mindful Attention and Awareness Scale (MAAS; Brown and Ryan, 2003) for mindfulness. However, the MAAS has limitations: There are serious concerns as to whether the MAAS measures mindfulness (e.g., van Dam et al., 2018), in particular, it does not measure the acceptance component (Sauer et al., 2013) and does not measure non-judgmental awareness (Baer

et al., 2006). Due to these issues, we used the CHIME which is based on all previous operationalizations of mindfulness (Bergomi et al., 2014). Nevertheless, the corresponding hypothesis did not reach significance. But overall, the relevant literature suggests that mindful individuals process death-related stimuli differently (e.g., Park and Pyszczynski, 2017). Though, the results encourage the investigation of different questionnaires when using TMT-paradigms.

Lastly, a possible influence of self-esteem instability was supposed due to similar results on other facets of self-esteem in TMT research (Rothschild et al., 2019). One explanation for the unconfirmed hypothesis could be that self-esteem instability has sometimes been considered with the global self-esteem level. However, without accounting for the global level of self-esteem, self-esteem instability was also associated with relevant variables like verbal defensiveness (Kernis et al., 2008). Relevant research demonstrated relations between instability and defense styles. In this sense, Zeigler-Hill et al. (2007) showed associations between self-esteem instability and immature defenses like rationalization.

4.2 Practical implications

The study provides evidence that it is not that easy to boost motor-performance with one short single psychological priming intervention. To evoke death anxiety through priming seemed not to be a relevant method which should applied in sport science as a short psychological method for performance improvement. If there are effects with other methods of mortality salience and with relation to the dispositional mindfulness and the self-esteem of the person, the effects seemed to be rather small. Psychological training for motor performance improvement needs time. Students should be aware that there seemed to be no psychological induced short cut for the improvement of motor performance.

4.3 Limitations and future research

Beside the strength of a pre-registered, well-powered study using Linear mixed-models and the fact that neither the participants nor the experimenter was aware of the condition, the study has limitations: Although the word task was designed similarly to previous studies, the one-syllable words were used for the first time as no German-language items were available from other publications. Consequently, it remains unclear whether the word pairs used could have influenced the results due to their valence or semantics. Moreover, the German words for the manipulation (Tod; Schmerz) differ more clearly in word length than the English-language originals (dead or death; pain), whereas we doubt that this can explain the absence of effects. Concerning the measurement of grip strength, it should be noted that a constant adjustment was chosen for the grip width. This was done for standardization but not the ideal setting for all participants. Lastly, the assessment of self-esteem instability in daily life faces challenges, as filling in the questionnaire takes time and can provoke reactivity. In addition, it was impossible to assess whether the subjects filled in the questionnaires accurately without being disturbed.

Finally, the work provides evidence that subliminal death confrontation does not influence individuals who do not engage in weightlifting. However, a false-negative result cannot be excluded, as TMT findings have already been replicated in many cultures and countries (Burke et al., 2010). Future studies should investigate mindfulness and self-esteem using more typically dependent variables, such as worldview defense. Finally, it should be emphasized that transparent and sufficiently powered studies, as was the case in this work, are necessary to address the question of the validity of the MS hypothesis.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://osf.io/yh6k7/?view_only=5e29264db0c642b784a1f9b766fa7a22.

Ethics statement

The studies involving humans were approved by Ethical committee of Regensburg University (reference number: 22-2840-101). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

CB: Conceptualization, Data curation, Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. PJ: Conceptualization, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Publisher's note

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EDITED BY
Yang Cao,
Örebro University, Sweden

REVIEWED BY
Dushad Ram,
Shaqra University, Saudi Arabia
Karin Matko,
Chemnitz University of Technology, Germany

*CORRESPONDENCE
Bindu M. Kutty
✉ bindu.nimhans@gmail.com

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Practice and proficiency of Isha Yoga for better mental health outcomes: insights from a COVID-19 survey

Saketh Malipeddi[1], Seema Mehrotra[2], John P. John[3] and Bindu M. Kutty[1]*

[1]Centre for Consciousness Studies, Department of Neurophysiology, NIMHANS, Bengaluru, Karnataka, India, [2]Department of Clinical Psychology, NIMHANS, Bengaluru, Karnataka, India, [3]Multi-modal Brain Image Analysis Laboratory, Department of Psychiatry, NIMHANS, Bengaluru, Karnataka, India

Introduction: The COVID-19 pandemic has brought about unparalleled suffering on a global scale, affecting both physical and mental well-being. In such challenging times, it becomes crucial to identify interventions that can alleviate negative mental health outcomes, such as stress, while promoting positive mental health outcomes, like well-being. We report the effectiveness of a mind–body practise, Isha Yoga, in promoting well-being.

Methods: We conducted an online survey, during the COVID-19 pandemic, with Yoga practitioners ($n = 1{,}352$) from the Isha Yoga tradition in Karnataka, India. We evaluated stress and well-being attributes using conventional psychometric questionnaires. Subsequently, we requested the Isha Yoga practitioners to share another survey with their friends and family members, assessing similar outcomes. From the respondents of this shared survey ($n = 221$), we identified individuals who currently did not engage in any form of Yoga or meditation, constituting the non-Yoga control group ($n = 110$). To enhance the reliability and validity of our study and minimize the limitations commonly associated with online surveys, we adhered to the CHERRIES guidelines for reporting survey studies.

Results: Isha Yoga practitioners had significantly lower levels of stress ($p < 0.001$, $g_{Hedges} = 0.94$) and mental distress ($p < 0.001$, $g_{Hedges} = 0.75$) while reporting significantly higher levels of well-being ($p < 0.001$, $g_{Hedges} = 0.78$) and affective balance ($p < 0.001$, $g_{Hedges} = 0.80$) compared to the control group. Furthermore, expertise-related improvements were observed in these outcomes, and a dose–response relationship was found between regularity of Isha Yoga practice and outcome changes. A minimum 3–4 days of weekly practice showed significant differences with the control group. In addition, we investigated the effect of Isha Yoga on stress and well-being among the healthcare workers (HCWs) in our sample and observed better mental health outcomes.

Discussion: These findings collectively underscore the benefits of Mind and Body practices like Isha Yoga on various aspects of mental health and well-being, emphasizing its potential as an effective and holistic approach for promoting a healthy lifestyle among diverse populations, including healthcare workers, even in difficult circumstances such as the COVID-19 pandemic.

KEYWORDS

COVID-19 pandemic, Yoga, meditation, Isha Yoga, mental health, perceived stress, well-being

1 Introduction

The COVID-19 pandemic has profoundly impacted human well-being worldwide, leading to significant suffering. A large-scale Centers for Disease Control and Prevention (CDC) survey conducted during April–June 2020 in the USA showed a staggering 3- to 4-fold increase in symptoms of anxiety and depression compared to the same period in 2019 (1). This highlights the ongoing mental health pandemic (2). Prior to the pandemic, in 2017, one in seven Indians suffered from mental disorders of varying severity (3). Further, according to the 2016 National Mental Health Survey, the overall prevalence of common mental disorders, including anxiety and depressive disorders, in India was 5.1 percent (4). Though high-quality studies from India during the pandemic are limited (5), a few survey studies reported a significant increase in cases during the pandemic (6, 7). For example, an online survey in India ($n = 1,871$) conducted under the aegis of the Indian Psychiatric Society found that 74.1 percent of all survey respondents had moderate stress, 40.5 percent had anxiety or depression, and 71.7 percent had poor well-being (7). During such challenging times, it becomes crucial to address the need for interventions that promote positive mental health outcomes, including well-being and balance, while mitigating negative outcomes such as stress, anxiety, and depression, ultimately enhancing overall quality of life.

Well-being is defined as "a complex construct that concerns optimal experience and functioning" (8) and includes components of hedonic and eudaimonic well-being. The hedonic aspect, also called subjective well-being, focuses on happiness, higher positive feelings, and lower negative feelings (9, 10). Whereas the eudaimonic aspect, also called psychological well-being, places an emphasis on meaning, purpose and self-actualization (8, 11). The World Health Organization (WHO) closely links health and well-being, defining health as "a state of complete physical, mental, and social well-being, not just the absence of disease or infirmity" (12). The pandemic increased the global prevalence of depression by 27.6 percent (95% UI (uncertainty interval): 25.1–30.3), resulting in an additional 53.2 million cases and anxiety disorders by 25.6 percent (95% UI: 23.2–28.0), resulting in an additional 76.2 million cases worldwide (13). The same study showed that, in South Asia, there has been an increase in the prevalence of major depressive disorder by 36.1% (95% UI: 29.7–42.8) and anxiety disorders by 35.1% (95% UI: 28.2–42.0). Further, a meta-analysis found that the prevalence of depression was 37.12 percent, anxiety was 41.42 percent, and stress was 44.86 percent among health care workers (HCWs) during the pandemic (14). It is quite disturbing to observe such a high prevalence of negative symptoms that impair human quality of life, well-being, and social functioning, ultimately affecting humanity itself.

Mind and Body practices (MBPs) such as Yoga and meditation have emerged as popular, credible, and effective interventions in promoting positive outcomes and reducing negative outcomes (15, 16). Mindfulness meditation has been extensively studied and shown to reduce stress and improve well-being (17). Other practices such as Heartfulness, Raja Yoga, and Transcendental Meditation have also reported similar beneficial effects (18–20). Notably randomized controlled trials (RCTs) further reinforce the findings of earlier research (21, 22). A growing body of evidence suggests a link between Yoga practises and lower levels of stress, anxiety, and depression, as well as greater well-being (23–28). However, it is essential to recognize that the primary purpose of Yoga lies not in these incidental benefits, but rather to provide a path to overcoming suffering and realizing one's true nature. In India, diverse traditions of Yoga exist, among which is Isha Yoga.

Isha Yoga, an international school of Yoga, offers a holistic system that integrates all four paths of Yoga – Karma, Bhakti, Gnana, and Kriya – and provides methods to promote well-being. Each of these practices is designed to enhance physical, mental, and emotional well-being (26, 29–32). Studies with Isha Yoga practices reported reduced stress levels, increased mindfulness, and enhanced well-being (23, 25, 33, 34), improved cardiac sympatho-vagal balance (29), heightened visual attention (35), elevated levels of BDNF and CAR (30), increased anandamide levels (36), enhanced immune system functioning indicated by higher anti-viral interferon gene expression (37), elevated EEG gamma power during meditation (38), and so on. Several survey studies were conducted among Isha Yoga practitioners during the COVID-19 pandemic, and they reported lower negative mental health outcomes and higher positive mental health outcomes, showing its potential as a useful mind–body intervention (23–25, 34). However, some of these studies had low sample sizes. Further, no studies were carried out in the Indian population, requiring the need for the present study.

Moreover, we have been conducting research to assess the neuroscientific aspects of Isha Yoga practices for the last five years. We were able to demonstrate various trait and state effects of Isha Yoga practice among the advanced practitioners, including unique brain oscillatory dynamics indicative of "relaxed alertness," greater attention as indexed by a greater P300 amplitude, and higher well-being and lower perceived stress scores (manuscript in preparation). To demonstrate the generalizability of these findings to a larger population of Isha Yoga meditators, we conducted the current online cross-sectional survey, during the COVID-19 pandemic, using a large sample of more than 1,300 Isha Yoga practitioners. Our aim was to address gaps in research and provide additional insights into the effects of Isha Yoga practises among Indian participants. Based on the existing literature on Isha Yoga, other meditative traditions, and what we observed in our EEG study, we began the online survey with the hypothesis that practising Isha Yoga would be associated with lower negative outcomes (perceived stress and mental distress) and higher positive outcomes (well-being and balance). Furthermore, we hypothesized that the practitioner's expertise and proficiency would be critical in influencing outcome measures.

Finally, it is essential to recognize that internet/web-based surveys often come with methodological concerns like non-representativeness of the sample, self-selection bias, non-response bias, and so on, that can potentially affect their validity (39, 40). To ensure the rigor and reliability of our study and to overcome some of the above-mentioned limitations, we adhered to appropriate guidelines (41).

2 Methods

2.1 Participant recruitment and sampling methodology

This study was conducted as a cross-sectional online survey using Google Forms in the southern Indian state of Karnataka from August to October 2021 (survey provided in the

Supplementary file). By October 2021, the total active COVID-19 cases in the state were 9,621, and the total cases were 29,82,089 (42). Also, a large proportion of the Karnataka adult population (75% by December 2021) had been vaccinated with both doses (43). The government had also eased the lockdown measures as the number of cases dropped. During this period, Isha Foundation helped us in distributing the survey among its meditator population in Karnataka. Individuals who had participated in at least one Isha Yoga program, such as Hatha Yoga or Inner Engineering, were referred to as Isha Yoga practitioners. The Isha Foundation maintains a database of all such individuals, and in Karnataka, this number was 40,682 as of October 2021. This population was considered the target population, and an address-based sampling strategy was employed. All the individuals in the target population were contacted via email in two separate campaigns conducted in August and October. Advertisement to contact the Isha meditators is provided in the Supplementary file. Information regarding the number of emails sent, the number of unique opens, and the number of unique clicks was obtained from Google Analytics data.

Survey statistics for Isha meditators are given below:

Month	Mails sent to	Unique opens	Unique clicks
August	39,833	5,977 (15%)	690
October	40,682	9,611 (24%)	1,200

Total unique opens: 15,588.

Total unique clicks: 1,890.

Total responses: 1,352.

Participation rate: 71.53% [(Total responses/Total unique clicks) *100].

The CHERRIES guidelines (41) (Table 1) were followed in conducting the survey, ensuring adherence to appropriate standards for reporting the results of internet-based surveys.

Additionally, Isha Yoga meditators were requested to nominate at least one friend or family member and share another survey with them (Supplementary sheet). This group was intended to serve as a control group for comparison. A combination of convenience sampling and snowball sampling strategies was employed to gather responses from these groups. In total, 221 responses were received from these sources. Questions 16–19 in the survey for Isha nominees were included to ensure that people who had never practised Yoga or meditation ($n = 110$) were included as controls for the Isha Yoga practitioners. The practice characteristics of these participants are provided in Supplementary Table S2.

2.2 Inclusion and exclusion criteria

2.2.1 For Isha Yoga practitioners

The inclusion criteria for participation in the study were:

- Practicing only Isha Yoga
- Age $\geq$ 18
- Ability to read and understand English
- Resident of Karnataka

2.2.2 For controls

The inclusion criteria for being part of the sample were:

- Currently practice no form of Yoga or meditation
- Age $\geq$ 18
- Ability to read and understand English
- Resident of Karnataka

2.3 Isha Yoga

Isha Yoga trains people to achieve inner well-being. A unique aspect of Isha Yoga is that it does not have any philosophy or belief system. Isha Yoga encompasses various practices like Shambhavi Mahamudra Kriya, Shoonya, and Samyama (26, 31, 44). Shambhavi Mahamudra Kriya is offered as part of the Inner Engineering program, which is designed to help individuals explore and enhance their inner well-being. Inner Engineering has two components: Inner Engineering Online (IEO) and Inner Engineering Completion (IEC) (32, 33). IEO, a 4-week self-paced program, consists of seven 90-min sessions that provide participants with practical techniques and insights to manage their physical, mental, and emotional well-being. It promotes intellectual inquiry and includes Upa Yoga (preparatory Yoga involving body movement and breath practices). IEO is a pre-requisite for IEC, where Shambhavi Mahamudra Kriya is taught. It is a 21-min multi-component practice involving pranayama (breath modulation), AUM chanting, bandhas (engagement of muscular locks), and breath watching meditation (23, 44). Inner Engineering is a foundational program in Isha. Only after being initiated into Shambhavi Mahamudra Kriya is one eligible for advanced programs such as Shoonya and Samyama. Shoonya Meditation in Isha Yoga is an advanced meditation practice. The term "Shoonya" translates to "no-thingness." It is a "conscious non-doing" practice that is to be practised for 15-min, twice daily. This meditation technique aims to help individuals experience a state of inner stillness (38). Samyama is an intensive residential program that spans eight days and is conducted in an environment of complete silence. It is an advanced practice that combines two fundamental spiritual processes in the Yogic tradition: Pragna, the path of awareness, and Samadhi, the path of dissolution (44).

2.4 Outcome measures

Each participant was asked to respond to 4 validated psychological questionnaires assessing-

- Negative outcomes: stress (Perceived Stress Scale, PSS) and mental distress (anxiety and depression) (PHQ-4)
- Positive outcomes: subjective well-being (WHO-WBI) and balance (SPANE-B)

The details of the questionnaires are given below.

2.4.1 Perceived Stress Scale

The Perceived Stress Scale (PSS) is a well-established tool for assessing individual's perceived stress over the past month and consists of 10 items. It is known for its brevity and user-friendly nature

TABLE 1 The checklist for reporting results of internet E-surveys (CHERRIES).

Item category	Checklist item	Explanation
Design	Describe survey design	- Target population: Isha Yoga practitioners in Karnataka - Controls: Nominated by Isha Yoga practitioners and people known to the study authors - Sampling type: o Isha Yoga – Address based sampling o Controls – Convenience and snow-ball sampling
IRB (Institutional Review Board) approval and informed consent process	IRB	This study was approved by the NIMHANS human ethics committee (NIMH/DO/ETHICS SUB-COMMITTEE MEETING/2018)
	Informed Consent	Consent was taken from all the study participants
	Data protection	All the personal details taken from the survey respondents remains with the study authors. No one has access to this. Data is password-protected.
Development and pre-testing	Development and testing	Some of the questions in the survey were developed following feedback from experts in the field of Yoga and well-being. Whereas, other questions are from already validated psychological questionnaires like PSS, WHO-WBI, etc.
Recruitment process and description of the sample having access to the questionnaire	Open survey versus closed survey	Open survey
	Contact mode	By mail
	Advertising the survey	Surveys were sent to the Isha Yoga practitioners in Karnataka. Isha Foundation helped the study authors to reach out to the participants. Survey announcement is provided in the **Supplementary data**. Mailing list: o Isha Yoga practitioners: Yes, database of Isha practitioners in Karnataka o Controls: No, nominated by Isha practitioners and others known to authors
Survey administration	Web/E-mail	By Email. Responses were captured automatically by google forms.
	Context	Surveys were sent to a clearly defined target population of Isha Yoga practitioners in Karnataka. Because of this, sample is highly likely to be representative of the Isha Yoga population in Karnataka.
	Mandatory/voluntary	It was a voluntary survey
	Incentives	No incentives were provided for participating in the survey
	Time/Date	Timeframe for data collection: August to October, 2021
	Randomization of items or questionnaires	Items were not randomized or alternated
	Adaptive questioning	No, this was not followed
	Number of Items	Number of questionnaire items per page were in the range 6–10
	Number of screens (pages)	Number of pages were 7
	Completeness check	All the questions in the survey were mandatory. Wherever appropriate, items had non-response options such as "not applicable" or "prefer not to say." This way, selection of one response was enforced.
	Review step	Respondents could edit their responses while filling the survey. This would not be possible once they complete the survey.
Response rates	Unique site visitor	Google analytics data helped us capture the number of people with unique clicks and unique opens.
	View rate (Ratio of unique survey visitors/unique site visitors)	Isha Yoga practitioners: 12.12% [(1,890/15,588) * 100] Controls: Cannot be calculated because of sampling type
	Participation rate (Ratio of unique visitors who agreed to participate/unique first survey page visitors)	Isha Yoga practitioners: 71.53% [(1,352/1,890) * 100] Controls: Cannot be calculated because of sampling type
	Completion rate (Ratio of users who finished the survey/users who agreed to participate)	Isha Yoga practitioners: 98.47% [(1,352/1,373) *100] Controls: 96.92% [(221/228) *100]
Preventing multiple entries from the same individual	Cookies used	Cookies were not used. Duplicate entries were prevented by making it mandatory for the survey respondents to enter their email address.
	IP check	No
	Log file analysis	No
Analysis	Handling of incomplete questionnaires	Completion rates were high. All questions were mandatory.
	Questionnaires submitted with an atypical timestamp	This was not done
	Statistical correction	Tests were corrected for multiple comparisons using Holm's method

(45). Participants respond to each item using a 5-point Likert-type scale, ranging from 0 = never to 4 = very often. The final score is obtained by summing all the item responses and can range from 0 to 40, with higher scores indicating higher perceived stress levels. Interpretation: a score of 0–13 indicates low stress, 14–26 indicates moderate stress, and 27–40 indicates high stress. The internal reliability of the data was assessed using Cronbach's alpha, and the calculated value was 0.86.

2.4.2 The four-item Patient Health Questionnaire for anxiety and depression (PHQ-4)

The PHQ-4 (Patient Health Questionnaire-4) is designed to assess anxiety and depression in the general population (46). It consists of only four questions, with two items measuring anxiety and the other two measuring depression. Each item is rated on a 5-point Likert-type scale, ranging from 0 = Not at all to 4 = Nearly every day. The total score is obtained by summing the scores for each of the four items. A PHQ-4 score falling within the range of 0–2 indicates normal mental distress, 3–5 suggests mild mental distress, 6–8 indicates moderate mental distress, and 9–12 suggests severe mental distress. Anxiety is calculated by summing the scores for items 1 and 2, with a total score of 3 or higher indicating the presence of anxiety. Similarly, depression is calculated by summing the scores for items 3 and 4, and a total score of 3 or higher suggests the presence of depression. The internal reliability of the data was assessed using Cronbach's alpha, and the calculated value was 0.8.

2.4.3 Scale of Positive and Negative Experience (SPANE)

The SPANE (Scale of Positive and Negative Experience) is a 12-item scale that measures positive feelings (SPANE-P), negative feelings (SPANE-N), and affect balance (SPANE-B) (10). Participants rate the frequency of experiencing each item on a scale ranging from 1 "Very rarely or never" to 5 "Very often or always." The SPANE-P score is derived by summing the scores for the six positive items, resulting in a range of 6 (lowest) to 30 (highest) for positive feelings. Similarly, the SPANE-N score is obtained by summing the scores for the six negative items, also ranging from 6 to 30 for negative feelings. The SPANE-B score is calculated by subtracting the SPANE-N score from the SPANE-P score, yielding a difference score ranging from −24 (the lowest affect balance) to 24 (the highest affect balance). A score close to 24 indicates that an individual "very rarely or never" experiences negative feelings and "very often or always" experiences positive feelings, suggesting a high level of well-being and affective balance. The internal reliability of the data was evaluated using Cronbach's alpha, and the resulting coefficient was 0.92.

2.4.4 WHO Well-Being Index (WHO-WBI)

The World Health Organization Well-Being Index (WHO-5), developed in 1998, is a concise questionnaire consisting of five items to assess the subjective well-being of individuals (47). Respondents rate each item on a scale ranging from 5 "all of the time" to 0 "at no time." To calculate the raw score, the individual's responses for all five items are summed. The raw score can range from 0 to 25. Percentage scores are obtained by multiplying the raw scores by 4, resulting in scores that vary from 0 (indicating the lowest level of well-being) to 100 (representing the highest level of well-being). The internal reliability of the data was evaluated using Cronbach's alpha, and the resulting coefficient was 0.9.

2.4.5 Others

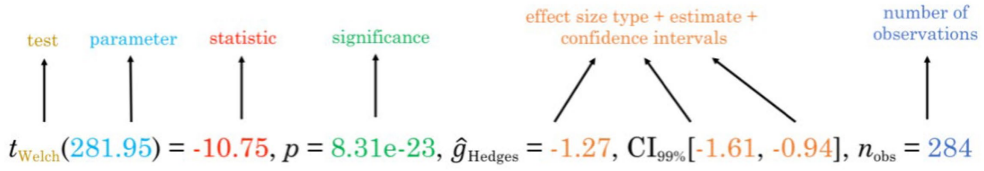
In addition, the survey included various questions, covering aspects such as participants sleep patterns, physical activity levels, dietary habits, medical history, and the impact of COVID-19. For the Isha Yoga practitioners, specific questions were included to assess their daily practices (questions 13–18 in the Isha meditators survey provided in the Supplementary file). This included questions about the types of practices they engage in regularly, the frequency and duration of their daily practice, the total number of hours they have practiced in their lifetime, and their self-rated proficiency in their practice. After consultation with experts in the Isha Yoga tradition, these questions were utilized to categorize the Isha meditators into different levels of expertise, such as novice practitioners (NOV), intermediate practitioners (INT), and advanced practitioners (ADV), as outlined in Supplementary Table S3. The survey for the Isha Yoga nominees included questions pertaining to their engagement with Yoga and meditation practices. This was done to ensure that individuals who currently practice other forms of Yoga were excluded from the analysis, thus maintaining a clear distinction between the Isha Yoga practitioners and the no-Yoga (control) group. Isha Yoga practitioners were also grouped based on practice regularity: Regular practitioners (≥5 times/week, $n = 1{,}097$); moderately regular practitioners (3–4 times/week, $n = 139$); and Irregular practitioners (<3 times/week, $n = 108$). These cut-offs were determined based on a previous study that used similar grouping (31). These categorizations allowed for a more detailed examination of the impact of different levels of practice regularity within the Isha Yoga practitioner population.

2.5 Statistical analysis

The statistical analyses were performed using RStudio Version 1.4.1106. RStudio provides a user-friendly integrated development environment for R, offering efficient data manipulation, visualization, and statistical analysis capabilities. Several R packages were utilized, including ggplot2 (48), ggsci (49), ggstatsplot (50), dplyr (51), effectsize (52), and performance (53), for conducting the necessary analysis. The selection of these R packages was driven by their established reputation for robust analysis and compatibility with the nature of our dataset and research objectives. Descriptive statistics such as mean, median, and standard deviation (SD) were calculated as appropriate for the data. Parametric tests were employed throughout as the sample sizes were large (54, 55). Between-group comparisons were conducted using Welch's one-way ANOVA. Post-hoc analyses were performed to further examine significant differences between groups using the Games-Howell test. These post-hoc tests aimed to minimize type 1 errors or false positives. Multiple comparisons were adjusted using Holm's method.

Effect size estimation was carried out using measures such as hedges g, omega squared tests and Cramer's V. Effect sizes were reported with 95% confidence intervals. The practical significance of effect sizes is crucial for understanding the real-world implications of observed differences or relationships in a study. While statistical significance indicates whether an observed result is likely due to chance, effect sizes provide information about the magnitude or strength of that result. A large effect size suggests that the observed phenomenon has a substantial impact, while a small effect size indicates a more modest influence. For example, in medical research,

a treatment might be statistically significant but have a small effect size, raising questions about its meaningful impact on patient outcomes. A significance level of $p < 0.05$, a standard in statistical hypothesis testing, was considered significant, and exact p values were reported accordingly. All statistical reporting adhered to the guidelines provided by the American Psychological Association (56), which were followed in the ggstatsplot package (50). An example is given below.



Categorical data (sleep quality and quantity, diet, and physical activity levels) were presented in the form of percentages and analyzed using the Chi-Squared test. A significance level of $p < 0.05$ was considered statistically significant. A 95% confidence interval was calculated and reported alongside the effect size to provide a range of plausible values for the population parameter.

3 Results

3.1 Participants

Supplementary Table S4 provides the comparison of Isha meditators and Isha Yoga nominees (all the survey respondents). Table 2 provides the subject characteristics for the final sample.

3.2 Mental health outcomes: overall differences

3.2.1 Perceived stress

The mean Perceived Stress Scale (PSS) score for the Isha Yoga practitioners is 13.61, which indicates low stress, whereas that of the controls is 19.52, which indicates moderate stress ($p < 0.001$) (Figure 1). The effect size was large.

3.2.2 Mental distress

The Isha Yoga practitioners (IYP) exhibited a mean mental distress score of 1.85, which is considered a normal value, whereas that of the control group is 3.88, which indicates moderate mental distress ($p < 0.001$) (Figure 2). This difference was associated with a medium effect size.

3.2.3 Who well-being index

The mean WHO Well-being (WHO-5) score for Isha Yoga practitioners was 71.43, which was significantly higher compared to the control population with a score of 57.16 ($p < 0.001$) (Figure 3). We observed a medium effect size.

3.2.4 SPANE balance

Isha Yoga practitioners demonstrated significantly greater positive affective balance with a mean score of 11.65, compared to the control population with a mean score of 5.36 ($p < 0.001$) (Figure 4), with a large effect size.

Overall, we observed effect sizes ranging from medium to large. To contextualize these findings, meta-analyses have demonstrated that cognitive-behavioral therapy (CBT), a gold-standard treatment for mental health disorders such as anxiety and depression, typically yields effect sizes within the medium range (57–59).

3.3 Mental health outcomes: impact of expertise of Isha Yoga

The results of the one-way ANOVA analysis indicated a significant difference in mental health outcomes of perceived stress (Figure 5), mental distress, balance, and well-being (Supplementary Figures S1–S3) among the 1,207 subjects based on the expertise of the Isha Yoga practitioners. Specifically, advanced Isha practitioners exhibited the most significant differences from the control group across all four scales. Intermediate practitioners showed smaller differences compared

TABLE 2 Subject characteristics: final sample.

Characteristics	Meditator group	Controls (no-Yoga group)
Total sample (*N*)	1,097	110
Age-range (in years):	*n* (%)	*n* (%)
18–29	249 (22.69%)	53 (48.18%)
30–44	559 (50.95%)	42 (38.18%)
45–64	251 (22.88%)	14 (12.72%)
65 years or above	38 (3.46%)	1 (0.9%)
Gender		
Male	626 (57.06%)	39 (35.45%)
Female	470 (42.84%)	71 (64.54%)
Prefer not to say	1 (0.09%)	0
Education		
High school or some college	37 (3.37%)	16 (14.54%)
Bachelor's degree or equivalent	557 (50.77%)	39 (35.45%)
Postgraduate degree	486 (44.30%)	52 (47.27%)
Prefer not to say	17 (1.54%)	3 (2.72%)
Alcohol consumption		
Yes	47 (4.28%)	7 (6.36%)
Social drinker	160 (14.58%)	20 (18.18%)
No	890 (81.13%)	83 (75.45%)
Smoking		
Yes	54 (4.92%)	7 (6.36%)
No	1,043 (95.07%)	103 (93.63%)
Substance use in the last 6months		
Yes	28 (2.55%)	4 (3.63%)
No	1,069 (97.44%)	106 (96.36%)

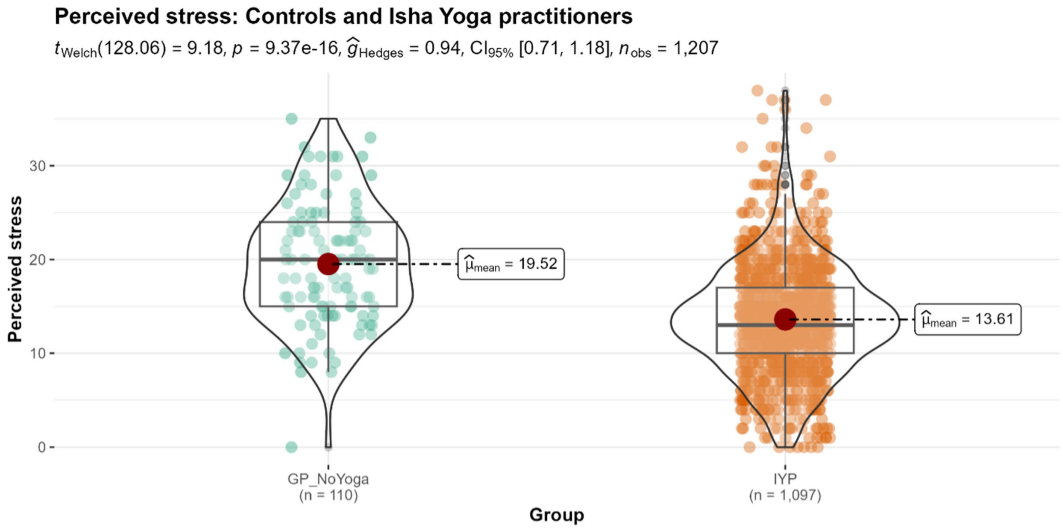


FIGURE 1
Differences in perceived stress score levels between controls and Isha meditators. GP_NoYoga, General population no Yoga (Controls); IYP, Isha Yoga practitioners.

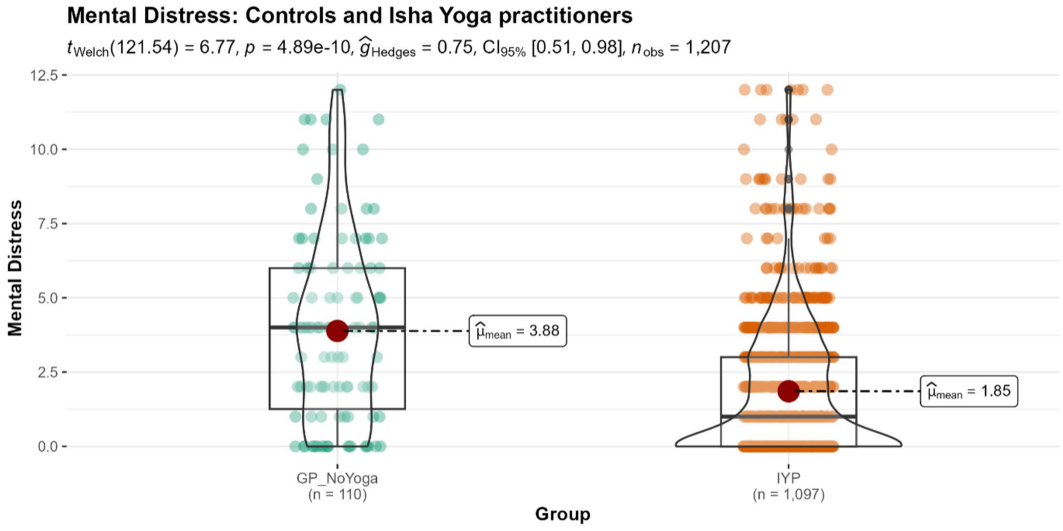


FIGURE 2
Differences in mental distress levels between controls and Isha meditators. GP_NoYoga, General population no Yoga; IYP, Isha Yoga practitioners.

to the control group, followed by novice practitioners. These findings suggest an association between the proficiency of practice of Isha Yoga and better mental health outcomes. Effect sizes were large.

3.4 Mental health outcomes: impact of regularity of Isha Yoga practice

The analysis examining the impact of regularity of Isha Yoga practice revealed significant differences between the groups across all four scales (Figure 6; Supplementary Figures S4–S6). However, pairwise comparisons indicated no statistically significant differences between the irregular Isha Yoga practitioners (practicing less than 3 times per week) and the control group in any of the scales. Similarly, no statistically significant differences were observed between the moderately regular Isha practitioners (3–4 times of practice per week) and the regular Isha practitioners (minimum 5 times of practice per week) in any of the scales.

3.5 Mental health outcomes: by life-time hours of practice

Most significant changes in mental health outcomes occurred within the initial 100 h of practice (Figures 7, 8; Supplementary Figures S7, S8).

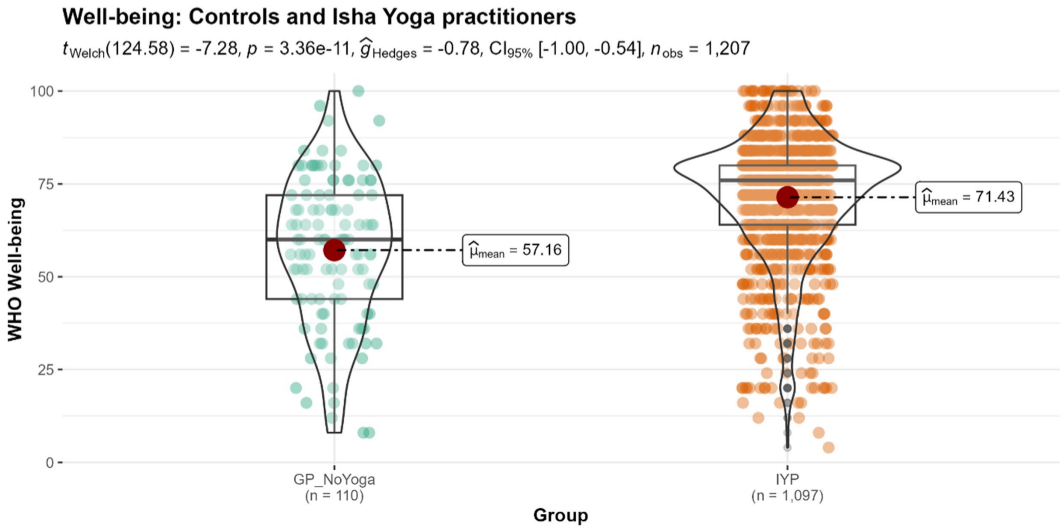


FIGURE 3
Differences in the levels of well-being between controls and Isha meditators. GP_NoYoga, General population no Yoga; IYP, Isha Yoga practitioners.

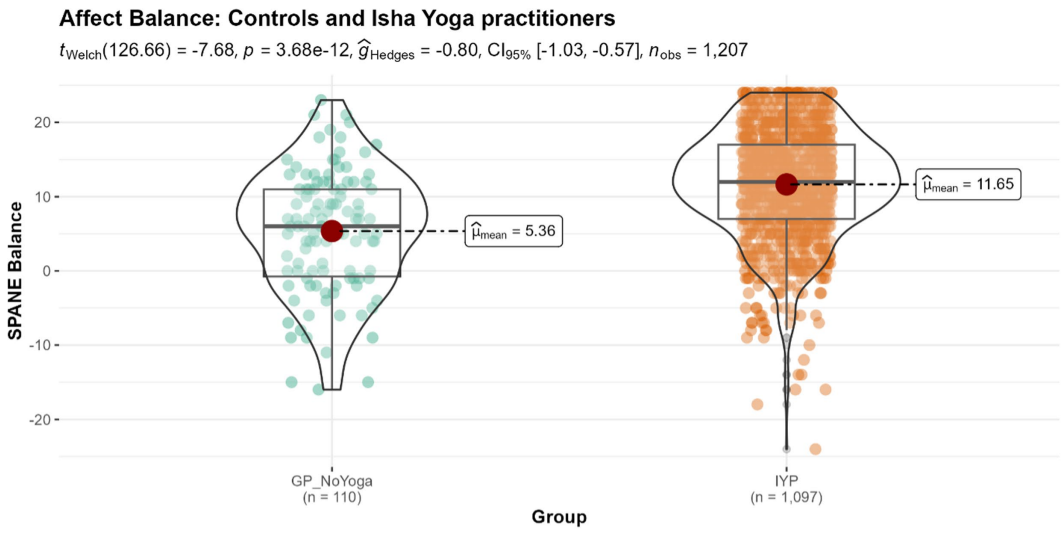


FIGURE 4
Differences in the levels of affect balance in controls and Isha meditators. GP_NoYoga, General population no Yoga; IYP, Isha Yoga practitioners.

Scores showed a tendency to plateau after 500 h of practice, up to 3,000 h of practice. Results indicate an improvement in scores beyond 3,000 h of practice. These outcomes based on years of practice and practice time per day show similar changes (Supplementary Figures S9, S10).

3.6 Mental health outcomes: impact of Isha Yoga on health-care workers (HCW's)

Analyses indicated that there were statistically significant differences in all four scales (balance, mental distress, perceived stress, and well-being) between health care workers (HCW's) who practiced Yoga and HCW's who did not practice any form of Yoga (Figure 9; Supplementary Figure S11). Additionally, the effect sizes observed were medium (for mental distress and well-being) and large (for perceived stress and balance).

In addition to the outcomes discussed above, we also assessed sleep, diet, and physical activity among our survey respondents. The findings indicate that there were significant differences between the groups in both sleep quality ($p < 0.001$) (Supplementary Figure S12) and sleep quantity ($p < 0.001$) (Supplementary Figure S13). However, the effect size observed for both sleep quality and quantity was very small according to standard conventions (60). Our results also showed significant associations between Isha Yoga practises and the consumption of a pre-dominantly vegetarian diet (Supplementary Figure S14). There were no significant differences in physical activity levels between the groups (Supplementary Figure S15).

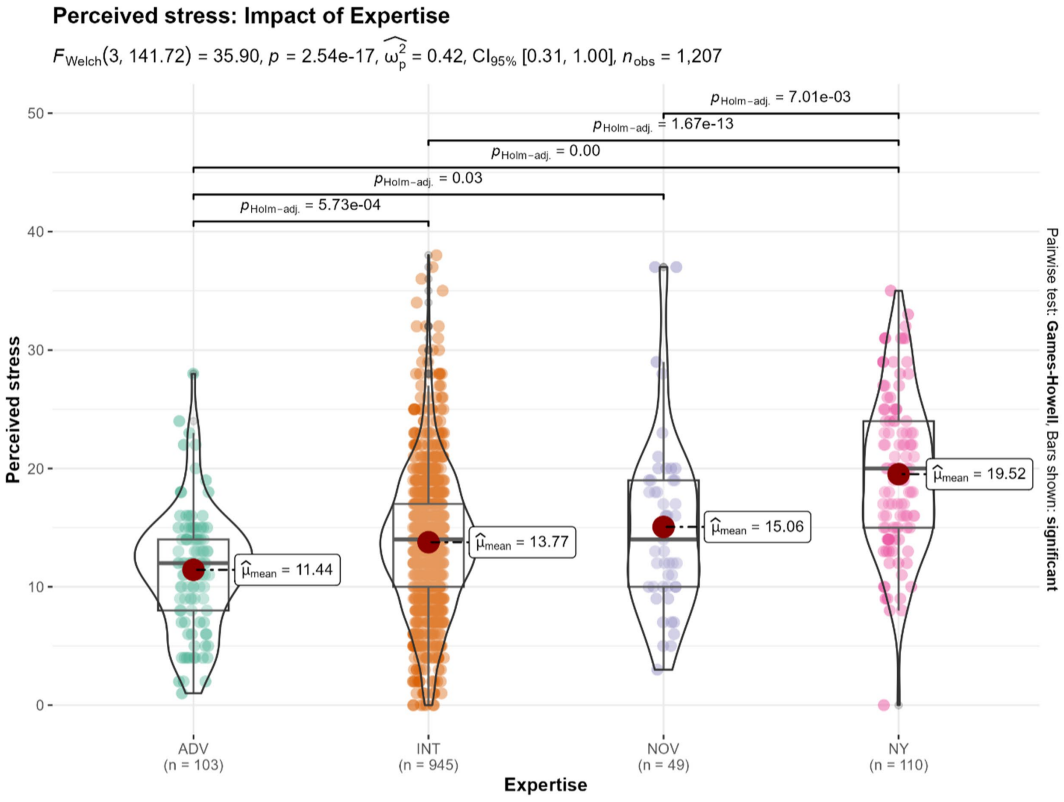


FIGURE 5
Differences in the levels of perceived stress, based on the impact of expertise among Isha Yoga practitioners. ADV, Advanced Isha Meditators ($n = 103$); INT, Intermediate Isha Meditators ($n = 945$); NOV: Novice Isha Meditators ($n = 49$); NY, No Yoga control group ($n = 110$).

4 Discussion

Against the backdrop of a global increase in stress and stress-related disorders, including anxiety and depression (1, 3, 5, 13), our survey study, carried out during the COVID-19 pandemic, investigated the levels of perceived stress, mental distress, WHO well-being, and affect balance in a group of Isha Yoga practitioners and controls. The effect of proficiency and regularity in the Isha Yoga practise were also evaluated. Our findings revealed significant associations, with medium-to-large effect sizes, between the practise of Isha Yoga and better mental health outcomes. Proficiency played a key role, with advanced Isha Yoga practitioners showing the most favorable outcomes. The study underscored the importance of regular practice, as those non-compliant with Isha Yoga showed outcomes similar to controls. Further, a minimum 3–4 days of weekly practice showed significant differences with the control group. Importantly, our results suggest that even a relatively brief engagement in Isha Yoga, with fewer than 100 lifetime hours or less than a month of practice, is associated with better outcomes.

Traditional treatment approaches for stress-related disorders, such as anxiety and depression, often carry undesirable side effects (61, 62) and have been linked to the development of metabolic disorders (63). Compounding the challenge, approximately one third of individuals do not respond to conventional treatments, presenting a significant clinical hurdle (64, 65). At the same time, in India, there is a huge treatment gap of 80.4% (4). These factors underscore the necessity for preventive and integrative approaches in addressing these conditions. Meta-analyses have demonstrated that yoga practices may serve as valuable complementary treatment options for individuals dealing with anxiety and depression (66–68). Yogic breathing practises have also been shown to be effective for improving stress, anxiety, and depression, with small-to-medium mean effect sizes reported (69).

In this context, our findings of lower perceived stress and mental distress among Isha meditators compared to controls are promising. These results align with other studies on Isha meditators. For instance, a 10-min Isha Yoga practice, incorporating Yoga Namaskar and Nadi Shuddhi Pranayama, delivered online over 4 weeks, reduced perceived stress levels in US undergraduate students (25). Similarly, a 6-week practice of Shambhavi Mahamudra Kriya resulted in lower levels of perceived stress in a group attending a 4-day Inner Engineering retreat (31). Some studies on Isha Yoga have shown promising outcomes in reducing anxiety and depression. For instance, one study reported a statistically significant decrease in anxiety (effect size, $d = 0.60$) and depression (effect size, $d = 0.48$) among participants who attended an advanced 8-day Isha Samyama meditation retreat, with the effects sustained three months after the retreat. Those with higher baseline levels of anxiety and depression experienced greater reductions after the retreat (26). Similarly, another study observed a significant reduction in anxiety (by 23%, effect size = 0.60) and depression scores (by 26%, effect size = 0.31) among participants of a 4-day advanced Isha Yoga retreat (36). Despite these positive findings, further research on Isha Yoga, particularly employing randomized controlled trials with active

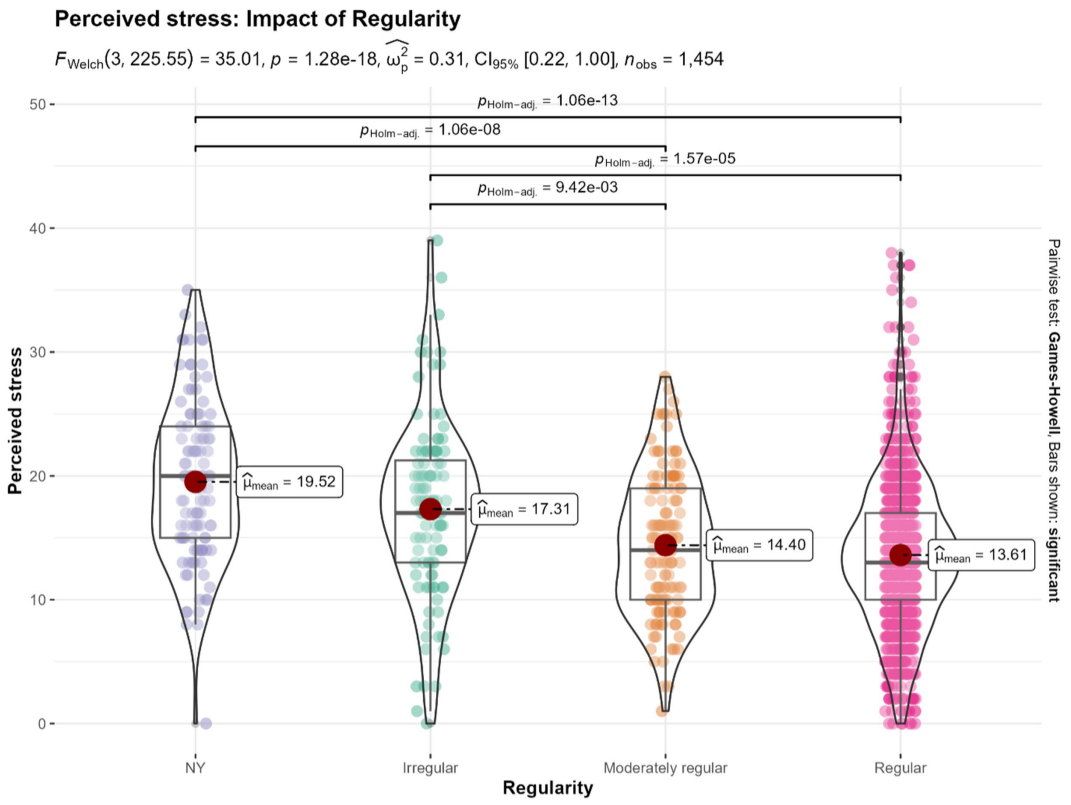


FIGURE 6
Differences in the levels perceived stress based on the impact of regularity of practice among Isha Yoga practitioners. NY: No Yoga control group ($n = 110$). Irregular: Less than 3 times of practice per week ($n = 108$). Moderately regular: 3–4 times of practice per week ($n = 139$). Regular: Minimum 5 times of practice per week ($n = 1,097$).

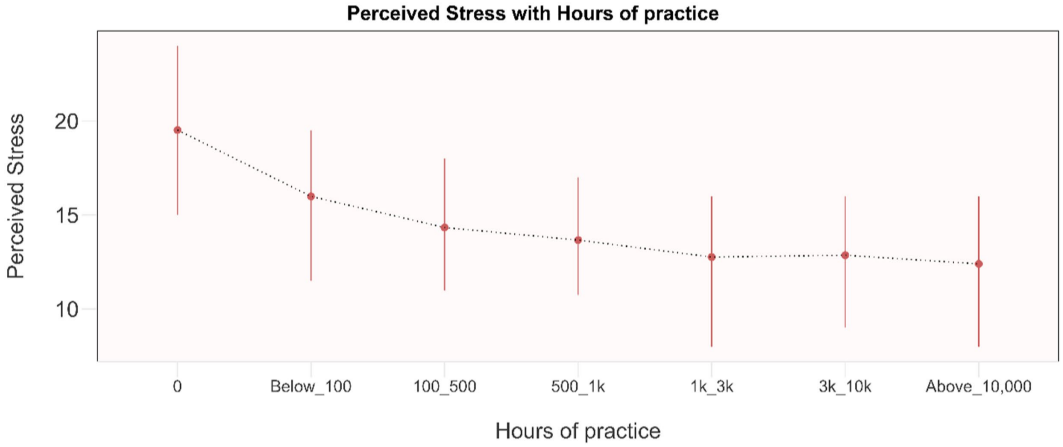


FIGURE 7
Dose–response relationship between perceived stress and total life-time hours of practice. Results are presented as mean and IQR. 0: No Yoga practice ($n = 110$). Below_100: Less than 100 life-time hours of Isha Yoga practice ($n = 87$). 100_500: 100 to 500 life-time hours of Isha Yoga practice ($n = 289$). 500_1k: 500 to 1,000 life-time hours of Isha Yoga practice ($n = 228$). 1k_3k: 1,000 to 3,000 life-time hours of Isha Yoga practice ($n = 245$). 3k_10k: 3,000 to 10,000 life-time hours of Isha Yoga practice ($n = 158$). Above_10,000: Greater than 10,000 life-time hours of Isha Yoga practice ($n = 90$).

comparators, is necessary to gain a more comprehensive understanding of the significance of Isha Yoga practices in reducing stress, anxiety, and depression.

While ample research exists to demonstrate the effectiveness of Mind and Body practices in mitigating negative outcomes, there is a relative scarcity of studies showcasing their impact on positive

FIGURE 8
Dose–response relationship between WHO well-being and total life-time hours of practice. Results are presented as mean and IQR. 0: No Yoga practice ($n = 110$). Below_100: Less than 100 life-time hours of Isha Yoga practice ($n = 87$). 100_500: 100 to 500 life-time hours of Isha Yoga practice ($n = 289$). 500_1k: 500 to 1,000 life-time hours of Isha Yoga practice ($n = 228$). 1k_3k: 1,000 to 3,000 life-time hours of Isha Yoga practice ($n = 245$). 3k_10k: 3,000 to 10,000 life-time hours of Isha Yoga practice ($n = 158$). Above_10,000: Greater than 10,000 life-time hours of Isha Yoga practice ($n = 90$).

outcomes (70). In our survey, we found significant associations between Isha Yoga practises and higher levels of well-being and affect balance. Similar to ours, a study reported increased general well-being levels after six weeks of practice of Shambhavi Mahamudra (31). Furthermore, a randomized controlled trial (RCT) conducted with a waitlist control crossover assessed the effectiveness of 12 weeks of online Isha Upa Yoga intervention in US undergraduate students and found that the practise led to improved well-being scores in both the intervention and crossover control groups (25). Additionally, another study showed enhanced vitality, a sense of meaningful work, and workplace engagement among employees of a Fortune 500 company who participated in an Isha Inner Engineering Online program (32).

Similar improvements in positive outcomes have been found in studies on other practices like Sahaja Yoga and Sudarshan Kriya (71, 72).

Mind and Body practices (MBPs) like Isha Yoga likely bring about a reduction in negative outcomes and an increase in positive outcomes by enhancing overall self-regulation. Studies show that MBPs achieve this by reducing mind-wandering, increasing attention, and fostering present-moment awareness, enabling individuals to consciously respond to stress and uncertainty, even during challenging times like the COVID-19 pandemic (73–75). For instance, research has demonstrated increased attention in Isha Yoga practitioners after an advanced meditation retreat (35). Meditators also exhibit decreased default mode network (DMN) activity, a marker of mind-wandering (76). In Isha meditators, an advanced Isha Yoga program led to increased connectivity between the salience network (SN) and DMN, indicating reduced mind-wandering and heightened present-moment focus (77). Further, during deep meditation, there is an increase in theta and gamma EEG power, signifying heightened attention and awareness of the present moment. For instance, a study revealed that Isha Yoga practitioners experienced an increase in EEG gamma band power during Shoonya meditation (38). Certain brain regions crucial for attention and awareness, like the Pre-frontal Cortex, Insular Cortex, Anterior Cingulate Cortex, and Hippocampus, have been found to be altered in MBP practitioners (78, 79). Studies have shown that strengthened neural connections between pre-frontal and limbic regions in Yoga and meditation practitioners contribute to reduced stress and improved well-being (80–82).

Furthermore, Mind and Body practices (MBPs) exert beneficial effects in a bottom-up manner by impacting the parasympathetic and sympathetic nervous systems, reducing inflammation, and influencing the stress reactivity pathways (83). Isha Yoga, with its components of Hatha Yoga, Pranayama, and Kriyas, is believed to influence the mind in this manner. Studies have shown that Isha Yoga practitioners experience increased heart rate variability (HRV) and sympathovagal balance, indicating improved autonomic nervous system function (29, 84). Additionally, a study demonstrated a robust cortisol awakening response (CAR) in Isha Yoga practitioners following a 3-month retreat, suggesting better stress regulation (30). Likewise, another study reported 2-3-fold lower CRP levels (C-reactive protein, a marker of inflammation) in Isha meditators compared to controls, indicating lower systemic inflammation (26). Modulation of the Hypothalamic–Pituitary–Adrenal (HPA) axis and Sympathetic Adrenal Medullary (SAM) axis by MBPs creates a feedback loop to the brain, influencing mood and behavior, ultimately leading to reduced negative outcomes and enhanced positive ones. The two approaches, both top-down and bottom-up, work in synergy to provide a comprehensive framework for understanding how MBPs, such as Isha Yoga, have the potential to reduce negative outcomes and enhance positive ones, even in a high-stress population like health-care workers (HCWs). The interplay between the mind and body through these practices paves the way for greater self-regulation, emotional resilience, and a heightened sense of well-being.

Our study outcomes were influenced by the level of expertise in Yoga, with better results observed in individuals with more Isha Yoga experience, consistent with findings from other Yoga and meditation traditions (19, 20, 85, 86). Duration of practice and engagement in advanced Yoga techniques by experts likely contributed to these differences. Regularity of practice was also crucial, as irregular practitioners (less than 3 times per week) did not show significant differences compared to the control group, aligning with findings from other studies (23, 25, 31). We investigated the

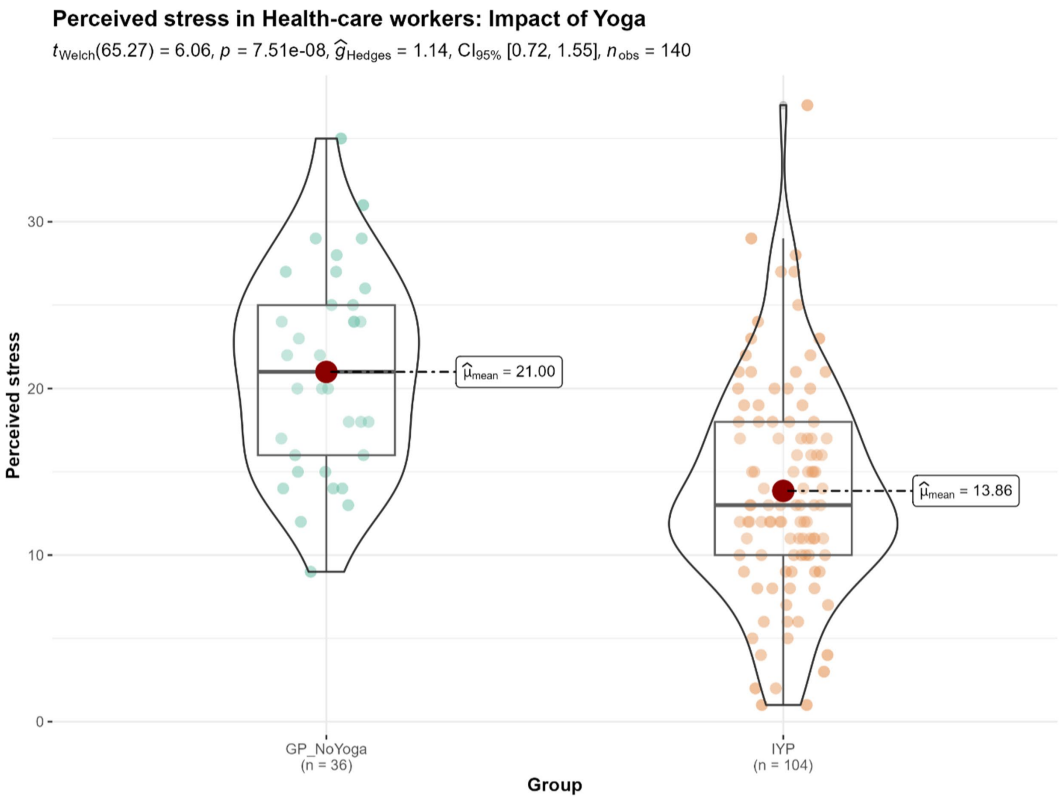


FIGURE 9
Differences in the levels of perceived stress in the Yoga-practicing health care workers (HCW's) ($n = 104$) and no-Yoga HCW's ($n = 36$). GP_NoYoga, General Population No Yoga; IYP, Isha Yoga practitioners.

minimum amount of practice needed to yield benefits and found that practicing at least 3–4 times per week may be sufficient to decrease stress and promote well-being. The most significant changes tended to occur within the initial 100 life-time hours of practice with subsequent changes happening more gradually and plateauing. Even practicing Yoga for less than 30 min produced significant differences compared to not practicing at all. A study on Isha Yoga showed that reductions in perceived stress and improvements in general well-being only happened in those who were compliant with the practice (31). In addition, in a meta-analysis of mindfulness-based practices, researchers discovered a modest yet significant correlation between the amount of self-reported home practice and positive psychological outcomes ($r = 0.26$) (87). In contrast, another meta-analysis discovered no statistically significant relationship between the amount of daily practise and favorable outcomes (88). These contradictory findings necessitate further investigation. However, it is essential to recognize that the true purpose of Yoga goes beyond merely reducing stress and enhancing well-being. Yoga can have both state and trait effects on individuals (89, 90). These trait effects depend on consistent and regular practice, to the extent that one lives in that state of consciousness every moment. However, given that many people start practicing Yoga with the intention of reducing stress and improving well-being, our observations regarding these dose–response relationships could be encouraging. The results show that meaningful benefits can be experienced with relatively manageable commitments, serving as motivation to incorporate Yoga into daily routines and enhance overall well-being.

Considering factors such as diet, sleep, and physical activity is crucial when evaluating an individual's health and well-being. In our study, we observed no statistically significant differences in physical activity levels between the control group and Isha meditators, suggesting that physical activity may not have directly contributed to the observed changes in mental health outcomes. However, we did find significant differences between the groups in terms of sleep and diet. Most of the Yoga practitioners shift to a predominantly vegetarian diet, as observed in our survey, following initiation into Yogic practises (26, 30). However, the link between a vegetarian diet and better mental health outcomes remains debatable, with conflicting evidence (91, 92). Future studies on Yoga should control for dietary factors to gain further insights. On the other hand, sleep has been consistently shown to influence mental health outcomes positively (93). It is plausible that practicing Yoga may have led to better sleep quality, thereby contributing to the observed improvements in mental well-being. Nevertheless, further research is necessary to gain a deeper understanding of this relationship.

4.1 Strengths and limitations

Internet surveys are prone to various biases, including the non-representative nature of the sample and the volunteer effect (self-selection of participants) (39, 40). A significant strength of our study is that we were able to precisely target our survey to the intended group. Moreover, our decision to focus exclusively on one Yoga tradition, Isha Yoga, contributed to the homogeneity of the Yoga type,

thereby enhancing the study's internal validity. Furthermore, the substantial number of survey respondents and a good participation rate of 71.53% further strengthen the study's credibility. These factors collectively lead us to believe that the sample of our study is likely to be representative of Isha meditators in Karnataka, adding to the high external validity of our findings.

Another strength of our study lies in our adherence to appropriate guidelines for survey studies. Just as there are established guidelines for randomized trials (CONSORT) and systematic reviews (QUORUM), CHERRIES provide essential guidelines for conducting survey studies (41). By following these guidelines to the extent possible, we aimed to ensure the validity and credibility of our survey results, distinguishing our study from many others that may not adhere to such standards. Furthermore, our analysis was conducted in accordance with relevant guidelines (56, 60, 94) ensuring comprehensive and accurate statistical reporting. Additionally, we incorporated effect sizes for most of the observed outcomes, and the findings revealed medium-large effect sizes, further strengthening the significance of our results. These effect sizes suggest that the practice of Isha Yoga, regardless of its duration, is associated with a significant reduction in stress and improvement in well-being. However, it is important to acknowledge that our study's cross-sectional design limits our ability to establish causality in the observed associations. To address this limitation and gain deeper insights, more longitudinal studies focusing on Isha meditators are warranted.

Lastly, the volunteer effect or the self-selection of participants may have biased our final sample. In addition, the selection of only English-speaking individuals in the study may have introduced a language and regional bias, potentially affecting the study's generalizability to a broader population. Further, we relied on self-reported survey data to assess the outcomes, potentially introducing recall bias. To address this concern, future studies should aim to incorporate objective parameters alongside self-reported measures. Unfortunately, due to the constraints imposed by the COVID-19 pandemic, we were unable to include such objective assessments in our study. Nevertheless, future research should strive to overcome this limitation and integrate objective measurements to enhance the overall reliability of results.

5 Conclusion

Our study demonstrates significant associations between practice of Isha Yoga and better mental health outcomes, particularly during the COVID-19 pandemic. Isha Yoga practitioners showed lower levels of stress and mental distress, alongside higher well-being and balance, compared to controls. However, establishing a causal relationship is intricate, underscoring the need for longitudinal studies and randomized controlled trials. Expertise-related improvements were observed in these outcomes. The findings show a dose–response relationship between Isha Yoga practise and better outcomes. Importantly, our findings indicate that even a relatively brief engagement in Isha Yoga, with less than 100 lifetime hours of practice or less than a month of regular practice, is associated with notable improvements in outcomes. Additionally, the regularity of practice emerged as a crucial factor, as those not compliant with Isha Yoga practice demonstrated outcomes similar to controls.

Some of the strategies to improve compliance to Yoga practice are:

(a) Community engagement: Foster a sense of community through group sessions and community-based programs to provide social support and motivation.
(b) Incentives and rewards: Offer incentives such as discounts, rewards, or recognition to participants for consistent attendance and achievements.
(c) Technology integration: Develop and promote online resources, apps, or virtual classes to accommodate busy schedules and enhance accessibility.
(d) Personalized approaches: Tailor programs to individual needs and preferences. Offer one-on-one sessions or personalized plans for those with specific health concerns or limitations.

Future research should aim to overcome the limitations of the present study, including its cross-sectional design, reliance on subjective measurements, and the self-selection bias of participants. It is imperative to explore causal relationships and consider diverse samples from global datasets to account for cultural and social factors influencing various mental health outcomes. Additionally, it is crucial to emphasize that these practices should be regarded as a complementary intervention rather than a substitute for conventional mental health treatments. In conclusion, our findings highlight the potential of Isha Yoga practices as accessible and effective methods for enhancing well-being, supporting their integration into public health strategies.

Presented below are ten recommendations for policymakers and healthcare providers:

(a) Research and education

- Conduct research: Invest in scientific research to establish the effectiveness of yoga in promoting physical and mental health.
- Education programs: Develop educational programs to increase awareness about the benefits of yoga among healthcare professionals, policymakers, and the general public.

(b) Integration into healthcare systems

- Encourage healthcare providers to include yoga as part of treatment plans for various health conditions, such as stress, anxiety, depression, and chronic diseases.
- Training for healthcare professionals: Provide training for healthcare professionals to integrate yoga practices into their treatment approaches.

(c) Community-based programs

- Community centers and schools: Implement yoga programs in community centers, schools, and workplaces to make it accessible to diverse populations.
- Subsidies and incentives: Provide subsidies or incentives for organizations that incorporate yoga into their wellness programs.

(d) Accessibility and inclusivity

- Make yoga classes affordable or offer subsidies to ensure that individuals from all socioeconomic backgrounds can participate.
- Culturally sensitive approaches: Consider cultural diversity and tailor programs to be inclusive and respectful of different cultural backgrounds.

(e) Workplace wellness programs

- Incentives for employers: Provide incentives for employers to offer yoga classes as part of workplace wellness programs, recognizing the potential benefits for employee health and productivity
- Flexible scheduling: Encourage flexible scheduling to accommodate employees participating in yoga classes.

(f) Public awareness campaigns

- Promote benefits: Launch public awareness campaigns to highlight the physical and mental health benefits of yoga
- Online resources: Develop online resources, including videos and informational materials, to make yoga practices accessible to a broader audience.

(g) Collaboration with Yoga organizations

- Partnerships: Collaborate with yoga organizations and instructors to design and implement effective and evidence-based programs
- Certification standards: Establish certification standards for yoga instructors to ensure quality and safety.

(h) Policy support

- Insurance coverage: Advocate for insurance coverage of yoga classes when recommended by healthcare professionals for specific health conditions.
- Legal recognition: Recognize and support the legal standing of certified yoga instructors, ensuring their ability to contribute to public health initiatives.

(i) Research funding

- Allocate funding: Allocate funding for further research on the long-term health benefits of yoga and its potential role in preventive medicine

(j) Monitoring and evaluation

- Outcome evaluation: Implement systems to monitor and evaluate the outcomes of yoga programs in terms of public health impact, cost-effectiveness, and participant satisfaction.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Nimhans Human Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SaM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. SeM: Methodology, Supervision, Writing – review & editing. JJ: Methodology, Supervision, Writing – review & editing. BK: Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1280859/full#supplementary-material

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EDITED BY
Guodong Zhang,
Southwest University, China

REVIEWED BY
Cong Yin,
Capital University of Physical Education and Sports, China
Zhuang Changkuan,
Hainan Normal University, China

*CORRESPONDENCE
Xiujie Ma
✉ ma.xiujie@outlook.com

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Effects of tai chi, ba duan jin, and walking on the mental health status of urban older people living alone: the mediating role of social participation and the moderating role of the exercise environment

Baoyuan Wu[1], Guoyan Xiong[1], Peng Zhang[2] and Xiujie Ma[1,3]*

[1]School of Wushu, Chengdu Sports University, Chengdu, China, [2]College of Physical Education and Sports, Beijing Normal University, Beijing, China, [3]Chinese Guoshu Academy, Chengdu Sports University, Chengdu, China

With the global trend of aging, lacking of interpersonal communication and spiritual support and companionship have had a great impact on the mental health of older people living alone. This study examines the multifaceted impacts of engaging in tai chi, ba duan jin, and walking on the mental wellbeing of older people residing alone in urban areas. Additionally, this research aims to explore the association between tai chi, ba duan jin, and walking, and the mental health status of urban older people living alone, by considering the mediating influence of social participation and the moderating influence of the exercise environment. To do so, 1,027 older people living alone in six Chinese cities were investigated using the Physical Activity Rating Scale (PARS-3), the Geriatric Health Questionnaire (GHQ-12), the Social Participation Indicator System Scale, and the Exercise Environment Scale. SPSS 25.0 was utilized for conducting mathematical statistical analysis, specifically for doing linear regression analysis. Additionally, AMOS was employed to develop the study model. We found that a significant negative correlation between tai chi, ba duan jin, and walking and mental health status; among these, tai chi had the greatest impact on the mental health status of urban older people living alone. Social participation mediated the relationship between tai chi, ba duan jin, walking, and mental health status, and the exercise environment had a moderating effect on this relationship. The findings of this study indicate that tai chi, ba duan jin, and walking have a positive impact on the mental health of urban older people living alone, which can be influenced by the mediating efficacy of social participation and the moderating effect of the exercise environment.

KEYWORDS

tai chi, ba duan jin, walking, urban older people living alone, social participation, exercise environment, mental health

1 Introduction

The seventh national census predicted that by the end of 2021, 18.9% of China's population would be over 60 and 14.2% over 65 (1); which marked the beginning of the "silver wave" era in China. At the same time, the family unit is getting smaller. The family unit is growing towards nuclearization and downsizing, and so is the number of older people living alone and empty nesters (2). Older people who live alone are widowed, separated, or have other long-term living reasons and do not have children or other companions nearby, moreover, they are characterized by restricted behavior, poor perceptual skills, low social interaction behavior, and dependency (3). The unique lifestyle and intergenerational interactions of older adults living alone, as opposed to those living with their spouses, children, or grandkids, make them more vulnerable to unpleasant feelings (4). All of these are originated from the family incompleteness, lacking of communication with loved ones, spiritual satisfaction, lack of emotional support, and, over time, loneliness, isolation, and other difficulties overcoming negative emotions. As people age, all of these may be end up with depression, loneliness, and other mental diseases. As a result, older people's mental health has become a major concern for society.

Socialization has been shown to be important in achieving lifespan and mental health in older persons, and keeping positive relationships with society increases the likelihood of embracing a happy old age (5). Physical engagement has been recommended as early as the 1990s as an activity that enhances an individual's interpersonal network and has social qualities as they strengthen themselves (6). Physical exercise has now been identified as a driver of physical and mental maintenance, prevention of premature illness, and healthy longevity in older persons (7). Weakened exercise capacity and physical age, decrease the stride speed and horizontal span, poor flexibility, and the physical strength, which prevent the older people to participate in strenuous physical activity. This makes it impossible for the majority of older people to participate in strenuous physical activities (8). In this case, most older people will prioritize sports with low intensity, soft movements and low flexibility requirements. Besides, due to the influence of the traditional Chinese cultural environment, traditional Chinese healthcare sports are highly favored by middle-aged and older people. Among them, tai chi and ba duan jin, as one of the representatives of traditional Chinese healthcare sports programs, have soft and slow as well as continuous and connected movements. They require that "qi is induced by intention, used to move the body, internal qi is generated in the dan tian." Additionally, the principle of qi and blood circulation of yin and yang and exchange of reality and emptiness regulates the balance of qi and blood in all body areas and promotes older people's physical and mental health (9). Through a three-month trial, Chan et al. discovered that tai chi can improve the social participation and mental health of isolated older people (10). Another intervention trial study of ba duan jin found that ba duan jin training, combined with cognitive behavioral therapy (CBT), significantly improved the levels of loneliness and depression of homebound older adults as well as their physical and mental health (11). Walking is also an exercise for older people, and it is a low-cost and low-injury strategy to stay healthy that has been shown to improve their mental health (12) and reduce negative feelings (13). Therefore, three exercise programs—tai chi, ba duan jin and walking which older people living alone can participate in on a daily basis, were selected for use in this study to explore the relationship with mental health.

Substantial research has been conducted on the impact of physical exercise participation on older adults' mental health; however, some gaps remain. For example, active participation in physical exercise by older adults is conducive for the improvement of their social network (14), and higher social participation can provide older adults with more social support and reduce the likelihood of depression, which improves their mental health (15). Nevertheless, few studies have examined the intrinsic links between tai chi, ba duan jin, walking, social participation, and the mental health of older people living alone. Secondly, in the process of older adults' exercise, the safety of the surrounding exercise environment, rationality of planning, and landscape pleasantness can meet the requirements of older people with regard to the exercise environment. In addition, safe and comfortable sports venues also enable older adults to achieve real relaxation of the body and mind and better experience the beauty of the movement (16). Hence, the exercise environment is a contributing factor to the impression of physical activity in older people. Nevertheless, the existing study has not shown a definitive correlation between the exercise setting and the impact of tai chi, ba duan jin, slow walking, and the mental well-being of elderly individuals who reside alone. Finally, fewer studies have focused on urban older adults living compared to those that have sampled older people or empty nesters, and study sample sizes were also modest.

With the changing family demographic structure in China, the number of older people living alone is increasing, and how to address their unpleasant psychological difficulties has become a pressing issue. As a result, this study chooses social participation as the mediating variable and exercise environment as the moderating variables to investigate the effects of tai chi, ba duan jin, and walking on the psychological health of urban older adults living alone. In addition, it attempts to clarify the relationship between tai chi, ba duan jin, and walking, social participation, exercise environment, and psychological health, as well as its internal mechanism, to provide a reference point for achieving healthy aging in this demographic group.

2 Development of hypotheses

2.1 Relationship between tai chi, ba duan jin, and walking and mental health

Since its inception, pertinent research has demonstrated that the traditional Chinese national sports and health regimens of tai chi and ba duan jin have a considerable positive impact on the mental and physical wellbeing of their practitioners. Long-term practice of tai chi has been found to be beneficial for mental health, as evidenced by the reduction of psychological issues such as anxiety, depression, and mood disorders in older adults (17–19). Li et al. (20) conducted a randomized controlled trial and found that older practitioners of tai chi reported better levels of life satisfaction, positive emotions, and wellbeing, and lower levels of psychological distress, depression, and negative emotions. Practicing ba duan jin for an extended period of time greatly improves the physical function, walking ability, anxiety, and balance of older persons, and it also improves quality of life and lowers pain and falls (21). Exercise in the ba duan jin style helps to develop and increase mental health as well as to calm the body and

mind and control emotions (22). In addition, walking is simple and easy to perform, and the amount of activity can be controlled and altered by the individual, it is independent of environmental, equipment, and other factors. Continuous walking exercise can improve the endocrine and hormonal indexes of the older people's body, reduce the psychology of frustration, and improve depression and mental health (23–25). Consequently, tai chi, ba duan jin, and walking were chosen as exercise programs for this study. Based on the preceding analysis, we propose the following hypothesis:

> *Hypothesis I*: Tai chi, ba duan jin, and walking all have different negative correlations with the mental health status of urban older people living alone.

2.2 The mediation effects of social participation

Social participation is a vital means for older people to integrate into society and adapt to social change as well as for a relationship between individual behavior and society (26). Active social participation can improve the lives of older people, enabling them to better integrate into the collective environment of the community and to gain greater social support (27), and allow them to stay connected to society and encourage active aging (28). The relationship between tai chi and social participation has now been explored by some scholars. Studies have shown that when performing a tai chi group exercise, the benefits to the practitioners' physical, emotional, and social functioning are significant (29); In addition, older adults who did not engage in any social activities had their social networks strengthened and their psychosocial wellbeing improved after practicing tai chi with their peers' assistance (30). Further, participation in tai chi practice stabilizes older adults' social activeness and reduces the risk of loneliness and social isolation (31). It has also been found that both ba duan jin and slow walking lead to the participants' improved socialization and the participants' enhanced social participation (32, 33). As a result, tai chi, ba duan jin and walking are effective approaches to promote social interaction among older persons. Studies have demonstrated that encouraging formal social participation not only reduces depressive symptoms and enhances quality of life, but it also prevents mental health decline (34). In contrast, older adults who rarely or never participate in social activities have higher levels of psychological distress (35), whereas older adults with high levels of social participation are significantly less likely to suffer from mental illness than those with low levels of social participation (36). Increasing social participation can therefore be used to improve the mental health of older people and prevent the onset of chronic diseases in old age (37). Previous research has confirmed that tai chi, ba duan jin and walking influence older people' social participation and that social participation can influence their mental health. Consequently, can tai chi, ba duan jin, and walking indirectly influence the mental health status of urban older people living alone through social participation? We thus propose the following hypothesis:

> *Hypothesis II*: Social participation mediates the relationship between tai chi, ba duan jin, and walking and mental health status.

2.3 The moderating effects of the exercise environment

Numerous studies have demonstrated the impact of the exercise environment on practitioners' mental health. The physical and emotional experiences that exercisers gain from it vary depending on the type of environment in which they practice, which means that the psychological consequences of various exercise environments may also differ. The perceived esthetics of the exercise environment and the facilities' convenience and accessibility increase the likelihood that people will be physically active (38). In addition, the size of sports equipment and amenities may influence people's physical exercise behavior (39). In addition, safer walking paths and easy access to facilities affect older people's active participation in physical activity (40). The exercise environment influences physical exercise as well as its effects on the practitioner's perceived mood and wellbeing, and even the same behavior may have opposite effects depending on the exercise environment (41). Furthermore, physical exercise levels are influenced by the exercise environment (42), and the more the outdoor and indoor physical activity facilities (e.g., with walking paths/trails, outdoor tennis courts, gardens, etc.), the greater the number of older adults who do physical exercise, the greater the frequency and duration of exercise, and the higher its level (43). As a result, the exercise environment has a significant role in affecting activity levels in older persons (44). When participants exercised in a better environment with better facilities, tai chi, ba duan jin, and walking had a stronger influence on their mental health condition. In other words, the exercise environment may strengthen the link between tai chi, ba duan jin, and walking and mental wellness. As a result, the following hypothesis was advanced:

> *Hypothesis III*: The exercise environment moderates the relationship between tai chi, ba duan jin, walking and mental health status.

In summary, this study built a research model of the mediating and moderating mechanisms of tai chi, ba duan jin, and walking with the mental health status of urban older people living alone, using mental health status as the dependent variable; tai chi, ba duan jin, and walking as the independent variables; social participation as the mediator variable, and exercise environment as the moderating variable (Figure 1). It provides implications for future studies on tai chi, ba duan jin, walking, and the mental health of older people living alone to promote their mental health.

3 Materials and methods

3.1 Study design and participants

The number of senior people (60 and older) in Chengdu City was expected to reach 3.208 million by the end of 2021, accounting for 20.61% of all households. The proportion of older persons in homes aged 70 and up to the total geriatric population climbed to 51.81% (45), demonstrating that the city is already transforming into an aging society. As a result, Chengdu City was selected as the research site, and the findings have promising implications for understanding the mental health and healthy aging of olderly people living alone. In this study,

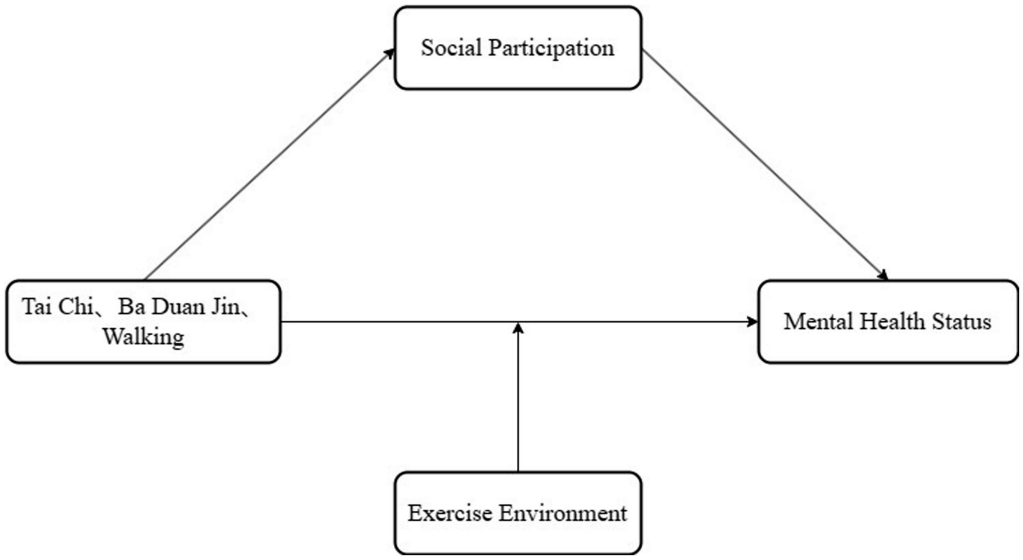

FIGURE 1
A hypothesized model of the relationship between tai chi, ba duan jin, and walking and mental health status.

we examined the tai chi, ba duan jin, walking, and mental health of older citizens living alone in six metropolitan areas outside of large cities: Xindu District, Pixian County, Wenjiang District, Shuangliu District, Gaoxin District, and Longquanyi District. We adopted random sampling to ensure the rationality of sample distribution, the number of questionnaires in each urban region was essentially limited to around 200. The inclusion and exclusion criteria had to be defined as we considered the relationship between tai chi, ba duan jin, walking, and the mental health status of urban older people living alone. Criteria for inclusion: (1) individuals 60 years of age or older; (2) Chengdu permanent residents; (3) older people who fit the description of living alone, meaning they are childless or separated and have lived alone for at least a year; (4) informed consent and voluntary participation; and (5) clear consciousness, the ability to read and verbally express oneself, and the ability to interact with the investigators are required. Exclusion criteria were (1) questionnaires that took less than 90 s to complete and (2) responses that were identical, duplicated, or invalid. Figure 2 depicts the screening procedure for the study sample.

The questionnaire was administered on-site and complemented by an electronic questionnaire on the Questionnaire Star website, which took around 3–5 min to complete. Two to three researchers contacted administrators of community or street offices to conduct household surveys, as well as visiting areas where the older people are active, and they used Questionnaire Star to distribute the questionnaires to the designated groups. Prior ethical approval was obtained from the Chengdu Institute of Physical Education. Before the participants completed the questionnaire, the researcher explained the study's original goal, as well as how the research data would be used and what the associated risks were. Then, they presented the informed consent form to the participants and asked them to sign it. The researcher would answer any questions that the participant did not understand and, if necessary, provide an oral explanation in the participant's dialect. After completing the survey, participants were given red packets or gifts as a token of appreciation. Finally, we recovered 1,246 questionnaires, including 1,051 offline questionnaires and 195 online questionnaires, with 1,027 valid questionnaires retrieved at an effective recovery rate of 82.4%.

3.2 Measurement tool design and reliability testing

3.2.1 Exercise scale

Measurement of tai chi, ba duan jin, and walking exercise among urban older people living alone was conducted using the Physical Activity Rating Scale (PARS-3) revised by Liang et al. (46, 47), which is divided into three dimensions: tai chi, ba duan jin, and walking. A five-point scale from 1 to 5 was used to examine the amount of exercise in terms of three dimensions: intensity, time, and frequency of participation in physical activity. Exercise amount = intensity × time × frequency, intensity, and frequency from 1 to 5 grades, respectively, scored 1–5 points; moreover, time from 1 to 5 grades, respectively, scored 0–4 points, with the highest score being 100 points and the lowest being 0 points. The higher the total score measured, the greater the amount of exercise was. The activity rating scale was as follows: ≤ 19 = low exercise; 20–42 = moderate exercise; ≥43 = heavy exercise. The Cronbach's α coefficients of these three scales in this study were 0.809, 0.825, and 0.806, respectively.

3.2.2 Mental health status scale

Mental health status was measured using the Geriatric Health Questionnaire (GHQ-12), a self-assessment screening tool that has been successfully used in Chinese samples (48, 49). The GHQ-12 is a unidimensional scale with 12 items on a 0–1 scale; each entry presents four options, with the first two responses scored as 0 and the last two scored as 1 point, with the total score ranging from 0 to 12 and a cut-off value of 3. A total score of 3 indicates a proclivity to develop a psychiatric disorder, while a score of less than 3 indicates normalcy. Higher total GHQ-12 scores are associated with lower levels of mental health. In this investigation, the Cronbach's α coefficient for this scale was 0.947.

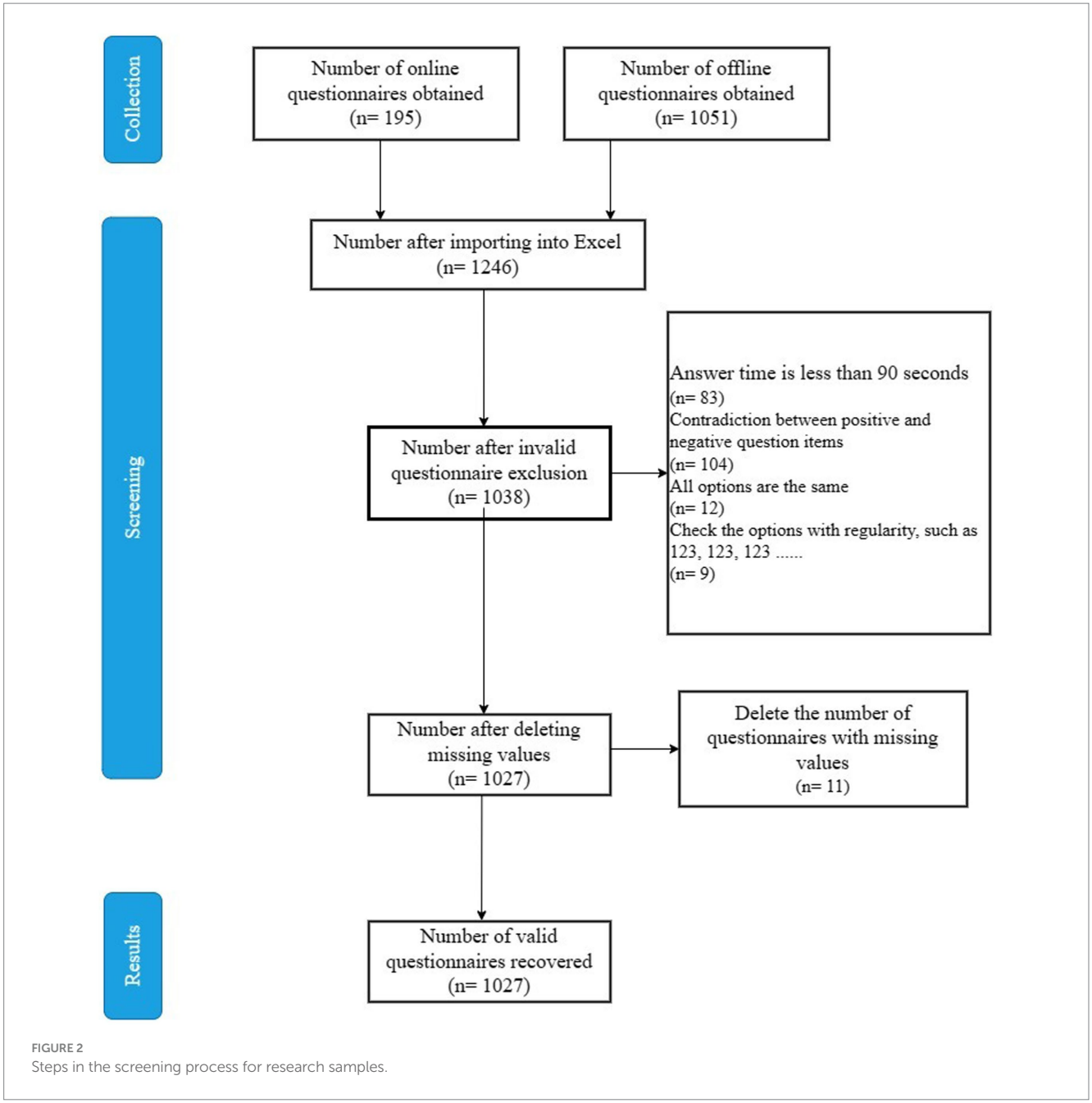

FIGURE 2
Steps in the screening process for research samples.

3.2.3 Social participation scale

The social participation index system constructed by Xiu-Ping Wei was used to assess the social participation level of the older people living alone (50, 51). It contains two dimensions of cultural organization activities and personal activities in family affairs and scored on a 5-point Likert scale, with "not participating" scored as 1, "not monthly, but sometimes" scored as 2, "not weekly, but at least once a month" scored as 3, "not daily, but at least once a month" scored as 4, and "not daily, but at least once a week" scored as 5; higher scores indicate higher levels of participation. In this study, the first 25% of the overall score of social participation was classified as high, the middle 50% as medium, and the final 25% as low. In this investigation, the Cronbach's α coefficient for this scale was 0.867.

3.2.4 Exercise environment scale

The exercise environment was measured using the revised exercise environment scale by Choe et al. (52), which is divided into four dimensions: walkability, safety, exercise equipment, and exercise center. The total score ranges from 0 to 4, and a higher score indicates a higher level of exercise environment. In this study, the first 25% of the overall score of exercise environment was classified as high, the middle 50% as medium, and the final 25% as low. The Cronbach's α coefficient for the scale in this study was 0.677.

3.2.5 Control variables

Since the mental health of urban older people living alone can be affected by personal and social factors, we used gender, age,

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education, monthly income, and marital status as control variables to reduce the risk of statistical bias.

3.2.6 Statistical analysis

First, we evaluated the valid questionnaire data with SPSS26.0. We employed AMOS 24.0 to validate the model, which was estimated using the great likelihood approach, Further, we examined the structural validity of the scale. To establish cluster validity, we conducted a confirmatory factor analysis (CFA) and utilized average variance extracted (AVE) and combination reliability (CR) to further examine the scale's reliability and validity.

Second, we adopted Pearson's correlation coefficient and other methods to analyze the linear associations of tai chi and ba duan jin with walking, social participation, and mental health status of urban older people living alone. Then, we validated the model using AMOS24.0 to verify the mediating role of social participation between tai chi, ba duan jin, walking, and mental health status. Moreover, we employed the Bootstrap method to test whether a mediating effect of social participation exists between tai chi, ba duan jin, walking, and mental health status of urban older people living alone. Currently, the Bootstrap technique is a popular way to test the mediating impact. This method entails repeating sampling from the original sample and determining whether or not the coefficient of the mediating effect is significant using a 95% confidence interval (53).

Finally, we utilized linear regression to examine the role of exercise environment in the association between tai chi, ba duan jin, and walking and the mental health status of urban older people living alone. In this study, we performed the three-step test of Hierarchical Moderated Regression (HMR) analysis and used the interaction terms of the variables to test for moderating effects. In more detail, we conducted the empirical test as follows, with SPSS 26.0 utilizd to statistically analyze tai chi, ba duan jin, and walking. Correlation analysis was utiliszd for first hypothesis testing based on testing for common method bias, followed by moderated model testing using linear regression analysis. Step by step, this model was separated into three linear regression models. As shown in Table 1, model 1 (M1) was fitted first, with gender, age, education, monthly income, and marital status as control variables and tai chi, ba duan jin, and walking scores as independent variables for regression fitting. Model 2 then added a moderating variable (exercise environment) on top of model 1. Model 3 finally added an interaction term (product term of the independent and the moderating variables) on top of model 2.

3.2.7 Validity testing

First, as shown in Figure 3, the absolute values of the standardized loading coefficients are all more than 0.6 and exhibit significance when each measurement relationship is examined; this shows that the measurement relationship is sound. Furthermore, as shown in Table 2, all AVE values for each factor are greater than 0.5, and all CR values for each factor are greater than 0.7; this implies that the data of this analysis have good aggregation (convergence) validity and thus good construct validity and consistency. Again, most of the model-fitting indicators of the validated factor analysis results in Table 3, χ^2/ df < 3, GFI > 0.9, RMSEA < 0.10, RMR < 0.05, CFI > 0.9, NFI > 0.9, TLI > 0.9, reach the standard, showing that the model fits well. As a result, the questionnaire in this research has a high level of internal reliability and validity.

4 Results

4.1 Sample situation analysis

This study collected a total of 1,027 valid questionnaires, as indicated in Table 4. The participants included 443 men (43.14%) and 584 women (56.86%), of whom the majority were between the ages of 60 and 64 (37.97%); most of them had an elementary school education or less (46.93%), were widowed, and had a monthly income ranging from 3,000 to 4,000 yuan.

In addition, older people living alone participated in tai chi (44.6%), ba duan jin (49.37%), and walking (44.99%) with less exercise; more older people living alone were found to have possible psychological problems (62.03%); 47.03% had a moderate level of social participation, and 75.37% were in a high level of exercise environment. Although the sample data cannot explicitly demonstrate the association between tai chi, ba duan jin, and walking and the mental health status of older adults living alone, they help readers and researchers thoroughly comprehend the sample's characteristics.

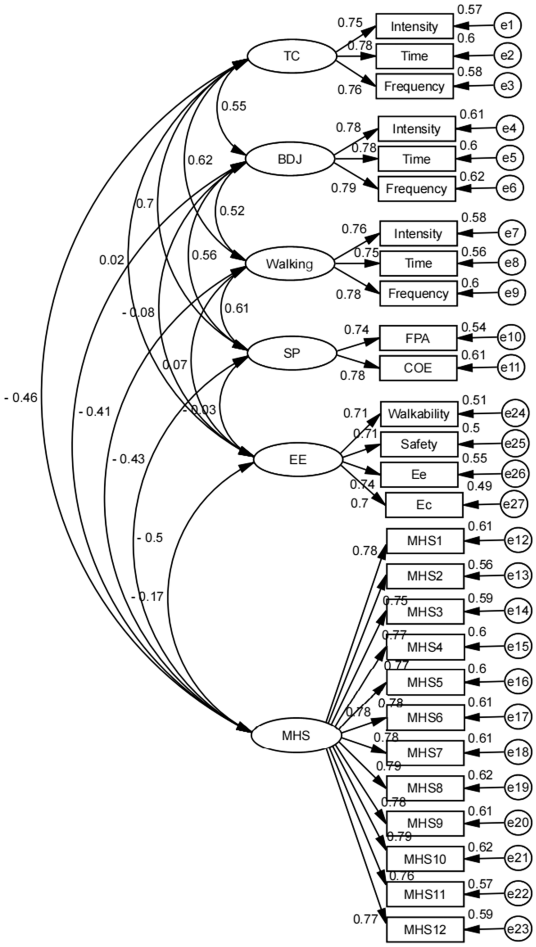

FIGURE 3
Validated factor analysis model diagram (TC, Tai Chi; BDJ, Ba Duan Jin; SP, Social Participation; EE, Exercise environment; MHS, Mental Health Status; FPA, Family Personal Activities; COE, Cultural Organization Events; Ee, Exercise equipment; Ec, Exercise center).

TABLE 1 Moderated effects test results ($n = 1,027$).

	Variable	Model 1			Model 2			Model 3		
		B	t	*p*	B	t	*p*	B	t	*p*
TC	Constant	2.327	15.536	0.000**	2.349	15.825	0.000**	2.329	16.011	0.000**
	TC	−0.35	−14.143	0.000**	−0.348	−14.23	0.000**	−0.28	−10.554	0.000**
	EE				−0.292	−5.215	0.000**	−0.377	−6.635	0.001**
	TC*EE							−0.396	−5.981	0.000**
	R^2	0.169			0.191			0.219		
	Adjusted R^2	0.162			0.183			0.21		
	F-value	$F(9, 1,017) = 23.062$, $p = 0.000$			$F(10, 1,016) = 24.011$, $p = 0.000$			$F(11, 1,015) = 25.827$, $p = 0.000$		
	△R^2	0.169			0.022			0.028		
	△F value	$F(9, 1,017) = 23.062$, $p = 0.000$			$F(1, 1,016) = 27.200$, $p = 0.000$			$F(1, 1,015) = 35.769$, $p = 0.000$		
BDJ	Constant	2.386	15.59	0.000**	2.409	16.021	0.000**	2.412	16.196	0.000**
	BDJ	−0.317	−12.382	0.000**	−0.327	−12.989	0.000**	−0.285	−10.741	0.000**
	EE				−0.354	−6.227	0.000**	−0.401	−7.008	0.000**
	BDJ*EE							−0.309	−4.544	0.000**
	R^2	0.136			0.168			0.185		
	Adjusted R^2	0.129			0.16			0.176		
	F-value	$F(9, 1,017) = 17.838$, $p = 0.000$			$F(10,1,016) = 20.528$, $p = 0.000$			$F(11, 1,015) = 20.900$, $p = 0.000$		
	△R^2	0.136			0.032			0.017		
	△F value	$F(9, 1,017) = 17.838$, $p = 0.000$			$F(1, 1,016) = 38.780$, $p = 0.000$			$F(1, 1,015) = 20.650$, $p = 0.000$		
W	Constant	2.301	15.15	0.000**	2.313	15.375	0.000**	2.302	15.521	0.000**
	W	−0.326	−12.86	0.000**	−0.319	−12.694	0.000**	−0.239	−8.318	0.000**
	EE				−0.263	−4.618	0.000**	−0.343	−5.902	0.004**
	W*EE							−0.393	−5.481	0.000**
	R^2	0.145			0.163			0.187		
	Adjusted R^2	0.138			0.154			0.178		
	F-value	$F(9, 1,017) = 19.189$, $p = 0.000$			$F(10, 1,016) = 19.747$, $p = 0.000$			$F(11, 1,015) = 21.196$, $p = 0.000$		
	△R^2	0.145			0.018			0.024		
	△F value	$F(9, 1,017) = 19.189$, $p = 0.000$			$F(1, 1,016) = 21.322$, $p = 0.000$			$F(1, 1,015) = 30.040$, $p = 0.000$		

Dependent variable, mental health status; * $p < 0.05$; ** $p < 0.01$; TC, Tai Chi; BDJ, Ba Duan Jin; W, Walking; SP, Social Participation; EE, Exercise Environment; MHS, Mental Health Status.

TABLE 2 Questionnaire reliability and validity tests.

Variable	CR	AVE
TC	0.809	0.585
BDJ	0.825	0.611
Walking	0.806	0.581
SP	0.731	0.576
EE	0.807	0.511
MHS	0.947	0.6

TC, Tai Chi; BDJ, Ba Duan Jin; SP, Social Participation; EE, Exercise environment; MHS, Mental Health Status.

4.2 Descriptive statistics and correlation analysis

Based on the descriptive statistics, Table 5 shows the mean, standard deviation, correlation coefficient of the main variables. A significant negative correlation existed between tai chi, ba duan jin, walking, and mental health status (TC: $r = -0.405$, $p < 0.01$; BDJ: $r = -0.361$, $p < 0.01$; Walking: $r = -0.373$, $p < 0.01$). A significant positive correlation existed between tai chi, ba duan jin, walking, and social participation (TC: $r = 0.529$, $p < 0.01$; BDJ: $r = 0.436$, $p < 0.01$; Walking: $r = 0.480$, $p < 0.01$), and a significant negative correlation was found between social participation and mental health status ($r = -0.420$, $p < 0.01$). Thus, H1 and H2 were initially supported.

4.3 Analysis of mediation effects

Initially, based on the mediated effect model fitting indices presented in Table 6 ($\chi^2/df < 3$, GFI > 0.9, RMSEA <0.10, RMR < 0.05, CFI > 0.9, NFI > 0.9, TLI > 0.9), most of the model-fitting indices met the required threshold, indicating a well-fitted mediated effect model affecting the mental health status of older people living alone. Figure 4 illustrates the significant negative correlation between tai chi, ba duan jin, and walking on the mental health status of older people living

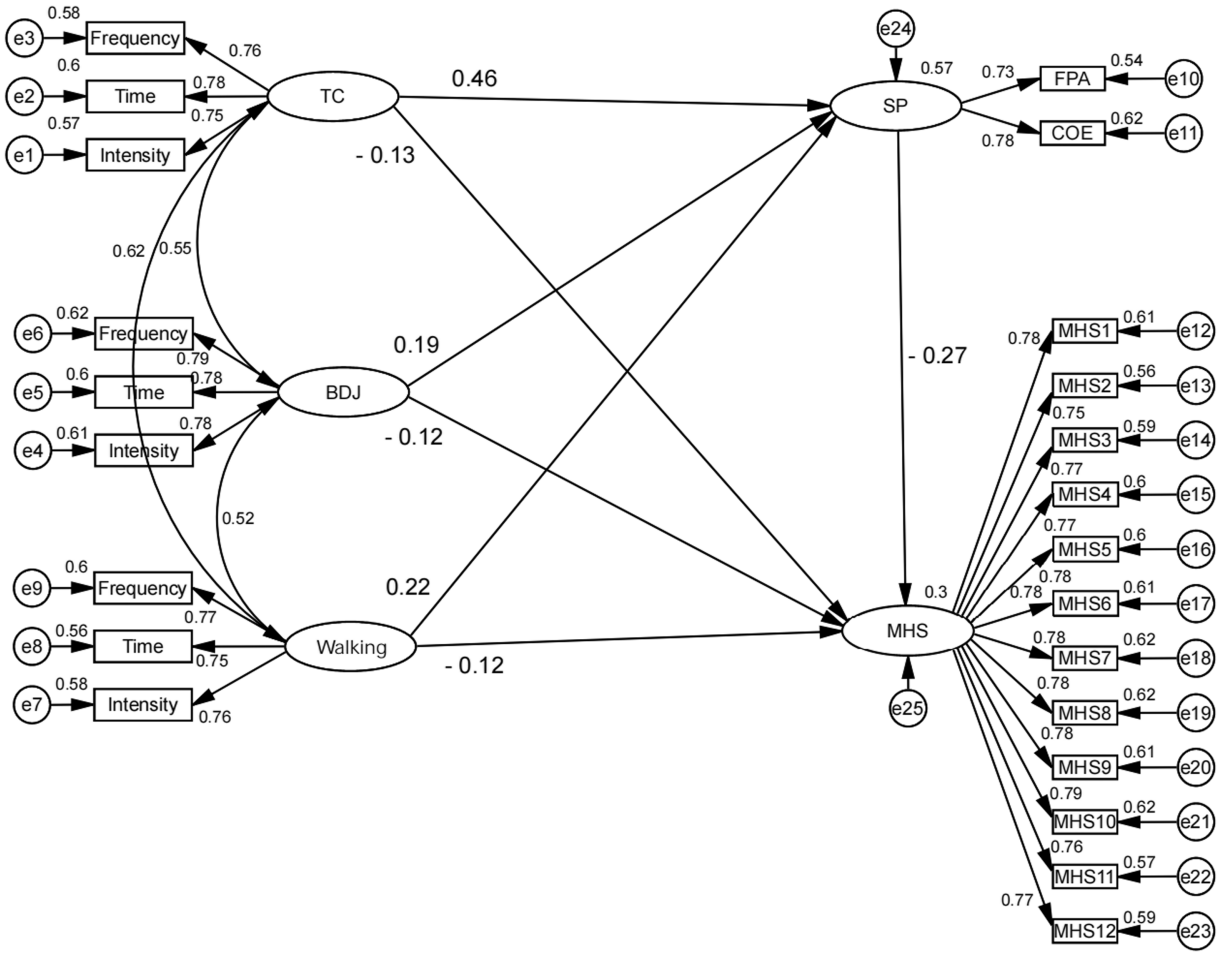

FIGURE 4
Structural equation modeling on the mediating role of social participation between tai chi, ba duan jin, walking, and mental health status (TC, Tai Chi; BDJ, Ba Duan Jin; SP, Social Participation; EE, Exercise environment; MHS, Mental Health Status; FPA, Family Personal Activities; COE, Cultural Organization Events; Ee, Exercise equipment; Ec, Exercise center).

TABLE 3 Questionnaire model fitting indicators.

	χ^2	*df*	χ^2/df	GFI	RMSEA	RMR	CFI	NFI	TLI
Model	480.774	309	1.556	0.968	0.023	0.019	0.988	0.968	0.987

GFI, goodness-of-fit index; RMSEA, root mean square error of approximation; RMR, root mean square error; CFI, comparative fit index; NFI, normed fit index; TLI, Tucker-Lewis index.

alone in the city. The path coefficients of tai chi, ba duan jin, and walking → mental health status (TC: $\beta = -0.13$; BDJ: $\beta = -0.12$; Walking: $\beta = -0.12$) are significant, indicating a direct effect of tai chi, ba duan jin, and walking on mental health status (Figure 4). The significant negative correlation suggests that tai chi exercise has a significant positive effect on the mental health condition of older adults living alone. H1 is valid because the question item indicates that tai chi from 1 to 5 indicates that the intensity ranges from weak to strong, and the mental health condition from 1 to 4 indicates that the mental health condition changes from good to bad. Furthermore, a mediating effect of social participation was observed between tai chi, ba duan jin, walking, and mental health status, as indicated by the path coefficients of tai chi, ba duan jin, walking → social participation (TC: $\beta = 0.46$; BDJ: $\beta = 0.19$; Walking: $\beta = 0.22$) and social participation → mental health condition ($\beta = -0.27$). We examined H2 in a preliminary manner.

The number of repeated samplings of the original sample must be at least 1,000 times in the Bootstrap mediated effects test (54), and if the Bootstrap mediated effects test result shows that the Bootstrap test CI does not contain a value of 0, the indirect effect is significant (55). In this study, we estimated the mediating effect Bootstrap95% CI using a sample of 5,000 times to investigate whether social participation mediated the association between tai chi, ba duan jin, walking, and mental health status. The findings are displayed in Table 7. The indirect effects of tai chi, ba duan jin, walking → social participation → mental health status were −0.123, −0.051, and −0.058, respectively, with Z-values of −3.324, −3.000, and −1.871, respectively. Moreover, the Bootstrap 95% CI generated

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TABLE 4 Demographic characteristics of the sample.

Variable	Frequency	Percentage
Gender		
Men	443	43.14
Women	584	56.86
Age		
60–64	390	37.97
65–69	248	24.15
70–74	191	18.6
75–79	105	10.22
≥80	93	9.06
Education level		
Primary and below	482	46.93
Middle School	348	33.89
High school and above	197	19.18
Marital status		
Unmarried	11	1.07
Separated	381	37.1
Divorced	184	17.92
Widowed	451	43.91
Income		
<3,000	219	21.32
3,000–4,000	423	41.19
4,000–5,000	290	28.24
>5,000	95	9.25
Tai Chi		
Mild exercise	458	44.6
Moderate exercise	277	26.97
Intense exercise	292	28.43
Ba Duan Jin		
Mild exercise	507	49.37
Moderate exercise	260	25.32
Intense exercise	260	25.32
Walking		
Mild exercise	462	44.99
Moderate exercise	274	26.68
Intense exercise	291	28.33
Mental health status		
No mental problems	390	37.97
Possible mental problems	637	62.03
Social participation		
Low level of social participation	272	26.48
Medium LEVEL of social participation	483	47.03
High social participation	272	26.48
Exercise environment		
Low exercise environment level	253	24.63
High exercise environment level	774	75.37

by this pathway did not contain 0: the 95% CI using the bias-corrected Bootstrap method yielded lower bounds of −0.212, −0.093, and −0.136 and upper bounds of −0.06, −0.023, and −0.011, respectively; and the 95% CI using the bias-corrected nonparametric percentile Bootstrap method yielded lower bounds of −0.203, −0.086, and −0.129, and the upper limits of −0.055, −0.019, and −0.008, respectively. This indicates that the mediating effect of social participation between tai chi, ba duan jin, walking, and mental health status was significant, with walking having the highest mediating effect; thus, H2 is valid. The direct effects of tai chi, ba duan jin, and walking → mental health status were −0.132, −0.125, and −0.119, respectively, and the z-values were −2.164, −3.378, and −2.245, respectively. The Bootstrap 95% confidence intervals generated by this pathway did not contain 0 for the direct indirect effects, and the total effects of tai chi, ba duan jin, and walking → mental health status were −0.255, −0.255, −0.255, and −0.255, respectively, −0.255, −0.176, −0.177, with Z-values of −5.426, −4.889, −3.933, respectively, and the Bootstrap 95% confidence intervals generated by this pathway did not contain 0. This indicates that the direct and total effects of tai chi, ba duan jin, and walking on mental health status were significant. In conclusion, since both the direct and indirect effects were significant, the three mediating effects of tai chi, ba duan jin, and walking were all partially mediated. Furthermore, the sequence of the effect sizes of tai chi, ba duan jin, and walking on the mental health status of older people living alone in the city is tai chi → walking → ba duan jin by comparing the size of the total effect value of these three activities on mental health status.

4.4 Analysis of moderation effects

Hypothesis H3 proposes that the higher the level of exercise environment, the higher the degree of influence of tai chi, ba duan jin, and walking on mental health status. For model 1, which aims to investigate the influence of the independent variables (tai chi, ba duan jin, and walking) on the dependent variable (mental health status) when the interference of the moderating variable (exercise environment) is not considered, Table 1 shows that tai chi, ba duan jin, and walking were significant (TC: $t = 14.143$, $p < 0.05$; BDJ: $t = -12.382$, $p < 0.05$; walking: $t = -12.86$, $p < 0.05$) and would thus have a significant effect relationship on mental health status, further validating Hypothesis H1. The test of the interaction between the effects of tai chi, ba duan jin, and walking and the exercise environment on mental health status (M2 & M3) found significant changes in F values from M2 to M3, with TC: F (10, 1,016) = 24.011, $p < 0.05 \rightarrow F$ (11, 1,015) = 25.827, $p < 0.05$; BDJ: F (10, 1,016) = 20.528, $p < 0.05 \rightarrow$ F (11, 1,015) = 20.900, $p < 0.05$; walking: F (10, 1,016) = 19.747, $p = 0.135 \rightarrow$ F (11, 1,015) = 21.196, $p < 0.05$. In addition, as shown in Table 1, the interaction terms of tai chi, ba duan jin, and walking with the exercise environment showed significance (TC: $t = -5.981$, $p < 0.05$; BDJ: $t = -4.544$, $p < 0.05$; walking: $t = -5.481$, $p < 0.05$). When affecting mental health status, the magnitude of the moderating variable (exercise environment) was significantly different at different levels.

To clearly present the moderating effect of exercise environment between tai chi, ba duan jin, walking, and mental health status, based on the method suggested by Aiken and West (56), the current study divided the mean (M) plus or minus one

TABLE 5 Descriptive statistics and correlation of variables.

Variable	M	S.D.	TC	BDJ	Walking	SP	EE	MHS
TC	31.094	25.009	0.765					
BDJ	29.321	24.841	0.451**	0.782				
Walking	31.109	24.712	0.497**	0.425**	0.762			
SP	26.848	5.847	0.529**	0.436**	0.480**	0.759		
EE	2.283	1.575	0.017	−0.068*	0.057	−0.027	0.715	
MHS	5.078	4.57	−0.405**	−0.361**	−0.373**	−0.420**	−0.151**	0.775

* $p < 0.05$; ** $p < 0.01$. M, Mean; S.D., Standard Deviation; TC, Tai Chi; BDJ, Ba Duan Jin; SP, Social Participation; EE, Exercise Environment; MHS, Mental Health Status.

TABLE 6 Model fit indices for the mediating effects of tai chi, ba duan jin, walking, social participation, and mental health status.

	χ^2	df	$\chi 2/df$	GFI	RMSEA	RMR	CFI	NFI	TLI
Model	393.054	220	1.787	0.969	0.028	0.022	0.987	0.971	0.985

GFI, goodness-of-fit index; RMSEA, root mean square error of approximation; RMR, root mean square error; CFI, comparative fit index; NFI, normed fit index; TLI, Tucker-Lewis index.

standard deviation (SD) of the exercise environment into high and low groupings and plotted the simple slope test graph (Figure 5). The test results revealed that the impacts of tai chi, ba duan jin, and walking on mental health status were stronger in high-exercise environments and weaker in low-exercise environments. This suggests that as the degree of exercise environment increases, the effect of tai chi, ba duan jin, and walking on the psychological health status of urban older people living alone improves, and hypothesis H3 is established.

5 Discussion

5.1 Tai chi, ba duan jin, walking, and mental health status of urban older adults living alone

This study aims to investigate the association between involvement in tai chi, ba duan jin, and walking and the mental health status of urban older adults living alone in China. According to the findings, most older adults living alone had poor levels of activity and psychological difficulties. Moreover, a substantial negative association was observed between tai chi, ba duan jin, walking, and mental health state, which was confirmed by correlation analysis. The result is consistent with previous findings indicating that the higher the degree of tai chi, ba duan jin, and walking among older people living alone, the lower the risk of psychological illnesses (57–59). The total effect values in Table 7 suggest that tai chi has the greatest impact on the mental health of older adults living alone. This could be because practicing tai chi allows practitioners to meditate and concentrate while avoiding distractions, and the abdominal breathing method utilized in tai chi is also good medicine for stress treatment. Studies have found that tai chi reduces anxiety and depression symptoms in practitioners and improves their mental health (60). A meta-analysis of 37 randomized controlled trials and five quantitatively lenient studies found that tai chi interventions improve various mental health indicators in different populations, including depression, anxiety, general stress management, and exercise self-efficacy (61). Another study discovered that frequent tai chi practice effectively reduces negative emotions (62) and boosts life satisfaction and wellbeing in older adults (20), improving their mental health even further. A clinical study showed that long-term walking and tai chi exercise can help middle-aged and older adults feel better emotionally, with particular benefits for depression (63). Walking has a clear impact on the release of negative emotions in older adults; this can raise hormone levels and make individuals feel less frustrated and less depressed, all of which lower the risk of mental issues (64). Regular practice of ba duan jin can also enhance mood, quality of life, and sleep among older people (65, 66). Regular practice of ba duan jin has been shown, in a randomized controlled experiment, to successfully manage tranquility and pleasantness, reduce anxiety, and improve the physical and mental health of older persons (67). As a result, the positive effects of tai chi, ba duan jin, and walking can also benefit the mental health status of urban older people living alone, confirming the research hypothesis that tai chi, ba duan jin, and walking are all differentially and negatively correlated with their mental health status.

5.2 The mediating effect of social participation

The study results confirmed H2, which indicates a significant mediating effect of social participation between tai chi, ba duan jin, walking, and the mental health status of urban older adults living alone. Tai chi interventions among older adults have been shown to increase social support and promote social participation (68), while higher levels of social participation are linked to lower levels of psychological disorders (69). In other words, social participation improves mental health, and engaging in social activities can consistently contribute to an individual's well-being in later life (70). In addition, among the direct effects of tai chi, ba duan jin, and walking on the mental health status of older adults people living alone, tai chi had the most significant effect, but of the indirect effects, walking produced the highest effect value, followed by ba duan jin. Walking has reduced exercise requirements, including its lower intensity and expense, could be the reason why older persons prefer to take part in such activities (71). Additionally, since older adults living alone spend

TABLE 7 Mediation effect test results.

Path		Estimate	Bootstrapping				SE	Z	STD. estimate
			Bias-corrected		Percentile				
			Lower	Upper	Lower	Upper			
Direct effect	TC → MHS	−0.128	−0.246	−0.007	−0.247	−0.007	0.061	−2.164	−0.132
	BDJ → MHS	−0.119	−0.189	−0.044	−0.19	−0.047	0.037	−3.378	−0.125
	Walking→MHS	−0.115	−0.212	−0.005	−0.212	−0.006	0.053	−2.245	−0.119
Indirect effect	TC → SP → MHS	−0.12	−0.212	−0.06	−0.203	−0.055	0.037	−3.324	−0.123
	BDJ → SP → MHS	−0.049	−0.093	−0.023	−0.086	−0.019	0.017	−3.000	−0.051
	Walking→SP → MHS	−0.057	−0.136	−0.011	−0.129	−0.008	0.031	−1.871	−0.058
Total effect	TC → MHS	−0.248	−0.343	−0.163	−0.34	−0.16	0.047	−5.426	−0.255
	BDJ → MHS	−0.167	−0.236	−0.096	−0.236	−0.097	0.036	−4.889	−0.176
	Walking→MHS	−0.172	−0.259	−0.084	−0.259	−0.083	0.045	−3.933	−0.177

TC, Tai Chi; BDJ, Ba Duan Jin; SP, Social Participation; EE, Exercise Environment; MHS, Mental Health Status.

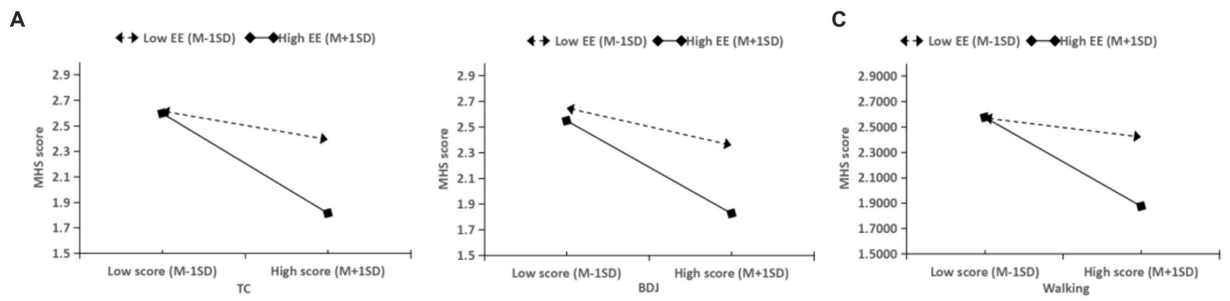

FIGURE 5
Moderating role of exercise environment between tai chi, ba duan jin, walking and mental health status. **(A)** Simple slope analysis of the moderating effect of exercise environment on the relationship between tai chi and mental health status; **(B)** simple slope analysis of the moderating effect of exercise environment on the relationship between ba duan jin and mental health status; **(C)** simple slope analysis of the moderating effect of exercise environment on the relationship between walking and mental health status.

the majority of their time on their own, the neighborhood recreational spaces such as community centers, shopping centers, and parks that they visit on a daily basis provide opportunities for walking (72), and walking to active places becomes an important physical exercise for them. Furthermore, studies have indicated that older people' social participation is more likely to be influenced by their ability to participate in physical activities including walking, jogging, and cycling in urban areas (73). According to Sun et al. (74), social participation improves older adults' mental health in both urban and rural areas. For example, it increases life satisfaction (75), decreases depression (76, 77), improves cognitive health, and lowers cognitive dysfunction in older adults (78). In a similar vein, boosting social participation levels and frequency of social encounters could help older persons with anxiety and depression by improving their mental health and quality of life (79). This viewpoint is further supported by this study's results. Tai chi, ba duan jin, and walking all affected the level of social participation of urban older adults living alone. Moreover, social participation has an effect on the mental health status of this group, and it also mediates the relationship between tai chi, ba duan jin, and walking and mental health status.

5.3 The moderating effect of the exercise environment

The study also sought to determine the exercise environment's moderating role in the relationship between tai chi, ba duan jin, and walking and mental health status; in other words, the effects of tai chi, ba duan jin, and walking on mental health status were strengthened when the level of the exercise environment was high. This shows that exercising in an area with a high degree of exercise environment can benefit older persons' mental health condition, which echoes the findings of earlier studies (80, 81). Research has found that with various walking paths in the exercise environment, older adults are more physically active (82), and factors such as accessibility to public spaces, proximity to amenities, the presence of parks near the community, and high levels of safety all positively influence older adults' physical exercise and health behaviors (83). Furthermore, Kim and Wu et al. indicated that exercising in green surroundings such as urban parks, walking greenways, and recreational equipment is more helpful to the mental health of older persons (84, 85). On one hand, walkable environments with pedestrian-supportive infrastructures, such as wooden benches for resting, safe vehicular access, nearby

amenities, and appropriate public transportation, can play a beneficial role in physical exercise, particularly for older adults living alone with limited mobility and functional limitations (86). On the other hand, exercising in high safety, walkability, good access to parks, and neighborhood environments make older adults feel more at ease and relaxed than in less favorable environments; thus, physical exercise in the latter environments has a better effect on older adults' mental health status (87, 88). This finding provides more evidence for the moderating impact of the exercise environment on the mental health of older adults living alone in urban areas.

5.4 Contributions

Firstly, based on earlier research, the impacts of tai chi, ba duan jin and walking on the mental health status of urban older adults living alone were investigated in greater depth by linking social participation, exercise environment, and mental health status. Secondly, this study found and verified the mediating relationship of social participation between tai chi, ba duanjin, and walking and the mental health of urban older adults living alone and provided reference suggestions for improving and enhancing the quality of their support system of social participation and mental health. In addition, the rest of the findings suggest a moderating effect of the exercise environment on the relationship between tai chi, ba duan jin, and walking and the mental health of urban older adults living alone. A better exercise environment has potential benefits of physical exercise, so it is a good choice for the communities to improve their unqualified exercise environments. Ultimately, this study provides directions and references for more mediating and moderating methods to enhance the mental health of urban older people living alone.

5.5 Limitations and future research directions

This study had limitations. Firstly, it only discussed three types of exercise— tai chi, ba duan jin, and walking—while disregarding other types of sports. Traditional Chinese sports such as six-character formula, five-animal exercise, yi jin jing, and tai chi sword may be studied in the future. Furthermore, we used the PARS-3 scale to assess the daily participation of older adults living alone in tai chi, ba duan jin, and walking in terms of the three dimensions of exercise intensity, time, and frequency; however, we did not assess other types of physical exercise. The International Physical Activity Questionnaire may be expanded in future research to include additional sports. Secondly, the Exercise Environment Scale employed in the study examined the exercise environments of senior individuals living alone in four dimensions, namely, walkability, safety, exercise equipment, and exercise facilities; however, it did not allow for a comparison of indoor and outdoor exercise environments. Future studies could expand on this basis by comparing indoor and outdoor workout conditions.

Finally, we used a cross-sectional study, which may not be able to infer causal relationships between variables as in other cross-sectional analysis studies. The study of tai chi, ba duan jin, and walking, and the mental health state of older adults living alone can be investigated in future research by a follow-up design and experimental research. In the meantime, the internal processes connecting the mental health condition of older single people and tai chi, ba duan jin, and walking are numerous; additional mediating and moderating variables, such as the community setting, social support, interpersonal relationships, and exercise modality, can be investigated. In addition, although this study set gender, age, education, monthly income, and marital status as control variables, control for covariates is lacking, which is a major limitation of this study. Future research should expand the model even more.

6 Conclusion

This study, distinctively, examined the links between tai chi, ba duan jin, walking, social participation, exercise environment, and mental health status in a sample of urban older Chinese people living alone. We observed a negative association between tai chi, ba duan jin, and walking and the mental health status of this group, with tai chi having the most influence. The relationship between mental health status and tai chi, ba duan jin, and walking was mediated by social participation, and the exercise environment could regulate the effects of tai chi, ba duan jin, and walking on mental health status. This study provides evidence to help clarify the association between tai chi, ba duan jin, and walking and the mental health condition of urban older adults living alone, which is essential to prevent mental issues in this group.

This study contends that the intervention role of social participation in the mental health status of urban older people living alone should be addressed, and that frequent tai chi, ba duan jin, and walking exercises can aid in mental health improvement. It is also critical to emphasize the importance of the exercise environment and to provide better exercise environment and conditioned facilities for older adults living alone to increase the attractiveness of the exercise environment to them, improve their level of physical exercise, and prevent the emergence of psychological problems.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the Chengdu Sport University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

BW: Conceptualization, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. GX: Methodology, Writing – original draft, Writing – review &

editing. PZ: Methodology, Writing – review & editing. XM: Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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EDITED BY
Guodong Zhang,
Southwest University, China

REVIEWED BY
Dalinda Isabel Sánchez-Vidaña,
Hong Kong Polytechnic University,
Hong Kong SAR, China
Krishna Dwivedi,
Swami Vivekananda Yoga Anusandhana
Samsthana, India

*CORRESPONDENCE
Raina Chhajer
✉ rainac@iimidr.ac.in

†These authors share first authorship

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Examining the impact of a restorative breath-based intervention "*Sudarshan Kriya Yoga*" at work: a field experiment

Raina Chhajer[1*†] and Chirag Dagar[2†]

[1]Humanities and Social Sciences Area, Indian Institute of Management, Indore, India, [2]XLRI - Xavier School of Management, Jamshedpur, India

Background: Human capital plays a crucial role in the success of an organization and further contributes to the broader goals of growth and development of society. In this regard, it is essential to ensure the well-being of employees at the workplace. Given the positive impact of yoga on psycho-physiological aspects of health, this study aims to examine the impact of a breath-based yogic intervention, *Sudarshan Kriya Yoga* (SKY), on stress, anxiety, thriving, general health, emotional well-being, social well-being, and psychological well-being among employees of a leading manufacturing firm in India.

Methods: Undertaking a randomized-control experiment design ($n = 64$), we examined the impact of SKY on stress, anxiety, thriving, general health, and emotional, social, and psychological well-being. Two certified instructors conducted the SKY intervention in a retreat format over 3 days.

Results: The analysis demonstrated positive outcomes across various aspects of participants' well-being, i.e., it significantly reduced their stress and anxiety and increased the levels of thriving, general health, and emotional, social, and psychological well-being. These findings are valuable for understanding the potential benefits of the SKY intervention.

Discussion: The findings provide support for considering SKY as a potential well-being intervention for employers at the workplace and society at large. Further exploration, implementation, and research in diverse contexts will be crucial to fully understand the long-term impact and scalability of the SKY intervention in promoting holistic well-being.

KEYWORDS

***Sudarshan Kriya Yoga* (SKY), breath-based interventions, workplace, stress, anxiety, well-being, health, thriving**

Introduction

Yoga is a holistic discipline and way of life originating from ancient India that promotes relaxation and a harmonious mental state and aims to integrate various aspects of an individual, including the physical, vital, mental, and spiritual dimensions (Nosaka and Okamura, 2015). Sage *Patanjali* described the yogic philosophy and practice in the classic text, *YogaSutras*, and outlined the eight-limbed path of yoga. The eight-limbed structure, i.e., *Ashtanga* yoga, comprises *yamas* (abstentions), *niyamas* (observances), *asanas* (postures),

praṇayama (control of breath), *pratyahara* (withdrawal of senses), *dharaṇa* (concentration), *dhyana* (meditation), and *samadhi* (oneness) (Novaes et al., 2020). Although people today identify yoga only with *asana*, denoting the physical practice of yoga, it represents one of the many tools aimed at self-transformation (Woodyard, 2011). Notably, in contemporary times, the common practice of yoga involves a combination of physical postures, breathing practices, and meditation (Collins, 1998).

The body of knowledge supporting the positive impact of yoga on health and well-being across diverse populations is expanding (see Evans et al., 2009; Hagen and Nayar, 2014; Park et al., 2015). Research indicates that yoga enhances positive emotions while reducing negative emotions (Narasimhan et al., 2011; Felver et al., 2015). Studies have also demonstrated that yoga helps mitigate stress (Gard et al., 2012; Rocha et al., 2012) and improve psychological states associated with high-stress levels, including excessive worry or anxiety (Li and Goldsmith, 2012) and mood (Streeter et al., 2010). In the context of the workplace comprising healthcare workers, employees at university, school principals, and employees, yoga has been found to be effective in decreasing stress, anxiety, depression, and insomnia and enhancing well-being (Van der Merwe and Parsotam, 2011; Nosaka and Okamura, 2015; Maddux et al., 2018; Cocchiara et al., 2019).

Praṇayama comprises the Sanskrit word *prana* (vital energy) and *ayama* (control). It involves a series of voluntary controlled breathing exercises that aim at manipulating the respiration activity, inhalation (*puraka*), retention (*kumbhaka*), exhalation (*rechaka*), and body locks (*bandhas*) (Novaes et al., 2020). Encompassing the breathing practices, which are intrinsic to *pranayama*, is the control and augmentation of breath, which is postulated as the bridge between the body and mind (Ankad et al., 2011). Sage *Patanjali* has ascribed *pranayama* with greater significance in *Ashtanga* yoga, even more than *asanas*, for keeping sound health (Sharma et al., 2013).

Pranayama techniques have demonstrated notable effects on both human physiology and psychology. The three processes of inhalation, retention, and exhalation can be either fast or slow, whereby research indicates that both fast and slow *pranayamas* are beneficial for sustained attention and the ability to shift attention and cardiac functions of the body (Udupa et al., 2003; Telles et al., 2008). The positive impact of *pranayama* on neurocognitive abilities has also been highlighted with enhanced performance on spatial and verbal memory tasks, auditory and visual reaction time, and other executive functions (Saoji et al., 2019). Research utilizing *pranayama* practices as interventions has highlighted a decrease in hypertension, respiratory rate, and stress levels, along with an increase in heart rate variability and the balance between sympathetic and parasympathetic nervous systems, among others (Peterson et al., 2017). Emerging research has also reported the efficacy of breathing practices in improving perceived stress, anxiety, negative affect, sleep, social connectedness, self-esteem, life esteem, and general well-being (Kamath et al., 2017; Novaes et al., 2020; Goldstein et al., 2022).

Extant literature indicates that mind–body interventions, including yoga and other meditation programs, render potential solutions in the form of tools and techniques to reduce stress and improve work-related outcomes such as greater productivity, reduced turnover, job satisfaction, and engagement at work (Jacobs and Blustein, 2008; Shiba et al., 2015; Axén and Follin, 2017). Importantly, owing to the vitality, creativity, and productivity it entails, the human capital of a society denotes an instrumental resource directly affecting the sustenance and development of businesses and impacting the growth, development, and social stability of nations (Hendricks, 2002; Wright and McMahan, 2011). However, in current work organizations, delivering extraordinary performance outcomes, always needing to be accessible, and working for long durations have become a norm (Von Bergen and Bressler, 2019). Literature indicates that higher individual initiatives are associated with higher work overload, job stress, and work–family conflicts, adversely impacting employee health, well-being, and performance (Bolino and Turnley, 2005). Consequently, work-related stress and burnout have been found to incur organizational costs, including decreased productivity, high employee turnover, and absenteeism (Garton, 2017; Hassard et al., 2018).

Given the adverse trickle-down effect of burnout and stress, implementing strength-oriented initiatives and targeting well-being has become imperative at the workplace. The World Health Organization (WHO) suggests that workplaces can be key to health promotion (Jia et al., 2018). As a result, to combat these challenges, organizations, including Google, Intel, and IBM, have introduced mindfulness, yoga, and breathing-based programs, such as "Search Inside Yourself," "Awake," and "Mindfulness," respectively, for their employees (Schaufenbuel, 2014, 2015; Gupta and Singh, 2019). Such programs in the workplace have seen significant growth wherein these have been deployed in the occupational setup and are not limited to addressing psychological concerns among employees but are being offered to the general workforce, and have shown positive results on outcomes such as distress, depression, burnout, health, job performance, compassion, empathy, and well-being (Lomas et al., 2019). In 2018, approximately 60% of mid-sized to large American companies disclosed that they provide their employees with access to courses in mindfulness, yoga, or meditation (Vonderlin et al., 2020). These include a broad array of sectors, including but not limited to technology firms (e.g., Microsoft and Apple), social media (e.g., Facebook and LinkedIn), industrial firms (e.g., Beiersdorf and Bosch), apparel and furniture (e.g., Nike and IKEA), financial and insurance service providers (e.g., Goldman Sachs), as well as political institutions. It has been found that these programs successfully alleviate stress, mitigate burnout, reduce mental distress and somatic complaints, and concurrently enhance mindfulness, well-being, and job satisfaction (Vonderlin et al., 2020).

Despite the growth in the study of *pranayama*, there still needs to be more understanding of the effectiveness of different breathing techniques (Novaes et al., 2020; Goldstein et al., 2022). While some organizations are adopting similar approaches, there is a need to implement more such mind–body-based restorative breathing interventions at work (Gupta and Singh, 2019). As a result, drawing on the body of knowledge representing yoga and *pranayama*, the current study looks at the breath-based intervention of SKY. SKY is a distinctive (rhythmic) yogic breathing technique designed and taught by the Art of Living Foundation, an international not-for-profit organization founded in 1981 by Sri Sri Ravi Shankar (Agte and Chiplonkar, 2008). This practice's gentle and distinct rhythm infuses each body cell with oxygen and *prana* (breath), eliminating both physical and emotional toxins (Pandya, 2014). Consistent practice contributes to the development of intuition, the sharpening of intellect, improved memory, heightened clarity, stress reduction, and the flourishing of creativity (Pandya, 2014).

Compelling evidence in the literature indicates that SKY is beneficial and offers a low-risk alternative practice for enhancing overall health and well-being (Sureka et al., 2014; Seppälä et al., 2020). Studies have demonstrated the significant positive effects of SKY concerning mental disorders, including post-traumatic stress disorder, depression, anxiety, and substance abuse among clinical populations (Zope and Zope, 2013; Seppälä et al., 2014). Additionally, SKY has been found to be effective in reducing anxiety, depression, and stress while increasing optimism among college students (Kjellgren et al., 2007). Emerging research from the workplace has also been affirming. In a sample from the border road organization, SKY was effective in stress regulation and consequently improved their workload tolerance capacity (Chandra et al., 2017). Furthermore, as a result of practicing SKY, healthcare professionals experienced a significant improvement in professional fulfillment, work exhaustion, and positivity (Kanchibhotla et al., 2022). Research conducted with participants from a technology, engineering, construction, and manufacturing organization reported stress reduction, increased life satisfaction, enhanced emotional stability, and improved emotional regulation among participants (Mulla and Vedamuthachar., 2014). Senior government officers reported similar positive impacts for better sleep quality, trauma reduction, cortisol regulation, and anger management (Kolhe, 2022).

While the literature supports the effectiveness of SKY in clinical populations (Zope and Zope, 2013), there is a need for additional research, especially in non-clinical contexts such as work organizations (Mulla and Vedamuthachar, 2014; Kolhe, 2022). Recognizing that the absence of psychological issues does not necessarily equate to optimal well-being (Keyes, 2007), through this study, we explore the effectiveness of a comprehensive breath-based SKY intervention and its ability to reduce stress and anxiety and enhance employees' well-being.

Stress at work is defined as "a situation wherein job-related factors interact with the worker to change his or her psychological and/or physiological conditions such that the person is forced to deviate from normal functioning" (Newman and Beehr, 1979). Research shows that job stress impairs employees' health, well-being, and performance (Kotteeswari and Sharief, 2014). Burnout is conceptualized in the context of stress at work as a consequence of being exposed to chronic work-related stressors (Hobfoll and Shirom, 2000). It is associated with job dissatisfaction, turnover intentions, and physical and emotional symptoms (Pines and Keinan, 2005).

Anxiety at work has been conceptualized as comprising of "(a) dispositional workplace anxiety, i.e., individual differences in levels of nervousness and tension about job performance, and (b) situational workplace anxiety, i.e., a transient emotional state of nervousness and tension about specific job performance episodes" (Cheng and McCarthy, 2018). Anxious individuals exhibit self-doubt and low confidence and find it challenging to manage untoward situations (Shell and Husman, 2008). Existing studies have essentially rendered a negative relationship between anxiety and performance, including selection tests (Proost et al., 2008) and job interviews (McCarthy and Goffin, 2004). Scholars point out that anxiety should be driven out for optimum functioning in organizations (Reio and Callahan, 2004).

Thriving at work involves two critical dimensions of psychological experience: vitality (affective) and learning (cognitive) (Spreitzer et al., 2005; Spreitzer and Porath, 2014). Thriving individuals have a joint experience of energy and a feeling of continuous improvement at work. Research indicates that energy management enables a thriving experience (Spreitzer and Porath, 2014).

Mental health holds an essential place in the occupational psychology literature. It is examined with respect to two perspectives. First, positive mental health encompasses behaviors, attitudes, and feelings associated with personal success and satisfaction. The second perspective denotes mental health as an absence of mental illness (Banks et al., 1980). In order to be comprehensive in measuring mental health, both views need adequate examination. The general health questionnaire (Goldberg and Williams, 1988) enables the measurement of common mental health problems and the detection of minor psychiatric morbidity (Jackson, 2007).

The concept of well-being has been examined from objective perspectives, such as financial resources, education, and environmental factors, as well as subjective viewpoints, including happiness and flourishing. While some theories focus on *hedonic* or high positive and low negative emotional aspects of well-being, others emphasize *eudaimonic* aspects (i.e., meaningfulness, purpose, and good life). In contrast, others blend *hedonic* and *eudaimonic* dimensions (Ryan and Deci, 2001). As per Keyes (2002), flourishing or high levels of well-being denote a state that is not merely an absence of illnesses but encompasses complete well-being accompanied by optimal functioning. We refer to this framework in the study, wherein well-being includes high emotional (positive affect and life satisfaction), social (positive social functioning), and psychological (*eudaimonic*) well-being.

This study delves into the significance of a breath-based intervention (SKY) that extends beyond the therapeutic effects and examines its potential and promise within the context of the workplace and organizations. The primary aim of the current study is to examine the impact of a three-day SKY intervention conducted in a retreat format on stress, anxiety, thriving, general health, emotional well-being, social well-being, and psychological well-being of employees from a leading manufacturing firm in India. We hypothesize that participants who complete the breath-based intervention (SKY) will likely report significantly higher levels of thriving and general health, as well as emotional, social, and psychological well-being while reporting significantly lower stress and anxiety levels.

Materials and methods

Participants

In our study, participants had to meet specific inclusion criteria to be eligible. These criteria included (a) being 18 years of age or older, (b) working a minimum of 30 h per week, (c) committing to the three-day duration of the intervention, (d) not currently undergoing any other form of psychological therapy with no plans to start such therapy during the study, (e) having no previous experience with SKY or mindfulness practices, and (f) reporting no severe health issues contraindicated by SKY. Individuals meeting these criteria were considered eligible and included in the study.

Using the software G-power 3 (Faul et al., 2007), we conducted a power analysis to determine the minimum number of participants needed for the mixed-design (within-between interaction) ANOVA analysis of the study. Based on earlier studies

highlighting small to large effects (Anderson et al., 1999; Kanchibhotla et al., 2022), the effect size was set at 0.25, alpha level at 0.05, and power of 0.95 (Cohen, 1992). Power analysis indicated a total sample size of 54 and a sample of 27 for each group was found to be sufficient.

Participants were recruited from a leading manufacturing firm in India in January 2023. Participants who worked in various departments of the organization in mid-level managerial positions were recruited via purposive sampling. Seventy one employees agreed to participate in this study. The 64 eligible participants based on the criteria mentioned earlier were randomly divided into two groups using a random number generator, with 33 employees assigned to the SKY group (SKY) and 31 to the control group (CTR). The mean age of the participants was 36 years, they were predominantly men (81.25%), and 46.87% had work experience of more than 10 years. All employees had completed graduation. Table 1 summarizes the sample characteristics, including gender, age, work experience, and education distributions. Figure 1 shows the flow chart of the experimental design of the study.

Procedure

The Institutional Review Board approved the study procedure (reference number IRB/02/2022-23/HSS). Online informed consent was obtained from the participants. Before obtaining informed consent, an initial rapport was established with the participants by conducting an online interaction session. Participants were clearly informed of the voluntary nature of their participation, and assurance was provided that all collected information would be utilized solely for research purposes. Additionally, it was emphasized that findings would be presented in an aggregate manner to safeguard individual confidentiality.

Participants received an information sheet and a consent form via email before the intervention, ensuring they were well-informed about the study's objectives and procedures. Following the data collection process, a rigorous coding procedure was implemented, with any identifiable information promptly removed to uphold participant confidentiality. These steps were undertaken to ensure a comprehensive and ethical consent process.

The participants completed the questionnaires online using Google Forms in the English language. The data collection was conducted with the help of a team from the organization's HR department external to the study, who were blinded to group assignments. The research assistant involved in data coding was also external to the study. While complete blinding of employees was challenging as they were from the same organization, explicit instructions were provided to participants to share SKY intervention content with their peers only after its conclusion.

Also, the SKY intervention was not conducted at the workplace or during their working hours. The SKY intervention was conducted at a remote location in a large hall with enough space for participants to practice yoga on the mat. These measures were implemented to minimize bias and enhance the study's internal validity to the extent possible given the context. Participants were asked to complete self-report measures twice: 1 week before (T1) and 1 week after (T2). The intervention was administered to the participants in the SKY group. Effects were evaluated at post-treatment. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

TABLE 1 Distribution of sample characteristics for SKY and control group.

Particulars	$n = 64$
Gender	
Female	12
Male	52
Age (years)	36 (1.5)
>30	14
31–40	31
<41	19
Work experience (years)	
>5	20
6–10	14
11–15	22
<16	8
Education	
Graduate	38
Masters	26

Intervention

Participants in the SKY group attended the APEX Programme offered by the Art of Living Foundation, an international non-profit organization founded by Sri Sri Ravi Shankar. Two certified facilitators with extensive experience conducting the SKY intervention conducted the intervention in English. The intervention spanned over 3 days with an overall engagement of 24 h in a retreat format. On all 3 days, participants were engaged for 3 h in the morning and 3 h in the afternoon. The participants practiced *yoga asanas*, *ujjayi pranayama*, SKY breathwork, and guided meditation every day (see Table 2, Brown and Gerbarg, 2005; Sloan and Kanchibhotla, 2023 for details). The intervention also included a discussion component. The control group did not receive any intervention. No incentives were provided to any study participant.

Measures

At pre-treatment and post-treatment, participants completed the following measures:

Stress at work

The Perceived Stress Scale, created by Cohen et al. (1983), is widely used to assess stress. In this study, four items of PSS were used. Sample items include, "*How often have you felt confident about your ability to handle your work-related problems?*." A five-point scale is used to score responses, where 0 signifies "never" and 4 indicates "very often," with higher scores equating to a higher stress level. The reliability calculated using Cronbach's α was 0.44 (T1) and 0.56 (T2) in the present study.

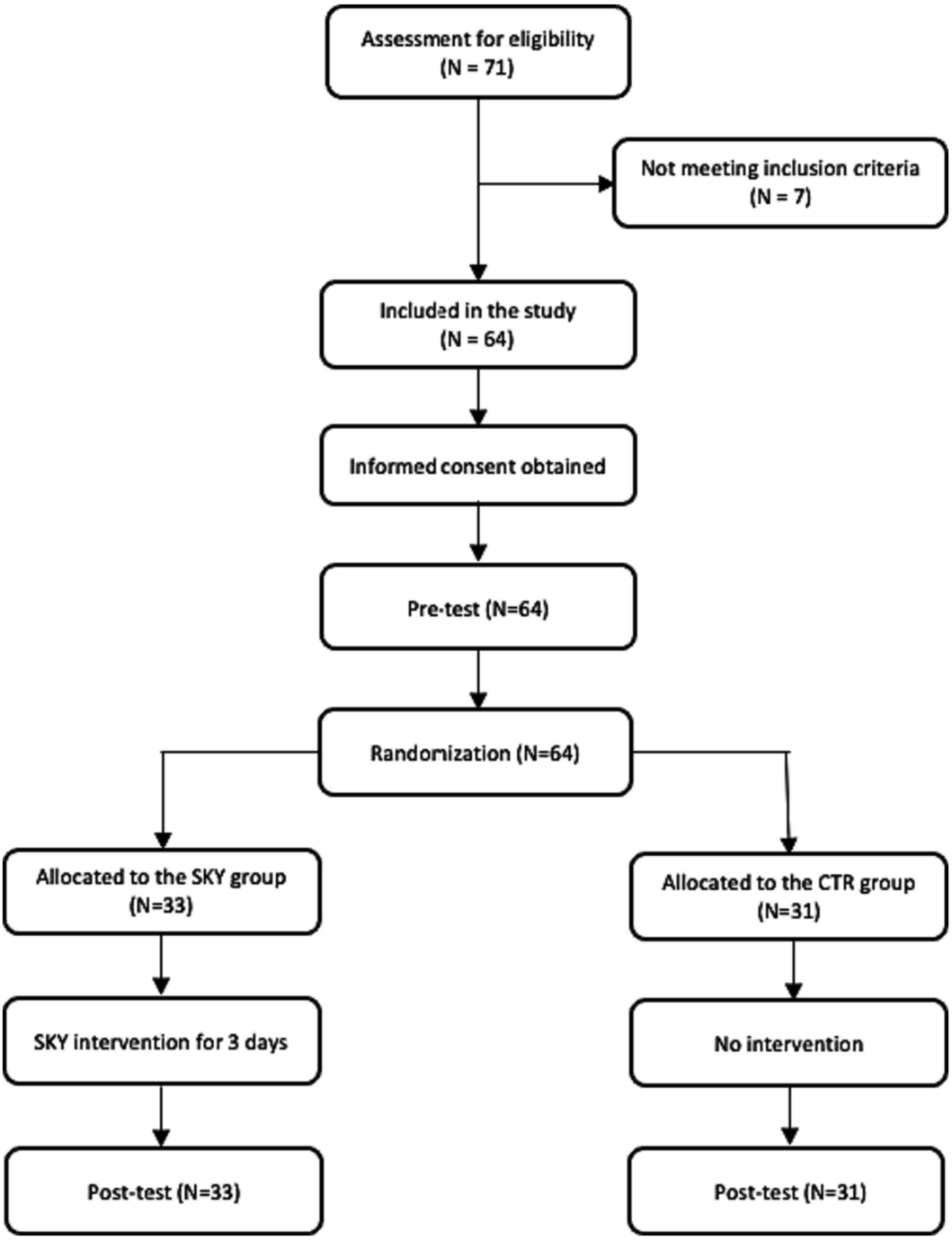

FIGURE 1
Flow chart showing the experimental design of the study.

Anxiety at work

We adopted seven items from the generalized anxiety scale developed by Spitzer et al. (2006). Respondents had to provide answers using a five-point Likert scale with the following categories: 1 (not at all) to 5 (extremely), with higher scores equating to a higher level of anxiety. The sample item includes, "*I am not being able to stop or control worrying*." The reliability calculated using Cronbach's α of anxiety measure was 0.74 (T1) and 0.77 (T2).

Thriving at work

We adopted the 10-item thriving at work scale developed by Porath et al. (2012). Respondents had to provide answers using a seven-point Likert scale with the following categories: 1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = neutral, 5 = somewhat agree, 6 = agree, and 7 = strongly agree. The sample item includes, "*I feel alive and alert*." The total score is obtained by summing the scores across all 10 items, with higher scores indicating greater thriving. The

TABLE 2 Overview of the SKY breathwork practice.

S. No.	Component	Content	Practice
1	*Ujjayi Pranayama*	**Victorious Breath** *Experiencing the conscious sensation of the breath touching the throat*	- 2–4 breaths per minute (bpm) - 10 breath cycles followed by 20 s rest
2	*Bhastrika Pranayama*	**Bellows Breath** *Rapid inhalation and forceful exhalation*	- 15–20 bpm - Three rounds followed by 20-s rest
3	*Om* Chanting	*Chanting with long expirations*	- 3 times - Followed by 15 s rest
4	*Sudarshan Kriya*	**Correct Vision via Purifying Activity** *Rhythmic, cyclical breathing involving slow, medium, and fast breathing cycles*	- Slow (20 bpm), medium (40–50 bpm), and fast (60–80 bpm) - 3 repetitions of 20 slow, 40 medium, 40 rapid cycles - End with 8–10 slow cycles and 5 min supine rest

reliability calculated using Cronbach's α of thriving at work measure was 0.86 (T1) and 0.87 (T2).

General health

We adopted 12 items from the general health questionnaire (GHQ-12) developed by Goldberg and Williams (1988). Respondents had to answer using a five-point Likert scale with the following categories: 0 (never) to 5 (very often). The sample item includes, "*I am able to concentrate.*" The total score is obtained by summing the scores across all 12 items, with higher scores indicating greater general health levels. The reliability calculated using Cronbach's α of general health measure was 0.84 (T1) and 0.85 (T2).

Emotional well-being

We adopted three items from the MHC-SF scale developed by Keyes (2016) to measure emotional well-being. Respondents had to provide answers using a five-point Likert scale with the following categories: 0 (never) to 5 (every day), with higher scores equating to a higher level of emotional well-being. The sample item includes, "*I am happy at work.*" The reliability calculated using Cronbach's α of emotional well-being measure was 0.77 (T1) and 0.75 (T2).

Social well-being

We adopted five items from the MHC-SF scale developed by Keyes (2016) to measure social well-being. Respondents had to provide answers using a five-point Likert scale with the following categories: 0 (never) to 5 (every day), with higher scores equating to a higher level of social well-being. The sample item includes "*That you belong to the organization.*" The reliability calculated using Cronbach's α of social well-being measure was 0.79 (T1) and 0.77 (T2).

Psychological well-being

We adopted six items from the MHC-SF scale developed by Keyes (2016) to measure psychological well-being. Respondents had to provide answers using a five-point Likert scale with the following categories: 0 (never) to 5 (every day), with higher scores equating to a higher level of psychological well-being. The sample item includes, "*That you like most parts of your personality.*" The reliability calculated using Cronbach's α of psychological well-being measure was 0.77 (T1) and 0.75 (T2).

Statistical analysis

To compare the differences in variables from pre- to post-intervention among the two groups, mixed-design analysis of variance (ANOVA) was employed to assess the interaction between the two factors, i.e., across time and group (Seltman, 2012; Anderson et al., 2016). Additionally, within-group analysis was conducted via repeated-measures ANOVA to test for the main effects of time (change from pre to post) on both SKY and CTR groups. We also conducted a between-group analysis based on an independent *t*-test to assess the difference between the two groups. Correlation analysis among the seven study variables was also conducted. All analyses were performed using SPSS Version 27 software, with the significance level set at 95%. The effect size was estimated as partial eta squared (partial η^2) for all ANOVA-based tests, while Cohen's *d* was estimated for the independent *t*-test. As suggested by Cohen (1988), effect sizes were considered Cohen's $d = 0.20$ as small, Cohen's $d = 0.50$ as medium, and Cohen's $d = 0.80$ as large.

Results

Descriptive statistics, including means and standard deviations for all measures for SKY and CTR groups at the two time points, are presented in Table 3. A baseline comparison of the two groups for all study measures was performed. The between-group analysis based on an independent *t*-test indicated a non-significant difference between the groups at pre-test stage for stress at work [$t\ (62) = 0.031$, $p = 0.975$, Cohen's $d = 0.02$], anxiety at work [$t\ (62) = -0.811$, $p = 0.420$, Cohen's $d = 0.21$], thriving at work [$t\ (62) = 0.550$, $p = 0.584$, Cohen's $d = 0.13$], general health [$t\ (62) = 0.411$, $p = 0.682$, Cohen's $d = 0.09$], emotional well-being [$t\ (62) = 0.499$, $p = 0.620$, Cohen's $d = 0.12$], and psychological well-being [$t\ (62) = 1.402$, $p = 0.166$, Cohen's $d = 0.35$]. However, there was a significant difference between the two groups at pre-test stage for social well-being [$t\ (62) = 2.489$, $p = 0.016$, Cohen's $d = 0.62$]. Correlations among study variables are presented in Tables 4, 5.

Stress at work

Mixed-design ANOVA revealed a significant time by group interaction, $F(1, 62) = 8.533$, $p = 0.005$, partial $\eta^2 = 0.12$. The

TABLE 3 Pre-test and post-test mean scores of both groups on all measures.

	SKY group (n = 33)		Control group (n = 31)	
Measures	Pre-test Mean (SD)	Post-test Mean (SD)	Pre-test Mean (SD)	Post-test Mean (SD)
Thriving	5.42 (0.79)	6.14 (0.65)	5.51 (0.42)	5.48 (0.42)
Emotional well-being	4.12 (0.35)	4.63 (0.64)	4.18 (0.60)	4.29 (0.64)
Social well-being	4.07 (0.16)	4.65 (0.33)	4.32 (0.57)	4.35 (0.54)
Psychological well-being	4.15 (0.28)	4.56 (0.32)	4.30 (0.53)	4.32 (0.47)
General Health	3.55 (0.47)	3.98 (0.42)	3.59 (0.48)	3.55 (0.56)
Anxiety	2.23 (0.91)	1.59 (0.37)	2.08 (0.49)	2.14 (0.53)
Stress	1.83 (0.67)	1.32 (0.61)	1.83 (0.58)	1.78 (0.53)

TABLE 4 Correlations among all study variables at T1.

	1	2	3	4	5	6	7
1. Thriving	1						
2. Emotional well-being	0.52*	1					
3. Social well-being	0.50*	0.62**	1				
4. Psychological well-being	0.62*	0.61**	0.54**	1			
5. General health	0.50*	0.31*	0.36**	0.37**	1		
6. Anxiety	−0.28*	−0.19*	−0.22*	−0.19*	−0.46**	1	
7. Stress	−0.15*	−0.26*	−0.20*	−0.15*	−0.45**	−0.23**	1

$N = 64$; $^{**}p \leq 0.001$, $^{*}p < 0.05$.

TABLE 5 Correlations among all study variables at T2.

	1	2	3	4	5	6	7
1. Thriving	1						
2. Emotional well-being	0.53*	1					
3. Social well-being	0.49*	0.64**	1				
4. Psychological well-being	0.63*	0.65**	0.56**	1			
5. General health	0.50*	0.32*	0.35**	0.38**	1		
6. Anxiety	−0.30*	−0.19*	−0.23*	−0.21*	−0.45**	1	
7. Stress	−0.18*	−0.27*	−0.21*	−0.16*	−0.46**	−0.28**	1

$N = 64$; $^{**}p \leq 0.001$, $^{*}p < 0.05$.

results indicate that participants' levels of stress differed significantly across the two-time points (at pre and post). There was a significant difference in stress of the two groups (SKY vs. CTR). The results of within-group analysis via repeated measures ANOVA revealed a significant change in the SKY group from the pre- to post-test, $F(1, 32) = 18.846$, $p = 0.000$, and partial $\eta^2 = 0.37$. For the CTR group, there was a non-significant change, $F(1, 30) = 0.217$, $p = 0.645$, and partial $\eta^2 = 0.007$. The between-group analysis based on an independent t-test indicated a statistically significant difference at the post-test stage [t (62) = 3.246, $p = 0.002$, and Cohen's $d = 0.80$]. Figure 2 suggests that the SKY group decreased stress across the two time points. In contrast, the CTR group did not significantly change from pre to post time point.

Anxiety at work

Mixed-design ANOVA revealed a significant time by group interaction, $F(1, 62) = 21.014$, $p = 0.000$, and partial $\eta^2 = 0.25$. The results indicate that participants' anxiety levels differed significantly across the two time points (at pre and post). There was a significant difference in anxiety between the two groups (SKY vs. CTR). The results of within-group analysis via repeated measures ANOVA revealed a significant change in the SKY group from the pre to post-test, $F(1, 32) = 21.775$, $p = 0.000$, and partial $\eta^2 = 0.41$. For the CTR group, there was a non-significant change, $F(1, 30) = 1.013$, $p = 0.322$, and partial $\eta^2 = 0.033$. The between-group analysis based on an independent t-test indicated a statistically significant difference at the post-test stage [t (62) = 4.876, $p = 0.000$, and Cohen's $d = 1.20$]. Figure 3

suggests that the SKY group showed a decrease in anxiety across the two time points, whereas the CTR group did not show a significant change from the pre to post time point.

Thriving at work

Mixed-design ANOVA revealed a significant time by group interaction, $F(1, 62) = 15.150$, $p < 0.000$, and partial $\eta^2 = 0.20$. The results indicate that participants' thriving levels differed significantly across the two time points (at pre and post). There was a significant difference in the thriving of the two groups (SKY vs. CTR). The results of within-group analysis via repeated measures ANOVA revealed a significant change in the SKY group from the pre to post-test, $F(1, 32) = 16.997$, $p = 0.000$, and partial $\eta^2 = 0.35$. For the CTR group, there was a non-significant change, $F(1, 30) = 0.122$, $p = 0.729$, and partial $\eta^2 = 0.004$. The between-group analysis based on an independent t-test indicated a statistically significant difference at the post-test stage [$t(62) = -4.596$, $p = 0.000$, and Cohen's $d = 1.17$]. Figure 4 suggests that the SKY group showed a steady increase in thriving across the two time points, whereas the CTR group did not show a significant change from pre to post time point.

General health

Mixed-design ANOVA revealed a significant time by group interaction, $F(1, 62) = 17.803$, $p = 0.000$, and partial $\eta^2 = 0.22$. The results indicate that participants' general health levels differed significantly across the two time points (at pre and post). There was a significant difference in the general health of the two groups (SKY vs. CTR). The results of within-group analysis via repeated measures ANOVA revealed a significant change in the SKY group from the pre to post-test, $F(1, 32) = 35.757$, $p = 0.000$, and partial $\eta^2 = 0.53$. For the CTR group, there was a non-significant change, $F(1, 30) = 0.248$, $p = 0.622$, and partial $\eta^2 = 0.008$. The between-group analysis based on an independent t-test indicated a statistically significant difference at the post-test stage [$t(62) = -3.440$, $p = 0.001$, and Cohen's $d = 0.86$]. Figure 5 suggests that the SKY group showed a steady increase in general health across the two time points. In contrast, the CTR group did not show a significant change from pre to post time point.

Emotional well-being

Mixed-design ANOVA revealed a significant time by group interaction, $F(1, 62) = 9.458$, $p = 0.003$, partial $\eta^2 = 0.13$. The results indicate that participants' emotional well-being levels differed significantly across the two time points (at pre and post). There was a significant difference in the emotional well-being of the two groups (SKY vs. CTR). The results of within-group analysis via repeated measures ANOVA revealed a significant change in the SKY group from the pre to post-test, $F(1, 32) = 26.865$, $p = 0.000$, and partial $\eta^2 = 0.46$. For the CTR group, there was a non-significant change, $F(1, 30) = 1.662$, $p = 0.207$, and partial $\eta^2 = 0.052$. The between-group analysis based on an independent t-test indicated a statistically significant difference at the post-test stage [$t(62) = -2.553$, $p = 0.013$, and Cohen's $d = 0.64$]. Figure 6 suggests that the SKY group showed a

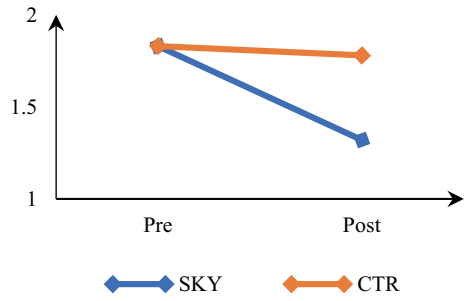

FIGURE 2
Pre-post comparison of stress.

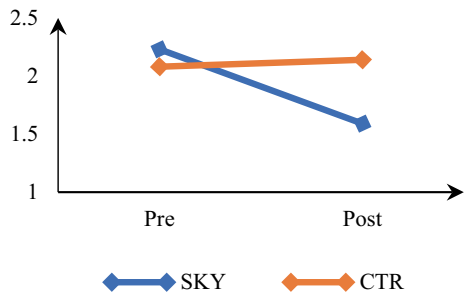

FIGURE 3
Pre-post comparision of anxiety.

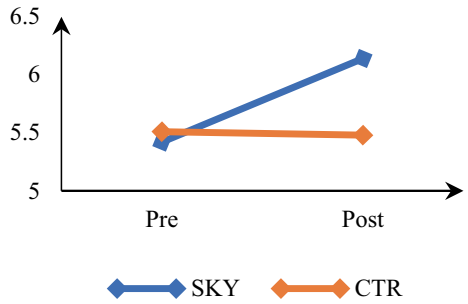

FIGURE 4
Pre-post comparision of thriving.

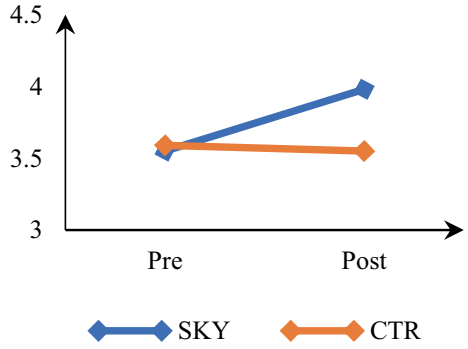

FIGURE 5
Pre-post comparision of general health.

steady increase in emotional well-being across the two time points, whereas the CTR group did not show a significant change from pre to post time point.

Social well-being

Mixed-design ANOVA revealed a significant time by group interaction, $F(1, 62) = 33.010$, $p = 0.000$, and partial $\eta^2 = 0.35$. The results indicate that participants' social well-being levels differed significantly across the two time points (at pre and post). There was a significant difference in social well-being of the two groups (SKY vs. CTR). The results of within-group analysis via repeated measures ANOVA revealed a significant change in the SKY group from the pre to post-test, $F(1, 32) = 100.000$, $p = 0.000$, and partial $\eta^2 = 0.76$. For the CTR group, there was a non-significant change, $F(1, 30) = 0.111$, $p = 0.741$, partial $\eta^2 = 0.004$. The between-group analysis based on an independent t-test indicated a statistically significant difference at the post-test stage [t (62) = −2.645, $p = 0.010$, and Cohen's $d = 0.65$]. Figure 7 suggests that the SKY group showed a steady increase in social well-being across the two time points, whereas the CTR group did not show a significant change from pre to post time point.

Psychological well-being

Mixed-design ANOVA revealed a significant time by group interaction, $F(1, 62) = 10.945$, $p = 0.002$, and partial $\eta^2 = 0.15$. The results indicate that participants' psychological well-being levels differed significantly across the two time points (at pre and post). There was a significant difference in the psychological well-being of the two groups (SKY vs. CTR). The results of within-group analysis via repeated measures ANOVA revealed a significant change in the SKY group from the pre to post-test, $F(1, 32) = 27.321$, $p = 0.000$, and partial $\eta^2 = 0.46$. For the CTR group, there was a non-significant change, $F(1, 30) = 0.059$, $p = 0.809$, and partial $\eta^2 = 0.002$. The between-group analysis based on an independent t-test indicated a statistically significant difference at the post-test stage [t (62) = −2.435, $p = 0.018$, and Cohen's $d = 0.59$]. Figure 8 suggests that the SKY group showed a steady increase in psychological well-being across the two time points, whereas the CTR group did not show a significant change from pre to post time point.

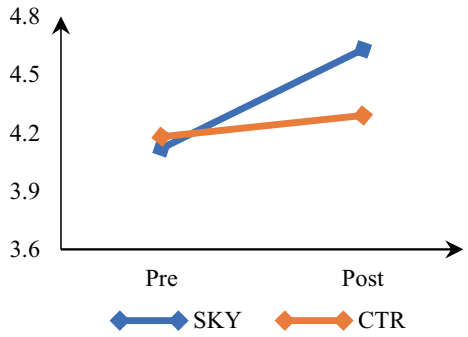

FIGURE 6
Pre-post comparision of emotional well-being.

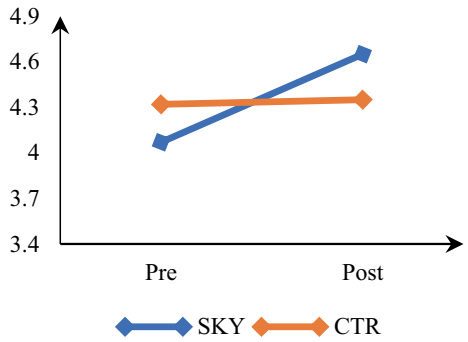

FIGURE 7
Pre-post comparision of social well-being.

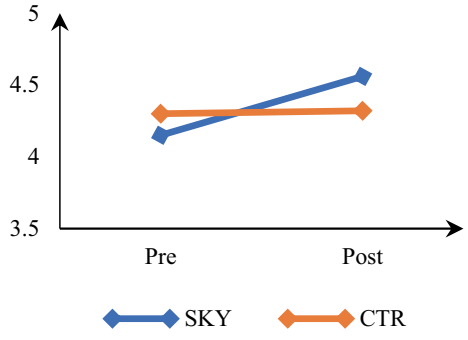

FIGURE 8
Pre-post comparision of psychological well-being.

Discussion

The study evaluated the effect of SKY intervention in alleviating stress and anxiety while promoting well-being among employees in a leading manufacturing firm. We employed a randomized-control group design. The overall results indicated that SKY had a significant effect on both negative and positive outcomes, i.e., there was a significant decline in stress and anxiety at work while a significant improvement in thriving at work, general health, emotional, social, and psychological well-being for the intervention group compared to the control group.

These findings are congruent with previous research highlighting the salubrious impact of SKY. In a sample of university students and employing a randomized controlled trial, Seppälä et al. (2020) reported that compared to the control, emotional intelligence, and mindfulness groups, SKY rendered greater benefits on the outcomes of depression, stress, mental health, positive affect, mindfulness, and social connectedness. In their study adopting convenience sampling and comparable groups, Sloan and Kanchibhotla (2023) noted that daily SKY practice was likely associated with being happier. They also reported a possible dose–response linkage of an increased frequency of SKY practice and happiness. The results of our study also concur with the prior studies that have examined the impact of SKY in the workplace. In a field experiment with a randomized wait-list control

design, Mulla and Vedamuthachar (2014) found that SKY intervention significantly reduced stress and blood cortisol levels and improved life satisfaction and emotional stability in a sample of executives working at L&T (a technology, engineering, construction, and manufacturing company). Notably, breath regulation has been linked to effective neuro-cognitive function (Nakamura et al., 2018). Breathing techniques further enhance cognitive functioning and psychological flexibility related to emotional control and psychological well-being (Zaccaro et al., 2018).

In the present study, given the focus on assessing the efficacy of SKY intervention for employees' well-being, we did not delve into determining the mechanisms of action underlying SKY. However, existing research on yogic and *pranayama* techniques provides insights into potential mechanisms. For instance, despite being a conscious process, diaphragmatic breath control unconsciously influences parasympathetic activation and conditions the autonomic nervous system, promoting a state of calmness and alertness (Jerath et al., 2006; Gard et al., 2014). The specific psychological mechanisms associated with yogic practices, including positive affect, mindfulness, self-awareness, interoceptive awareness, and self-compassion, are potential factors that could elucidate the impact of SKY on well-being and warrant further investigation (Park et al., 2021).

The current study contributes to research focusing on workplace well-being interventions. In specific ways, the findings lend support to the adoption of mind–body interventions such as yoga, meditation, and mindfulness as part of worksite stress management and wellness programs for desirable effects at the workplace (Wolever et al., 2012; Lomas et al., 2019; Kanchibhotla et al., 2022). The study reports parallel results, including stress reduction and improvements in mood, resilience, and psychological well-being (McCraty et al., 2003; Hartfiel et al., 2011).

Although the research on mindfulness-based interventions and the efficacy of physical activity programs in improving well-being across office-based workplace settings has grown (Abdin et al., 2018; Vonderlin et al., 2020), fewer studies have focused on the other mind–body-oriented approaches. Moreover, among these studies, the primary focus has been on reducing the adverse outcomes (e.g., coping with stress, anxiety management, and burnout) instead of positive outcomes (e.g., well-being and flourishing) (De Bruin et al., 2017; Cocchiara et al., 2019). This study addresses this concern by examining the impact of SKY on general health and holistic well-being. The current research also renders evidence that a breath-based SKY intervention is feasible to conduct in the workplace. Based on an organization's schedule, commitments, and resources, SKY intervention can be delivered as a long-term, focused workshop or session-based program via in-person or online modes.

Limitations

This study has certain limitations. Although the study had a small sample size and self-reporting, entailing the issues of demand characteristics, the findings are relevant for indicating the positive effects of SKY on psychological outcomes. Due to time and budget constraints, we could execute our field experiment at a single manufacturing firm, which limits the generalizability of findings to other sectors like information technology or finance. To address this limitation, future research may recruit participants from different firms to measure contextual variation among employees across different sectors.

Another limitation pertains to assessing the longitudinal impact and sustainability of the intervention since we collected data only before and after the SKY intervention. Future studies may include weekly practice sessions and data collection could be done again after a month or 3 months. This might provide further insights into the long-term effectiveness of SKY intervention on employees' overall well-being.

Although we have rendered evidence supporting the efficacy of SKY in enhancing employees' general health and well-being, the study did not explore the underlying mechanisms of action. Future research can examine the mediating variables through which SKY offers positive results. Furthermore, research may include physiological variables like blood pressure (BP), heart rate variability (HRV), or blood cortisol levels to measure the changes the breath-based intervention could have on the participants beyond the self-reported general health survey.

Recommendations for future research

Unfortunately, due to constraints such as the unavailability of resources and permissions from authorities, the current study did not incorporate follow-up assessments beyond the immediate post-intervention period (T2). This limitation is duly acknowledged, and we recognize the importance of longitudinal studies to assess the longer-term effects of interventions. In the future, we aspire to conduct longitudinal studies to provide a more comprehensive understanding of the sustained impact of the interventions over time.

Future research could be enhanced by incorporating observer-reported measures or objective outcomes to provide a more comprehensive understanding of participants' well-being and behaviors. Triangulating participants' responses by gathering data on their attitudes from supervisors or peers could further enrich the study. Additionally, exploring employee performance as an objective measure in future studies could contribute valuable insights to overall well-being assessment.

Recognizing the importance of addressing potential confounding variables, we have acknowledged this as a study limitation and proposed it as part of our future research agenda. To strengthen the validity of the study, we recommend incorporating control measures, such as monitoring any health risks, high levels of blood pressure, diabetes, or heart issues, as well as tracking the consumption of any substances like alcohol or cigarettes. These additional controls could assist in identifying and accounting for potential confounding factors that might influence the outcomes of the intervention.

In the present study, a non-active control group was employed; however, we acknowledge the potential for improvement by considering including an active control group in future research. This could involve allocating participants to engage in a non-similar activity, such as diary writing, to discern the specific effects of the interventions better. We have acknowledged this limitation in the discussion section, recognizing the value of incorporating an active control group to enhance the overall rigor of the research design in subsequent studies.

Conclusion

The therapeutic impact of yoga and SKY has explicitly been widely documented. However, in this study, we examined and indicated that the practice of rhythmic breath-based SKY intervention goes beyond the deficit-based approach of managing psychological issues of stress and anxiety and enhances thriving at work and general health, as well as the emotional, social, and psychological well-being of employees at work. It offers evidence of the efficacy of SKY as a potential, low-risk intervention to be considered by employers at the workplace for the benefit of the human capital, i.e., the organization's workforce.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Institutional Review Board of the Indian Institute of Management Indore (IRB/02/2022-23/HSS). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

RC: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Visualization, Writing – original draft, Writing – review & editing. CD: Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Garry Kuan,
Universiti Sains Malaysia Health Campus, Malaysia

REVIEWED BY
Shuwan Chang,
Chengdu Sport University, China
Liang Cheng,
Sichuan Sports College, China

*CORRESPONDENCE
Guodong Zhang
✉ lygd777@swu.edu.cn

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The effects of Tai Chi exercise on sleep quality among the elderly: a study based on polysomnographic monitoring

Chao Wang[1,2], Tao Jiang[3], Hansen Li[1], Guikang Cao[4] and Guodong Zhang[1,5]*

[1]Institute of Sports Science, College of Physical Education, Southwest University, Chongqing, China, [2]Youth League Committee of Hotan Normal College, HeTian Normal College, Hetian, China, [3]Physical Education Department, Mianyang High School, Mianyang, China, [4]Department of Psychology, Southwest University, Chongqing, China, [5]International College, Krirk University, Bangkok, Thailand

Background: Sleep disorders contribute to an increased risk of depression, cardiovascular issues, and various other diseases among older individuals. Consequently, enhancing the sleep quality of this demographic population has become a pressing concern. The objective of this study was to investigate the influence of an 8-week Tai Chi exercise intervention in the sleep quality of older adults.

Methods: Sixty individuals aged 60 years and above, recruited from the community around Southwest University in Beibei District, Chongqing City, were randomly assigned to either a control group (30 participants) or an intervention group (30 participants). The control group adhered to their normal daily routines during the 8-week experimental period, while the intervention group engaged in a 60-min Tai Chi practice three times a week for 8 weeks. Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), the Insomnia Severity Index (ISI), and the Epworth Sleepiness Scale (ESS). Additionally, the Polysomnographic Sleep Quality Monitoring System (PSG) was employed to monitor the sleep process before and after the Tai Chi intervention.

Results: After the experiment, significant differences were observed in PSQI and IEI scores between the intervention and control groups ($p < 0.05$). In the experimental group, the pre-post comparisons revealed a significant increase in time spent in bed ($p < 0.05$), total sleep time ($p < 0.05$), and non-REM sleep stage 2 ($p < 0.05$).

Conclusion: The findings indicate that Tai Chi exercise may improve subjective reported sleep quality. In addition, Tai Chi exercise may alleviate general drowsiness, extend sleep duration, and optimize the sleep process and structure. Consequently, Tai Chi exercise may be a suitable exercise to improve sleep quality in older individuals.

KEYWORDS

Tai Chi, sleep quality, polysomnography, sleep disorders, the elderly

1 Introduction

Sleep is a fundamental physiological need for humans, constituting one-third of an individual's life, that plays a crucial role in maintaining normal growth and development (1), which is closely linked to the overall health (2). In the context of rapid societal development and heightened social competition, the incidence of sleep disorders is

escalating. In China, one in three individuals experiences sleep disorders, and globally, sleep disorders affect 9%−15% of the population according to clinical diagnostic criteria. These disorders can lead to various adverse health consequences, including depression, anxiety, mood disorders, hypertension, diabetes, and stroke. They also pose public safety risks such as via road accidents. Sleep disorders have evolved into a significant societal and scientific problem that is affecting the wellbeing of people, thereby requiring immediate attention in China (3).

Across the world, the elderly are the most affected group. Data indicate that 30%−40% of the elderly experience sleep disorders, and 88% of those aged 65 years and above experience various degrees of sleep issues (4). Insomnia and excessive daytime sleepiness are prevalent health issues among the elderly, affecting up to 50% of older adults. A study funded by the National Institute on Aging, involving over 9,000 people aged 65 years and above, revealed that more than half of the participants reported experiencing at least one sleep disorder. Common symptoms found among older adults include difficulty falling asleep, interrupted sleep, early morning awakenings, and excessive daytime sleepiness. These issues contribute to compromised health, reduced physical activity, limitations in daily activities, poor physical functioning, increased depressive symptoms, and increased morbidity and mortality from cardiovascular diseases (5).

Currently, medication, cognitive-behavioral therapy (CBT), and physical exercise are the most common approaches to improving sleep quality. However, medications may have side effects such as gastrointestinal dysfunction, worsening insomnia, obesity (6), and, in extreme cases, even mortality (7). While CBT is effective with minimal adverse effects, it has a drawback of slow efficacy and a prolonged treatment cycle (8). On the other hand, exercise has demonstrated superior effectiveness in regulating sleep. Regular physical exercise is a safe, feasible, positive and effective method that plays a significant role in improving sleep quality in the elderly (9). Regular physical activity contributes to better sleep and reduce daytime sleepiness (10). Aerobic exercise specifically improves sleep quality in older adults, with its impact on sleep through the modulation of psychological and other parameters (11).

Tai Chi, a traditional Chinese martial art, comprises various forms involving slow, coordinated movements, postural alignment, and synchronized deep breathing. Tai Chi is also recognized as a form of Qigong, a traditional Chinese regimen promoting health (12). Characterized by slow body movements and moderate intensity, Tai Chi may be particularly suitable for older adults. Tai Chi has been practiced to improve cardiovascular health and physical fitness (13) as well as to mitigate the decrease in bone mineral density (BMD) caused by aging (14). Furthermore, research indicates that Tai Chi also contributes to alleviate fatigue, anxiety, depressive symptoms, and sleep disorders (13).

Currently, numerous studies collectively imply the effectiveness of Tai Chi in improving sleep health. The observed benefits include improved sleep quality, reduced insomnia (15), and decreased daytime sleepiness (5). Notably, similar benefits appear to exist among older adults (16–19). These findings bolster the idea of Tai Chi as a potential non-pharmacological intervention for improving sleep health among older adults. However, many relevant investigations predominantly relied on subjective measures such as the Pittsburgh Sleep Quality Index (PSQI), the Insomnia Severity Index, and the Epworth Sleepiness Scale. These scales, based on individual perceptions, lack a robust scientific foundation for evaluating detailed sleep conditions.

In this context, polysomnography (PSG) stands out as an objective measurement system that continuously and synchronously monitors over 10 physiological signals, including electrocardiogram (ECG), electroencephalogram (EEG), electromyogram (EMG), electrooculogram (EMG), oculomotorgram (EMG), thoracic respiration, and abdominal respiration throughout the duration of sleep. PSG allows the effective monitoring of the entire duration of sleep and is globally recognized as the gold standard of sleep measurement (20). Currently, PSG primarily serves in the diagnosis of sleep and psychiatric disorders, including tasks such as diagnostic typing of sleep apnea, severity assessment, treatment effectiveness evaluation, diagnostic evaluation of excessive narcolepsy (episodic somnolence, OSAS), and exploration of reactions to the reality of sleep disorders associated with psychiatric conditions (21).

This study aimed to evaluate the influence of Tai Chi exercise on the sleep of elderly individuals, employing both objective and subjective measures. Our research hypothesis is that Tai Chi exercise has the potential to enhance both subjectively perceived and objectively measured sleep conditions.

2 Materials and methods

This study constituted a randomized controlled trial aimed at investigating the effects of Tai Chi on sleep conditions in older adults.

2.1 Participants

The study participants were recruited from urban communities near the Southwest University School Hospital in Chongqing, China, specifically from Chaoyang Street, Tiansheng Street, Bei Wen Quan and Longfeng Community, spanning from June 2020 to December 2020. This study involved 60 individuals aged between 60 and 79 years who were randomly assigned to either the Tai Chi intervention group (4 men and 26 women) or the control group (4 men and 26 women). General information regarding the elderly individuals in both groups exhibited no significant differences ($P > 0.05$), ensuring baseline comparability.

Table 1 provides a summary of the basic information of the study participants. Upon obtaining informed consent andcompleting baseline assessments, participants were randomly assigned to the intervention groups in a 1:1 ratio using computer-generated random numbers. The randomization process involved no stratification or blocking factors. Participants remained unaware of their group assignments until the baseline assessment was concluded. Importantly, the individuals responsible for generating the randomization plan refrained from participating in the screening or testing processes. Five participants in the control group withdrew voluntarily for personal reasons.

TABLE 1 Basic information of the study participants.

Groups	Gender	Age	Educational attainment	Number of people
Intervention group	Man 13.3%; Woman 87.7%	66.0 ± 4.97	10.700 ± 2.1838	30
Control participants	Man 13.3%; Woman 87.7%	69.1 ± 4.56	9.58 ± 2.9268	30

2.2 Inclusion criteria

The inclusion criteria for the study participants were as follows: (1) older adults aged 60 years and above; (2) scores equal to or greater than 26 on the Brief Mental State Examination (MMSE) scale; (3) the absence of illnesses impacting postural control, such as vestibular sensory system disorders or visual system disorders; (4) no clinical neurological and psychiatric disorders, with participants not currently using antidepressant, anxiety, or related medications; and (5) understanding and voluntarily agreeing to participate in the experiment while meeting the eligible criteria. After screening on-site and through WeChat, a total of 60 older adults were included in the experimental study.

2.3 Exclusion criteria

This study listed the following exclusion criteria: (1) individuals involved in any other form of sport during the intervention period; (2) participants who had already undergone other types of sleep improvement interventions; (3) individuals unable to arrive at the designated location for the intervention within a fixed timeframe; (4) individuals using sleep medications; and (5) elderly individuals with a long-term Tai Chi practice history.

2.4 Dropout criteria

Participants were considered for dropout if they met the following criteria: (1) participants with two or more consecutive absences during the intervention period; (2) individuals with <20 total interventions; (3) participants engaging in other forms of physical activity during the intervention period; (4) those experiencing adverse physical reactions during the intervention process; and (5) participants voluntarily withdrawing from the intervention trial, completing their involvement in the trial.

2.5 Procedure

In this study, the elderly participants were randomly assigned to either the control group or the intervention group. Both groups underwent assessments of their subjective sleep, with specific post-intervention measures conducted accordingly. The subjective sleep quality of both the intervention and control groups was evaluated 1 week before the experiment and 1 week after its completion. Throughout the 8-week experimental period, the control group maintained regular physiological activities and living habits. Meanwhile, in the intervention group, Polysomnographic Sleep Quality Monitoring System was employed to monitor the all-night sleep of each older adult 1 week before the experiment and again 1 week after the intervention. The experimental procedure is shown in Figure 1.

2.6 Schedule

The Tai Chi intervention group practiced a 24-pattern Tai Chi exercise three times a week (Monday, Wednesday, and Friday) for 60 min during the 8-week experimental period from 7:00 a.m. to 8:00 a.m. In the second phase, due to the late dawn time during the winter and the safety concerns, the practice time was rescheduled to 7:30 a.m. to 8:30 p.m. A check-in will be carried out prior to each Tai Chi exercise practice to ensure the attendance of the experimental participants and improve the quality of the intervention.

2.7 Experimental setting

We offered flexibility in scheduling for participants to engage in Tai Chi exercise under our guidance within specified timeframes. Participants had the liberty to choose a convenient time slot to participate in the 24-pattern Tai Chi exercise based on their personal schedules. Meanwhile, the control group adhered to their original lifestyle habits, refraining from any form of physical exercise, and engaged in online health lectures conducted once every 2 weeks.

For the experimental intervention group, we employed two experienced martial arts teachers (one man and one woman) with more than 5 years of teaching experience. The teaching approach involved one teacher and one assistant to ensure that participants could grasp the fundamental principles of Tai Chi. The teachers addressed related questions from the elderly participants after each session. Considering the lower physical fitness and organ function of elderly, the difficulty of certain complex and potentially hazardous movements (e.g., right stomping, left and right downward movement) was adjusted based on their actual condition, prioritizing safety while facilitating skill mastery and practice.

Over the course of 8 weeks, the intervention group mastered the 24 simplified Tai Chi styles. Wushu teachers thoughtfully organized the teaching content and practice duration to align with the participants' abilities and acceptance levels. This approach aimed to help the elderly master all movements early on, gradually progressing to practicing the complete sets of movements. The detailed course content is outlined in Table 2.

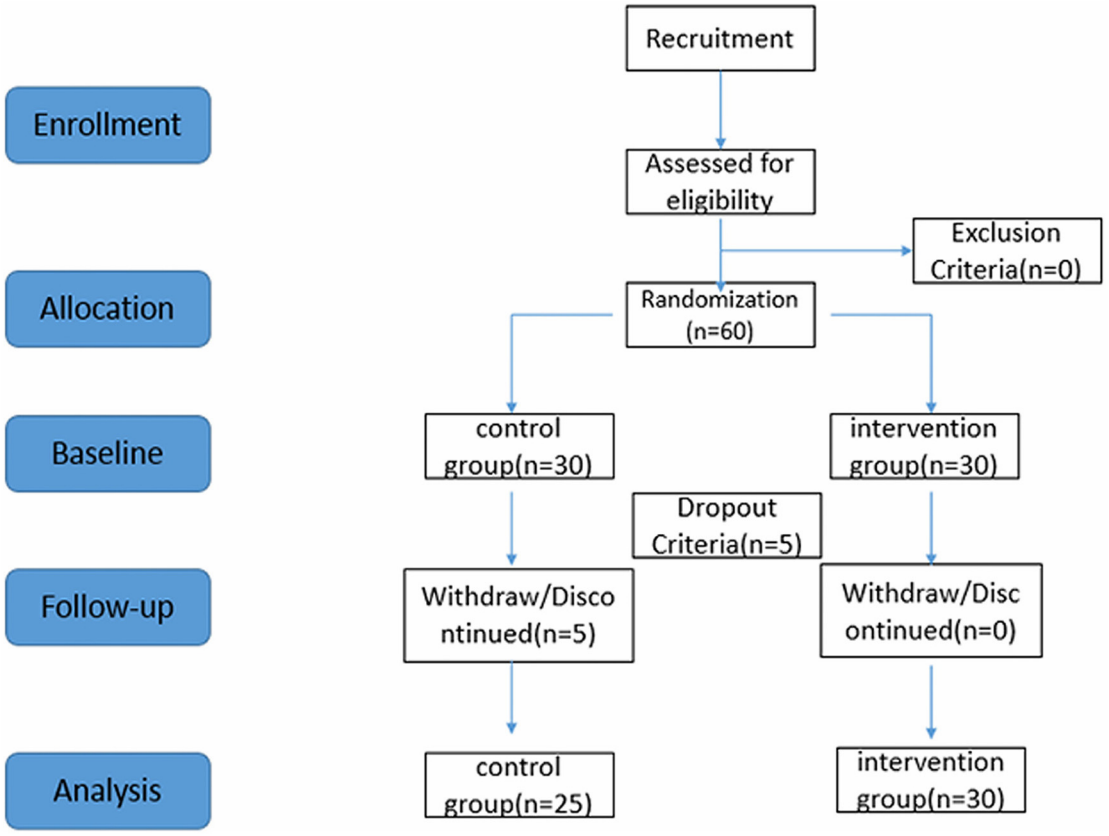

FIGURE 1
The experimental procedure and timeline.

2.8 Measurements

2.8.1 Questionnaire

In this study, the Pittsburgh Sleep Quality Index (PSQI), the Epworth Sleepiness Scale (ESS), and the Insomnia Severity Index (ISI), developed by Buysse et al. (22), psychiatrists at the University of Pittsburgh, USA, were utilized to assess the sleep quality in the elderly population.

2.8.2 Polysomnographic sleep monitoring system (PSG)

For this study, a polysomnographic monitoring system of the model E-Series EEG/PSG Recording System, manufactured by Compumedics Ltd., Australia, was employed.

(1) Test conditions: All-night sleep monitoring was conducted under conditions similar to those experienced by the patients, ensuring a setting free of interference, quiet, and conducive to sleep.
(2) Intervention method: Polysomnographic sleep monitoring was carried out on all patients in the intervention group 1 week before and 1 week after the experiment. To ensure the smoothness of the monitoring process, we visited the patient's home 1 h before the experiment to communicate with the them. Through verbal communication, we emphasized the safety and timeliness of the monitoring process, ensuring that it remains uninterrupted by external factors. The monitoring duration typically ranged from 22:00 h on the same day to 07:00 hon the next day.
(3) Monitoring indicators: Polysomnography primarily observes the sleep process, sleep maintenance, sleep structure, and related sleep indicators.

Specific indicators for sleep include the following factors:

Time in bed refers to the total duration recorded from the beginning to the end of monitoring.
Sleep time refers to the duration recorded from the beginning of the patient's sleep to their awakening.
Total sleep time is calculated as the patient's sleep time minus their awakening time.
Awakening time refers to the total time of the patients being awake during the course of sleep monitoring.
N1 time refers to the total time of entry into the first stage of non-rapid-eye-movement sleep, representing light sleep.
N2 time refers to the total time from the end of the first stage of non-REM sleep to the second stage.
N3 time refers to the total time from the end of the second stage of non-REM sleep to entering deep sleep.

TABLE 2 Tai Chi program content.

	Preparatory activity (15 min)	Main exercise (45 min)	Tidying up activity (10 min)
Course content	1. Unarmed gymnastic exercises; 2. Arrow-quiver, stroke, squeeze, press, and other individual movement exercises	1. Learn 24 Simplified Tai Chi Forms, including: I. Starting; II. Wild Horse Separating Mane; III. White Crane Shining Wings; IV. Knee-wrapping and Reversing Steps; V. Hand-waving Pipa; VI. Inverted Rolling Humerus; VII. Left Range Sparrow's Tail; VIII. Right Range Sparrow's Tail; IX. Single Whip; X. Clouded Hands; XI. Single Whip; XII, Right down independent; XVIII, left and right shuttle; XIX, the bottom of the sea needle; XX, flash through the arm; XXI, turn around to move blocking whacking; XXII, such as sealing like a closed; XXIII, the cross hand; XXIV, the closing trend of 24 technical action. 2. After completing the corresponding learning tasks, carry out before and after action coherence practice.	1. Static stretching of the back of the thighs at a bent over position; 2. Anterior thigh stretch; 3. Standing shoulder shake
Role of exercises	1. Unarmed gymnastics practice process so that the practitioner in the exercise before the whole body muscle to get active mobilization effect. 2. The practice of individual technical movements can strengthen the mastery and understanding of technical movements of the elderly in the process of practice.	1. Practicing 20-Style Simplified Tai Chi can maintain a state of calmness and peace of mind and consciously regulate the body to achieve the most suitable state of relaxation. The slow continuation of the exercises is good for the blood circulation of the elderly and promotes the mobility of the joints, and the coherent movement of the whole set of exercises can enhance the coordination of the body. 2. The related pace of movement can enhance the lower limb strength of the elderly to a certain extent.	1. Single leg support, opposite side of the heel on the ground, hook the back of the foot hands to the front of the foot (the head of the upper limb can not be bent downward and look forward). Relax the calf muscles and the back of the thigh muscles. 2. Hold the pole with one hand and pull the same side of the foot toward the hip with the same side hand. Relax the rectus femoris and anterior thigh muscles. 3. Stand with your legs parallel to each other and shake your shoulders up and down naturally. Relax the shoulder and arm muscles on both sides.

REM stage refers to the time spent in REM sleep.
Sleep latency refers to the sum of the time of SLL sleep latency, N2 latency time, and N3 latency time.
Sleep efficiency is calculated as the ratio of the time of sleep to the time of being in bed.
Sleep duration refers to the number of awakenings, ratio of total awakening time to total sleep time.
Sleep Structure: (a) SLL Latency Time; (b) Sleep Latency Time; (c) N1 Latency Time; (d) N2 Latency Time; (e) REM Latency Time; (f) Non-rapid Eye Sleep (N1%, N2%, N3%, and REM%) as a percentage of total sleep time.

2.9 Statistical analysis

This study was structured as a randomized controlled trial, focusing on comparing outcomes between the experimental and control groups after the intervention. Consequently, the independent samples *t*-test was utilized to compare data collected in the two groups after the intervention. However, due to COVID-19 restrictions preventing the collection of objective data (using PSG) in the control group, a paired-samples *t*-test was employed to assess whether the objective data significantly changed from baseline to the post-intervention test in the intervention group. A two-tailed p-value < 0.05 was deemed statistically significant.

3 Results and analyses

3.1 A comparison of PSQI, ISI, and ESS scores between groups

The PSQI and ISI scores of the intervention group were significantly lower than those of the control groups after the intervention. However, no significant difference between the two groups was found in terms of ESS scores.

3.2 A comparison of objective sleep assessments in the intervention group

3.2.1 A comparison of sleep processes in the intervention groups

In the intervention group, the time in bed (TIB) ($p < 0.05$), time in sleep (TST) ($p < 0.05$), and non-REM sleep stage 2 (N2) ($p < 0.01$) were significantly improved after the intervention. The time of non-REM sleep stage 3 (N3) was reduced. There were some increases in the data of the other groups, but none of them were statistically significant ($p > 0.05$) (Table 3).

As illustrated in Figure 2, the N1 sleep time basically remained unchanged. After the intervention, N2 sleep time substantially increased, demonstrated with a scatterplot of the N2 sleep time in the elderly, but the sleep time was significantly increased. N3 sleep time experienced a small decline in the elderly, and deep sleep time was more aggregated, while REM sleep time increased.

3.2.2 Comparison of sleep persistence in the intervention group

The waking time of the experimental group significantly increased after the intervention ($p < 0.05$), and there was no significant difference in other indicators throughout the intervention ($p > 0.05$) (Table 4).

TABLE 3 Comparison of PSQI, ISI, and ESS scores on subjective scales after the experiment.

Type of scale	Periods	Control groups	Intervention group	*t*	*p*
PSQI	Pre-intervention	5.885 ± 3.7982	6.077 ± 4.010	−0.511	0.611
	Post-intervention	6.039 ± 2.9730	4.885 ± 4.430	2.054	0.044*
ISI	Pre-intervention	3.923 ± 6.1769	4.466 ± 4.1591	−0.344	0.731
	Post-intervention	4.555 ± 0.8932	3.269 ± 5.0244	2.652	0.010*
ESS	Pre-intervention	4.115 ± 4.5460	4.462 ± 4.1591	−0.769	0.444
	Post-intervention	4.192 ± 4.1859	4.385 ± 2.4013	−0.092	0.926

*Indicates a *p*-value of <0.05 for the Control and Intervention Group comparisons.

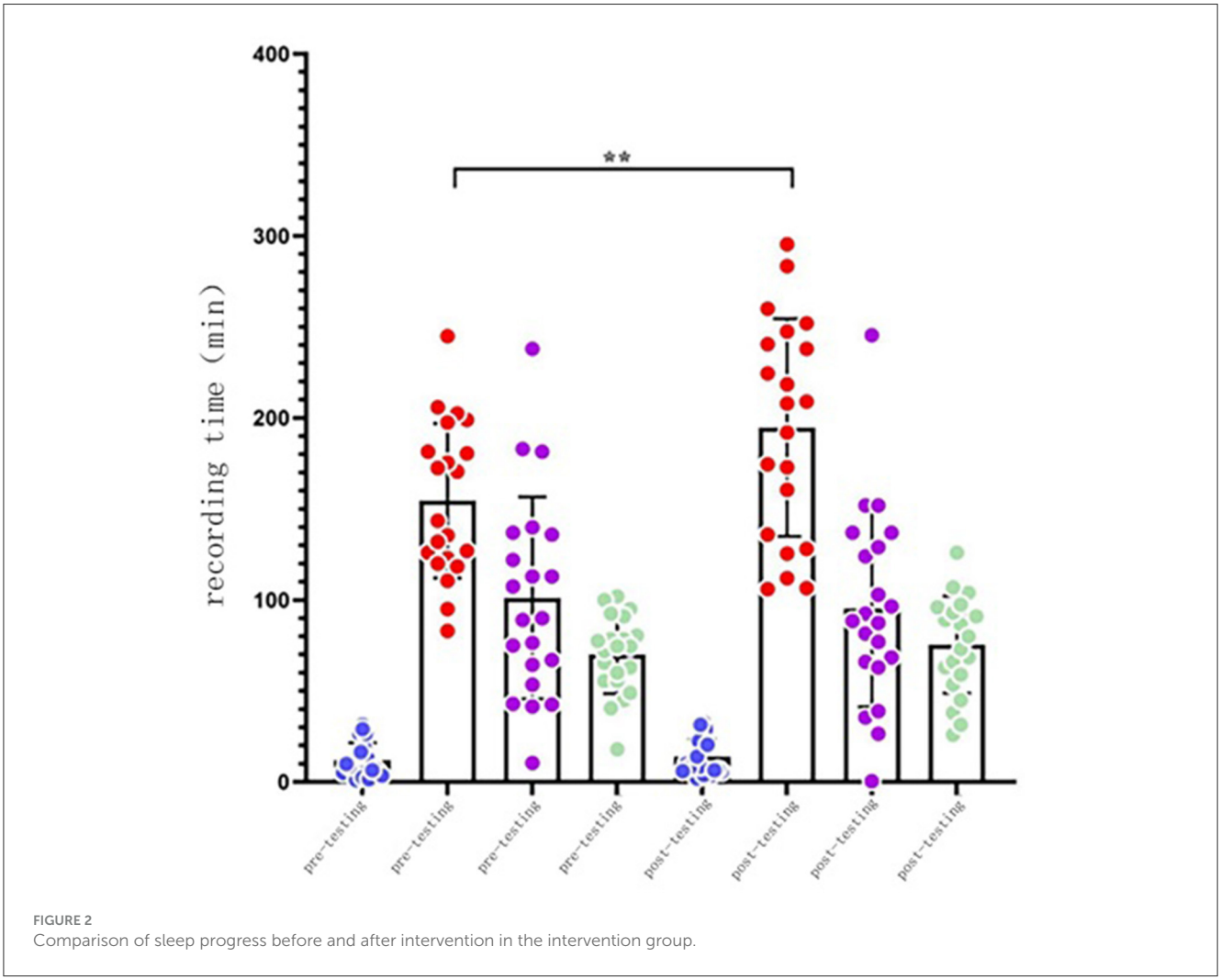

FIGURE 2
Comparison of sleep progress before and after intervention in the intervention group.

TABLE 4 Comparison of sleep processes before and after the experiment in the intervention group.

Experimental group	Bed time	Total sleep time	N1 time	N2 time	N3 time	Sleep latency	REM latency
Pre-intervention/min	526.1 ± 36.6	337.7 ± 54.1	11.9 ± 9.6	154.5 ± 42.4	101.1 ± 55.5	50.4 ± 47.5	145.6 ± 63.7
Post-intervention/min	567.3 ± 51.9	379.5 ± 62.2	13.8 ± 9.8	194.8 ± 59.8	95.3 ± 54.0	48.6 ± 45.6	155.1 ± 66.5
t	−2.814	−2.760	−1.497	−3.365	0.758	0.115	−0.507
p	0.011*	0.012*	0.149	0.003*	0.457	0.909	0.618

$P < 0.05$* significant difference; $p < 0.01$** highly significant difference.

TABLE 5 Comparison of sleep persistence before and after the experiment in the intervention group.

	Pre-intervention	Post-intervention	*t*	*p*
Awake time	188.5 ± 66.9	187.9 ± 59.4	0.038	0.970
Number of times awake	18.9 ± 8.0	22.8 ± 9.4	−2.679	0.014*
Percentage of awakening	0.35 ± 0.11	0.33 ± 0.09	0.929	0.364
Number of sleep entries into REM	5.6 ± 3.3	5.3 ± 3.2	0.542	0.594

$P < 0.05$* significant difference; $p < 0.01$** highly significant difference.

3.2.3 Comparison of sleep structure in intervention groups

The non-rapid eye movement (NREM) sleep time ($p < 0.01$) and the percentage of non-rapid eye movement (NREM) sleep stage 2 of the intervention group were significantly increased ($p < 0.05$) after the intervention. However, no other significant change was observed (Table 5).

4 Discussion

This study aimed to evaluate the influence of Tai Chi exercise on sleep quality of elderly population using both subjective and objective measures. Our research hypothesis was broadly verified, indicating that Tai Chi exercise may positively change both subjective and objective sleep quality among the normal elderly population. Specifically, scores on the Pittsburgh Sleep Quality Index and Insomnia Severity Index, but not on the Narcolepsy Scale, were significantly decreased following the exercise intervention (based on the comparisons between groups). Although the polysomnography-monitored data were only restricted to the intervention group, significant improvements were observed in time in bed, total sleep time, N2 time in bed, N2 time, and awakening time, indicating significant changes in the sleep structure.

4.1 Effect of Tai Chi on sleep quality

Our findings based on questionnaire are in line with those of previous studies. For example, we found lower ISI scores in the intervention group, which supports a systematic review, suggesting that Tai Chi exercise can improve sleep quality in healthy elderly individuals and serve as an adjunct for those with insomnia (23). Meanwhile, we also found lower PSQI scores in the Tai Chi intervention group post-intervention, which supports the previous review that Tai Chi improved self-rated sleep quality among older people (24). Taken together, these findings have highlighted the value of Tai Chi exercise for health promotion of older people.

The effects of Tai Chi exercise on sleep may be explained using the following perspective. On the one hand, Tai Chi may increase the volume of daily physical activity, leading to additional energy consumption and ultimately promoting sleep quality (25). On the other hand, Tai Chi may reduce negative emotional symptoms, thereby promoting sleep health. For example, many studies have suggested that Tai Chi may reduce depression (26, 27), which is possibly accompanied by improved sleep quality (28). Furthermore, Tai Chi exercise also involves the regulation of vegetative nervous system, leading to a decrease in the excitability of sympathetic nerves and an organized cerebral cortex. As a consequence of these adjustments, the quality of sleep can be possibly improved (29).

4.2 Effects of Tai Chi on sleep processes

The sleep process in individuals over 60 years of age consists of the N1, N2, and N3 sleep stages, as they do not experience the fourth stage of deep sleep. We found that Tai Chi exercise increased total sleep time, prolonged duration of N2 sleep stage, and reduced sleep latency. These findings align with the results of the studies by Irwin et al. (30) and Fan et al. (31), indicating that traditional Chinese medicine (TCM), Tai Chi, and western medicines can improve sleep structure, sleep process, and sleep maintenance in patients with depressive sleep disorders of the heart-spleen deficiency type. Notably, the study conducted by Fan et al. focused on patients with depression and sleep disorders, whereas the current study investigated normal elderly individuals.

It is widely acknowledged that exercise can influence sleep (32), and assessing the effects of physical activity on sleep using polysomnography provides an objective perspective, helping to eliminate the influence of subjective factors. For instance, low-intensity physical activity has been associated with objective benefits related to deep sleep parameters in older adults (33), and interventions involving different physical activity methods, such as treadmill exercise, have shown positive effects on insomnia (34). Our study, from the perspective of Tai Chi exercise, again confirms the effectiveness of physical exercise in improving objectively measured sleep conditions. Nevertheless, it should be noted that our objective measures were carried out only in the Tai Chi intervention group due to the COVID-19 pandemic; hence, the findings were derived from pre-post comparisons. These comparisons could be affected by time-related external factors, such as seasonal changes in human physiology; therefore, our findings must be taken into consideration with caution.

4.3 Research limitations

Our sample was recruited based on the maximum effort given the available resources; however, the recruitment of 60 participants is still insufficient. Based on our analysis, the achieved statistical power was 0.48 (independent samples *t*-test) and 0.75 (paired samples *t*-test) (based on a two-tailed test with an effect size of 0.5). This flaw may have reduced our ability to detect effects, increased

the type I error rate, and limited the generalizability of our findings. Therefore, future experiments with larger samples are still needed to replicate our findings. In the results of polysomnography, testing was conducted only before and after the intervention in the intervention group. Additionally, the shorter intervention period and lower frequency of intervention may have contributed to the data sensitivity issues. Further in-depth studies are required to explore the effect of Tai Chi exercise on the sleep process of the normal elderly population.

5 Conclusion

We conducted a controlled intervention to examine the influence of Tai Chi on the sleep conditions of older adults. Although we did not recruit a satisfactory sample size due to the COVID-19 pandemic and failed to conduct all planned tests, our preliminary results provide initial evidence of the positive effects of Tai Chi on improving sleep quality in older adults. The improvement in objective sleep measures based on instrument measurements complement previous questionnaire surveys regarding this topic.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Ethics Review Board of University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

CW: Writing – original draft. TJ: Writing – review & editing. HL: Writing – review & editing. GC: Writing – review & editing. GZ: Writing – review & editing, Supervision.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EDITED BY
Zi Yan,
Merrimack College, United States

REVIEWED BY
Nathan Dreesmann,
Virtual Therapeutics, United States

*CORRESPONDENCE
Hongcheng Luo
925409269@qq.com

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The application of virtual reality meditation and mind–body exercises among older adults

Dong Gao[1], Yuqin Su[2], Xing Zhang[3], Hansen Li[2], and Hongcheng Luo[4]*

[1]College of Physical Education, Chongqing University of Posts and Telecommunications, Chongqing, China, [2]Institute of Sports Science, College of Physical Education, Southwest University, Chongqing, China, [3]Department of Physical Education and Sport, Faculty of Sport Sciences, University of Granada, Granada, Spain, [4]School of Physical Education, Xichang University, Xichang, China

Virtual reality (VR)-based mindfulness is a promising method to improve the health of older adults. Therefore, many attempts have been made to explore the application of VR-based mindfulness, such as VR meditation and mind–body exercises, in older adults. Generally, current studies indicate the heavy reliance on apparatus for implementing VR-based mindfulness interventions. In VR meditation, the crucial apparatus is VR headsets. In VR mind–body exercises, three essential components are required: motion capture sensors, main consoles, and display screens. In the aspect of health promotion, VR meditation is an effective method for improving mental health, pain, and quality of life in older adults. VR mind–body exercises contribute to increasing the mental health and physical function of older adults. Furthermore, VR mind–body exercises may be combined with other forms of exercise as a mixed method to promote the health of older adults. VR-based mindfulness interventions enhance the meditation and mind–body exercises experience for older adults while improving accessibility. However, their implementation still encounters a series of challenges, such as cost, technical anxiety, and apparatus-related issues. Additionally, we recommend future research to examine the optimal exercise dose for VR mind–body exercises to maximize their health benefits.

KEYWORDS

virtual reality, public health, mindfulness, meditation, elderly, mind–body exercises

1 Introduction

In recent decades, the global population has experienced unprecedented demographic shifts due to the aging population (Zhao et al., 2022). As this trend continues, it is projected that by 2050, approximately 22% of the world's population will consist of individuals aged 65 and older (Zenebe et al., 2021; Zhao et al., 2022). The aging process involves a natural decline in physiological functions, including reduced performance in various organ systems, and a decreased ability to withstand physical, cognitive, and psychological stressors (Norman et al., 2021). These age-related changes increase the risk of health problems among older adults. In the context of an aging population, this leads to substantial economic burdens and an increased demand for healthcare services on a global scale (Collado-Mateo et al., 2021; Norman et al., 2021). Therefore, there is an urgent need to develop various health promotion strategies to enhance the health of older adults.

Mindfulness practice is the intentional cultivation of non-judgmental awareness and presence in the present moment, often achieved through meditation and mind–body exercises (Gupta, 2021). While rooted in Buddhist traditions, mindfulness practice has gained increasing attention from researchers in medicine and psychology (Scheepers et al., 2020; Fendel et al., 2021). In the past decades, researchers have identified various health benefits associated with mindfulness practice, such as improving mental health problems (Enkema et al., 2020), life quality (Valikhani et al., 2020), pain (Ngamkham et al., 2019), cardiovascular disease (Conversano et al., 2021), and other diseases (Giulietti et al., 2023; Naude et al., 2023). At present, mindfulness-based intervention has been widely implemented in various secular populations: spanning from pre-school children to older adults (Jamieson and Tuckey, 2017; Carsley et al., 2018; Odgers et al., 2020; Kriakous et al., 2021; Zhang et al., 2021). However, the implication of mindfulness practice still faces a range of challenges. On one hand, mindfulness practice requires conscious effort and can be challenging to maintain, particularly for novice meditators who may already be using substantial cognitive capacity to enhance their self-regulatory skills (Seabrook et al., 2020). On the other hand, many factors can impact the implementation of mindfulness practice, such as environment, attention, cognition, physiology, emotional well-being, and social relationships (Seabrook et al., 2020; Li, 2022; Ma et al., 2023). Therefore, traditional mindfulness practice requires under the guidance of professional trainers in specific locations (e.g., meditation center and hospital) (Ma et al., 2023). However, this method limits the accessibility of mindfulness practice, particularly for older adults.

In order to improve the accessibility of mindfulness practice, extensive exploration has been undertaken (Hendrixson, 2020; May and Maurin, 2021; Wu et al., 2022). One promising solution is the application of virtual reality (VR) technology in mindfulness practice. VR technology allows individuals to engage with multisensory experiences in immersive 3D environments, potentially enhancing their mindfulness practice (Lee et al., 2023). To date, some studies have examined the application of VR technology to meditation and mind–body exercises for older adults (Chen et al., 2020; Hendrixson, 2020). However, comprehensive information on the implementation of VR meditation and mind–body exercises in older adults is still lacking (Figure 1). Therefore, we conducted this review based on published literature to address the following questions:

i. How are VR meditation and mind–body exercises implemented in older adults?
ii. What is the impact of VR meditation and mind–body exercises on the health of older adults?
iii. What are the strengths and challenges of implementing VR meditation and mind–body exercises in older adults?

FIGURE 1
VR-based mindfulness.

2 VR meditation

2.1 Implementation

2.1.1 Apparatus

VR headsets are a crucial component of VR meditation. Typically, a VR headset comprises a screen and lenses projecting the virtual environment directly in front of the user's eyes, elevating the meditation experience (Li et al., 2021). Additionally, VR headsets often feature built-in headphones or speakers to further enrich the user's multisensory immersive experience. Traditionally, VR headsets operate as output devices, necessitating a connection to main consoles (e.g., Xbox, PS, PC, and smartphone) for generating the intervention environment (Dzardanova and Kasapakis, 2022). However, it's essential to note that main consoles are not always obligatory components. With the advancement of VR technology, all-in-one VR headsets (e.g., PICO 4 VR Headset, HTC Vive Focus 3 Headset, Meta Quest Pro VR Headset) have been developed (Wang et al., 2023). This type of device is equipped with a built-in processor, offering independent processing, input, and output functions (Al Arafat et al., 2021). Hence, there is no need for connections to a main console, eliminating wired constraints. Additionally, in order to reduce the cost of VR interventions, some researchers have tried to use mobile phone VR headsets (e.g., the Destek V5 headset) (Trueba et al., 2023a,b). These devices are relatively inexpensive and require users to insert their smartphones into the headset to experience virtual reality content (Huang and Wang, 2021).

2.1.2 Implementation process

The implementation process of VR meditation is as follows:

i. Preparation phase: Firstly, researchers formulate an intervention plan. Subsequently, researchers prepare VR apparatuses and select suitable videos based their design. Finally, researchers provide participants with guidance and instructions related to VR meditation.
ii. Implementation phase: First, participants wear VR headsets and personalize settings to enhance their meditation experience. Subsequently, participants follow the instructions for meditation practice. Finally, after completing meditation practice, participants remove VR headsets. Throughout the VR

meditation process, supervisors in the real world provide support and guidance to ensure participant safety.

iii. Testing and evaluation phase: Researchers will request participants to complete a series of questionnaires and tests at specific stages of a study, such as before and after meditation intervention, depending on their study design.

To minimize the risk of potential adverse events such as motion sickness and eye strain among older adults, VR meditation interventions are typically set for 5–15 min (Sarkar et al., 2022; Cinalioglu et al., 2023a,b). Furthermore, the implementation of VR meditation in older adults generally follows two methods: remote and in-person. In the in-person method, participants engage in VR meditation at a location prepared by the researchers, such as a hospital (Cinalioglu et al., 2023a). In the remote method, participants receive the necessary apparatus and online guidance to practice VR meditation in their own homes. Some studies also conducted post-intervention interviews with participants to gather insights into their experiences, emotions, and feedback regarding VR meditation (Hendrixson, 2020).

2.2 Benefits

In the past decades, meditation has been considered an effective method for improving the physical and mental health of older adults (Weber et al., 2020; Reangsing et al., 2021). In VR meditation, similar findings were also observed. In terms of mental health, studies by Cinalioglu et al. (2023b) and Trueba et al. (2023a,b) claimed that VR meditation can reduce stress and alleviate negative mood symptoms (e.g., anxiety and depression) in older adults. However, these three studies only published abstracts in The American Journal of Geriatric Psychiatry, and detailed information is unavailable. Additionally, Sarkar et al. (2022) explored the impact of VR meditation on older adults with knee osteoarthritis and found a significant reduction in negative emotions following the intervention, with this effect still noticeable after 24–48 h. Although not statistically significant, Sarkar et al. (2022) also observed an improvement in positive emotions among older adults after VR meditation. In terms of physical health, Sarkar et al. (2022) found that a 10-min VR meditation is a safe and feasible intervention for improving chronic pain, both overall and knee-specific, in older adults with osteoarthritis. Another study examining the impact of VR meditation on older adults' quality of life found that a 3-week VR meditation program effectively enhanced overall quality of life (Hendrixson, 2020). This finding may imply an improvement in overall physical and mental health conditions.

One perspective suggests that VR meditation may be more effective than traditional meditation because it enhances the meditation experience (Ma et al., 2023). However, there is limited research comparing the health benefits of VR meditation to traditional meditation. One reason for the limited research might be that VR meditation is a new and emerging research topic, and many related studies may still be in progress. Additionally, researchers within the field of VR meditation may have diverse research priorities, and their focus not be solely concentrated on one theme. Therefore, it remains unclear whether the enhanced meditation experience translates into greater health benefits for older adults. Given this, we recommend future research to explore the most effective meditation methods. Furthermore, future studies should identify potential variations in the health benefits of VR meditation among different populations, such as older adults vs. younger individuals, males vs. females, and the general public vs. specific groups.

2.3 Strength

The strengths of VR meditation are as follows:

i. Meditation experience: VR meditation offers a more immersive and engaging experience compared to traditional meditation. The use of virtual environments and sensory stimuli can enhance the sense of relaxation and concentration during meditation. In the study conducted by Sarkar et al. (2022), participants expressed that VR meditation enhanced their meditation experience, with 94.7% of participants expressing their willingness to engage in VR meditation again.

ii. Accessibility: VR meditation can be easily accessed and practiced from the comfort of one's own home. For instance, in the research by Cinalioglu et al. (2023a), participants were allowed to receive remote guidance and engage in VR meditation interventions within their homes. This accessibility is advantageous for older adults with limited mobility.

iii. Personalization: VR meditation programs can be customized to cater to individual needs and intervention objectives. This customization is advantageous for enhancing the personalization and specificity of meditation.

2.4 Implementation challenge

The implementation challenges of VR meditation are as follows:

i. Cost: VR meditation requires specialized apparatus, such as a main console + VR headset or an all-in-one VR headset. The prices for all-in-one VR headsets typically range between $200 and $500, with high-end devices featuring advanced display technology, tracking systems, and processors costing more, such as the Pimax Crystal VR headsets. Traditional VR headsets are generally more affordable, ranging in price from $100 to $300, but they require connection to a main console. The cost of these devices can be a barrier to widespread adoption, particularly among older adults in developing countries. Fortunately, some researchers are exploring low-cost VR meditation intervention solutions (Trueba et al., 2023a,b). They utilized free VR mobile apps and the Destek V5 headset (a mobile phone VR headset priced at a few tens of dollars) to investigate the effectiveness of VR meditation in improving the mental health of older adults. Their future findings could potentially benefit economically disadvantaged populations.

ii. Technical Anxiety: Some older adults may express concerns about using VR devices due to a lack of familiarity (Trueba et al., 2023a,b). Training and technical support may be necessary to alleviate their technological anxiety.

iii. Simulator sickness: Prolonged use of VR headsets can lead to discomfort or sickness. Current studies typically control the duration of VR meditation. Meanwhile, Sarkar et al. (2022)

indicated that older adults generally reported scores of 0 (none) or 1 (slight) for each symptoms on the simulator sickness questionnaire, which measures the severity of 16 symptoms (such as headache, eye strain, and blurred vision) experienced during VR interventions (Sevinc and Berkman, 2020). Nevertheless, some older adults still reported experiencing severe migraines the day after the intervention (Sarkar et al., 2022).

iv. Apparatus: Certain apparatuses may lack stability and could malfunction, leading to interruptions during interventions (Trueba et al., 2023a,b). Additionally, compatibility issues between VR videos and devices may affect intervention implementation (Trueba et al., 2023a,b).

v. Video Content: Most VR videos are primarily designed for entertainment purposes and may not be suitable for VR meditation (Trueba et al., 2023a,b). Furthermore, language support for the videos may also pose a potential issue (some languages may not be supported) (Trueba et al., 2023a,b).

3 VR mind–body exercises

3.1 Implementation

3.1.1 Apparatus

Traditionally, implementing VR mind–body exercises requires hardware support such as motion capture sensors, main consoles, and display screens (Kim et al., 2013; Rahman, 2023). In VR mind–body exercises, motion capture sensors are utilized to capture and monitor participants' physical movements through cameras, infrared depth sensors, and various other sensors (Kim et al., 2013). Main consoles (e.g., Xbox, PS, or PC) are then used to link motion capture sensors, acquire motion capture-related data, and establish the VR environment (Kim et al., 2013). Display screens play a crucial role in presenting the virtual environment, showcasing visual elements related to movements and activities like exercise instructions, environmental backgrounds, and virtual participants (Rahman, 2023). Simultaneously, display screens serve as tools for providing feedback, enabling participants to observe their movements and actions, thereby facilitating self-monitoring and improvement (Rahman, 2023).

One thing to note is that current studies typically utilize display screens to present the VR environment when investigating the impacts of VR mind–body exercises on older people (Hsieh et al., 2019; Rahman, 2023). Wearable devices, such as standalone VR headsets and all-in-one VR headsets, are currently seldom employed. This may be associated with controlling research risks. In VR mind–body exercise interventions, older adults participate in a series of physical activities, and the potential motion sickness induced by using VR headsets may elevate the risk of exercise-related injuries (Cucher et al., 2023).

3.1.2 Implementation process

The implementation process of VR meditation is as follows:

i. Preparation phase: Firstly, researchers prepare VR apparatuses and set them up in a suitable location. Subsequently, researchers prepare the necessary software for VR mind–body exercises and formulate the intervention plan. Finally, researchers provide participants with guidance and instructions related to VR mind–body exercises.

ii. Implementation phase: Firstly, participants follow researchers' instructions for warm-up. Subsequently, they engage in mind–body exercises guided by a VR system. Finally, under the guidance of the researchers, participants completed relaxation activities after the intervention. Throughout the VR meditation process, in addition to the virtual coach, medical personnel/researchers/coaches are typically present to monitor and support participants as needed.

iii. Testing and evaluation phase: Researchers will request participants to complete a series of questionnaires and tests at specific stages of a study, such as before and after meditation intervention, depending on their study design.

In VR mind–body exercises, to enhance the quality of motion capture and ensure participant comfort during viewing, motion capture sensors and display screens are positioned at appropriate heights (approximately 1 m above the ground) and distances (approximately 2–2.5 meters from the participants) (Hsieh et al., 2019; Rahman, 2023). VR mind–body exercises typically select slow, continuous movements such as Tai Chi and yoga (Kim et al., 2013; Rahman, 2023). A session typically lasts for 30–45 min, during which participants can view their own movements and receive motion scores (Kim et al., 2013; Hsieh et al., 2019; Rahman, 2023). Additionally, a virtual coach provides visual and verbal feedback on participants' movements to ensure the correct execution of each motion (Hsieh et al., 2019; Chen et al., 2020; Rahman, 2023).

3.2 Benefits

Tai Chi and yoga are the main events in VR mind–body exercises. In terms of mental health, a study conducted by Hsieh et al. (2019) examined the impact of 6 months of VR Tai Chi on older adults with cognitive issues. Their research found that VR Tai Chi intervention significantly improved abstract thinking and judgment abilities in older adults. However, no significant outcomes were observed in long-term memory, short-term memory, attention, mental manipulation, orientation, language, drawing, and animal name fluency. Another study investigated the effects of VR Tai Chi on the mental health of older adults during the COVID-19 pandemic (Kim et al., 2022). Their research revealed that older adults experienced improvements in mindfulness and enjoyment after the VR intervention. In terms of physical health, Hsieh et al. (2019) found that VR Tai Chi improves the aerobic endurance, lower extremity endurance, balance, and gait speed of older adults. Similar findings were also observed in mixed VR mind–body exercises. The study by Kim et al. (2013) indicates that a combined intervention of VR Tai Chi and yoga improved hip muscle strength and balance in older adults. Furthermore, one study compared the health benefits of older adults participating in VR Tai Chi versus traditional Tai Chi (Chen et al., 2020). The results indicated that VR Tai Chi may have greater potential in improving balance function and strength.

In addition, some studies indicate that combining VR mind–body exercises with VR non-mind–body exercises can improve the health of older adults. For example, Padala et al. (2017) found that a combined intervention of VR yoga, strength training, and aerobic

training improved the balance of older adults. Chao et al. (2015) used a similar mixed intervention and observed improvements in balance, mobility, and depression among older adults. These findings suggest that VR mind–body exercises may have the potential to combine with other forms of exercise.

In summary, current findings indicate that VR mind–body exercises and mixed exercises, including VR mind–body exercises, may positively impact the physical and mental health of older adults. This conclusion aligns with previous research based on traditional mind–body exercises (Zou et al., 2018; Wu et al., 2019). However, which intervention method is the most effective remains unclear, and further research is needed to explore this.

3.3 Strength

The strengths of VR meditation are as follows:

i. Exercise quality: Some mind–body exercise events, such as the full Tai Chi sequence, can be challenging for older adults (Chen et al., 2020). VR interventions provide real-time visual and auditory feedback. Specifically, participants can see their own movements and postures during the intervention, receiving guidance from a virtual coach. This can help them improve the quality of their exercise.
ii. Accessibility: Learning certain mind–body exercises can be challenging, as mentioned above. In traditional mind–body exercises, older adults may need to visit specific locations for instruction from a coach. In VR interventions, participants can receive guidance from a virtual coach, which opens up the possibility of home-based exercise. Research by Kim et al. (2013) suggests that VR mind–body exercises can improve physical function among older adults in an unsupervised environment, where VR feedback can replace the role of a coach.
iii. Immersion: VR technology offers a highly immersive experience, making it easier for participants to engage and enjoy the exercise. According to Rahman (2023), most participants reported that VR mind–body exercises were enjoyable.

3.4 Implementation challenges

VR mind–body exercises implementation not only encounters the challenges mentioned in the previous section, such as the cost, technical anxiety, and apparatus, but also confronts the following issues:

i. Exercise dose: VR mind–body exercises, such as Tai Chi and yoga, primarily consist of physical activities. Therefore, different exercise settings (e.g., intensity, frequency, and duration) may result in varying physical and mental health gains (Zhang et al., 2023a,b). However, there is limited evidence regarding the optimal exercise dose for VR mind–body exercises. Additionally, different older individuals may have different exercise dose requirements (Hsieh et al., 2019), and providing inappropriate exercise loads may lead to adverse effects. Thus, future research may need to further explore the optimal VR mind–body exercises dose under different conditions.
ii. Generalizability: Although research has identified the feasibility of seated Tai Chi exercise among frail older adults (Rahman, 2023), implementing VR mind–body exercise interventions in older individuals with functional impairments (e.g., mobility issues or memory problems) remains challenging due to the extensive amount of physical activity involved.

4 Limitation

When interpreting the findings of this study, it's important to consider some limitations. Firstly, our research suggests the positive impact of VR meditation and mind–body exercises on the physical and mental health of older adults. However, due to limitations inherent in our study design and the limited number of existing studies, our findings were not supported by quantitative analyses. Therefore, we recommend that future research conducts relevant meta-analyses as more related studies emerge. Secondly, our study focused on the implementation and effects of VR meditation and mind–body exercises in older adults. Therefore, the findings of this study cannot be generalized to other populations. Finally, the current research only included the application of VR Tai Chi and yoga in older adults. Consequently, our findings cannot be extrapolated to other types of VR mind–body exercises, such as VR pilates and Qigong. We encourage future experimental studies to explore various types of VR mind–body exercises.

5 Conclusion

The purpose of the current research is to summarize the implementation and impact of VR meditation and mind–body exercises in older adults. Our study indicates that VR headsets are critical devices for implementing VR meditation (Trueba et al., 2023a,b). However, in VR mind–body exercises, such devices are rarely used, and researchers typically employ a combination of motion capture sensors, main consoles, and display screens (Kim et al., 2013; Rahman, 2023). This could be to mitigate the risk of motion sickness (Cucher et al., 2023). In terms of health promotion, VR meditation has been shown to improve mental health (Trueba et al., 2023a,b; Cinalioglu et al., 2023b), pain (Sarkar et al., 2022), and quality of life (Hendrixson, 2020) in older adults. VR mind–body exercises contribute to enhancing the mental health (Hsieh et al., 2019; Kim et al., 2022) and physical function (Chen et al., 2020) of older adults. Furthermore, VR-based mindfulness interventions not only improved the quality of meditation and mind–body exercises but also enhanced their accessibility (Kim et al., 2013; Cinalioglu et al., 2023a). However, the implementation of these interventions still faces challenges such as cost (Trueba et al., 2023a,b), simulator sickness (Sarkar et al., 2022), technical anxiety (Trueba et al., 2023a,b), and apparatus-related issues (Trueba et al., 2023a,b). Moreover, despite the positive impacts of VR mind–body exercises on the health of older adults observed in current research, the optimal exercise dose remains unclear. Therefore, future research should focus on addressing the issue of the optimal dosage for VR interventions.

Author contributions

DG: Writing – review & editing, Funding acquisition, Visualization. YS: Writing – review & editing, Visualization. XZ: Visualization, Writing – original draft, Writing – review & editing. HLi: Writing – original draft, Writing – review & editing. HLu: Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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EDITED BY
Yang Cao,
Örebro University, Sweden

REVIEWED BY
Isaac Treves,
Massachusetts Institute of Technology, United States
Ellen Choi,
Toronto Metropolitan University, Canada

*CORRESPONDENCE
Jutta M. Tobias Mortlock
✉ jutta.tobias-mortlock@city.ac.uk

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How to create a mindful community of practice: exploring the social functions of group-based mindfulness practices facilitated via Zoom during COVID-19

Jutta M. Tobias Mortlock*, Hotri Himasri Alapati and Trudi Edginton

Department of Psychology, School of Health and Psychological Sciences, City St George's, University of London, London, United Kingdom

This exploratory qualitative study was conducted to investigate the experiences of individuals who have been participating in online mindfulness sessions with an online mindfulness community since the beginning of COVID-19, i.e., during a period of heightened uncertainty and social isolation. The study's purpose was to better understand the social functions of regularly practicing mindfulness in this online community of practice. Analyses from semi-structured interviews reveal how shared mindfulness practice may foster several pillars of connection and interbeing in this community of practice. These include improved mind–body awareness, coupled with a unique sense of trust and connection, which may have helped cultivate collective alignment and a sense of common humanity among research participants. Findings are discussed through the lens of interdependence theory, resulting in several exploratory propositions on how to create a mindful community of practice. The study concludes with a call for more research in this understudied research domain and invites mindfulness researchers and practitioners to test these propositions further. Its overall aim is to stimulate debate among individuals and groups intent on creating a mindful community in their workplace, educational setting, or neighborhood.

KEYWORDS

mindfulness, online, COVID-19, community of practice, interbeing, social connection, interdependence theory, meditation

1 Introduction

In Eastern contemplative traditions, mindfulness is considered a method – or practice – with a specific purpose: to develop lucid, metacognitive awareness of one's experience in order to clearly comprehend and transform suffering (Bodhi, 2011). In the scientific literature, the link between mindfulness and well-being has been extensively studied and mindfulness meditation is now widely utilized as part of mental health interventions (Wielgosz et al., 2019) including in workplaces (Kelloway et al., 2023). Furthermore, leading mindfulness scholar Jon Kabat-Zinn argues that mindfulness has transformative potential: mindfulness helps cultivate capacity to alleviate suffering and promote wellbeing for individuals as well as for communities and the world at large (Kabat-Zinn, 2011). In this paper, we incorporate Kabat-Zinn's assertion about the transformative potential of mindfulness and lean on Bodhi (2011) and Kudesia

(2019) to define mindfulness by its purpose, as a metacognitive practice to deeply understand and transform suffering and generate wellbeing, for one and all.

Communities of practice are groups of individuals who come together regularly to learn together, to share knowledge, and to benefit from belonging to a community of shared interests (Wenger, 1998). When people practice mindfulness together regularly, they can be considered a mindful community of practice. Typically these initiatives last two to three months, and then the intervention stops. But what happens when people in a workplace come together for a longer period of time to practice mindfulness? What are the social functions (in other words, the beneficial effects of actions or processes in a social system; Merton, 1949) of group-based mindfulness practice in an online mindfulness community of practice created during COVID-19? This is the question at the heart of our study.

In this paper, we focus our attention on the transformative potential of mindfulness. Specifically, our work responds to calls for more research on how mindfulness may help generate wisdom and transform suffering, not only for individuals but for everyone (Bahl et al., 2016; Daniel et al., 2022; Tobias Mortlock, 2023). Scholars have theorized on why and how mindfulness can be transformative beyond beneficial individual change, for social groups and even for society as a whole. For example, du Plessis and Just (2022) argue that mindfulness can transform the way we think about ourselves and others through critical reflexivity. In addition to critical reflection on personal and social issues, Vu and Burton (2020) propose that mindfulness encourages moral reflexivity with the potential to transform learning, including management learning in organizations. Perera et al. (2024) suggest that the potential of mindfulness practice to balance cognitive and emotional aspects of decision-making can transform workplaces by promoting more ethical decisions and by mitigating against discrimination. Moreover, in the United Kingdom (UK), a growing number of politicians have started practicing mindfulness and appear to consider mindfulness as more than mental training that brings along individual benefits, instead contributing to a flourishing society (Bristow, 2019). Finally, practitioners call for more rigorous research exploring how mindfulness can help cultivate transformative leadership (Paul, 2023).

However, empirical research examining the potential of mindfulness to transform entire communities is still scarce. In other words, today much prominent mindfulness theory and practice is concerned with cultivating awareness of the self, predominately focusing on the breath to help calm one's mind and take on the stance of a non-judgmental observer of one's thoughts and feelings through silent meditative practice (Kabat-Zinn, 2005; Williams and Penman, 2011). Scientific studies focusing on how mindfulness may help transform relationships *between* individuals are more rare than those investigating how it may help cultivate transformation *within* individuals. An exception is case study research of community-based activism in the UK and Germany, proposing that the Buddhist notion of *interbeing* – a term coined by influential Buddhist monk and writer Thich Nhat Hanh which relates to humans being inextricably mutually engaged with each other – is an essential aspect of social change and the transformation of society (Schmid and Taylor Aiken, 2021). Another exception is Tobias Mortlock et al. (2022) mixed-methods study combining individual with collective mindfulness training in a high-stress military setting, suggesting that innovative mindfulness training interventions may cultivate transformative capacity not only for individuals but for entire work teams.

Indeed, scientists report that mindfulness can cultivate beneficial outcomes not only for the self but also for others (c.f. Schindler and Friese, 2021, for a recent review). For example, several studies suggest that brief mindfulness training interventions may be effective in helping workers behave more prosocially (Hafenbrack et al., 2020) and that even 8 to 15 min of mindful breathing can increase workplace civility (Hafenbrack et al., 2024). Other empirical work (by the same lead author) indicate that being in a state of mindfulness may in fact *reduce* people's motivation to feel guilt or engage in prosocial reparative behaviors (to mend broken relationships; Hafenbrack et al., 2022). While meta-analytic analyses do report that there is a significant correlation between mindfulness practice and prosocial outcomes (Berry et al., 2020; Donald et al., 2019), these comprehensive reviews also highlight concerns about publication bias and challenges regarding replicating these findings. Notably, Berry et al.'s (2020) meta-analysis makes a critical distinction between the cultivation of compassionate and empathetic attitudes through mindfulness practice and the translation of these attitudes into actual prosocial behaviors, particularly when such behaviors would incur a cost to the individual (e.g., sharing expertise with a colleague or offering shelter to a person in need), and conclude that there is no conclusive evidence supporting the universally salubrious effect of mindfulness meditation on actual prosocial behavior. It may be that it matters more than we previously thought *how* people practice mindfulness together for social benefits of mindfulness practice to occur – hence our particular focus on examining mindfulness practice in groups.

In fact, in the contemplative traditions, mindfulness is understood as a socially engaged practice. As mentioned above, one of the core tenets of Eastern mindfulness is the intent to help people realize their *interbeing* nature. According to Hanh (2020), human experiences and the realities we create are all interconnected, and realizing this lays the path toward collectively understanding and overcoming suffering. We are more interdependent than we think: mindfulness in one person - as well as mindlessness - often impacts the level of mindfulness in another. Recall the last time you said or did something mindless to another person; this has likely influenced their capacity to be, to become, or to remain calm and non-judgmental. By the same token, meditation, the core mechanism of generating mindfulness, can be defined as "the practice of concentration, or stopping and looking deeply, in order to realize the truth of interbeing" (Hanh, 2020, p. 88). This means we can make space to cultivate mindfulness within ourselves, as well as cultivate mindfulness 'in the space between you and me'.

Based on the above-mentioned theoretical frameworks for understanding mindfulness in groups and organizations, as well as a broader understanding of mindfulness and its benefits, the field is well-positioned to better understand collective mindfulness practices and using qualitative, narrative methods to examine the social purposes of mindfulness.

In this study, we explore the experiences of members of an online mindfulness community of practice at a large metropolitan University who have come together to practice mindfulness and gentle mind–body exercises since the beginning of the COVID-19 pandemic, i.e., approximately 4 years to date. In this university setting, online-facilitated mind–body sessions have been offered by experienced mindfulness facilitators three times a week and participants were invited to log on and join the online mindful community at any point.

The study is qualitative in nature. Sixteen semi-structured interviews were conducted with volunteers from the above online mindfulness community of practice, to gain an understanding of their motivation to engage with the community, to explore how they have experienced the mind–body practices, the community, and any outcomes of being a member of this community. Interviews were transcribed and analyzed using inductive thematic analysis (Braun and Clarke, 2006) by two members of the research team (not the mindfulness facilitators), ensuring adequate interrater reliability, comparing and discussing major themes in two iterations.

In the sections that follow, we situate the study in its theoretical rationale, explain study research design and setting in detail, before presenting the results from our exploratory analyses. The paper concludes with a discussion of the study's implications for theory and practice as well as an outline of the study's research limitations and opportunities for follow-up research.

2 Theoretical background

2.1 Theoretical rationale

People can practice mindfulness alone or they can practice mindfulness with other people in a group setting within a community of mindful practice. Our study focuses on the social purpose of mindfulness, in other words its mission to cultivate wellbeing beyond individual transformation which has not been fully explored. Lacking knowledge about how individual and group processes and outcomes of people practicing mindfulness in communities of practice interact is problematic from a theoretical, practice-based and pragmatic perspective. There are at least two potential avenues through which mindfulness may prompt social transformation as an individual or as part of a community of practice: On one hand, there may be social or interpersonal benefits to an individual practicing mindfulness, for example increased prosocial behavior (Hafenbrack et al., 2020). This improved prosociality may come about because individual mindfulness practice not only helps an individual become aware of and regulate their own emotions and behavior, but this self-awareness and self-regulation may *transcend* the self, prompting prosocial attitudes and actions such as empathy and compassion (Vago and Silbersweig, 2012). On the other hand, when people practice mindfulness together, individuals involved in such group-based mindfulness practice may benefit from another's mindfulness practice. This is because mindfulness practice can be 'contagious', in a positive way: it may prompt *interpersonal* mindfulness, defined as self- as well as other-awareness with nonjudgment and nonreactivity (Pratscher et al., 2018). Khoury et al. (2023) speculate on the mechanisms involved in generating these personal benefits through interpersonal mindfulness: prosocial behaviors initiated by a person who practices mindfulness may facilitate awareness and understanding of internal somatic and emotional states, emotion regulation, empathy and mindfulness of another person in their presence. In addition, developing embodied awareness of the self may contribute to a greater understanding of how the minds and bodies of others interact with the self to enhance interpersonal connection and wellbeing.

Mindfulness and mindful movement based mind–body interventions have reliably been shown to be effective in increasing individual wellbeing in a variety of contexts including workplaces, schools and universities (Creswell, 2017; Bartlett et al., 2019; Vonderlin et al., 2020). In the scientific literature, mind–body practices have been defined as those "whose origins lie outside of the Western culture, typically combining muscle-strengthening, balance training, light-intensity aerobic activity, and flexibility in one package" and include a variety of yoga, tai chi, and other physical activities that also consider mental practices such as mindfulness, relaxation, and spirituality (Powell et al., 2018, 1). Mind–body practices emphasize the interconnectedness of the mind, body and heart in order to soothe the parasympathetic nervous system and strengthen polyvagal tone that in turn allows the individual to gently pause before responding and thus regulate emotion and enhance decision-making (ibid.). The exploration of neurobiological mechanisms underpinning the benefits of mindfulness training have identified measurable changes in the brain associated with attention, perspective taking and cognitive flexibility (Hölzel et al., 2011; Tang et al., 2015; Edginton, 2020) including hemispheric synchronicity (Lomas et al., 2014) and structural changes in the insula, a region of the brain that processes body awareness and emotional awareness (Sharp et al., 2018). A robust evidence base has been established for mindfulness as a mind–body intervention for stress reduction and improvements in wellbeing based on the efficacy of guided practices and inquiry (Farb et al., 2015; Pérez-Peña et al., 2022). The inclusion of inquiry within the group, which fosters connection and a sense of shared understanding, combined with mindful awareness, may foster beneficial change (Pérez-Peña et al., 2022).

The growing evidence base on the efficacy of mindfulness has predominantly focused on in-person groups across a range of community, workplace, educational and clinical settings. More recently there has been an interest in online mindfulness-based interventions which have also been shown to be effective in raising wellbeing and reducing employee stress (Spijkerman et al., 2016; Stratton et al., 2017). The success of these online interventions support earlier findings that the inclusion of group-based mindfulness practices and mindful inquiry may be core components that underpin beneficial changes associated with mindfulness training and the creation of a community of practice. There is some research exploring the opportunities and challenges associated with mindful communities of practice, notably their potential to generate care and compassion in work settings (Correia and Strehlow, 2018). *Online* communities of practice have become more prevalent in recent years, especially in the wake of the COVID-19 pandemic. Little is known in the scientific literature about online mindfulness communities of practice, yet we do know that workplaces interested in bringing people together in an online mindful community need to balance potential concerns (perceived lack of personal connection, fear of cyber bullying, and so on) with potential benefits (in particular convenience and flexibility; El Morr et al., 2020). Our study sits at the intersection of three literatures: social functions of individual mindfulness practice, mindfulness practice in a group setting, and online communities of practice.

2.2 Relevant theoretical frameworks

2.2.1 Situated learning theory

Social learning is as simple as it is powerful: people learn by watching other people (Bandura, 1977). Situated learning is an educational theory that emphasizes the contextual and relational nature of learning that occurs in adult education (Herrington and

Oliver, 2000) and in Communities of Practice (CoPs; Handley et al., 2006). It is based on Vygotsky's work proposing that humans develop through social interaction (Vygotsky, 1994). Situated learning occurs when individuals collectively make sense of situations, in particular in non-routine contexts such as when people get together outside of their ordinary work convention (Huzzard, 2004). Critical reflection and contextual sense-making are deemed essential ingredients of situated adult learning (Welsh and Dehler, 2013).

2.2.2 Online communities of practice

Social scientists Jean Lave and Etienne Wenger first coined the term "community of practice" in the early 1990s, describing a group of people who share a passion or concern and who come together and interact regularly in order to learn to do it better (Lave, 1991; Wenger, 1998). These communities are characterized by their shared interest, their collective learning and knowledge creation, and their shared practice and identity (Wenger, 1998). CoPs have been shown to be effective in generating knowledge sharing, learning, and professional development (Monaghan, 2010). In particular, community psychosocial wellbeing is cultivated through CoP and community practice interventions (Ohmer and Korr, 2006). In addition, a recent systematic review of public health CoPs suggests that reflective practice, structured problem-solving, and diverse networking may help in generating beneficial outcomes for CoP participants (Barbour et al., 2018).

Online CoPs, also known as electronic networks of practice, are platforms where participants with a shared concern or passion interact to deepen their knowledge, expertise, and social networking capacity (Zhang and Watts, 2008; Gunawardena et al., 2009). Research has shown that online CoPs have various benefits. They can provide opportunities for individuals to engage in ongoing discussions, share personal experiences, and provide emotional support (Prescott et al., 2020). In addition, they may act as therapeutic spaces, offering support and understanding for individuals facing health challenges (Coulson et al., 2017). Finally, online CoPs foster sustained learning and engagement between individuals in particular if they are characterized by trust and interpersonal commitment (Chang et al., 2015).

2.2.3 Online mindfulness programmes

Over the last decade, mindfulness-based interventions (MBIs) have increasingly been offered online. For example, individuals can join time-bound online MBIs delivered via the internet or group videoconferencing technology, such as the 8-week Mindfulness-Based Stress Reduction (MBSR) or Mindfulness-Based Cognitive Therapy (MBCT) training courses (Moulton-Perkins et al., 2022).

Scholars have begun evaluating the effectiveness of these new formats of mindfulness programmes (Spijkerman et al., 2016; Sommers-Spijkerman et al., 2021). Evidence from one of the first narrative syntheses of 10 online MBSR or MBCT programmes indicates that these may be as effective as in-person delivered mindfulness training, yet only three of these demonstrated moderate to high methodological quality (Moulton-Perkins et al., 2022). More recent systematic reviews and meta-analyses indicates that online MBIs can generate modest but significant benefits (Sommers-Spijkerman et al., 2021; Johnson et al., 2024), yet we still know too little about who signs up for and who drops out of online mindfulness programmes, how often individuals should log on or attend to benefit, or who might benefit most.

Understanding drop-out rates for mindfulness programmes is particularly important because we know that in mindfulness, practice really does matter in terms of helping generate beneficial outcomes (Parsons et al., 2017). This argument is supported in a systematic review of 8 RCTs of online MBIs offered during COVID-19; overall, a more beneficial effect could be detected for MBIs with a longer duration as well as for those who offered repeated intervention options (Witarto et al., 2022). However, according to Vargas-Nieto et al.'s (2024) systematic review of digital MBIs for repetitive negative thought, we lack solid data on drop-out rates for online mindfulness (the authors suggest that only four out of the 13 studies included in their review reported adequate completion rates), and drop-out ranges widely, with completion rates ranging from 21 to 85%.

In addition, a recent systematic review of 56 Randomized Controlled Trials (RCT) s of mind–body interventions to manage chronic pain, delivered using technology-enabled channels, found that only two thirds (that is, 38 out of the 56 included studies) provided a recommended 'dose' for adherence, i.e., how often to attend, log on, or practice the recommended techniques to experience benefits (Johnson et al., 2024). The authors of that same review explain that only three quarters of included studies (43/56) tracked intervention adherence, ranging from 69 to 92%, yet measuring this is crucial to gauge the effectiveness of online MBIs. These findings echo the findings of Sommers-Spijkerman et al. (2021) comprehensive meta-analysis of 97 online mindfulness RCTs, reporting overall statistically significant to moderate effectiveness in reducing depression, anxiety, and stress, yet stating that less than 25% of these (22 out of the 97 included studies) had defined cut-off rates for adherence, and over 75% (76 out of 97) did not measure drop-outs.

In terms of understanding for whom online mindfulness programmes might be most beneficial, in Witarto et al.'s (2022) systematic review of online MBIs during COVID-19 a sub-group analysis seemed to suggest that older adults may benefit comparatively more than other age groups; the authors speculate that this may be due to older individuals' greater capacity for engaging in acceptance-based processes. The same effect was not found across the other systematic reviews and meta-analyses we could identify. Furthermore, a recent systematic review of 13 online MBIs specifically focused on university students found small but significant reductions in depression, anxiety, and stress (yet no link to improved wellbeing), which appeared to show comparatively higher effect sizes than MBIs for other adults (Gong et al., 2023). The authors of that review speculate that this may be due to university students being more familiar with technology-based interventions. In a similar vein, Yogeswaran and El Morr's (2021) systematic review of (two) online mindfulness interventions to improve medical student mental health suggests these may be effective, yet warn that high drop-out rates diminish this potential benefit. Scholars call for more research specifically exploring the community dimensions of group mindfulness practice facilitated online, to counteract low program usage and high drop-out (Ahmad et al., 2018).

2.2.4 The social effects of individual mindfulness practice

We know that mindfulness practice can reduce symptoms of various mental health conditions (Creswell, 2017), as well as enhance mind–body connection (Grasser and Marusak, 2023), improve cognitive functioning (Lodha, 2022) and strengthen physical health (Cardle et al., 2023). We also know that a disposition toward

interpersonal mindfulness – an interpersonal awareness of moment-by-moment experiences both within oneself and also within another person by paying attention to the other's verbal and nonverbal communication – is linked to improved interpersonal communication (Pratscher et al., 2019) and improved intercultural communication effectiveness (Khukhlaev et al., 2022). In addition, *social* mindfulness theory is concerned with paying attention to the interests and concerns of others and by engaging in "other-regarding actions that arise from other-regarding motives" (van Doesum et al., 2013). Social mindfulness can reduce social hostility (van Lange and van Doesum, 2015) and arises via empathy and perspective-taking (Gerpott et al., 2020).

The evidence base on this topic appears incomplete, in an important and arguably understudied way: while we agree that it is important to understand the outcomes of mindfulness training and practice, it is also important to deeply understand the process of how individual mindfulness practice may – or may not – engender social effects. In other words, much empirical work to date has focused on the benefits of mindfulness *programs*, not examining the benefits of *membership* in a mindfulness program. This approach may also contribute to resolving why individual mindfulness practice may not always bring along social benefits, as mentioned in our Introduction.

2.2.5 Mindfulness practice in groups

Nowadays there is an abundance of mindfulness Apps and online mindfulness resources available to individuals interested in learning to practice mindfulness, such as the Headspace™ App or the Calm™ App. However, people typically learn mindfulness practices in groups, for example by attending an 8-week group mindfulness-based stress reduction (MBSR) course based on the seminal work of Kabat-Zinn (1982) and Creswell (2017) or through attending an amended group course based on MBSR or one of its evidence-based derivatives. One of these is the 8-week group program mindfulness-based cognitive therapy (MBCT; Segal et al., 2002). The outcomes of these group-based mindfulness training programs has been studied extensively. For example, in a longitudinal and rigorously designed study comparing MBCT with antidepressant treatment, researchers found that MBCT training is as effective as taking antidepressants even 2 years after completing the program (Kuyken et al., 2015). This impressive finding strongly indicates that learning to practice mindfulness in groups over time is effective.

MBSR pioneer Kabat-Zinn (1982) suggested that the group setting in the course plays a pivotal role in promoting mindful interactions – and thus mindfulness – among participants. There is empirical support for this view: Imel et al.'s (2008) examination of 59 MBSR groups found that being in a group while taking part in an MBSR course accounted for 7% of the variability in reducing psychological stress symptoms. The mechanism for this appears to be driven by MBSR instructors using their mindfulness skills to observe and adapt to group dynamics in real-time, aiming to (a) enhance the group's collective understanding of mindfulness, (b) improve the group's ability to listen deeply to each participant's experiences, and (c) encourage individuals to more openly share their experiences (Imel et al., 2008). Indeed, the group setting in mindfulness practice seems to significantly influence participants' learning experience – which may be positive or negative – depending on the mindfulness facilitator's skill in using the "group as a vessel on a shared journey" (Cormack et al., 2018, 735).

Specific examples pointing to the potential superiority of group-based mindfulness meditation over solitary meditation includes improved weight management when meditating in a group (Mantzios and Giannou, 2014) and enhanced social cohesion in groups meditating together (Hanley et al., 2022). Furthermore, a recently published meta-analysis indicates that group-based mindfulness-informed therapy is slightly more effective that standard (individual) cognitive behavioral therapy (Ferreira et al., 2022). Mindfulness practice can also help groups function better overall, because it helps group members become aware of their individual reactions to others in nonjudgmental ways (Michalski and Smith, 2023).

However, other direct empirical comparisons of mindfulness practice in groups vs. practicing alone found no differences in effectiveness of group-delivered and individually delivered MBCT for reducing depression and somatic disease (Schroevers et al., 2016) as well as no differential effect of participating in a mindfulness intervention alone vs. as part of a group on improved character or mindfulness skills (Matiz et al., 2018). This means more research is needed to further illuminate the potential benefits of mindfulness practice in group settings.

2.3 Study focus

Bringing together the literatures we have discussed above in the context of the present study, the research question (RQ) for our inquiry is, what are the social functions of group-based mindfulness practice in an online mindfulness community of practice created during COVID-19. Furthermore, we explore this RQ in the context of situated learning theory. This is because the theoretical context for the study is collective reflection, learning, and sense-making.

3 Materials and methods

3.1 Research setting

This study came about in the context of a large metropolitan university (the first and last authors' institution) offering 30 min drop-in mindfulness practice sessions via an online platform (Zoom) to staff and students over lunchtime, three times a week. The sessions were run by three experienced mindfulness trainers with specific expertise in Mindfulness-Based Stress Reduction (MBSR), alternating mindfulness facilitation so that there was always one trainer facilitating. Participation was free, no prior meditation experience was necessary, and anyone could join a session at any time. The sessions had been created in the wake of the COVID-19 pandemic to support student and staff wellbeing.

Each session followed the same broad structure: the facilitator welcomed the participants and invited them to share briefly how their mind was (or share a reflection that the facilitator initiated) on a voluntary basis (nobody was forced to share); then the facilitator guided the online group through a 10 to 15 min gentle mind–body meditative practice involving gentle relaxation, mindfulness meditation, and/or gentle stretching practice; and the session finished with another inquiry, specifically an invitation to the participants to share how their mind was then, after the practice (or share anything else related to the practice or session). Throughout, the facilitator

followed Crane et al. (2015) disciplined improvisation approach to the inquiry, namely seeking (as much as possible) to foster affiliation and intersubjective connection within the group of people present and gently steer communication toward nonjudgmental sharing of universal, embodied experience (as opposed to story-telling or sharing self-criticism).

The study was conducted during the summer of 2022; 2.5 years after the start of offering the drop-in mindfulness sessions at the university. By then, approximately 330 online mindfulness sessions had been run. Approximately 300 individuals had taken part in at least one session. On average between 10 and 20 individuals logged on to a session, and there were approximately 50 individuals who had participated regularly (i.e., at least once a week for several months). Over the several years that the online mindfulness sessions were running by the time the study was conducted, the sessions were reasonably well-known at the university. People joined and dropped out for a variety of reasons; scheduling conflicts contributed to drop-outs, so did changes in work patterns or individuals moving away and thus into other life contexts, as well as varying degrees of prioritizing practicing mindfulness alone vs. as part of this particular group. The individuals who formed part of our empirical study were drawn from the approximately 50 individuals who joined reasonably regularly, and thus were the community of practice for this study.

Our methodology reporting approach follows APA publication recommendations for qualitative empirical research (Levitt et al., 2018).

3.2 Research design

The research design for this study follows an interpretivist research paradigm, meaning that we aim to understand human behavior through subjective interpretation (Denzin and Lincoln, 2005). This paradigm shaped our relativist research ontology, assuming that there are multiple realities in life and different people may experience the same event differently, and a critical realist epistemology, which determined our research question by seeking to understand our participants' interpretations of the world in their context and through their perceptions (Willig, 2013).

3.2.1 Participant recruitment

Following approval to conduct the study from the first and last authors' university Institutional Review Board (IRB), participants were recruited on a volunteer basis by sending email communication to all individuals who had attended at least five of the lunchtime online mindfulness practice sessions over the course of a month (as outlined above). The total number of participants was 16. We chose this exploratory sample size leaning on Hagaman and Wutich (2017) who suggest that 16 or fewer qualitative interviews are sufficient to uncover common themes when conducting research with generally homogeneous populations and on Saunders and Townsend (2016) who suggest that the norm for sample size in organizational psychology research is between 15 and 60 individuals.

3.2.2 Participant characteristics

The 16 individuals below volunteered to participate in the study, provided informed consent, and were interviewed by two research assistants not affiliated with the online mindfulness sessions. They were between the ages of 20 to 60 years. In Table 1, we outline the demographics we captured for the participants, notably gender, and their roles (student or staff at the university). Out of the participants, 3 were male and 13 were females, which was representative of the participants who attended. The age range was spread relatively widely; 5 participants were in their 20s, four in their 30s, 3 in their 40s and 50s, respectively, and one person was in their 60s. Five students at the university were interviewed, 7 staff members, and 4 individuals who were affiliated but neither staff nor student at the university.

3.2.3 Interview procedure

A semi-structured interview schedule was developed and pilot-tested before conducting interviews with the research participants. The main focus of the questions was to understand the participants' experience of the online mindfulness sessions. Questions explored how they found out about the sessions; when they started regularly logging on; what their motivation was for joining; how regularly they attended; how they would describe their experience of the sessions and how this experience may have changed over time; whether they stopped joining at some point and what factors might have contributed to that and/or what drove them to re-join the sessions subsequently; what mindfulness meant to them and how they practiced mindfulness; how they experienced the online mindfulness community; and any other feedback participants were willing to share.

Interviews were arranged via email at a convenient time for the participant and conducted online. Having ensured that informed consent was provided, the researcher ensured that the participant understood the purpose of the study and the procedure. Interviews were audio-recorded following verbal consent from participants; these audio-recordings were destroyed upon transcription. Each interview took between 25 and 40 min and was debriefed in accordance with ethical guidelines.

TABLE 1 Demographics of the participants included in the study.

Name (anonymised)	Gender	Age range	Student or staff
Sarah	Female	20s	Student
Ruma	Female	50s	Student
Olivia	Female	40s	Staff
Ava	Female	60s	Staff
Matthew	Male	30s	Staff
Emma	Female	20s	Student
Zoe	Female	30s	Staff
Sriya	Female	50s	Staff
Lauren	Female	50s	n/a
Sophia	Female	20s	n/a
Emily	Female	30s	Staff
Jessica	Female	40s	n/a
Daniel	Male	20s	Student
Dounia	Female	30s	n/a
Hossnara	Female	20s	Student
Noah	Male	40s	Staff

The informational power among the sample of participants appeared satisfactory (Malterud et al., 2016). This was demonstrated by the fact that both interviewers reported no significant additional new insights collected during their last interview and concluded that data saturation seemed to have been reached (Guest et al., 2020).

3.3 Analytic approach

Interview transcripts were analyzed using Braun and Clarke's (2006) Thematic Analysis in several stages to identify, analyze, and report on findings in the data. Two researchers (the first and second author) developed initial codes inductively and individually, first by hand, then by grouping them electronically, and sharing and discussing these in three iterations. After each iteration discussion, the researchers went back to the transcripts to re-code and re-identify major themes and subthemes before sharing their interpretations again, until intercoder reliability was high and identified themes and subthemes were virtually identical across the two researchers (O'Connor and Joffe, 2020).

3.4 Reflexivity

Reflexivity in qualitative research is concerned with researchers critically investigating their own beliefs, judgments, and biases which may skew the reporting of results (Jamieson et al., 2023). In line with the principles of subjectivist research paradigms guiding this study, it is important to note that both researchers involved in the data analysis have been immersed in the study in different ways (the first author served as one of the mindfulness session facilitators; the second author was one of the data collection researchers) and therefore bring a degree of researcher bias to the data analysis (Braun and Clarke, 2012). To mitigate this and minimize bias in reporting, the researchers repeatedly engaged in reflection during the analysis process to realign their understanding about the research process and its aim, and in particular how each of them might be influencing this process (Lazard and McAvoy, 2020). Assumptions and expectations about the data were shared in order to disentangle these from the empirical data as much as possible.

4 Results

4.1 Summary

Four key thematic codes and their respective subthemes were identified in the data analysis: Collective alignment; common humanity; improved mind–body awareness; and unique mutual trust and connection in the online mindfulness community of practice we studied. Overall, our research participants said they found the online drop-in sessions helpful and they appeared to benefit from being a member of the online mindful community of practice. Particularly noteworthy was that not only did the opportunity to engage in group-based mindfulness practice seem to help improve individuals' mind–body awareness; it also seemed to help foster a unique sense of social connection among the members of the online community of practice.

All four thematic codes and their subcodes are outlined in Table 2. These capture the core findings from our interviews. The first key theme was about the group-based setting for the online mindfulness drop-in sessions. This seemed to provide a helpful social structure for participants' mindfulness practice – all the more so as many participants juxtaposed this to the felt sense of social isolation that COVID-19 presented. Second, interviewees seemed to benefit particularly from the fact that online sessions participants were invited to share what was on their minds and how they were feeling before and after the mindfulness practice. This appeared to contribute to them feeling less alone on one hand, and to helping them understand their own personal feelings better. Third, mind–body awareness seemed to have improved through regular participation in the online mindfulness sessions, potentially linked to the regular practice of actively sharing insights and feelings in the group. And finally, the sessions appeared to have

TABLE 2 Qualitative themes and subthemes alongside illustrative quotes.

Thematic code	Subtheme	Illustrative quotes
1. Collective alignment	1.1 Helpful structure	*"There was a regular pattern and routine to it" (Sarah)*
	1.2 Help with individual practice	*"It was kind of convenient, and at other times it was necessary" (Ruma)*
	1.3 A sense of community	*"I did very much enjoy that community aspect of it, connecting with the others and that sort of community we built up" (Noah)*
2. Common humanity	2.1 Feeling less alone	*"you were not alone in dealing with the kind of weirdness of situations" (Olivia).*
	2.2 Understanding one's own feelings better	*"outlet for just like for 20 s saying how I feel and checking in with how I feel" (Ava)*
3. Improved mind–body awareness	3.1 Reconnecting with the body	*"I found myself learning about myself. Basically, I think I had been very detached from myself and my body" (Emma)*
	3.2 Group practice getting them out of the thought bubble	*"[the group] practice helps you to be more observant about the world around you to take a minute to think about what other people might be thinking rather than just trapped inside your own thought bubble" (Daniel)*
4. Unique mutual trust and connection	4.1 Absence of social pressure	*"you just were responsible to be there and to be open" (Zoe)*
	4.2 Mutual care	*"I felt that connection, I felt comfortable talking. I guess that that trust was built and hard for me to pinpoint exactly what lead to that but it did feel like a space where you felt trust and safe" (Sriya)*

fostered a unique sense of social connection among members of the mindful community. More specifically, our interviewees suggested that they felt connected to fellow drop-in session participants in unusually deep and precious ways.

When analysing the thematic codes further, we put them into two sub-groups, and found that the combination of the first sub-group is likely to have helped bring about the themes in the second sub-group. In other words, improved mid-body awareness *and* unique mutual trust and connection (two of our thematic codes as outlined further below) helped generate a combination of the two other thematic codes; namely collective alignment and common humanity. We therefore arranged the four key themes in a (tentative) logical relationship, as outlined in Figure 1.

Table 2 shows the four key thematic codes used for the data analysis, alongside subthemes and illustrative quotes from interviewees.

Quotes are attributed to interviewed participant by adding pseudonyms per participant.

Each theme is illustrated further below.

4.2 Collective alignment

Three sub-themes emerged for this first thematic code; (a) helpful structure; (b) help with individual practice; and (c) a sense of community.

The first of these is concerned with the fact that the online drop-in mindfulness sessions occurring three times a week was perceived as a helpful structure in the lives of the participants. In the words of Noah, *"[I] think it gave a structure to my day … the discipline of attending at a regular time and engaging with the practice, that was really helpful."* Many of the regular participants in the mindful community had been joining the sessions since the beginning of the pandemic, and the sessions seemed to offer them a regular break from their stressful lives. Several interviewees emphasized that the regular sessions provided much-needed structure for organizing their days. One person suggested *"I remember quite strongly feeling that it was a really nice sort of clearing a space in the middle of your day, which was very good."* (Olivia). Others said they liked *"there was a regular pattern and routine to it"* (Sarah).

Some interviewees shared that they were somewhat astonished that the short, regular structure of the drop-in sessions proved helpful to them. One regular participant shared that *"expectations were like it's definitely not going to work, so give it a little trial period, but yeah, pleasantly surprised"* (Ruma). Another reflected on the fact that the sessions were short and in the middle of the work day, adding that she was *"actually surprised what you could get from that"* (Lauren).

In sum, the regularity of the sessions appeared to bring stress relief. The quote below sums up this sentiment:

> *"It was very, very difficult in [my work] sector … I'm trying to say that the world I was working in … was … under a lot of strain and devastation really. So it was really … helpful to come to this quiet time for lunch. Usually twice a week, and just to find space to do it."* (Zoe).

The second sub-theme revolved around the effect of the group-based practice setting: it was perceived as helping the participants with their individual mindfulness practice. Many of the interviewed participants indicated that practicing mindfulness in the online group encouraged them to practice in the first place. As Ruma said, "*it was kind of convenient, and at other times it was necessary*." Several explained that they found practicing mindfulness with other people easier than practicing alone, saying that *"it would help me with my own discipline of practicing, I find it easier, yes, in a group than to do it myself."* (Noah). Some of the interviewees had left the online community for a variety of reasons, and insisted that the group setting had been conducive to regular mindfulness practice. The sentiment that the mindful community had been valuable in promoting regular individual mindfulness practice is summarized in the statement below:

> *"I am nowhere near as regular with practicing now that I am not practicing online [in the group], and I do not have that outlet for just … 20 s saying how I feel and checking in with how I feel"* (Ava).

The final sub-theme related to the group-based setting of the mindfulness sessions was focused on a sense of community. Specifically, interviewees made statements such as "*I did very much*

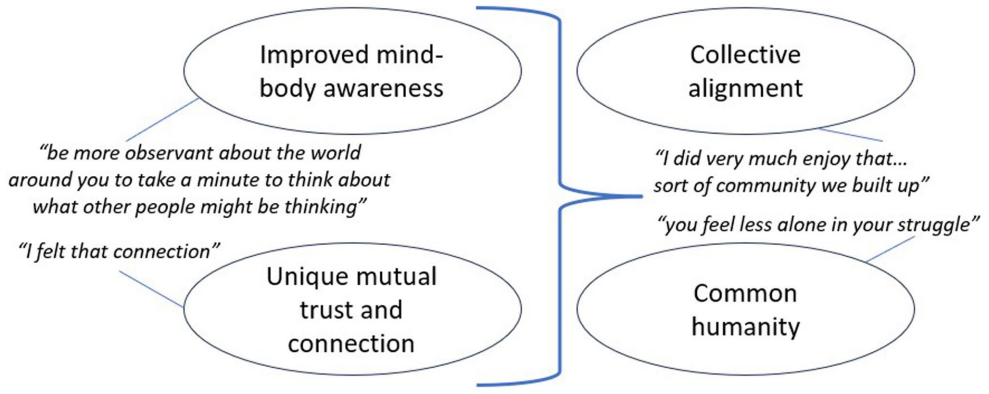

FIGURE 1
Logical relationship between key themes alongside illustrative quotes.

enjoy that community aspects of it, connecting with the others and that sort of community we built up" (Noah), indicating that over time, the online drop-in sessions had fostered a sense of connectedness and shared experience. In addition, this emerging sense of community seemed to have been perceived as affirming to the participants, particularly by promoting a shared sense of understanding the world around them. Essentially, the online mindfulness sessions provided space for much-needed shared experiences, as expressed in the quote below:

> *"It was really validating because during that time there was a collective experience that you were not aware of what was happening until you came into the mindfulness sessions and people were saying, oh I also feel like that and that bit on the news made me feel as well like that and that was very validating."* (Ava).

4.3 Common humanity

Two subthemes are discussed in the context of this second thematic code: (a) feeling less alone; and (b) understanding one's own feelings better. Both are situated in the context of the invitation by the facilitators to actively share a thought or feeling at the beginning and end of the online drop-in sessions. Interviewees seemed to particularly enjoy sharing at the end of the session and listening to others' reflections. One person explained, *"coming back to [the practice] and reflecting and what went right and seeing how other people felt it's good"* (Sophia).

The first subtheme here is about feeling less alone and isolated. Some of this seemed to be specifically because of listening to other participants share some of their struggles. In the words of one interviewee, actively sharing during the practice meant *"hearing the types of issues that other people are struggling with, so that you feel less alone in your struggle"* (Daniel). Another person related that sharing how they were feeling *"was very useful because you just saw that you have a bigger whole, you know, you were not alone in dealing with the kind of weirdness of situations"* (Olivia).

The second subtheme relates to understanding one's own feelings better, because of being in a context in which individuals are encouraged to actively share their thoughts and feelings. Being gently encouraged to share what was on their minds seemed to provide an opportunity to work out in the first place what *was* on their minds, in that moment. In the words of one interview participant, the online community offered an *"outlet for just like for 20 s saying how I feel and checking in with how I feel"* (Ava).

Expressing feelings was deemed superior than silent meditative practice alone. This is because the act of articulating out loud how participants were feeling was seen not only as an opportunity for connection but also an opportunity to understand more deeply what was real for the person in that moment. The quote below illustrates this insight:

> *"We can write things down, we can notice ourselves, but when we articulate it to a group and possibly get some, some feedback, or sometimes some support … and actually hearing yourself speak out the words… it's different from just thinking … I'm acknowledging more deeply how I'm feeling when I say it aloud to somebody else"* (Sarah).

Moreover, listening to others reflect on their mental state during the mindfulness practice was deemed valuable, precisely because other people's insights seemed to help generate personal insight. In the words of one of our interview participants:

> *"It was great to, in the group, connect with people in different situations from myself, because sometimes that helps, helps with reflection to understand that everyone's circumstances and my own trends is transient. They're not fixed."* (Matthew).

4.4 Improved mind–body awareness

The third key thematic code refers to improved mind–body awareness. This is in itself not surprising as mindfulness practice generally fosters mind–body awareness. Yet this increased mind–body awareness seems to also have come about because the group setting in the online mindfulness community seemed to have enabled learning about the self.

As expected, about half of the interviewed participants in the online community identified that the mindfulness drop-ins had helped them improve their mind–body awareness, in other words their embodied felt sense of being present in mind and body. Facilitated mindfulness practices included gentle yoga stretches, exploring different types of perceptual awareness such as focusing and subsequently broadening attention on particular aspects of seeing, listening, feeling and so on, as well as mindful breathing and mindful movement. The two sub-themes here were (a) reconnecting with the body; and (b) the group practice getting them out of the thought bubble.

First, several interviewees mentioned that they welcomed the regular opportunity to consciously shift attention onto themselves. An opportunity they would not ordinarily use even if they blocked time in their diaries to *"have 20 min quiet time … I do not think I would have engaged with myself quite as much as they allowed me to engage"* (Emily).

The core insight here is that their awareness of their five senses seemed to have improved. This, in turn, seemed to have strengthened their sense of connection between mind and body. The idea of *re*connecting mind and body was central to this theme, with an interviewee recalling the following:

> *"I found myself learning about myself. Basically, I think I had been very detached from myself and my body. For most of my life, and I think practices like mindfulness has really helped me to connect"* (Emma).

Second, and perhaps more interestingly, the mindfulness practices seemed to have provided a welcome break from being lost in thought and reconnecting with others and with the world around them. Becoming more embodied seemed to be at the heart of this theme, with interviewed participants explaining that they enjoyed getting out of their minds and getting back into consciously feeling their body alongside others. The notion that the practice *"relaxes your body and relaxes your mind"* (Emily) was a common theme here among interviewees. One participant reflected on the positive energy that could be felt between individuals getting together to practice mindfulness, adding that *"if you have got a whole room full of people*

meditating and feeling calm, there's something that's happening on a subconscious cellular level that adds to the experience" (Daniel). This effect is particularly noteworthy as people were not physically in the same room yet a different, beneficial energy seemed to emerge nonetheless. The same participant summarized this benefit of practicing together, online, as:

> *"[the group] practice helps you to be more observant about the world around you to take a minute to think about what other people might be thinking rather than just trapped inside your own thought bubble"* (Daniel).

4.5 Unique mutual trust and connection

The final key thematic code is unique mutual trust and connection. The following two subthemes emerged on the impact of the drop-in sessions for the interviewed participants and point toward a unique degree of trust and connection that some of the participants appeared to have felt toward each other. They are (a) absence of social pressure; and (b) mutual care. Both of these relate to the fact that people from a wide range of groups were invited to participate in the drop-in sessions, including current and former students and staff members. Several interviewees commented on the fact that different people from different parts of the organization would be *"coming together to reflect and think and take this time out,"* and added *"I think [connecting with really different people] is a really powerful thing"* (Olivia).

The first of these subthemes is about the somewhat paradoxical idea that this particular social setting did not bring with it the usual social pressure to follow conventional norms of behavior, such as being nice or outwardly taking care of each other. Participants expressed in particular a sense of relief that the sessions were not about being *"responsible to look after people"* and at the same time they welcomed the fact that *"you just were responsible to be there and to be open"* (Zoe). In other words, whenever someone logged on to a particular mindfulness drop-in session, they would not need to behave in a particular way toward each other and instead were allowed to simply *be*.

Notably, it seems that being released from this particular social pressure meant that session participants could be genuinely there for each other, *"listen to each other and respect each other and also give each other space" (Zoe).* The lack of social pressure in this setting was mentioned by several interview participants as valuable, precious even, as the statement below suggests:

> *"I just felt I did not feel any pressure to be a certain way or hold feelings for anyone or if I was feeling really stressed, anxious, or down I could just come with that to the mindfulness without having to pretend that it wasn't there or be a certain way. Yeah, that was a really unique space that was completely different to being with friends and family"* (Ava).

The second subtheme in this category leads on from the first, in that interview participants shared that there seemed to be mutual care among session participants as a result of the unique social bond that people felt for each other. An interviewee explained that in the sessions *"there's a sense of nurturing, so it feels very psychologically safe, of caring about ourselves and each other"* and that *"people have mentioned things that they are struggling with, or ways that they were feeling that were fairly personal and intimate, in some cases, you know, and what they got back from the group was support and loving kindness"* (Daniel). Essentially, the community seemed to offer a space for giving and receiving social support informally.

This sense seemed particularly palpable among participants who joined the sessions frequently. In essence, the more frequently people participated, the stronger this sense of mutual care seemed to become, which meant that *"the people who were joining regularly were very willing to be vulnerable, to share how they are, which I have never experienced before"* (Jessica). In the words of another one of our interviewees:

> *"I felt that connection, I felt comfortable talking. I guess that that trust was built and hard for me to pinpoint exactly what lead to that but it did feel like a space where you felt trust and safe"* (Sriya).

One participant, however, indicated that the online nature of the group meant that the connection was less natural than it would have been in a face to face setting. She explained, *"there was less of a human connection with the others, we had a bit of a chat, and I could relate to some of what they were saying but there was less room for that side of things which I would have liked"* (Lauren). Clearly, online connection cannot really replace real human interaction and connection.

In sum, the data indicates that an atmosphere of mutual trust and care seemed to have emerged for the majority of the people interviewed for the study *despite* an absence of pressure to act in conventional ways toward each other.

We discuss these findings and what they may contribute to theory and practice in the section below.

5 Discussion

This inquiry is about exploring the social functions of group-based mindfulness practices in an online mindfulness community of practice created during COVID-19, with a particular focus on understanding the process – and potential benefits – of being a member of a community of practice engaging in regular gentle mind–body exercises together over Zoom. We examined the exploratory qualitative data we collected within a situated learning context. In other words, the underlying assumption for our investigation was that the members of the community of practice under study would engage in learning in the specific situation in which their learning occurred.

Besides drawing on situated learning as context, we structure the discussion through the lens of interdependence theory, a framework that examines the influence of social orientations, such as cooperation or conflict, within contexts where outcomes are interdependent (Kelley and Thibaut, 1978). This is for the following reasons: While we acknowledge that mindfulness theory and practice needs to understand intrapersonal (or intrapsychic) processes, it is helpful to make sense of our findings with an interdependence lens. Interdependence theory asserts that it is the interpersonal dynamics that predominately shape individuals' perceptions, motivations, and behaviors (Rusbult and Van Lange, 2008). Essentially, the theory posits that these interpersonal interactions form the emotional landscape within which individuals make decisions and take actions. In addition, interdependence theory offers a fruitful pathway to

integrate mindfulness theorizing with the contemplative tradition's emphasis on other-orientation and interdependence, aspects that may not yet have been fully explored in the contemporary mindfulness discourse (see Gergen, 2009). Echoing the Dalai Lama's insights, profound wisdom is realized when individuals acknowledge and value the interconnectedness of their own interests with those of others (Dalai Lama, 2005).

5.1 A special note on the special context of this study

Before outlining the study's proposed contributions to theory and practice, it is necessary to draw attention to the fact that the study was conducted during the COVID-19 pandemic, and every reader will know that this was an unprecedented time of apprehension and ambiguity for most. It is reasonable to assume that mindfulness practice is well-suited to address feelings of uncertainty, loss, and confusion that inevitably came along with the pandemic (Antonova et al., 2021). There is also evidence that mindfulness appears to have been protective against negative affect arising during COVID-19 (Treves et al., 2023). Moreover, in a systematic review of 16 nonpharmacological interventions developed during the pandemic to promote the mental health of children that include mindfulness, Quiroga et al. (2025) found that these were potentially effective. The authors also suggest that interventions designed during COVID-19 are likely to be useful in other future crisis situations, yet note a significant risk of bias across the studies they examined, hence caution against drawing firm conclusions.

Our study is no different in this regard: it was conducted during an especially unusual time, its design prevents us from making any generalizable predictions, and it is situated in a scientific literature that is still in its infancy. As a case in point, online group psychotherapy pioneer Haim Weinberg who had been facilitating online discussions on the topic among 400 group therapists from 30 nations for over 25 years synthesized these insights in his (2020) practice review of online group psychotherapy for the COVID-19 context. His recommendations included that the lack of physical presence in virtual meetings and distorted eye contact may warrant increasing therapists' self-disclosure (TSD) and enhanced verbal interactions. While there is certainly scientific support for the use of TSD in therapeutic settings, a more recently published study of two independent samples of therapists ($N = 1705$) and patients ($N = 772$) interacting online early on during the pandemic suggests that therapists perceive the use of TSD as more helpful in fostering real relationships than patients (Luo et al., 2024). Clearly, the COVID-19 pandemic helped accelerate our understanding of online group therapeutic interventions, including online mindfulness groups. Yet scholars call for more research to better grasp their potential (Andrews et al., 2024; Quiroga et al., 2025). Our study responds to this call.

5.2 Implications for theory

Based on our empirical investigation, we make three exploratory propositions intent on stimulating follow-up empirical research at the intersection of literatures on online communities of practice, mindfulness practice in groups, and the social effects of individual mindfulness practice. We have arranged these exploratory propositions in a logical relationship, as depicted in Figure 2. In essence, we speculate based on our exploratory data set that the combination of proposition 1 and 2 may result in proposition 3, and all three may contribute to creating a mindful community of practice.

Taken together, these propositions aim to stimulate further empirical research in this understudied area, by formulating a proposed – and testable – combination of elements for how to create a mindful community of practice. Leading on from the sections outlining this work's implications for theory and practice below, we outline follow-up research opportunities for further empirical examination, potential correction, and extension of our propositions.

5.2.1 Proposition 1: creating opportunity for common humanity

Our data suggests that the online mindful community of practice we studied first and foremost helped individuals experience common humanity, in other words, share a felt sense of belonging, at least during the time they practiced mindfulness together. The participants we interviewed repeatedly mentioned that the online mindfulness community provided respite from the isolation many people felt because of the COVID-19 pandemic.

A basic assumption in mindfulness is that there is suffering in the world, and this suffering can be alleviated through mindfulness practice. In the context of this study our data indicates that the mindfulness-based community of practice we examined helped individuals enjoy a sense of community, even if only temporarily.

This is because in our study, the personal mindfulness practice that was cultivated because individuals regularly logged on to the online mindfulness group seemed to help them feel less alone (thematic code 2.1), understand their own feelings better (thematic code 2.2), and the group practice seemed to get them out of their own thought bubble (thematic code 3.2). Thus they appeared to become better able to recognize helpful as well as unhelpful thoughts, emotions and impulses with a deeper awareness of universal experiences, challenges and concerns leading to authentic connection and a sense of belonging within the community of practice. Mindfulness scientists

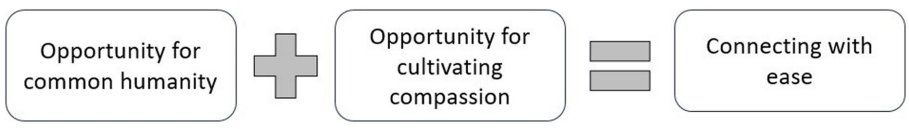

FIGURE 2
Logical relationship of propositions for how to create a mindful community of practice.

have been able to reliably establish the two-fold mechanism through which mindfulness practice operates; consciously experiencing awareness as well as acceptance is key here (see Carmody et al., 2009; Vago and Silbersweig, 2012; Lindsay and Creswell, 2017). The group setting appears to have served as a facilitator for this, because our participants indicated that their individual mindfulness practice improved in the group setting. This echoes the writings of Thich Nhat Hanh who emphasized that the practice of mindfulness should be a socially engaged practice rather than something individuals cultivate in isolation of others (Hạnh, 1998).

From an interdependence perspective, experiencing common humanity also involves reducing the power of *ego*. In the mediative traditions *ego* is explained as a sense that the self exists entirely independently and separately from others, which leads to ignorance, paranoia, and confusion (Trungpa, 2002). The mind–body practices intent on fostering stronger embodiment in our community participants seemed to have helped them to relax into their bodies, and appreciate their common humanity, which appeared to have offered some respite from being lost in their "thought bubbles" and sense of existing as separate from others. According to mindfulness philosophy this helps individuals realize that they "no longer have to maintain the existence of ego [and] can afford to be open and generous" (ibid., p. 168). We speculate that the regular, repeated group setting of the community of practice may cultivate this stance of openness comparatively more than when individuals practice mindfulness by themselves.

This is why we propose the following:

> *Proposition 1: Practicing mindfulness in a community of practice may help create opportunities for experiencing common humanity.*

5.2.2 Proposition 2: creating opportunity for cultivating compassion

Leading on from Proposition 1, the mindful community of practice we studied appeared to have created opportunities for cultivating compassion among its members. Compassion has been defined as a distinct emotion geared at facilitating cooperation and an intent to protect those who suffer (Goetz et al., 2010). Interdependence theory posits that people think and act in relation to each other. A growing body of mindfulness scholarship is focusing on the mental space between individuals, arguing that *interpersonal* mindfulness – the state of being mindful while interacting with others – helps shape healthy relationships (Pratscher et al., 2019). Interpersonal mindfulness practices and trainings based on Gregory Kramer's Insight Dialog (Kramer, 2007) such as relational mindfulness (Donaldson-Feilder et al., 2019; Donaldson-Feilder et al., 2022) have become increasingly popular in mindfulness science and practice, because of their growing evidence base in fostering *interpersonal* awareness and acceptance.

In particular the combination of feeling a part of a community (thematic code 1.3) and mutual care (thematic code 4.2), coupled with an absence of social pressure (thematic code 4.1) seem to have produced this effect. As the data in this study suggest, research participants indicate that by listening to each other during the online drop-in mindfulness sessions, they experienced a sense of community that seemed unique and precious in its warm and supportive quality. This is related to how compassion is defined in the contemplative traditions. Compassion is basic warmth toward oneself and toward others, which can be operationally defined as an absence of interpersonal aggression (Trungpa, 2002). This warmth is crucial for the development of healthy relationships.

We speculate that in the online mindful community of practice we studied, the foundation for compassion may have been cultivated. We suggest this because communication in the online mindfulness community of practice was carefully managed by the facilitator. Specifically, the facilitator encouraged a ritual of listening to what others were sharing at the beginning and end of the online mindfulness practice sessions. The act of listening to each other at the beginning and end of the mindfulness sessions seemed to have enabled individuals to engage in socially induced processes of *decentering*; shifting their perspective to gain psychological distance (Bernstein et al., 2015; Shapiro et al., 2006). Decentering, also referred to as *reperceiving*, is typically discussed in the context of intrapsychic experiences, in other words, the metacognitive practice of shifting one's perspective "from *within* one's subjective experience *onto* that experience" (Bernstein et al., 2015; p. 599, emphasis added). In the social context we discuss here, decentering may have played a role in community building, because it may have fostered a mental shift for the members of the mindful community of practice, from an exclusive focus on *personal* wellbeing through mindfulness toward *interpersonal* wellbeing. This is similar to how Epstein (2013) conceptualizes the link between mindfulness and psychotherapy, essentially suggesting that listening to others enables a shift in mindfulness practice from a solitary and self-focused aspiration to watch one's own thoughts and feelings toward an interpersonal meditation that helps cultivate compassion between people.

The repeated nature of this interpersonal communication ritual may have been the second 'ingredient' for how to create a mindful community of practice. This is why we propose the following:

> *Proposition 2: Practicing mindfulness in a community of practice may help cultivate compassion.*

5.2.3 Proposition 3: connecting with ease

Mindfulness is multifaceted (Daniel et al., 2022) and multi-dimensional (Sutcliffe et al., 2016). This means we can practice mindfulness to make space *within* ourselves, and we can also focus our attention mindfully on the space *between* people. More specifically, our data overlaps with Vogus et al. (2014) who theorized that the affective (or mood-based) foundation of a mindful group are equanimity and a prosocial orientation; in other words when people interact with each other with motivations marked by equanimity and prosociality, collective mindfulness emerges (Vogus et al., 2014). We speculate that the particular, unique type of social connection marked by mutual trust and connection that our participants have described (theme 4) is linked to increased prosociality and enhanced equanimity. Additionally, equanimity may be related to our data's themes of understanding one's own feelings better (theme 2.2) and in particular the group practice getting them out of the thought bubble (theme 3.2).

This paper is about creating a community of practice, of a particular kind: a *mindful* community of practice. In Buddhism, the essential pillars of mindfulness practice are referred to as the 'three jewels': the teacher or facilitator (in Buddhism this has originally been the Buddha); the teaching elements or topics to focus on during the

practice (traditionally referred to as the *dharma*); and the community of mindfulness practitioners (referred to as the *sangha*; Hanh, 2020). Of course, in a traditional Eastern contemplative context, the *sangha* would consist of monastics coming together to meditate, but in today's world this word also refers to a community of Buddhist practitioners regularly practicing mindfulness together. While this paper is not concerned with religious or spiritual mindfulness practice, we argue that creating connections among mindfulness practitioners during mindfulness practice may be an important element of mindfulness, perhaps not emphasized enough in the scientific community studying mindfulness meditation over the last four decades.

People who interact with each other mindfully seem to have one *collective mind* (Weick and Roberts, 1993). A visual metaphor for this is a flock of geese flying through the sky in unison, with each goose adapting its individual flight path to align with the direction – and needs – of the flock as a whole. Interdependence theory conceptually overlaps with Hanh's notion of *interbeing*, because both emphasize the inextricable connection between people that shapes people's lives and their experience. Connecting with each other has been at the heart of the community of practice we studied. Especially the sense of relief that participants shared about feeling an absence of the typical social pressures that many of us experience in conventional social settings, such as making small talk, comparing oneself to others, and so on (theme 4.1) seemed to have cultivated what we call *connecting with ease*.

Experiencing ease and thus an absence of pressure is an essential aim in mindfulness practice. The word "budh" in Buddhism means "to wake up," "to understand at a deep level." As referred to at the outset of this paper, the purpose of mindfulness is to understand and transform suffering (Bodhi, 2011). Therefore, helping individuals 'wake up' from suffering and the potential fear of interpersonal connection is an essential component of creating a mindful community of practice. Today, many individuals in industrialized nations suffer from loneliness and social isolation, shying away from forging meaningful social connections, which in turn puts them at risk for premature mortality (Holt-Lunstad et al., 2015). Among our participants, there was a felt sense of delight in connecting with others, coupled for some with a certain degree of surprise at experiencing a lack of social pressure in this setting. We speculate that many of us in today's world may benefit from experiencing anew that social connection can be healing and that it can reduce, rather than increase, pressure and stress.

We therefore suggest that to help transform suffering for oneself as well as for others, which is at the core of the intent or purpose of mindfulness practice, it may be helpful to foster connections among mindfulness practitioners with an emphasis on 'waking up' from the struggles we all face in our lives by connecting with each other regularly, as Buddhist meditators have done in a *sangha*, in ways marked by equanimity and prosociality. Leading on from this, we propose the following:

> *Proposition 3: Practicing mindfulness in a community of practice may help facilitate connecting with ease.*

5.3 Implications for practice

Clearly, group mindfulness practice requires skillful facilitation. The competence of mindfulness facilitation can be learned through a variety of reputable mindfulness training institutions globally, and is typically assessed through the evidence-based Mindfulness-Based Interventions Teaching Assessment Criteria (MBI; TAC; Crane et al., 2013). In addition, the characteristics of inquiry in group-based mindfulness practice can be likened to "disciplined improvisation"; flexibly interacting with participants after mindfulness practice in ways that build intersubjective connection and interpersonal affiliation (Crane et al., 2015).

To the best of our knowledge, there is a lacuna of academic research on how to create a mindfulness-based community of practice. Leaning on Wenger (1998) and Lave (1991) who suggest that communities of practice need to consistently foster a shared sense of interest – here mindfulness – as well as a felt sense of community and regular practice of the shared interests, we therefore make the following specific recommendations for individuals intent on creating a mindful community of practice, organized around three main themes. This may be especially important during periods of societal change – and today's world seems to be marked by ongoing social change, as well as heightened anxiety and uncertainty.

5.3.1 Facilitate regular and varied mindfulness practices

Make it easy for people to join in regular group mindfulness sessions. Offer short sessions at several different times and days a week. Online mindfulness practice is becoming increasingly common and is convenient for people to log on to.

Include gentle yoga, mindful movement, and other mind–body explorations in the mindful community practices, to strengthen the conscious link between mind and body among group participants.

Explore different ways in which community members may experience mindfulness in the group practices. According to Crane et al. (2017), mindfulness-based training always needs to include essential elements such as an understanding of human suffering and mental health – and depending on the needs of those practicing mindfulness, new and different elements may be added, such as varying the degree of physical activity during the mindfulness session. Experiment by introducing community members to different practices and inquire which ones may be more appropriate for the community of practice.

5.3.2 Facilitate connection with ease

Ensure that all mindfulness practices are participant-centered and grounded in mind–body awareness as well as non-judgmental interpersonal sharing. If appropriate, then gently encourage people to build personal relationships in informal ways.

Refrain from managing group membership or attendance. Keep participation voluntary and open.

5.3.3 Facilitate compassionate communication

Invite participants in a group mindfulness session to share what is real for them, without forcing participation from anyone. Lead by sharing authentically yourself. If appropriate, you may want to engage in *leading with vulnerability*, in other words, sharing what you feel in the moment, rather than saying what you may believe others want to hear.

Consider integrating the offering of a mindful community of practice with other workplace initiatives such as training and

development, induction activities, or during regular organizational meetings. This may increase the potential of embedding the routine of people coming together to practice mindfulness regularly.

5.4 Limitations and follow-up research opportunities

As noted previously, this study was conducted during an extraordinary time, with a group of participants who came together during Covid-19. A small group of volunteers from the mindfulness community of practice were sampled, which means that insights captured were bound to be biased toward those of research participants, rather than expressing more universally applicable views. It is plausible that participants in the sample shared a subset of relevant insights, or other insights were not represented in the data. Furthermore, the interview questions were exploratory in nature, and the lack of targeted questions and our exploratory analysis made it impossible to test whether the online mindfulness community of practice was beneficial, and how. Of course, the fact that only one mindfulness community of practice was sampled further restricts the potential to generalize from the findings presented here. In addition, while the interviewers collecting the data for this study were not members of the community of practice, it is conceivable that participants did not freely share all feedback, as it was known to them that at least one of the facilitators of the sessions was involved in the research study. Finally, there is also risk of bias because two of the authors of this study were involved in delivering the online mindfulness sessions, and one of the interviewers was involved in the data analysis.

Follow-up research can extend the insights presented here in several ways. First, it would be helpful for future research to test out the suggested propositions on how to create a mindful community of practice, for example by exploring the relative contribution of individually focused mindfulness practices versus interpersonal elements in the community. Second, quantitative surveys of mindfulness groups could investigate the attitudes of participants toward their own wellbeing, their learning, and the relationship quality with other participants. Constructs such individual mindfulness, team mindfulness, and psychological safety could be included in measures in such studies, to understand the relationship between individual-level outcomes and interpersonal outcomes. Finally, more longitudinal explorations of mindfulness groups would help us understand the characteristics of how a mindful community of practice is formed and sustained.

6 Conclusion

This study took place during COVID-19, a highly exceptional period in the life of everyone. Its specific aim was to explore the social functions of group-based mindfulness practice facilitated regularly online at a large metropolitan University during that time. Findings suggest overall that the online mindful community may have offered a welcome and unexpected safe space to cultivate mutual trust and connection, as well as increased mind–body awareness. These two key factors seemed to be linked to a sense of collective alignment and common humanity. Our findings are discussed through an interdependence theory lens and result in three exploratory, testable propositions on how to create a mindful community of practice.

While the study focused on a mindful community of practice that was formed during a time of unprecedented instability and extreme social isolation for many, and while its research design and exploratory analysis render it impossible to draw firm conclusions, it nonetheless sheds new light on how mindful pillars of interbeing and connection may be formed in an online community of practice. We argue that more research is needed in this understudied domain, in order to extend the transformative potential of mindfulness for one and all.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors upon request, without undue reservation.

Ethics statement

This study involving humans was approved by the Research Ethics Committee of City St George's, University of London. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JT: Writing – original draft, Writing – review & editing, Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Supervision, Visualization. HA: Formal analysis, Investigation, Methodology, Project administration, Writing – review & editing. TE: Resources, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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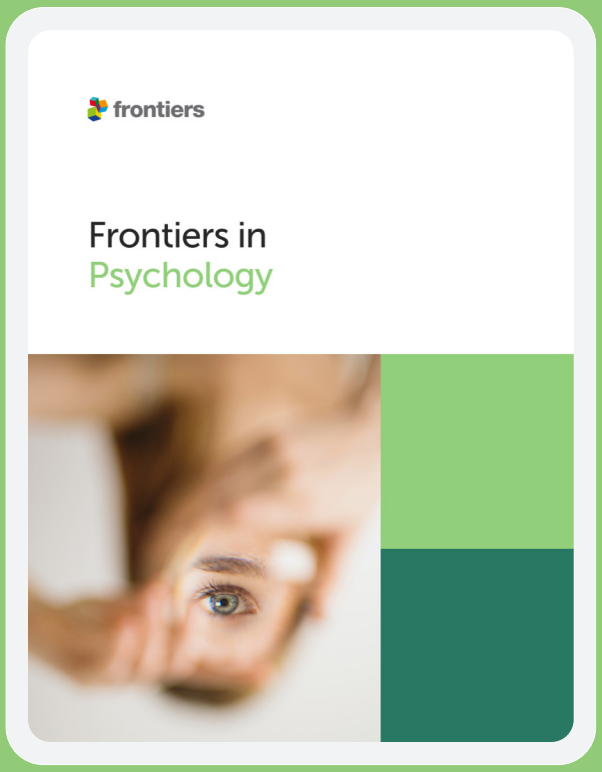

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