frontiers | Frontiers in Rehabilitation Sciences

TYPE Brief Research Report
PUBLISHED 06 December 2024
DOI 10.3389/fresc.2024.1427446

OPEN ACCESS

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RECEIVED 02 October 2024
ACCEPTED 03 May 2024
PUBLISHED 06 December 2024

CITATION
MacDonald EE, Pellerine LP, Miller KE, Frayne RJ and O'Brien MW (2024) More absolute moderate-to-vigorous physical activity is associated with better health-related quality of life in outpatients with an acquired brain injury.
Front. Rehabil. Sci. 5:1427446.
doi: 10.3389/fresc.2024.1427446

More absolute moderate-to-vigorous physical activity is associated with better health-related quality of life in outpatients with an acquired brain injury

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Health-related quality of life (HRQoL) is a patient-perceived measure of physical, social, and emotional health. Acquired brain injury (ABI) occurs due to damage to the brain after birth. Individuals with an ABI typically present with reduced HRQoL and require additional support to maintain their HRQoL. Although structured exercise training has been shown to improve HRQoL in individuals with ABI, there is little research on habitual, real-world activity. Most activity research characterizes moderate-to-vigorous physical activity (MVPA) in absolute terms; however, relative physical activity levels have been promoted for research in clinical populations. We tested whether longer MVPA durations, measured in absolute/relative levels, are associated with higher HRQoL in outpatients with ABIs. In total, 26 adults (54 ± 13 years, 16 females) with ABI completed the Quality of Life After Brain Injury questionnaire, a 6-min walk test (a measure of aerobic fitness; 490 ± 105 m), and wore an activPAL device 24 h/day for 7 days. Participants had an average HRQoL score of 53.4 ± 15.0 (out of 100), with 20 of 26 showing impaired HRQoL (score <60). Absolute MVPA (74.6 ± 91.0 min/week, $b = 0.09$, $p = 0.03$) was associated with HRQoL, whereas total physical activity (565.7 ± 264.8 min/week, $p = 0.47$), light physical activity (LPA; 491.1 ± 224.3 min/week, $p = 0.98$), and step count (5,960 ± 3,037 steps/day, $p = 0.24$) were not. Neither relative LPA (521.4 ± 244.9) nor relative MVPA (33.5 ± 34.9 min/week) were associated with HRQoL (both p values > 0.14). Targeting more absolute MVPA, but not necessarily relative MVPA, may be an effective strategy for interventions aiming to improve HRQoL in individuals with ABI.

KEYWORDS

physical activity intensity, relative physical activity, 6-min walk test, quality of life, brain injured patients

Introduction

Acquired brain injury (ABI) occurs when brain damage is sustained after birth (1). ABI is typically categorized into two types: traumatic brain injury (TBI) and non-traumatic brain injury (NTBI) (2). TBI results from external forces, such as a concussion or motor vehicle accident, whereas NTBI arises when internal factors, like brain tumors or strokes, damage brain tissue (3). ABI commonly impairs neurological, physical, cognitive, and behavioral functions, with the severity of the deficit depending on the injury (4). Thus, individuals with ABI require additional support and resources to maintain their quality of life. Health-related quality of life (HRQoL) is a subjective, patient perception-focused measurement of physical, social, and emotional health (5). HRQoL is used not only as an indicator of overall health and the burden of disease on quality of life (6), but also for evaluating treatment methods and lifestyle adaptations (7). HRQoL measures can be either generic (e.g., SF 36-Item Short Form Survey) or disease-specific [Quality of Life After Brain Injury (QOLIBRI)] (8), with generic questionnaires being less applicable to clinical populations, specifically those with ABI (9), because of the unique physical, cognitive, emotional, and behavioral impairments experienced by this population (7). Understanding the impact of lifestyle adaptations on improving HRQoL is of particular importance when studying individuals with ABI.

The Canadian 24-h movement guidelines recommend that adults engage in at least 150 min of moderate-to-vigorous physical activity (MVPA) per week (10). Engaging in MVPA is associated with reduced risk of all-cause mortality, cardiovascular disease, and cancer mortality (11) and improved cognitive function (12). In populations of individuals with ABI, the duration of physical activity is consistently lower than the physical activity guideline recommendations (13). In a review of 26 physical activity monitoring studies, it was observed that accelerometry-based step counts were 50% lower in people with a stroke compared to those in aged-matched controls (14). In addition, an increase in self-reported and objectively measured physical activity in individuals post-stroke was associated with improved HRQoL, as assessed by the SF-36 (15). A systematic review of the effects of exercise interventions in individuals with ABI suggests that exercise, regardless of type (e.g., aerobic, resistance), improves HRQoL, as determined by the SF-36 (16). A non-randomized control trial of the Physical Activity and Sport for Acquired Brain Injury program demonstrated improvements in the physical and mental domains of HRQoL (17). Collectively, these studies emphasize that engaging in exercise interventions, specifically, self-reported physical activity, leads to improvements in HRQoL, indicating that such interventions should be a key component of care for outpatients with ABI. The continued use of the SF-36 highlights the need for more research using disease-specific instruments to determine whether these HRQoL benefits are consistently observed with such measurements. In addition, there is limited understanding of habitual, real-world physical activity in outpatients with ABI, as previous research has focused on structured exercise interventions. The reliance on self-report questionnaires for physical activity, especially when there are increased self-reported errors in patients with ABI (18), indicates the need for more research using objectively measured habitual physical activity.

Traditionally, physical activity has been characterized in terms of absolute activity intensity thresholds, depending on metabolic equivalents of the task (METs; a multiple of resting energy expenditure), with light physical activity (LPA) being any activity <3 METs and MVPA being classified as ≥3 METs (19). However, it is recommended by both the Canadian Society for Exercise Physiology (CSEP) and the American College of Sports Medicine (ACSM) that physical activity intensities be individualized to aerobic fitness, with MVPA defined as activity above 40% of maximal METs (MET_{max}) (20, 21). More aerobically fit individuals typically meet the absolute guidelines for MVPA more readily than those with lower fitness levels (22). Given patients with ABI typically have lower aerobic fitness than the general population (23), it may be of particular importance to consider relative physical activity intensities that scale MVPA in relation to their maximal aerobic fitness.

The purpose of this study was to evaluate the relationship between physical activity and HRQoL in outpatients with ABI. It is hypothesized that increased time spent in both absolute and relative MVPA would be associated with higher HRQoL, as assessed by the ABI-specific QOLIBRI, in outpatients with ABI.

Materials and methods

Study design

Participants were recruited from an ABI Rehabilitation Day program at the NeuroCommons center in Bedford, Nova Scotia. Each participant wore an activPAL device for 24 h/day over 7 days. Participants were then asked to complete the QOLIBRI questionnaire to assess HRQoL. Finally, the participants completed the 6-min walk test (6MWT) (see below).

Participants

In total, 26 adults (54 ± 13 years, 16 females) from the Nova Scotia Health's ABI Rehabilitation Day program between August 2022 and September 2023 were included. The sample included 16 individuals with NTBI (e.g., stroke) and 10 with TBI (e.g., concussion; 8 of 10 had a concussion). Participants were included if they were >18 years of age, scored >90 on the Functional Independence Measure, and could safely engage in MVPA. Of an original 30 participants, 4 were excluded due to incomplete or unusable physical activity data resulting from software issues or user error (e.g., a participant removed the monitor before the collection period ended) ($n = 3$) or because the HRQoL questionnaire was not completed ($n = 1$). Based on a large effect size ($f^2 = 0.35$), a linear regression model indicated that a minimum of 25 participants were needed, assuming a two-tailed test with $\alpha = 0.05$ and $\beta = 80\%$ power [G*Power, v3.1 (24)].

Research ethics approval was obtained from the Nova Scotia Health's Research Ethics Board (REB #39067), and all participants provided informed consent before data collection.

Health-related quality of life

HRQoL is a subjective, patient perception-focused measurement of physical, social, and emotional health (5). The QOLIBRI is a validated instrument for measuring HRQoL in individuals with ABI (8). It is a 37-item scale with six subsections: cognition, emotion, daily autonomy, social relationships, mental impairments, and physical impairments, with responses recorded on a five-point Likert scale. The responses for Parts A–D of the QOLIBRI questionnaire were scored numerically (e.g., "not at all" = 0, "very" = 5), while responses for Parts E and F were inversely scored (e.g., "not at all" = 5, "very" = 0). The mean score for each section was calculated (e.g., sum of section A values/number of questions in section A), and the six section means (A–F) were then averaged to calculate a total mean score (sum of section mean scores/6). The total mean (e.g., 3.8 out of 5) was converted to a 0–100 scale (0 = no HRQoL, 100 = perfect HRQoL). This conversion was done by subtracting one from the total mean and multiplying by 25 [e.g., $(3.8 - 1) \times 25 = 70$). A higher QOLIBRI score indicates better HRQoL, with a threshold score of <60/100 indicating low or impaired HRQoL (25).

Six-min walk test

The 6MWT is a validated method for estimating maximal aerobic fitness (VO_{2max}) in individuals with ABI (26). A track was set up with two plastic cones placed 30 m apart, marking the points at which participants were to turn 180°. Participants were asked to walk around the cones as many times as possible for 6 min. Participants were given scripted verbal encouragement every minute. The final distance was recorded to the nearest centimeter. Height and weight were measured using a calibrated stadiometer and a physician's scale (Health-O-Meter, McCook, IL, USA) to the nearest 0.5 cm and 0.1 kg, respectively. Body mass index was then calculated as $\text{body mass (kg)}/\text{height (m)}^2$. VO_{2max} was estimated using the following equation:

$$59.44 - 3.83 \times \text{sex (1: males; 2: females)} - 0.56 \times \text{age (years)} - 0.48 \times \text{BMI (kg/m}^2) + 0.04 \times \text{the 6MWT (m)} \quad (27).$$

Free-living activity monitoring

The activPAL inclinometer (V3 or V4, Pal Technologies Ltd., Glasgow, UK) was used to objectively measure physical activity and sedentary time. The activPAL is a validated device for assessing free-living posture (28) and physical activity (29). All participants wore the activPAL for 24 h/day over 7 days, following previous wear time recommendations (30). The activPAL was waterproofed and secured using a nitrile finger cot and transparent medical dressing to the midline of the right thigh, one-third of the way between the hip and knee (31).

Raw activPAL data were exported into the PAL analysis software (version 5.8.5) for initial data processing, which produced a range of activity summaries. Further processing of these summaries was conducted using a customized MATLAB program (MathWorks, Portola Valley, CA, USA), that calculated daily averages for time awake, standing time, and sedentary time. An additional LabVIEW program (National Instruments, Austin, TX, USA) determined time spent in each physical activity intensity via step rate thresholds determined based on body mass index (32). Time spent above step rate thresholds corresponding to LPA and MVPA were determined (see below).

Absolute and relative physical activity

Absolute MVPA corresponds to time spent in >3 METs. Relative physical activity thresholds were calculated using >40% of MET_{max} based on the 6MWT-determined maximal aerobic fitness. For older adults (>55 years old), VO_{2max} was divided by 2.7 to calculate MET_{max}, while for younger adults (≤55 years old), VO_{2max} was divided by 3.5 to determine MET_{max}.

The step rate corresponding to absolute and relative MVPA was calculated using the height of the individual for younger adults according to the following equation:

$$\text{Step rate} = 73.490 - (0.513 \times \text{height}) + (59.867 \times \text{METs}) - (8.500 \times \text{METs}^2) + (0.436 \times \text{METs}^3),$$

while the step rate for older adults was calculated using BMI according to the following equation:

$$\text{Step rate} = -84.321 + (91.209 \times \text{METs}) - (12.968 \times \text{METs}^2) + (0.772 \times \text{METs}^3) + (2.211 \times \text{BMI}) - (0.549 \times \text{BMI} \times \text{METs}) \quad (33).$$

Statistical analysis

The relationships between each physical activity intensity (LPA and MVPA), both in absolute and relative intensity terms and HRQoL were analyzed using linear regressions. Age and physical fitness (via the 6MWT) are known factors that can affect the physical activity level of an individual (34). Accordingly, the covariates included for comparing absolute physical activity, sedentary time, standing time, and step count with HRQoL were age and 6MWT. Analyses using *relative* physical activity intensity only included age as a covariate due to the integration of 6MWT into the calculation of relative intensity thresholds. The relationship between age (via Pearson's correlation), sex (via independent samples *t*-test), and ABI type (via independent samples *t*-test) with HRQoL was determined. All statistics were completed using SPSS version 28.0 (IBM, NY, USA). Multicollinearity was assessed using variance inflation factors, all of which were less than the standard threshold of 10 (all, <1.4). Statistical significance was accepted as $p < 0.05$. All data are presented as mean ± standard deviations.

Results

Participants included in this study had a mean age of 54 ± 13 years, a body mass index of 30.4 ± 7.6 kg/m^2, and an average 6MWT distance of 390 ± 105 m (Table 1). Participants engaged in absolute LPA for 491.1 ± 224.3 min/week and in MVPA for 74.6 ± 91.0 min/week. Relative LPA averaged 521.4 ± 244.9 min/week, while relative MVPA averaged 33.5 ± 34.9 min/week. Participants had an average HRQoL score of 53.4 ± 15.0 (out of 100). In this sample, 77% of participants ($n = 20/26$) had an impaired HRQoL score of <60/100 (25). Scores on each individual section of the QOLIBRI are listed in Table 2. Age ($p = 0.29$), sex ($p = 0.07$), and ABI type ($p = 0.39$) were not associated with HRQoL. In addition, there were no differences in age ($p = 0.18$) or sex distribution ($p = 0.68$) between those with TBI and those with NTBI.

In a covariate-adjusted model that considered age and 6MWT distance, absolute MVPA was positively associated with HRQoL ($\beta = 0.09$, $p = 0.03$; Figure 1), whereas total, LPA, and step count (all p's = 0.24) were not. In addition, HRQoL was not associated with relative physical activity for total, LPA, or MVPA (all p values s > 0.14; Figure 2). Also, no associations were observed between standing time or sedentary time and HRQoL (both p values > 0.95).

Discussion

The purpose of this study was to examine the relationship between physical activity and HRQoL in outpatients with ABI. Consistent with our hypothesis, more time spent in absolute MVPA was associated with increased HRQoL independent of age and 6MWT. However, no associations were observed for either relative physical activity or absolute total physical activity. The findings of this study support the beneficial impact of absolute MVPA on HRQoL in individuals with ABI who have habitually low HRQoL (scored <60/100) (25).

Physical activity is defined as any movement produced by skeletal muscles that increases energy expenditure above resting levels (35). It is recommended by both the CSEP and the ACSM that physical activity intensities be individualized based on factors such as aerobic capacity or physical functioning, affecting those with both high and low fitness levels (20, 21). Our study demonstrated that absolute MVPA was associated with better HRQoL, and there was no association for any intensity of relative physical activity. These findings differ from the CSEP and ACSM organizational recommendations, suggesting that a sufficient *absolute* intensity of movement may be needed to improve HRQoL rather than scaling MVPA to individual fitness. Future work is needed to determine the most effective activity interventions for this population. Considering that individuals with ABI typically do not meet guideline recommendations for physical activity duration (13) and have much lower average HRQoL scores than the general population (9), this research indicates that increasing the amount of physical activity to meet absolute thresholds of MVPA (e.g., brisk walking, cycling) may be an effective strategy to improve HRQoL in individuals with ABI.

For individuals with ABI, physical activity is an effective method to improve cognitive function (36), cardiovascular fitness (37), and overall mood (38). The QOLIBRI uses a threshold score of <60/100 to indicate impaired HRQoL (25). The majority of our sample (77%) reported average values of <60, with a total sample average of 53.4/100. Due to the variety of factors that encompass HRQoL (mental, physical, and emotional domains), there may be several mechanisms underpinning the association of MVPA with HRQoL. Increased MVPA has been shown to decrease bodily pain and can help reduce chronic pain (39, 40). Regular physical activity promotes pain relief by reducing N-methyl-D-aspartate receptor phosphorylation, reducing serotonin transporter expression, and increasing serotonin levels (40). In addition, increased MVPA has also been associated with improved physical functioning (41), including increased muscle strength, aerobic capacity, and bone density, which are closely

TABLE 1 Participants' descriptive characteristics, habitual posture, and physical activity outcomes.

Variable	Participant (n = 26)
Age (years)	54 ± 13 (24–72)
Acquired brain injury (TBI, NTBI)	10, 16
Sex (male participants, female participants)	10, 16
Height (cm)	164.5 ± 8.6 (146.0–181.0)
Weight (kg)	82.8 ± 24.7 (50.0–169.0)
Body mass index (kg/m^2)	30.4 ± 7.6 (21.4–60.6)
6MWT (m)	490 ± 105 (187–723)
Step count (steps/day)	5,960 ± 3,037 (757–14,793)
Sedentary time (h/day)	10.6 ± 2.4 (5.8–16.1)
Standing time (h/day)	4.7 ± 2.1 (0.7–9.0)
Absolute LPA (min/week)	491.1 ± 224.3 (93.0–1,097.1)
Absolute MVPA (min/week)	74.6 ± 91.0 (0.4–344.9)
Relative LPA (min/week)	521.4 ± 244.9 (24.7–1,294.3)
Relative MVPA (min/week)	33.5 ± 34.9 (0.5–120.6)
Absolute MVPA step rate threshold (steps/min)	110.6 ± 4.3 (105.5–127.6)
Relative MVPA step rate threshold (steps/min)	115.7 ± 14.2 (73.3–140.4)

TBI, traumatic brain injury; NTBI, non-traumatic brain injury; 6MWT, six-minute walk test; HRQoL, health-related quality of life; LPA, light physical activity; MVPA, moderate-to-vigorous physical activity.
Data are presented as mean ± SD (range).

TABLE 2 QOLIBRI questionnaire scores by section, total mean, and scaled adjustment.

QOLIBRI section	Mean score
Part A: cognition (7 questions)	3.1 ± 0.9 (1.4–5.0)
Part B: emotions (7 questions)	2.9 ± 0.8 (1.3–4.7)
Part C: daily autonomy (7 questions)	3.1 ± 0.9 (1.6–4.9)
Part D: social relationships (6 questions)	3.3 ± 1.0 (1.5–5.0)
Part E: mental impairments (5 questions)	3.4 ± 0.8 (2.2–5.0)
Part F: physical impairments (5 questions)	3.1 ± 0.8 (1.2–4.2)
Total mean	3.1 ± 0.8 (1.8–4.3)
Adjusted HRQoL (out of 100)	53.4 ± 15.0 (20.9–82.8)

Data are presented as mean ± SD (range). The QOLIBRI questionnaire responses for Parts A–D were scored numerically (e.g., "not at all" = 0, "very" = 5). QOLIBRI responses for Parts E and F were inversely scored (e.g., "not at all" = 5, "very" = 0). The mean score for each section was calculated (e.g., sum of section A values/number of questions in section A). The six-section means (A–F) were then averaged to calculate a total mean score (sum of section mean scores/6). The total mean (e.g., 3.8 out of 5) was converted to a 0–100 scale (0 = no HRQoL, 100 = perfect HRQoL). This conversion was done by subtracting one from the total mean and multiplying by 25 [e.g., (3.8 − 1) × 25 = 70].

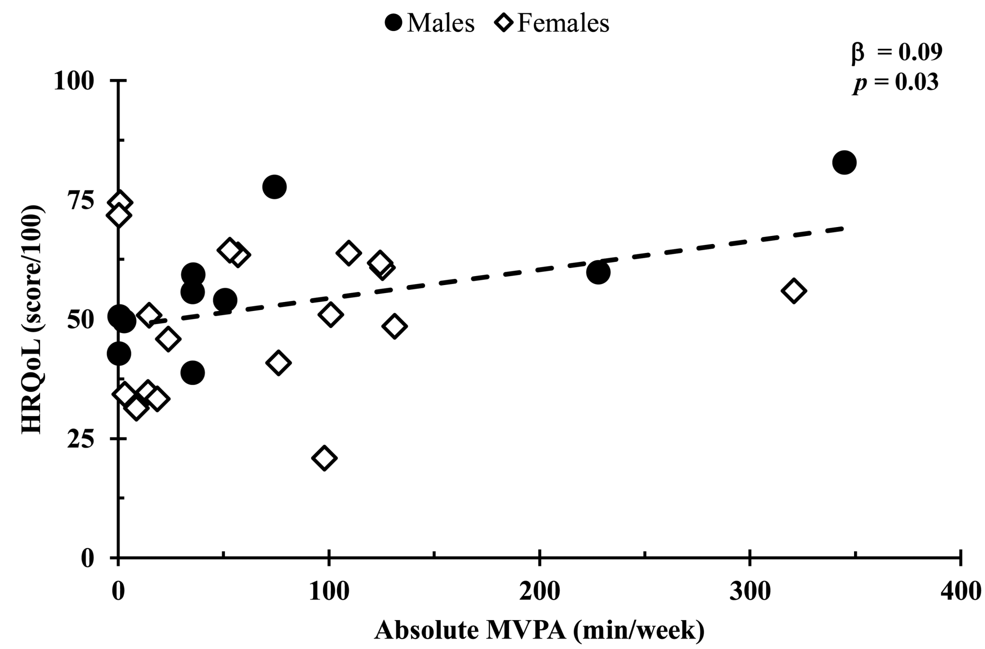

FIGURE 1
Comparison of the absolute MVPA duration with HRQoL scores. Relationships were determined using multiple regression, with a covariate-adjusted model including age and 6-min walk test distance. Circles represent males, while diamonds represent females. Data are presented for $n = 26$.

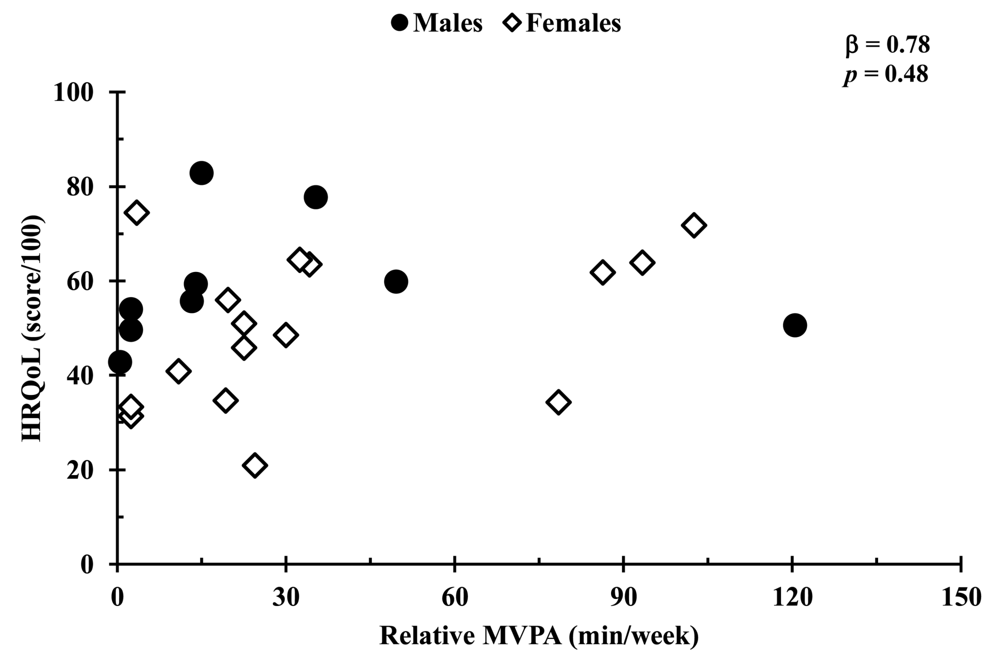

FIGURE 2
Comparison of relative MVPA duration and HRQoL scores. Relationships were determined using linear regression, with a covariate-adjusted model including age. Circles represent males, while diamonds represent females. Data are presented for $n = 26$.

linked with HRQoL (42). Increased physical activity is associated with improved overall mood (38), reductions in anxiety and depression (43), exercise-induced neurogenesis (44), and improved self-efficacy (45). In addition, HRQoL may be impacted by the social aspect of exercise, as increased social activity is associated with higher HRQoL (46, 47). This effect may also work collectively when exercise is conducted outdoors, as spending more time outdoors has been shown to improve self-rated health and reduce negative emotions (48). The factors linking MVPA and HRQoL are likely to be multi-factorial, spanning the emotional, mental, and physical domains. Future research should explore absolute-intensity MVPA intervention models in clinical populations and investigate the mechanistic underpinnings of improved HRQoL.

The primary limitation of the study is its cross-sectional design, which prevents the determination of causality. However, this work is important for directing future intervention studies and applies novel, disease-specific HRQoL outcomes, objective habitual activity monitoring, and consideration of relative activity thresholds. Our results may not be extrapolated to the general population, as this study implemented an ABI-specific scale of HRQoL in outpatients diagnosed with ABI. In addition, our sample consisted of outpatients who could walk without assistance; thus, our results may not apply to individuals with ABI who have acute injuries or mobility challenges. Furthermore, maximal aerobic fitness was estimated based on a published equation for 6MWT (27), rather than directly measured with a VO_{2max} test. However, our observations provide valuable insight into a relatively understudied perspective regarding the most optimal physical activity intensity and threshold for those with ABI.

In outpatients with ABI, who generally report impaired HRQoL, engaging in more absolute-intensity MVPA was associated with better HRQoL. Strategies that investigate and promote the impact of more absolute MVPA may be beneficial lifestyle behaviors that improve HRQoL.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors upon reasonable request.

Ethics statement

The studies involving humans were approved by the Nova Scotia Health Research Ethics Board. 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

EM: Writing – original draft. LP: Writing – review & editing. KM: Writing – review & editing. RF: Writing – review & editing. MO: Writing – original draft.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

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.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

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