



OPEN ACCESS

EDITED BY

Maurizio Bertollo,
G. d'Annunzio University of
Chieti–Pescara, Italy

REVIEWED BY

Francisco Contreras,
University of Barcelona, Spain
Giuseppe Sartori,
University of Padua, Italy

*CORRESPONDENCE

Laura Mandolesi
laura.mandolesi@unina.it

SPECIALTY SECTION

This article was submitted to
Movement Science and Sport
Psychology,
a section of the journal
Frontiers in Psychology

RECEIVED 30 May 2022

ACCEPTED 29 August 2022

PUBLISHED 28 September 2022

CITATION

Passarello N, Varini L, Liparoti M, Troisi
Lopez E, Sorrentino P, Alivernini F,
Gigliotta O, Lucidi F and Mandolesi L
(2022) Boosting effect of regular sport
practice in young adults: Preliminary
results on cognitive and emotional
abilities. *Front. Psychol.* 13:957281.
doi: 10.3389/fpsyg.2022.957281

COPYRIGHT

© 2022 Passarello, Varini, Liparoti,
Troisi Lopez, Sorrentino, Alivernini,
Gigliotta, Lucidi and Mandolesi. This is
an open-access article distributed
under the terms of the [Creative
Commons Attribution License \(CC BY\)](#).
The use, distribution or reproduction
in other forums is permitted, provided
the original author(s) and the copyright
owner(s) are credited and that the
original publication in this journal is
cited, in accordance with accepted
academic practice. No use, distribution
or reproduction is permitted which
does not comply with these terms.

Boosting effect of regular sport practice in young adults: Preliminary results on cognitive and emotional abilities

Noemi Passarello¹, Ludovica Varini¹, Marianna Liparoti²,
Emahnuel Troisi Lopez³, Pierpaolo Sorrentino⁴,
Fabio Alivernini², Onofrio Gigliotta¹, Fabio Lucidi² and
Laura Mandolesi^{1*}

¹Department of Humanities, "Federico II" University of Naples, Naples, Italy, ²Department of Social and Developmental Psychology, "Sapienza" University of Rome, Rome, Italy, ³Department of Motor Sciences and Wellness, University of Naples "Parthenope", Naples, Italy, ⁴Institut de Neurosciences des Systemes, Aix-Marseille University, Marseille, France

Several studies have shown that physical exercise (PE) improves behavior and cognitive functioning, reducing the risk of various neurological diseases, protecting the brain from the detrimental effects of aging, facilitating body recovery after injuries, and enhancing self-efficacy and self-esteem. Emotion processing and regulation abilities are also widely acknowledged to be key to success in sports. In this study, we aim to prove that regular participation in sports enhances cognitive and emotional functioning in healthy individuals. A sample of 60 students (mean age = 22.12; SD = 2.40; M = 30), divided into sportive and sedentary, were subjected to a neuropsychological tests battery to assess their overall cognitive abilities (Raven's Advanced Progressive Matrices, APM), verbal and graphic fluency (Word Fluency Task and modified Five Point Test, m-FPT), as well as their emotional awareness skills (Toronto Alexithymia Scale, TAS-20). Our results showed that sportive students performed better than sedentary ones in all cognitive tasks. Regarding emotional processing abilities, significant differences were found in the TAS-20 total score as well as in the Difficulty Describing Feelings (DDF) subscale and the Difficulty Identifying Feeling (DIF) subscale. Lastly, gender differences were found in the External-Oriented Thinking (EOT) subscale. Overall, our findings evidence that PE has positive effects on cognitive functioning and emotion regulation, suggesting how sports practice can promote mental health and wellbeing.

KEYWORDS

sport, cognition, emotion regulation, physical activity, alexithymia

Introduction

Physical exercise (PE) is defined as a form of physical activity that is planned, structured, and repetition-based, with the goal of improving or maintaining individual components of physical fitness. PE is defined as a sports activity when an individual systematically trains under expert supervision for a specific technical gesture (Mandolesi et al., 2018).

A substantial body of evidence has shown that PE induces a brain plasticity phenomenon (Fernandes et al., 2017; Mandolesi et al., 2018) that represents the ability of the brain to reorganize and change after proper stimulation, thus improving its performance (Serra et al., 2011; Mandolesi et al., 2017; Gelfo et al., 2018).

For a few years now, the beneficial effects of PE on mood and cognition across the life span have become a topic of interest. Much evidence suggests that PE improves behavior and cognitive functioning, reducing the risk of various neurological diseases, protecting the brain from the detrimental effects of aging, facilitating body recovery after injuries, and enhancing self-efficacy and self-esteem (Lista and Sorrentino, 2010; Basso and Suzuki, 2017). Cross-sectional studies have shown that PE boosts memory abilities, attentional processes' efficiency, and executive functioning (Colcombe and Kramer, 2003; Grego et al., 2005; Pereira et al., 2007; Chieffi et al., 2017; Erickson et al., 2019). Specifically, executive functions are frequently targeted for PE studies, as they play a crucial role in both mental and physical health (Davis et al., 2011), success in school, and quality of life (Bailey, 2007), as well as social, cognitive, and psychological development (Diamond, 2016). Nonetheless, inhibition control, working memory, and cognitive flexibility are considered to be key abilities for sports practice (Ludyga et al., 2016).

Emotion processing and regulation skills are also widely acknowledged to be key to success in sports (Friesen et al., 2013). The ability to process and regulate emotions successfully is regarded by many as an important psychological skill in sportive individuals (Jodat et al., 2015). Several studies demonstrate the enormous benefits of structured and constant sports training in terms of improving motivation and emotional wellbeing (Ghasempour et al., 2013; Behroozi and Abdimoghdam, 2014). The ability to successfully process and regulate our emotions requires emotional awareness. In some individuals, this ability is deficient, resulting in difficulties identifying, describing, and analyzing what they are experiencing emotionally (Passarello et al., 2021). Considering the importance of emotional regulation in everyday life, constant and structured PE seems to be a protective factor for this difficulty (Jodat et al., 2015). In spite of this, there are still few studies that examine the correlation between sport and emotional regulation.

In this study, we aim to demonstrate that regular participation in sports can lead to an improvement in cognitive

and emotional functioning. To do this, a sample of 60 students (mean age = 22.12, SD = 2.40), divided into sportive and sedentary, were subjected to a neuropsychological tests battery to assess their overall cognitive abilities, and verbal and graphic fluency (Raven Advanced Progressive Matrices, APM; World fluency test; modified-Five Points Test, m-FPT), as well as their emotional awareness skills (Toronto Alexithymia Scale, TAS-20). We hypothesized that sportive students would demonstrate enhanced cognitive abilities, along with better skills at recognizing and describing their emotions, compared to sedentary students.

Materials and methods

Participants

We tested 60 students from the University of Naples "Federico II." A survey was conducted to ask students if they practice any type of sport, how long they had been practicing it, how often, and at what intensity. From the output of this survey, we selected our sample, and we sorted the students into two groups as follows: Sportive = 15 females (mean = 22; SD = 2.76) and 15 males (mean = 22.18; SD = 3.15); Sedentary = 15 females (mean = 23; SD = 2.04) and 15 males (mean = 21.30; SD = 1.26). Participants who had practiced sports for at least 2 years with a frequency of 3 times a week and with a moderate level of intensity belonged to the sportive group. All participants were in good health. Inclusion criteria were normal or corrected-to-normal vision and right-handedness. Alternatively, exclusion criteria comprised the current or past presence of psychopathology, psychiatric, neurological, or motor disorders, or other medical illness. The participants were voluntarily enrolled after written informed consent was obtained. The study was approved by the Local Ethics Committee of the University of Naples "Federico II" (protocol number: 12/2020) and was carried out in accordance with the Declaration of Helsinki.

Neuropsychological assessment

To evaluate the typical development of all the participants, Raven's Advanced Progressive Matrices (APM) (Raven, 1962) were administered. Specifically, we used set 1 consisting of the first 12 matrices. To complete each item, one must replace the missing part of a model, according to a criterion of increasing difficulty. Model figures consist of graphic patterns that change from left to right and from top to bottom; the subject must understand the underlying logic and apply it in order to come up with the solution. APM total score allowed us to assess abstract reasoning and global cognitive functioning.

Verbal fluency was also assessed through word fluency test (Carlesimo et al., 1996). In this test, participants were asked to produce as many words as possible, beginning with specified letters of the alphabet (A; F; S), in a limited time interval of 60 s. Total word produce, word errors (i.e., word beginning with a different letter), and word repetitions were analyzed.

The five-point test (FPT) is a highly reliable nonverbal measure of executive functioning, assessing the graphic-figural fluency of participants (Fernandez et al., 2009). In fact, it measures the ability of an individual to produce geometric drawings or unique figures within a given time interval (3 min) (Cattelani et al., 2011). The modified FTP version (m-FTP) consists of an A4 sheet with 40 square matrices, each containing five dots; four of them are placed at the vertices and one is placed in the middle. Participants must connect two or more dots in each square with straight lines. Additionally, they must not repeat the same shape two times and must not draw lines that do not connect the dots. Through this, we can examine three subdomains of executive functions, namely, flexibility, rule breaking, and strategic performance. The following parameters were evaluated: (A) total drawings: number of total drawings made in 3 min; (B) drawings with errors: number of drawings breaking the rules and/or repeating previously drawn shapes; (C) error index: number of drawings with errors divided by the number of total drawings multiplied by 100; (D) number of unique drawings: calculated by subtracting the number of drawings with errors from the number of total drawings; and (E) strategy index: number of drawings with strategy divided by number of unique drawings. All the neuropsychological instruments used are validated for the Italian language and culture (Di Fabio and Clarotti, 2007; Carlesimo et al., 1996; Cattelani et al., 2011).

Toronto alexithymia scale (TAS-20)

The TAS-20 (Bagby et al., 1994) is a 20-item self-report test considered to be the most reliable self-assessment questionnaire for measuring alexithymia, an affective-cognitive disorder characterized by difficulty in identifying and describing own emotions and in being interested in understanding those of others (Nemiah and Sifneos, 1970). TAS-20 consists of three subscales, each representing one aspect of alexithymia: the Difficulty Describing Feelings (DDF) subscale consisted of five items (2, 4, 11, 12, and 17); the Difficulty Identifying Feeling (DIF) subscale consisted of seven items (1, 3, 6, 7, 9, 13, and 14); and the External-Oriented Thinking (EOT) subscale, measuring the tendency of individuals to focus their attention externally, consisted of eight items (5, 8, 10, 15, 16, 18, 19, and 20).

Participants respond to TAS-20 using a 5-point Likert scale, where 1 indicates strongly disagree and 5 indicates strongly agree. Items 4, 5, 10, 18, and 19 are negatively keyed. Alexithymia scores are determined by summing responses to all 20 items,

TABLE 1 The 2 × 2 ANOVA outputs on advanced progressive matrices (APM).

Factors	F _{1,56}	p	P Tukey
Sport	5.13	0.02*	0.02*
Sex	0.01	0.90	0.90
Sport*Sex	1.25	0.28	0.28

* $p \leq 0.05$.

while scores for each of the subscales are determined by summing the responses in each scale. Scores of 61 or higher are considered alexithymic; scores of 50 or lower are considered non-alexithymic, with a borderline between 50 and 60. In this study, we used the Italian standardized and adapted version of the TAS-20 (Bressi et al., 1996).

Statistical analyses

All statistical analyses were conducted with the JASP 0.16.1.0 software. The 2 × 2 ANOVA was used to analyze the effect of gender (males, females) and sport practice (sportive, sedentary) on neuropsychological tests (APM, word fluency, and m-FPT) and TAS-20. $p \leq 0.05$ were considered statistically significant. *Post-hoc* comparisons were conducted through Tukey's test.

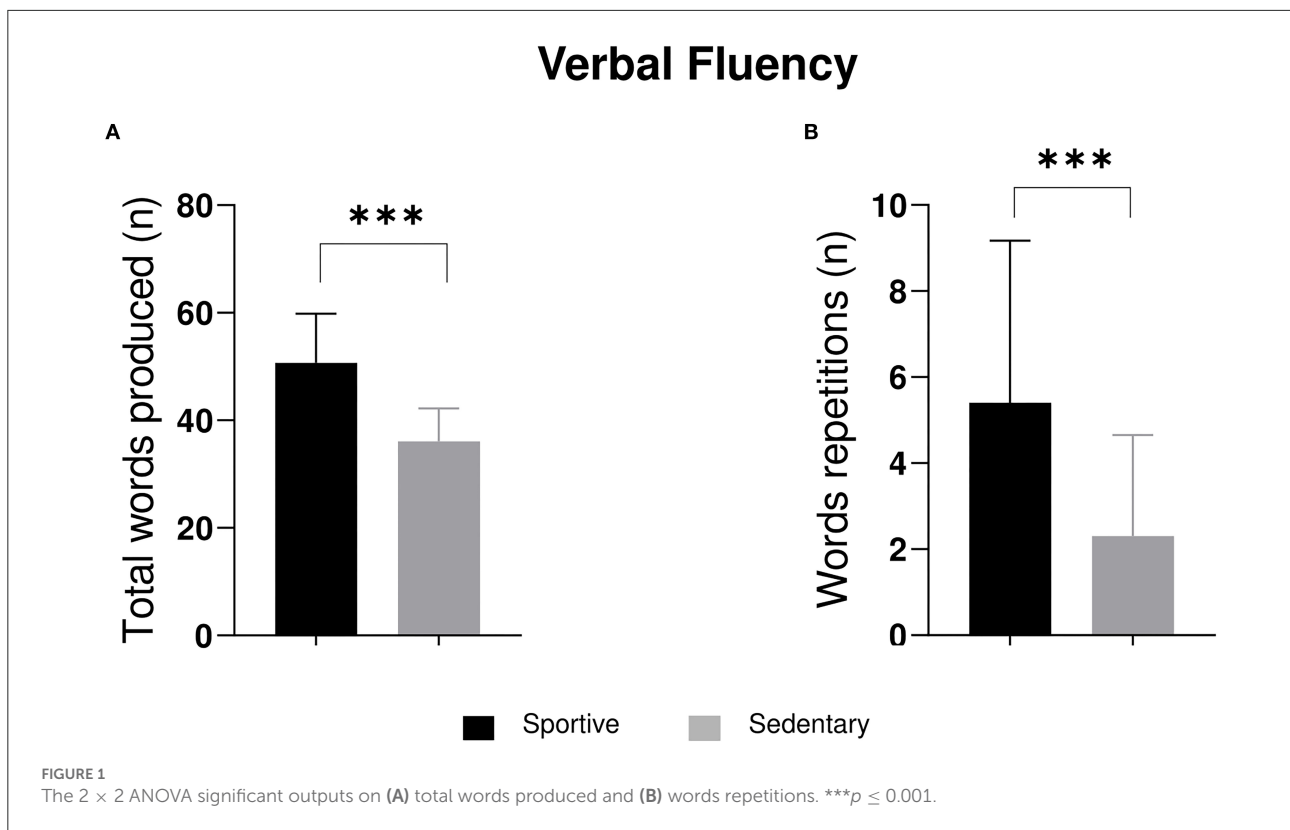
Results

Neuropsychological assessment

The 2 × 2 ANOVA outputs on APM are shown in Table 1, while word fluency and m-FPT outputs are shown in Figures 1, 2.

Significant differences were found in APM score ($F_{1,56} = 5.14$; $p = 0.03$), word production ($F_{1,56} = 52.62$; $p \leq 0.001$), and word repetition ($F_{1,56} = 14.60$; $p \leq 0.001$) for sport factor. *Post-hoc* comparisons revealed significant difference between sportive students and sedentary students in APM score (mean sportive = 10.80; mean sedentary = 10.16), word production (mean sportive = 50.70; mean sedentary = 36.07), and word repetition (mean sportive = 5.40; mean sedentary = 2.30). As for word errors, we found significant differences for sex factor ($F_{1,56} = 6.20$; $p = 0.02$). *Post-hoc* comparisons on word errors revealed significant differences between males and females (mean males = 1.43; mean females = 0.77).

Several results were found among m-FPT parameters. The 2 × 2 ANOVA revealed significant differences in the total drawing for sport factor ($F_{1,56} = 31.22$; $p \leq 0.001$) (Figure 2A). *Post-hoc* comparisons revealed a significant difference between sportive students and sedentary students in total drawings productions (mean sportive = 51.43; mean sedentary = 34.77). No significant



differences were found for sex ($F_{1,56} = 0.36$; $p = 0.55$) or interception ($F_{1,56} = 0.29$; $p = 0.59$).

Moreover, significant differences were found in total unique drawings for the sport factor ($F_{1,56} = 82.30$; $p \leq 0.001$) (Figure 2B). *Post-hoc* comparisons revealed a significant difference between sportive students and sedentary students in unique drawings productions (mean sportive = 47.30; mean sedentary = 29.60). No significant differences were found for sex ($F_{1,56} = 0.49$; $p = 0.49$) or interception ($F = 0.25$; $p = 0.62$). No significant differences were found in the error index for sports, sex, or interception.

Finally, significant differences were found in strategy for sport factor ($F_{1,56} = 7.15$; $p = 0.01$) (Figure 2C). *Post-hoc* comparisons revealed a significant difference between sportive students and sedentary students in strategy use for drawing (mean sportive = 0.14; mean sedentary = 0.10). No significant differences were found for sex ($F_{1,56} = 0.19$; $p = 0.66$) or interception ($F_{1,56} = 1.66$; $p = 0.20$).

TAS-20

Among our 60 participants, only two were found to be alexithymic with an average score of 65. The rest of the group obtained an average score of 44.93. Twenty of the remaining

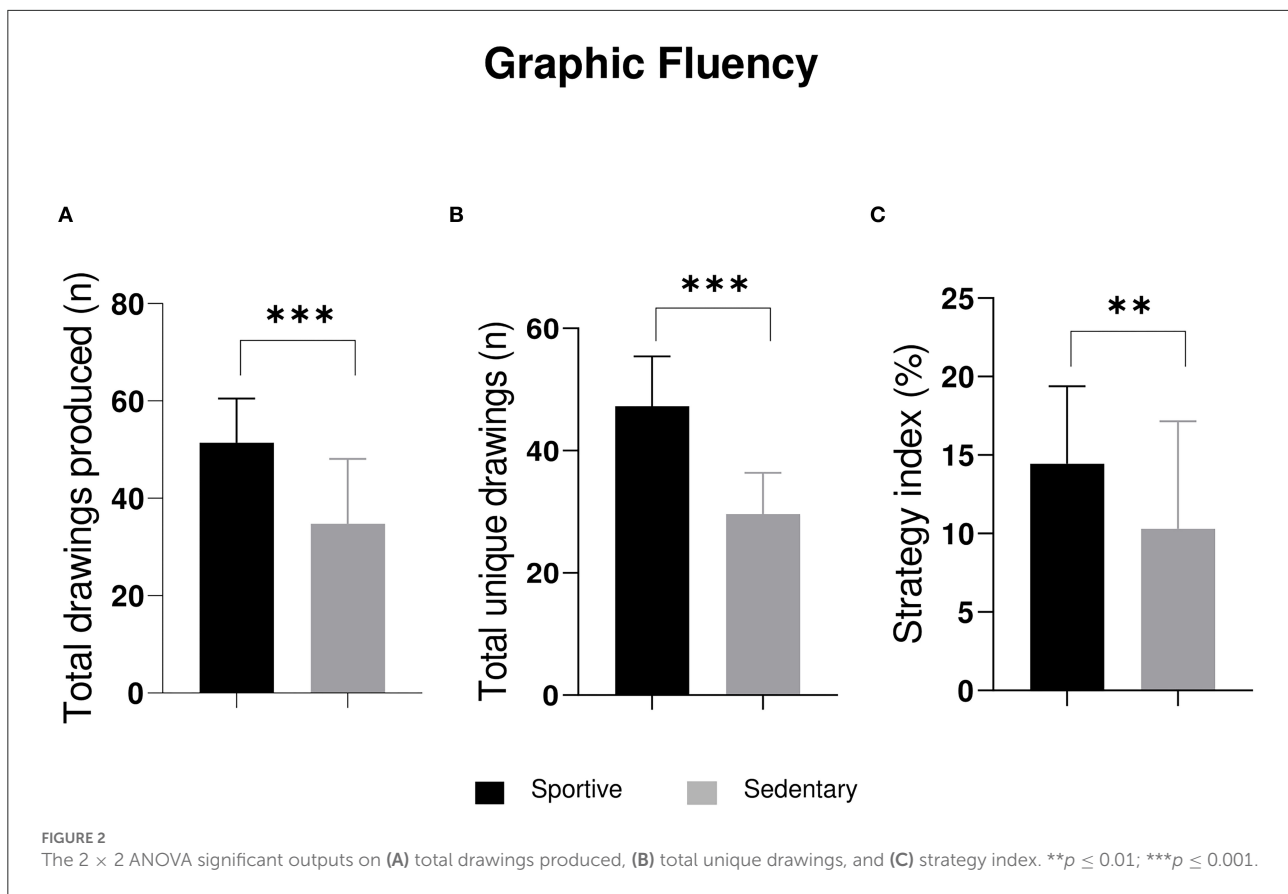
participants obtained an overall score that falls in the critical range of 50–60 (Supplementary Table 1).

As for TAS total score, the 2 × 2 ANOVA revealed a significant difference for sport factor ($F_{1,56} = 6.01$; $p = 0.02$) (Figure 3A). *Post-hoc* comparisons revealed lower alexithymic score in sportive students rather than sedentary students (mean sportive = 42.70; mean sedentary = 48.50). No significant differences were found for sex ($F_{1,56} = 0.18$; $p = 0.67$) or interception ($F_{1,56} = 0.26$; $p = 0.61$).

TAS factor DIF was significantly different for sport factor ($F_{1,56} = 4.52$; $p = 0.04$) (Figure 3B). *Post-hoc* comparisons revealed minor difficulties in identifying feelings in sportive students rather than sedentary students in total score (mean sportive = 11.70; mean sedentary = 13.90). No significant differences were found for sex ($F_{1,56} = 2.20$; $p = 0.14$) or interception ($F_{1,56} = 1.07$; $p = 0.80$).

TAS factor DDF was also significantly different for sport factor ($F_{1,56} = 4.37$; $p = 0.04$) (Figure 3C). *Post-hoc* comparisons revealed minor difficulties in describing feelings in sportive students rather than sedentary ones (mean sportive = 15.87; mean sedentary = 18.73). No significant differences were found for sex ($F_{1,56} = 48.60$; $p = 0.19$) or interception ($F_{1,56} = 72.60$; $p = 0.11$). No significant differences were found in EOT_A for sport, sex, and interception.

Finally, TAS factor EOT_B was significantly different for sex factor ($F_{1,56} = 7.78$; $p = 0.007$) (Figure 3D). *Post-hoc*

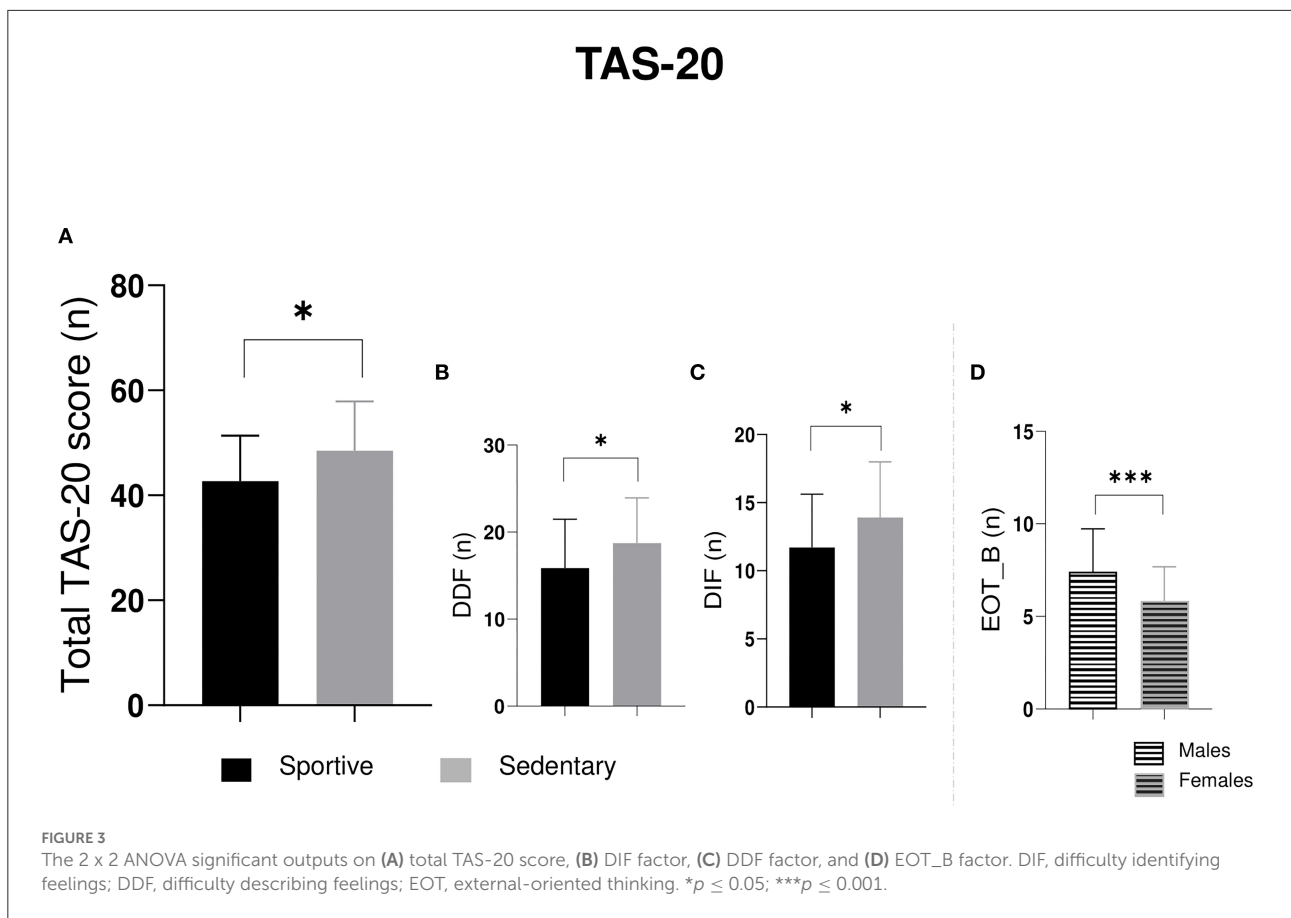


comparisons revealed more external-oriented thinking in males rather than females (mean males = 7.37; mean sedentary = 5.80). No significant differences were found for sport ($F_{1,56} = 0.09$; $p = 0.77$) or interception ($F_{1,56} = 0.08$; $p = 0.76$).

Discussion

In accordance with our hypotheses, our results showed that sportive students performed better than sedentary ones on tasks of global intelligence, verbal and graphic fluency, and emotional awareness. In spite of our sample consisting of students with typical development, as evidenced by the normal Raven matrices (APM) scores, we found that the sportive group performed better than the sedentary group in APM. Several studies showed that both children and young adults' experiences in sport and PE contribute to the mental acuity, skills, and strategies that are important for navigating challenges faced across the life span (Donnelly et al., 2016). Neuroscience advances have enabled significant progress in linking PE to cognitive performance, as well as to brain structure and function (Mandolesi et al., 2018). It was found that PE could determine structural changes in gray matter volume in frontal and hippocampal regions and enhance the release of neurotrophic factors, such as

peripheral BDNF (Serra et al., 2011; Mandolesi et al., 2018). These effects are reflected on cognitive functioning. In our study, sportive students performed better in word fluency task, producing more words than sedentary students. Further, aerobic exercise improves verbal fluency among healthy elderly (Bullo et al., 2015). This evidence validates the selective improvement hypothesis, which states that aerobic PE selectively improves brain activities associated with the frontal and prefrontal regions (Weinstein et al., 2012; Nocera et al., 2015, 2020). Indeed, PE is associated with high scores on tests that evaluate executive functioning (Verburgh et al., 2014; de Greeff et al., 2018; Xue et al., 2019; Serra et al., 2021). In our study, it is important to note that the m-FPT provides insight into executive functioning (Weinstein et al., 2012), and also in this test, we found significant differences in favor of sports students. It is important to note that, among our sample of sportive students, more repetitions of words were also recorded. However, the increased use of repetition by sportive students appears to be in contrast to the results discussed so far; this was only true for verbal fluency and not for graphic fluency. Sportive students were in fact more productive than the sedentary ones in the m-FPT, but more importantly, they produced more unique designs and used strategies more often. This dissociation between verbal and visuospatial abilities (including graphic fluency competencies)



has long been associated with a hemispheric lateralization (Lardone et al., 2021). Several studies have shown that performance in verbal fluency task was associated with increased left prefrontal activity, whereas performance in visuospatial fluency task was associated with increased bilateral prefrontal activity (Marin et al., 2017; Cipolotti et al., 2020). An interesting work (Elfgren and Risberg, 1998) takes also in account the cognitive strategy used during fluency tasks. Participants were asked to explain the type of strategy they used to solve both verbal and visuospatial task: they could have used a purely verbal strategy (i.e., think about nameable objects), a purely visual strategy (i.e., use visual imagery), or a mix of the two. In the visuospatial fluency task, participants used more mixed strategies, whereas in the verbal fluency task, they used mixed and verbal strategies. Both in visuospatial and verbal fluency tasks, the application of mixed strategies was associated with increased bilateral activity in the prefrontal cortex. Meanwhile, the application of verbal strategies only was associated with an increase in activity just in the left dorsolateral prefrontal cortex. We can speculate that PE enhances hemispheric lateralization, improving both verbal skills linked to left-hemisphere activity and visuospatial skills that appear to be linked to bilateral activity (Wang et al., 2016). However, it does not have a specific effect on

the left-hemisphere-related activity required to improve the use of appropriate strategies to solve verbal fluency tasks. Although more results are needed to confirm the latter hypothesis, we can conclude that regular practice of a sport improves overall cognitive functioning. Additionally, our results showed that sportive students were more aware of their own emotions than sedentary ones, displaying fewer difficulties in identifying and describing their own feelings. PE beneficial effects on emotional processing has been widely reported. Epidemiological studies have shown PE soothing effects on depression (Mammen and Faulkner, 2013) and anxiety (Knapen et al., 2009). Numerous studies have shown that most aerobic exercises, regardless of their type, lead to an enhanced positive mood afterward (Fernandes et al., 2017).

Alexithymia, or “no words for feelings,” is a personality trait that is associated with difficulties in emotion recognition and regulation (Swart et al., 2009). In sport, it is mostly associated with disorders, such as anxiety, depression, overtraining (burnout), addiction, and risky sports behavior (Woodman et al., 2009). However, some studies have proved that sport practice can improve emotional recognition and regulation, and accordingly, fewer alexithymic traits can be found in sportive individuals (18). These data agree with our result

in which sportive students have lower scores on TAS-20 (Figure 3A). It has been reported that sport practice had several benefits for students, including less difficulty in “identifying and distinguishing physical feelings and sensations,” better sleep, and higher scores on happiness and life satisfaction (Manfredi, 2022). Sportive students also showed more external-oriented thinking than sedentary ones. The results of our work do not directly confirm this finding, but they do detect a gender difference regarding factor 3B of the TAS-20 (external-oriented thinking). Specifically, males tend to use more external-oriented thinking than females, regardless of whether they practice sport. Based on this finding, it may explain why some scientific evidence suggests that alexithymia is associated with increased athletic activity, especially in high-risk sports. Although it is true that there is a greater prevalence of alexithymia in high-risk sports contexts (Woodman et al., 2009; Woodman and Welch, 2021), these data may also be biased due to gender. It is possible that the gender differences would be marked mainly in the verbalization of emotions and in external-oriented thinking, since both of these dimensions of alexithymia are more frequently associated with males, due to social desirability bias (Proença Lopes et al., 2022a,b). Since our sample was balanced by gender, we can speculate that sportive individuals are less alexithymic, and instead, the higher prevalence of alexithymia in high-risk sporting contexts is probably due to gender; however, more evidence is needed.

The results from our study agree with the majority of studies on PE and its effect on psychological wellbeing (Ghasempour et al., 2013). As pointed out by these studies, while practicing a sport, individuals not only acquire physical growth but also experience personal, mental, and emotional growth as well. Moreover, by creating a context for increasing their sense of empowerment and self-worth, sport's environment prevents young adults to develop psychological, emotional, and affective problems (e.g., alexithymia and its components). Sport practice can also improve positive attitudes and change negative beliefs and dysfunctional views of people's lives and their surroundings (Cox, 2012). To get the full picture, we also need to assess some socio-psychological factors that can contribute to the cognitive functioning differences between those who practice sports and those who lead a sedentary lifestyle. Indeed, the characteristics of sportive populations often include a favorable economic condition along with goal-directed behavior or proactivity that differ from those of sedentary ones (Hallmann and Breuer, 2014; Lucia et al., 2021). While these socio-economic factors have not been examined in this preliminary study, they provide a reflection for future research which will allow us to study the specific weights of each psychological factor involved in defining a specific “cognitive sportive profile.” There are, however, other limitations to our results, making them even more preliminary. A larger sample is needed to further strengthen the association between

sport practice and psychological wellbeing, which also allows us to consider individual and gender-related differences. It should be noted that most of our sample was composed of amateur tennis players who belonged to the same sports association. Since we know that different types of physical activity have different effects on our cognitive abilities, it would be worthwhile to investigate the effects of other sports disciplines. According to Mandolesi et al. (2018), the benefits of PE on cognitive functioning and wellbeing are different depending on whether the activity is performed aerobically or anaerobically. Moreover, there is a major difference between chronic and acute PE, with chronic aerobic exercise being mostly associated with structural and functional neuroplastic changes along with enhanced cognitive functions (Colcombe et al., 2006; Mandolesi et al., 2017). Finally, our study was conducted following COVID-19 lockdown during which our students continued to train and to resume outdoor physical activity once possible. It could be useful to know whether PE's beneficial effects are sustained if physical activity is interrupted for an extended period.

In conclusion, our preliminary results show that regular exercise and participation in sport can positively affect cognitive and emotional functioning. Our sportive students performed better than sedentary students in terms of global intelligence, graphic and verbal fluency, as well as recognizing and describing emotions. It can be concluded that the promotion of PE in young and at-risk populations is an important priority for the promotion of psychological wellbeing, considering its beneficial function.

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 Local Ethics Committee of the University of Naples Federico II (protocol number: 12/2020). The patients/participants provided their written informed consent to participate in this study.

Author contributions

NP, LV, and ML performed the research. NP, ET, and PS analyzed the data. NP, FA, OG, FL, and LM wrote the manuscript. All authors designed the research, read, revised, and approved the final manuscript.

Funding

This research was supported by funding from the Department of Humanities, University of Naples Federico II (Fondi ricerca dipartimentale 70%, 2020 and 2021) to LM.

Acknowledgments

We would like to thank Stefania Crimaldi, the amateur athletes of Tennis Club Petrarca, and the students of the Department of Humanities, University of Naples Federico II for making this study possible.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships

References

- Bagby, R. M., Parker, J. D. A., and Taylor, G. J. (1994). The twenty-item Toronto Alexithymia scale—I. Item selection and cross-validation of the factor structure. *J. Psychosom. Res.* 38, 23–32. doi: 10.1016/0022-3999(94)90005-1
- Bailey, C. E. (2007). Cognitive accuracy and intelligent executive function in the brain and in business. *Ann. N. Y. Acad. Sci.* 1118, 122–141. doi: 10.1196/annals.1412.011
- Basso, J.C., and Suzuki, W.A. (2017). The effects of acute exercise on mood, cognition, neurophysiology, and neurochemical pathways: a review. *Brain Plast.* 2, 127–152. doi: 10.3233/BPL-160040
- Behroozi, A., and Abdmoghadam, S. (2014). Role of sports on scales of mental health among a battalion of Iranian conscripts. *Ann. Mil. Health Sci. Res.* 12, 29–33.
- Bressi, C., Taylor, G., Parker, J., Bressi, S., Brambilla, V., Aguglia, E., et al. (1996). Cross validation of the factor structure of the 20-item Toronto Alexithymia Scale: an Italian multicenter study. *J. Psychosom. Res.* 41, 551–559. doi: 10.1016/S0022-3999(96)00228-0
- Bullo, V., Bergamin, M., Gobbo, S., Sieverdes, J. C., Zaccaria, M., Neunhaeuserer, D., et al. (2015). The effects of Pilates exercise training on physical fitness and wellbeing in the elderly: a systematic review for future exercise prescription. *Prev. Med.* 75, 1–11. doi: 10.1016/j.ypmed.2015.03.002
- Carlesimo, G. A., Caltagirone, C., and Gainotti, G. (1996). The mental deterioration battery: normative data, diagnostic reliability and qualitative analyses of cognitive impairment. The group for the standardization of the mental deterioration battery. *Eur. Neurol.* 36, 378–384. doi: 10.1159/000117297
- Cattelan, R., Dal Sasso, F., Corsini, D., and Posteraro, L. (2011). The modified five-point test: normative data for a sample of Italian healthy adults aged 16–60. *Neurol. Sci.* 32, 595–601. doi: 10.1007/s10072-011-0489-4
- Chieffi, S., Messina, G., Villano, I., Messina, A., Valenzano, A., Moscatelli, F., et al. (2017). Neuroprotective effects of physical activity: evidence from human and animal studies. *Front. Neurol.* 8, 188. doi: 10.3389/fneur.2017.00188
- Cipolotti, L., Molenberghs, P., Dominguez, J., Smith, N., Smirni, D., Xu, T., et al. (2020). Fluency and rule breaking behaviour in the frontal cortex. *Neuropsychologia* 137, 107308. doi: 10.1016/j.neuropsychologia.2019.107308
- Colcombe, S., and Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: a meta-analytic study. *Psychol. Sci.* 14, 125–130. doi: 10.1111/1467-9280.t01-1-01430
- Colcombe, S. J., Erickson, K. I., Scalf, P. E., Kim, J. S., Prakash, R., McAuley, E., et al. (2006). Aerobic exercise training increases brain volume in aging humans. *J. Gerontol. A Biol. Sci. Med. Sci.* 61, 1166–1170. doi: 10.1093/gerona/61.11.1166
- Cox, R. H. (2012). *Sport Psychology: Concepts and Applications, 7th ed.* New York: McGraw-Hill.
- Davis, C. L., Tomporowski, P. D., McDowell, J. E., Austin, B. P., Miller, P. H., Yanasak, N. E., et al. (2011). Exercise improves executive function and achievement and alters brain activation in overweight children: a randomized, controlled trial. *Health Psychol.* 30, 91–98. doi: 10.1037/a0021766
- de Greeff, J. W., Bosker, R. J., Oosterlaan, J., Visscher, C., and Hartman, E. (2018). Effects of physical activity on executive functions, attention and academic performance in preadolescent children: a meta-analysis. *J. Sci. Med. Sport* 21, 501–507. doi: 10.1016/j.jsams.2017.09.595
- Di Fabio, A., and Clarotti, S. (2007). *Advanced Progressive Matrices by Raven: Italian adaptation.* Firenze: Giunti O.S.
- Diamond, A. (2016). “Why improving and assessing executive functions early in life is critical,” in *Executive Function in Preschool-Age Children: Integrating Measurement, Neurodevelopment, and Translational Research.* Washington, DC: American Psychological Association. pp. 11–43.
- Donnelly, J. E., Hillman, C. H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., et al. (2016). Physical activity, fitness, cognitive function, and academic achievement in children: a systematic review. *Med. Sci. Sports Exerc.* 48, 1197–1222. doi: 10.1249/MSS.0000000000000901
- Elfgren, C. I., and Risberg, J. (1998). Lateralized frontal blood flow increases during fluency tasks: influence of cognitive strategy. *Neuropsychologia* 36, 505–512. doi: 10.1016/S0028-3932(97)00146-2
- Erickson, K. I., Hillman, C., Stillman, C. M., Ballard, R. M., Bloodgood, B., Conroy, D. E., et al. (2019). Physical activity, cognition, and brain outcomes: a review of the 2018 physical activity guidelines. *Med. Sci. Sports Exerc.* 51, 1242–1251. doi: 10.1249/MSS.0000000000000936
- Fernandes, J., Arida, R. M., and Gomez-Pinilla, F. (2017). Physical exercise as an epigenetic modulator of brain plasticity and cognition. *Neurosci. Biobehav. Rev.* 80, 443–456. doi: 10.1016/j.neubiorev.2017.06.012
- Fernandez, A. L., Moroni, M. A., Carranza, J. M., Fabbro, N., and Lebowitz, B. K. (2009). Reliability of the five-point test. *Clin. Neuropsychol.* 23, 501–509. doi: 10.1080/13854040802279675
- Friesen, A. P., Lane, A. M., Devonport, T. J., Sellars, C. N., Stanley, D. N., and Beedie, C. J. (2013). Emotion in sport: considering interpersonal regulation strategies. *Int. Rev. Sport Exerc. Psychol.* 6, 139–154. doi: 10.1080/1750984X.2012.742921

that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpsyg.2022.957281/full#supplementary-material>

- Gelfo, F., Mandolesi, L., Serra, L., Sorrentino, G., and Caltagirone, C. (2018). The neuroprotective effects of experience on cognitive functions: evidence from animal studies on the neurobiological bases of brain reserve. *Neuroscience* 370, 218–235. doi: 10.1016/j.neuroscience.2017.07.065
- Ghasempour, A., Jodat, H., Soleimani, M., and Zhalehshabanlo, K. (2013). Happiness as a Predictor of Psychological Well-Being of Male Athlete Students. *Ann. Appl. Sport Sci.* 1, 25–32.
- Grego, F., Vallier, J. M., Collardeau, M., Rousseu, C., Cremieux, J., and Brisswalter, J. (2005). Influence of exercise duration and hydration status on cognitive function during prolonged cycling exercise. *Int. J. Sports Med.* 26, 27–33. doi: 10.1055/s-2004-817915
- Hallmann, K., and Breuer, C. (2014). The influence of socio-demographic indicators economic determinants and social recognition on sport participation in Germany. *Eur. J. Sport Sci.* 14 (Suppl 1), S324–S331. doi: 10.1080/17461391.2012.704078
- Jodat, H., Ghasempour, A., and Tavakoli, A. (2015). Comparison of alexithymia in athlete and non-athlete students. *Ann. Appl. Sport Sci.* 3, 17–24. doi: 10.18869/acadpub.aassjournal.3.3.17
- Knapen, J., Sommerijns, E., Vancampfort, D., Sienaert, P., Pieters, G., Haake, P., et al. (2009). State anxiety and subjective well-being responses to acute bouts of aerobic exercise in patients with depressive and anxiety disorders. *Br. J. Sports Med.* 43, 756–759. doi: 10.1136/bjism.2008.052654
- Lardone, A., Turriziani, P., Sorrentino, P., Gigliotta, O., Chirico, A., Lucidi, F., et al. (2021). Behavioral restriction determines left attentional bias: preliminary evidences from COVID-19 lockdown. *Front. Psychol.* 12, 650715. doi: 10.3389/fpsyg.2021.650715
- Lista, I., and Sorrentino, G. (2010). Biological mechanisms of physical activity in preventing cognitive decline. *Cell. Mol. Neurobiol.* 30, 493–503. doi: 10.1007/s10571-009-9488-x
- Lucia, S., Bianco, V., Boccacci, L., and Di Russo, F. (2021). Effects of a cognitive-motor training on anticipatory brain functions and sport performance in semi-elite basketball players. *Brain Sci.* 12, 68. doi: 10.3390/brainsci12010068
- Ludyga, S., Gerber, M., Brand, S., Holsboer-Trachsler, E., and Pühse, U. (2016). Acute effects of moderate aerobic exercise on specific aspects of executive function in different age and fitness groups: a meta-analysis. *Psychophysiology* 53, 1611–1626. doi: 10.1111/psyp.12736
- Mammen, G., and Faulkner, G. (2013). Physical activity and the prevention of depression: a systematic review of prospective studies. *Am. J. Prev. Med.* 45, 649–657. doi: 10.1016/j.amepre.2013.08.001
- Mandolesi, L., Gelfo, F., Serra, L., Montuori, S., Polverino, A., Curcio, G., et al. (2017). Environmental factors promoting neural plasticity: insights from animal and human studies. *Neural Plast.* 2017, 7219461. doi: 10.1155/2017/7219461
- Mandolesi, L., Polverino, A., Montuori, S., Foti, F., Ferraioli, G., Sorrentino, P., et al. (2018). Effects of physical exercise on cognitive functioning and wellbeing: biological and psychological benefits. *Front. Psychol.* 9, 509. doi: 10.3389/fpsyg.2018.00509
- Manfredi, P. (2022). Benefits, risks and gender differences in sport, and exercise dependence: key role of alexithymia. *Int. J. Environ. Res. Public Health* 19, 5288. doi: 10.3390/ijerph19095288
- Marin, D., Madotto, E., Fabbro, F., Skrap, M., and Tomasino, B. (2017). Design fluency and neuroanatomical correlates in 54 neurosurgical patients with lesions to the right hemisphere. *J. Neurooncol.* 135, 141–150. doi: 10.1007/s11060-017-2560-3
- Nemiah, J. C., and Sifneos, P. E. (1970). Psychosomatic illness: a problem in communication. *Psychother Psychosom* 18, 154–160. doi: 10.1159/000286074
- Nocera, J. R., Mammino, K., Kommula, Y., Wharton, W., Crosson, B., and McGregor, K. M. (2020). Effects of combined aerobic exercise and cognitive training on verbal fluency in older adults. *Gerontol. Geriatr. Med.* 6, 2333721419896884. doi: 10.1177/2333721419896884
- Nocera, J. R., McGregor, K. M., Hass, C. J., and Crosson, B. (2015). Spin exercise improves semantic fluency in previously sedentary older adults. *J. Aging Phys. Act.* 23, 90–94. doi: 10.1123/JAPA.2013-0107
- Passarello, N., Greco, F., Piras, F., Cordella, B., Lai, C., Spalletta, G., et al. (2021). “No words for feelings”: a multidimensional analysis of the alexithymia construct. *Psychology Hub* 38, 41–50. doi: 10.13133/2724-2943/17529
- Pereira, A. C., Huddleston, D. E., Brickman, A. M., Sosunov, A. A., Hen, R., McKhann, G. M., et al. (2007). An in vivo correlate of exercise-induced neurogenesis in the adult dentate gyrus. *Proc. Natl. Acad. Sci. USA.* 104, 5638–5643. doi: 10.1073/pnas.0611721104
- Proença Lopes, C., Allado, E., Poussel, M., Essadek, A., Hamroun, A., and Chenuel, B. (2022a). Alexithymia and athletic performance: beneficial or deleterious, both sides of the medal? A systematic review. *Healthcare (Basel)* 10, 511. doi: 10.3390/healthcare10030511
- Proença Lopes, C., Allado, E., Poussel, M., Hamroun, A., Essadek, A., Albuissou, E., et al. (2022b). An Association between alexithymia and the characteristics of sport practice: a multicenter, cross-sectional study. *Healthcare* 10, 432. doi: 10.3390/healthcare10030432
- Raven, J. C. (1962). *Advanced Progressive Matrices: Sets I and II*. London: H.K. Lewis.
- Serra, L., Cercignani, M., Petrosini, L., Basile, B., Perri, R., Fadda, L., et al. (2011). Neuroanatomical correlates of cognitive reserve in Alzheimer disease. *Rejuvenation Res.* 14, 143–151. doi: 10.1089/rej.2010.1103
- Serra, L., Raimondi, S., di Domenico, C., Maffei, S., Lardone, A., Liparoti, M., et al. (2021). The beneficial effects of physical exercise on visuospatial working memory in preadolescent children. *AIMS Neurosci* 8, 496–509. doi: 10.3934/Neuroscience.2021026
- Swart, M., Kortekaas, R., and Aleman, A. (2009). Dealing with feelings: characterization of trait alexithymia on emotion regulation strategies and cognitive-emotional processing. *PLoS ONE* 4, e5751. doi: 10.1371/journal.pone.0005751
- Verburgh, L., Königs, M., Scherder, E. J. A., and Oosterlaan, J. (2014). Physical exercise and executive functions in preadolescent children, adolescents and young adults: a meta-analysis. *Br. J. Sports Med.* 48, 973–979. doi: 10.1136/bjsports-2012-091441
- Wang, J., D’Amato, A., Bambrough, J., Swartz, A. M., and Miller, N. E. (2016). A positive association between active lifestyle and hemispheric lateralization for motor control and learning in older adults. *Behav. Brain Res.* 314, 38–44. doi: 10.1016/j.bbr.2016.07.048
- Weinstein, A. M., Voss, M. W., Prakash, R. S., Chaddock, L., Szabo, A., White, S. M., et al. (2012). The association between aerobic fitness and executive function is mediated by prefrontal cortex volume. *Brain Behav. Immun.* 26, 811–819. doi: 10.1016/j.bbi.2011.11.008
- Woodman, T., Huggins, M., Le Scannf, C., and Cazenave, N. (2009). Alexithymia determines the anxiety experienced in skydiving. *J. Affect. Disord.* 116, 134–138. doi: 10.1016/j.jad.2008.11.022
- Woodman, T., and Welch, C. (2021). Alexithymia and the anxiolytic effect of endurance running. *Sport Psychol.* 36, 40–46. doi: 10.1123/tsp.2021-0039
- Xue, Y., Yang, Y., and Huang, T. (2019). Effects of chronic exercise interventions on executive function among children and adolescents: a systematic review with meta-analysis. *Br. J. Sports Med.* 53, 1397–1404. doi: 10.1136/bjsports-2018-099825