Mindfulness
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RESEARCH

Effects of Meditation Practice on Body Balance Training

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Abstract

Objectives Meditation may help athletes optimize performance, but measuring competitive results alone fails to isolate its specific effects. The present study evaluated whether meditation practice, in conjunction with stability exercises, improves body balance, a foundational skill relevant for action execution and athletic performance.

Method High school students ($n=81$) were randomly assigned to either an experimental group ($n=42$), or a control group ($n=39$). Both groups underwent a 6-week balance and stabilization training program, including standing on a fit-ball. The experimental group additionally practiced meditation, while the control group engaged solely in the physical training. Static monopodal stability and fit-ball balance proficiency were evaluated in both groups pre- and post-intervention.

Results While core stability improved to a comparable extent in both groups, the experimental group showed significantly greater gains in fit-ball balance. On average, the experimental group's falling rate was nearly one-third that of the control group (34.82%; highest Bayesian posterior probability 94% density interval: [17.60%, 52.29%]).

Conclusions These results indicate that meditation enhances skill acquisition and execution during complex balance tasks. Furthermore, they suggest that integrating meditation in athletic training regimens can significantly optimize balance control and overall performance.

Preregistration This study is not preregistered.

Keywords Meditation · Balance · Posture · Training · Sport

Optimal performance in sport is demanding because of the high level of requirements it leverages on, both in the physical and in the mental domain. The double nature of the athlete's commitment—physical and mental—has relevant implications and poses specific challenges in training and during competitions. Athletes not only have to develop and master sport-specific skills, but they must also be able to deploy them during competitions, when load and stress are higher. Moreover, to reach top performance athletes must train with commitment and perseverance. Obstacles to this may be boredom, lack of motivation, distractions, anxiety, fear, and stress.

Various studies reported that meditation practice may improve performance in different sports (e.g., Bertollo et al., 2016; Sappington & Longshore, 2015; Si et al., 2024) and proposed approaches based on meditation as a form of mental training (Baltzell & Summers, 2018; Bernier et al., 2009; Bühlmayer et al., 2017; Henriksen et al., 2019; Moore, 2009). Meditation may contribute to optimal performance in sport due to its effects on psychological dimensions relevant to the acquisition and expression of skills (Röthlin et al., 2020; Sánchez-Sánchez et al., 2023; Tang & Bruya, 2017). For example, meditation may enhance attention (Gao & Zhang, 2023; Kozasa et al., 2012; Lutz et al., 2009), improve emotion regulation (Chambers et al., 2009; Heppner et al., 2015; Josefsson et al., 2019; Kral et al., 2018; Ong & Chua, 2021), reduce stress (Chang et al., 2004; Fink & Ruiz, 2020; Furrer et al., 2015; John et al., 2011), and improve coping mechanisms for fatigue and pain (Nien et al., 2024; Zeidan & Vago, 2016).

In the scientific literature, mindfulness is a term used to mean both the training to achieve a mindful state and the state itself (Raffone & Srinivasan, 2017). We refer to

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mindfulness following Jon Kabat-Zinn's definition, according to whom it means *paying attention on purpose, in the present moment and non-judgmentally* (Kabat-Zinn, 2005); we call *meditation* the training practice. Through meditation, practitioners become aware of their thoughts and emotions, learning to accept them without judgment, and living what is happening in the present moment. For athletes, this means to stay focused on what is relevant for the task.

While sports are complex activities leveraging a multitude of skills, many additional factors—at both the individual and inter-individual levels—contribute to competitive results. Consequently, understanding how meditation improves performance is difficult if we rely only on ultimate competitive outcomes. To address this limitation, the present study aimed to test whether the benefits of meditation practice stem from the improvement of basic skills which underpin athletic proficiency. Specifically, we focused on body balance—a foundational skill for performance across athletic disciplines (Hrysomallis, 2011; Zemková & Zapletalová, 2022).

Method

Participants

Students from five high school classes were included ($n=81$, 50 females, aged 16 and 17 years). All the experimental procedures were conducted in accordance with the policies and principles contained in the Declaration of Helsinki.

Randomization into the experimental group (balance training plus meditation; $n=42$, 26 females) or control group (balance training alone; $n=39$, 24 females) was conducted at the class level rather than at the individual participant level: two classes were assigned to the experimental group, two classes were assigned to the control group, and the participants of a fifth class were individually randomized to either group. One participant in the experimental group did not practice meditation at all, and their data were excluded from subsequent analyses.

The experimental protocol was structured into five distinct phases, from participants' enrollment to final testing, as detailed in Fig. 1.

Procedure

Over a 6-week period (Phase 4, see Fig. 1), both groups trained every day in exercises aimed at enhancing balance, muscular control, and core stability. Participants in the experimental group also practiced meditation; however, no matching sham intervention was administered to the control group.

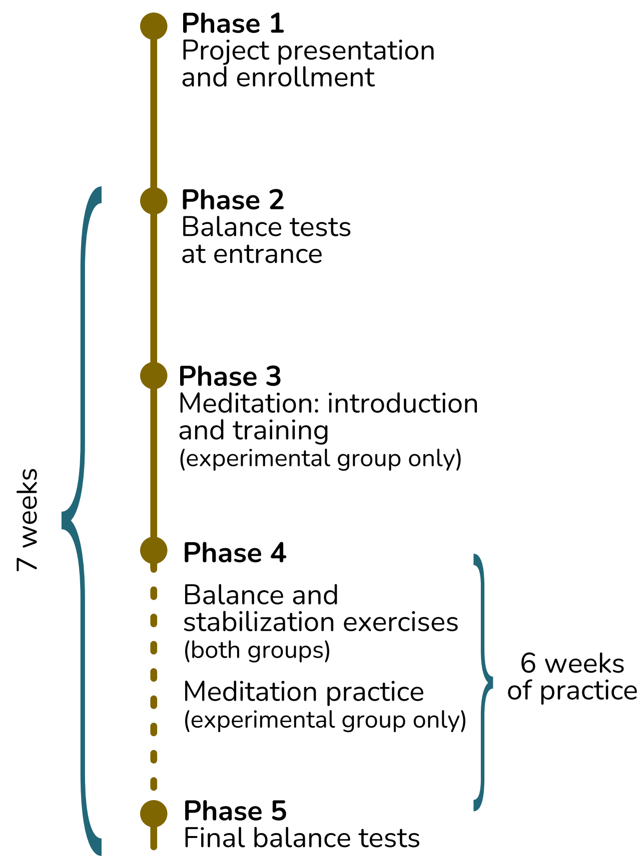

Fig. 1 Timeline and phases of the study

Core Stability and Balance Training

The exercises for stability training were mainly isometric and focused on trunk stability (different level of plank and side plank). In addition, the participants practiced four simple stability exercises on a fit-ball twice a week, at school. The exercises are briefly described in Online Resource 1.

Meditation Intervention

Participants in the experimental group were also instructed to practice meditation at home for 10 to 20 min daily for 6 weeks. To promote meditation practice and to enhance compliance, the experimental group practiced a further guided meditation session with a meditation instructor, at school, twice a week for the entire duration of the training protocol. The technique of meditation was Herbert Benson's Relaxation Response (Benson, 1976), which focuses attention on free breathing with eyes closed; while doing this, the participants simply become aware of the free thinking and sounds coming from the outside, without considering them as an obstacle to meditation, going back to follow breathing any time they realize their attention has moved away from it. In order to help the participants to break the train of thoughts and shift attention and awareness to breathing we asked them to mentally repeat a simple sound or word (e.g., "*one*" or "*oon*" or "*uu*") during exhalation. We did not ask them to keep a specific posture while practicing meditation; we only suggested to reach a comfortable posture that prevented muscular tensions or to fall asleep.

In order to monitor their daily practice, participants were required to complete a diary entry at the end of every meditation session.

Measures

To assess balance proficiency, we chose two tests, performed before and after the 6 weeks training: a static monopodal stance stability test and a bipodal stance stability test on a fit-ball.

Static Monopodal Stability Test

The participants performed a monopodal balance test with their eyes closed for 30 s. The measured variables were the ellipse area (cm^2) and the total path length (cm) of the center of mass displacement during the test. In order to evaluate monopodal balance, we recorded accelerations and angular speed using an inertial device (GyKo, Microgate Italy, Bolzano, Italy; sampling rate: 1000 Hz; sensitivity: acceleration up to 16 g; and angular speed, up to 34.9 rad/s). The sensor was fixed to the participant's back, at the level of first thoracic vertebra (T1), providing data about postural oscillation of the participant. Data were transmitted in real time to a personal computer via Bluetooth, and processed using Microgate software.

Bipodal Stability Test

Participants were requested to maintain a bipodal stance on a fit-ball (wearing shoes) for 60 s and the measured variable was the time to task failure, that is, the total amount of time standing balanced on the ball.

Data Analyses

To evaluate the body movements in upright monopodal balance with closed eyes, we compared the center of mass fluctuations using a Bayesian linear model, both within group (to test changes before and after training) and between groups. The test was performed balancing both on the left and on the right foot, and we performed the comparisons choosing, for each participant, the ones with the lowest postural sway.

We estimated the relative risk of the experimental group (that is, the risk of the experimental group relative to the risk of the control group: risk ratio or proportion) to fall off the fit-ball through the Cox proportional hazards model (Cox, 1972) within a Bayesian approach. According to the model, the hazard function at time t is

$$H(t;Z)=H_0(t)e^{Z\prime\beta}$$

where $\boldsymbol{Z}$ is a vector of covariates, $\boldsymbol{\beta}$ is a vector of regression parameters, $H_0(t)$ is the (unspecified) baseline hazard function, and $e^{Z\prime\beta}$ is the relative risk, that is the ratio of the hazard rate $H(t;Z=k)$ at time t to $H(t;Z=0)=H_0(t)$. We estimated the fall rate (failure rate) of the experimental group relative to the control group using the group as covariate (experimental group: $Z=1$; control group: $Z=0$), and calculated the fall rate for the experimental group as percentage of the hazard rate of the control group (fall rate proportion $=100 \cdot e^{\beta}$).

For all the analyses, we summarized the posterior distributions, providing their mean and 94% credible interval ($CI_{94\%}$), estimated by calculating the narrowest interval including the 94% of the posterior probability density: highest probability density interval ($HPDI_{94\%}$).

The Bayesian inference was performed via Markov Chain Monte Carlo (MCMC) sampling (through the No-U-Turn sampler algorithm (Hoffman & Gelman, 2014)), using 4 chains, 2000 steps each.

For data analysis and visualization, we used the Julia (v. 1.10.0 (Bezanson et al., 2017)) mathematical programming language. For the Bayesian analysis, we used the Stan probabilistic programming language (Stan Development Team, 2024) together with the Julia package StanSample.jl (v.7.8.0, https://github.com/StanJulia/StanSample.jl). The code for the Bayesian analysis is reported in the supplementary material (see Algorithms 1 and 2 in Online Resource 2).

Results

Training Practice

All participants accomplished the required balance training (6 weeks). The experimental group ($n=41$) practiced a median of 36 meditation sessions, (range [13, 54]), with a median duration of 14.50 min per session (range [7.27, 20.24]); no participant performed less than 30% of the prescribed meditation practice. Figure 2 summarizes these data. Meditation sessions may exceed the number of days assigned for training, as participants practiced meditation at home also in those days in which they attended the guided meditation session at school.

Balance

We tested balance at entrance and again after 6 weeks of core stability and balance training (performed by both groups)

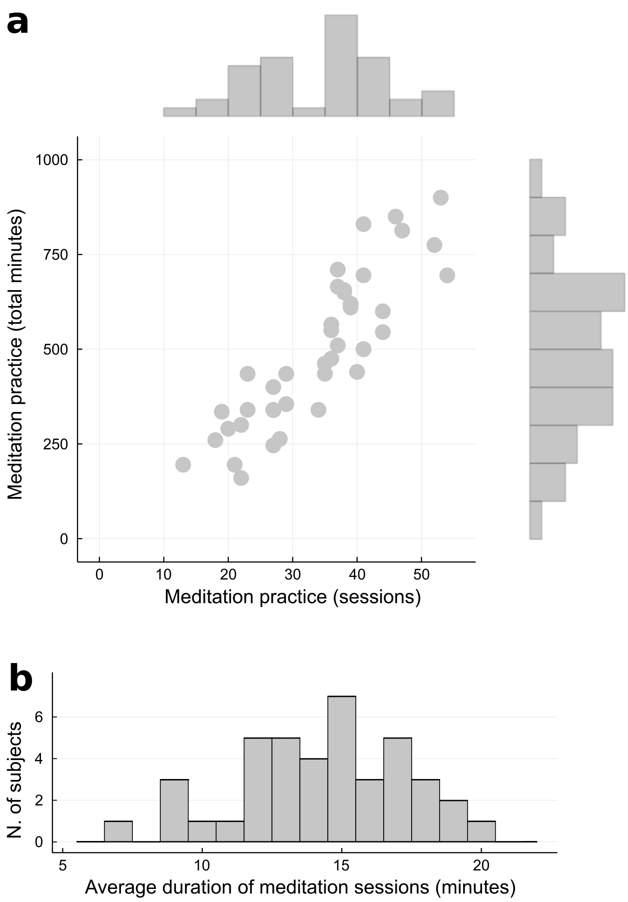

Fig. 2 Meditation practice. **a** Number of sessions *vs* cumulative meditation time. **b** Average duration of meditation sessions. $n=41$

and of meditation practice (performed by the experimental group only).

Monopodal Balance

Monopodal center of mass fluctuations with closed eyes—which evaluates stance on a flat, steady surface—showed no difference between groups at entrance and were inconsistently reduced in both groups after training, as results from the Bayesian linear model analysis ($\widehat{R}$: 1.0 and effective sampling size > 4700 for all parameters): compared to the test at entrance, the estimated average reduction of fluctuations (mean of the posterior probability distribution) was 7.19% for the control group (94% credible interval ($CI_{94\%}$): [−6.64%, 21.31%]; $n=39$); and 1.58% for the experimental group ($CI_{94\%}$: [−8.40%, 12.34%]; $n=40$; one participant in the experimental group did not perform the test after training and was excluded from these analysis), with an estimated average difference between groups (experimental vs control) of −5.61 percentage points ($CI_{94\%}$: [−22.72%, 12.02%] percentage points). A synthesis of the data and of the MCMC

Table 1 Percentage (and proportion) of participants which remained on the fit-ball during the final test at least 30 and 60 s, and median time on fit-ball. Experimental group $n=41$, control group $n=39$

Group	≥ 30 s	≥ 60 s	Median
Control	30.77% (12/39)	10.26% (4/39)	20 s
Meditation	75.61% (31/41)	43.90% (18/41)	45 s

results is reported in Supplementary Figures 1, 2 and 3 and in Supplementary Table 1 (see Online Resource 1).

Balance on Fit-Ball

At entrance, no participant was capable of maintaining a bipodal stance on the fit-ball. After 6 weeks of training, 10.26% ($n=4/39$) of the participants in the control group and 43.90% ($n=18/41$) of those in the experimental group successfully completed the task of standing 60 s on the fit-ball in the final test (Table 1 and Fig. 3).

To compare the ability to balance on the fit-ball, we performed a Bayesian analysis using the Cox proportional hazards model (Cox, 1972), estimating the probability to fall (task failure) of the experimental group relative to the control group (fall rate proportion or hazard rate ratio). With the group as covariate (see "Method"), the expected falling rate (mean of the posterior distribution) for the experimental group was almost one-third (34.82%) that of the control group (Fig. 4; $CI_{94\%}$: [17.60%, 52.29%]; $\widehat{R}$ for the β parameter: 1.0; effective sampling size: 3280).

Discussion

The main finding of this study is that 6 weeks of stability training alongside meditation practice enhanced performance on a highly challenging task—maintaining balance standing on a fit-ball—compared to stability training alone. While both the control and the experimental groups showed a comparable improvement in static monopodal balance on a flat, stable surface with eyes shut, the experimental group achieved significantly greater proficiency maintaining balance on the fit-ball. Specifically, survival analysis showed that participants in the control group exhibited a threefold higher hazard rate of task failure than those in the experimental group.

Balancing single footed on a flat, steady surface is a simpler task, even with eyes shut, than balancing on a ball. We hypothesize a double explanation for the comparable improvement in the monopodal task observed in the two groups. First, 6 weeks of balance and core stability training

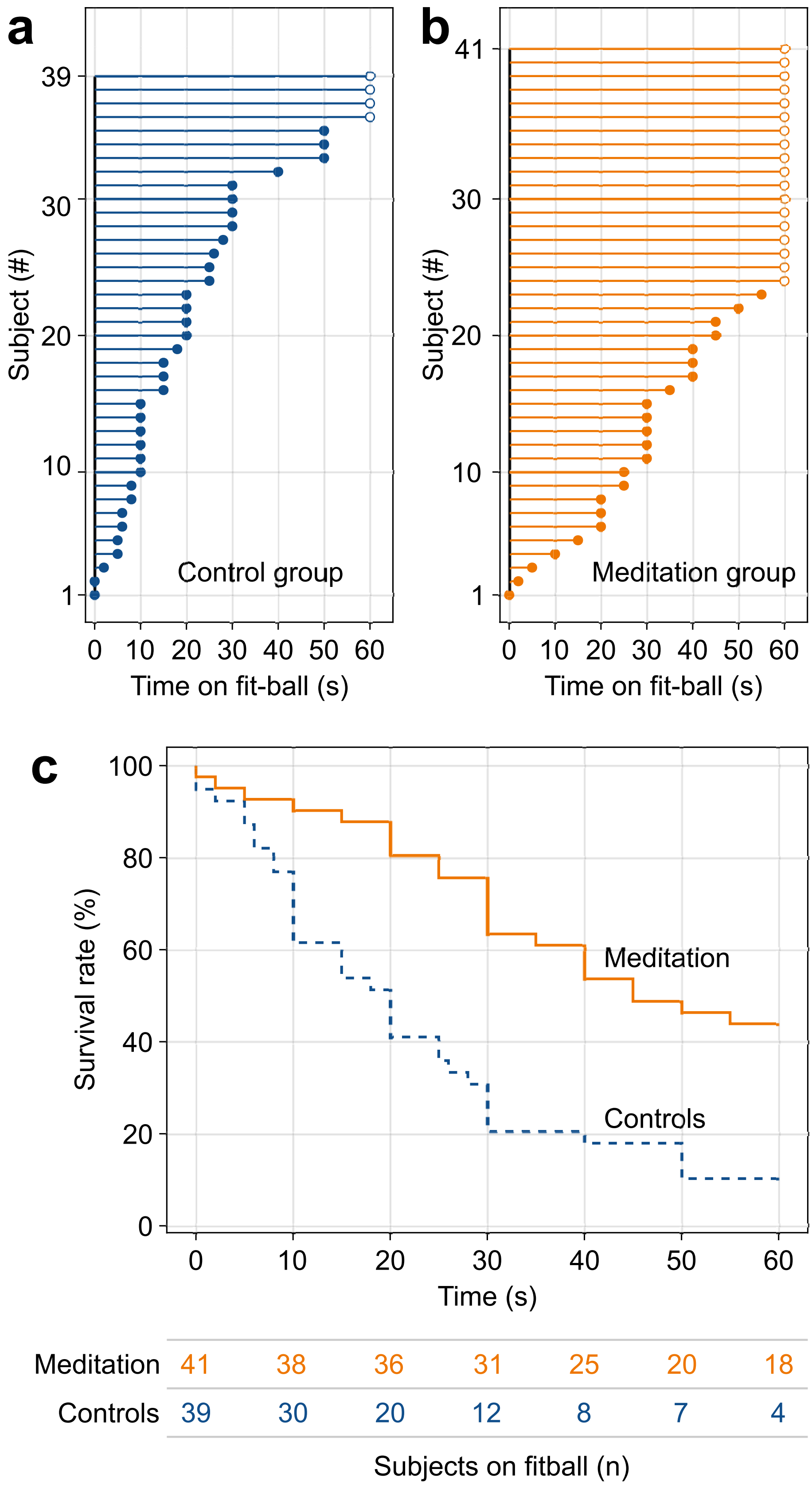

Fig. 3 Time on fit-ball in the final test. Participants were required to stand on a fit-ball up to 60 s. **a**, **b** Time on fit-ball for each participant in the control (**a**) and in the experimental (**b**) groups; empty circles: censored data. **c** Kaplan-Meier curves: time on fit-ball (survival) curves for the two groups, and number of participants at risk. Control group $n=39$, experimental group $n=41$

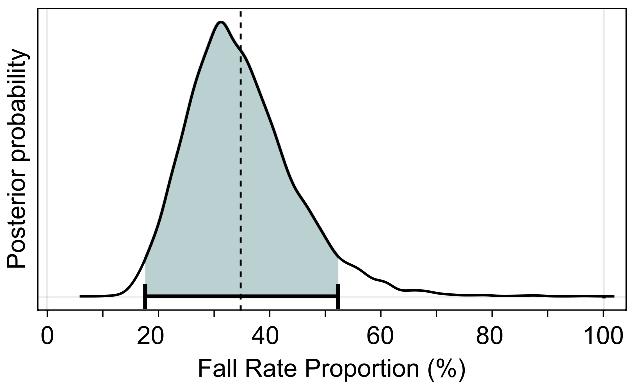

Fig. 4 Estimate of the relative task failure rate (fall rate from the fit-ball) in the experimental group. Posterior probability distribution of the task failure rate for the experimental group, as proportion of the task failure rate of the control group; black bar at the bottom and shadow area show the 94% credible interval (94% highest probability density interval); dashed line: expected falling rate (mean of the distribution). Bayesian Cox proportional hazards model, experimental group $n=41$, control group $n=39$

may be enough to improve control participants and meditators to the same extent in this simpler task. Second, being less demanding and perceived as safer (participants feel more in control and they do not risk to fall down unexpectedly), it did not evoke anxiety, fear, or negative thoughts about self-efficacy in meditators as well as in control participants.

Conversely, keeping balance on a highly unstable surface, such as on a ball, is a challenging task and potentially more anxiogenic. Consequently, the ability to manage negative emotions may be a primary reason underlying the effectiveness of meditation in improving balance on the fit-ball, with positive effects both on training effectiveness and on performance in the final test.

Meditation can optimize performance in two complementary ways: by increasing learning during training sessions and by helping to manage stress and anxiety, improving focus and adaptation during tests and competitions. During training, meditation practice may foster focused and sustained attention on the task (Gao & Zhang, 2023; Gardner & Moore, 2007; Röthlin et al., 2020; Wadlinger & Isaacowitz, 2011) promoting efficient allocation of brain resources (Fabio & Towey, 2018; Slagter et al., 2007) and a better integration of sensory signals relevant to balance. Accumulating evidence suggests that meditation allows for a finer processing of sensory signals, particularly proprioceptive and interoceptive (Pagnoni, 2019; Pagnoni & Guareschi, 2017; Pérez-Peña et al., 2022). Meditation practice develops in the trainee a greater presence in the "here and now" (Baltzell & Summers, 2018; Gardner, 2016) bringing benefits to tasks in which attention and concentration, sensory information, and body awareness are of primary relevance, as is the case of balance control. Furthermore, meditation promotes emotion regulation, which helps to avoid affective states disruptive of performance and motor coordination, such as anxiety and fear.

During competitions, performance may be sub-optimal or compromised due to cognitive-affective states (including anxiety, fear, expectations, lack of self-confidence or of concentration). These states are commonly triggered by ongoing situations or events (e.g., athlete's mistakes, opponents' actions, or interpersonal pressure from coaches and teammates), often related to past experiences. Nevertheless, recent psychological research established that the mechanisms through which negative emotions and thoughts affect performance are not directly related to the mere presence of these states, or to their origin, rather to the capability of athletes to deal with them (Gardner & Moore, 2007). A step towards the achievement of this competence is renouncing cognitive suppression or avoidance of negative states (Birrer et al., 2012; Hayes & Strosahl, 2004; Wenzlaff & Wegner, 2000) and in the last decades a progressively increasing amount of evidence has accumulated about mindfulness and acceptance, fostered through meditation, as an effective way to manage negative emotions and thoughts (Hölzel et al., 2011; Josefsson et al., 2019; Tang et al., 2015).

To summarize, 6 weeks of balance and core stability training alone may have been enough for the simpler task to be successfully trained and performed also by the control group, while for the more demanding and anxiety-inducing task, meditation training boosted both training effectiveness (skill acquisition) and balance control (performance during test).

A further point to consider is that meditation practice requires time, which adds to the time allocated to sport-specific training. This raises the question of whether increasing physical balance training—using that same amount of time—might yield equivalent or superior results. While further research is required to directly investigate this trade-off, it is relevant to note that beyond a certain volume, physical training may no longer be beneficial. First, increasing the training volume induces greater fatigue, which compromises not only ongoing performance but also long-term learning (Branscheidt et al., 2019). Second, excessive training, or a lack of variety, may also reduce motivation and compromise attention, impairing motor learning (Chua et al., 2019). Third, because motor skills and balance acquisition relies on neuroplastic consolidation processes within and between sessions (Luft & Buitrago, 2005), long training sessions are often unnecessary. Indeed, resting time and sleep between sessions are essential for long-term learning (Lugassy et al., 2018). Finally, it is often unfeasible to increase physical training within athletes' schedules.

Furthermore, even if additional training may yield greater proficiency, mindfulness provides a unique advantage: it is a meta-skill that extends benefits to other settings and tasks. Emotion regulation is valuable not just for the acquisition and mastery of a single skill but for a broader set of competences essential for performing under pressure, such as during competitions. Meditation exerts positive effects across many domains—including attention, emotion regulation, stress coping, health, interpersonal behaviors, and motivation—which are relevant for a wide variety of sports, making it a valuable tool for athletes across all disciplines.

To conclude, this study focused on balance, as it is a critical component for mastering sport activities and enabling the optimal expression of sport-specific skills. Recent research has hypothesized that meditation practice fosters an optimal attentional focus on task-relevant cues while improving the ability to cope with thoughts and emotions that disrupt performance (e.g., anxiety, fear) and training (e.g., stress, boredom) (Freudenthaler et al., 2017; Henriksen et al., 2019; Si et al., 2024). Crucially, our study demonstrates that these psychological benefits enhance not only the sport activity as a whole, but also the acquisition and control of the fundamental skills essential for optimal athletic performance.

Limitations and Future Directions

A limitation of this study is the absence of an active control or sham task to match the meditation intervention. Therefore, we cannot exclude that the observed differences could be partially attributed to a placebo or expectancy effect, as the experimental group's awareness of the intervention may have heightened their engagement or motivation during the training sessions and the testing tasks.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12671-026-02953-0.

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Author Contributions L.S. and D.A. devised the experiment; L.S., D.A., and B.R. designed the protocol; B.R. and D.A. trained the subjects in meditation; L.S. and B.R. tested the subjects and trained them in postural exercises; D.A. analyzed the results; D.A., B.R., and L.S. wrote the paper.

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Data Availability Data for all subjects are available as a *.csv file in Supplementary Material 3 online.

Declarations

Ethics Approval The study was approved by the high school board, which evaluated the appropriateness and the compatibility of the project with the educational and learning objectives for the students, and against possible ethical concerns about the procedure and data treatment; and by the Internal Review Board of the Department of Medicine of our institution (Prot IRB: 139/2023; Tit III cl 13 fasc. 5/2023).

Informed Consent All participants and their parents provided written informed consent for the students to be enrolled and participate in the study.

Competing interests The authors declare no competing interests.

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