

Development and Research Hot Issues of Mindfulness Training in Sports Research

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Abstract

With the widespread application of mindfulness training in the fields of mental health and behavioral science, its theoretical value and practical significance in sports research have gradually attracted attention. In order to systematically sort out the development context and research hot issues of mindfulness training in the field of sports, this paper uses the method of combining literature review and topic induction to conduct a comprehensive analysis of relevant research at home and abroad. By searching the research results on mindfulness and sports situations in databases such as Web of Science, Scopus, PubMed and China National Knowledge Network, we systematically collated them from aspects such as research development stages, intervention types, application fields and action mechanisms. The research results show that mindfulness training in the field of sports has experienced an evolution process from the introduction of psychotherapy paradigm, the expansion of competitive sports application to multi-scene integrated development, and the research theme has gradually shifted from mental health promotion to exercise performance optimization and comprehensive physical and mental regulation. Existing empirical research generally finds that mindfulness training can improve athletes' attention control, emotional regulation and stress coping styles to a certain extent, but there are still differences in its direct impact on sports performance. At the mechanism level, relevant research mainly explains its action process from three paths: attention regulation, emotion and cognitive regulation, and body awareness and action control. Based on the synthesis of existing research, this paper further proposes an integrated theoretical framework of "Mindfulness, Self-Regulation-Performance Stability", arguing that mindfulness training indirectly promotes performance stability in competitive situations by improving individuals' self-regulation abilities, rather than directly improving individual performance. At the same time, current research still has problems such as insufficient standardization of intervention models, lack of long-term follow-up research, and limited integration of multimodal evidence. The study believes that in the future, differentiated intervention research in different sports events should be strengthened, and multi-layer evidence verification should be carried out based on behavioral, physiological and neural indicators to promote the theoretical deepening and practical application of mindfulness training in the field of sports science.

Keywords

Mindfulness training; Sport Psychology; Athletic Performance.

1. Introduction

Against the background of highly competitive competitive sports, accelerating training rhythm and increasing competition pressure, athletes' sports performance is not only based on

athletes' own physical fitness and technical level, but psychological factors are also one of the important factors affecting sports performance. Psychological factors include but are not limited to stress, attention, anxiety, failure and rumination. Stress is a series of comprehensive reactions produced by athletes in training or competition scenarios when they perceive that external factors (such as performance goals, opponent's strength) do not match their own abilities. Attention is crucial to athletes' performance. It not only affects instantaneous performance during competition, but also continuously shapes athletes' cognitive level and competitive ability [1]. Long-term attention training can improve athletes' cognitive level and executive function, make them better adapt to different competition situations, thereby promoting sports performance. Anxiety, as a negative emotion, may lead to athletes' loss of attention and slowness in high-pressure competition environments, and may have doubts about their own abilities, thus affecting athletes' confidence and performance [2]. Failure rumination is a negative thinking pattern. Its outstanding characteristics are that individuals continuously and cyclically focus on the negative emotions they produce and various events associated with them. Rumination thinking will occupy too much limited cognitive energy, thereby disrupting individual cognitive efficiency and ultimately harming individual cognitive status [3]. Therefore, it is necessary to carry out psychological training. Traditional sports psychological training focuses on methods such as self-suggestion, relaxation training, image training and goal setting. Mindfulness training, as a kind of emerging psychological training with "awareness of the present and acceptance of experience" as the core, has gradually emerged in the field of sports in recent years and has become one of the key directions of sports psychology. Current domestic and foreign research shows that mindfulness training is widely used to improve sports performance, enhance concentration, improve competition anxiety, reduce negative thinking, promote emotional regulation, and can have a positive impact on psychological recovery after sports injuries and protection against sports burnout. However, mindfulness training in sports is still in the development stage, and its theoretical framework, intervention model, mechanism of action and local application still need to be further improved. Therefore, it is necessary to systematically sort out and analyze the development, research status, hot trends and future directions of mindfulness in the field of sports.

2. Research Methods

This study uses a combination of narrative review and evidence integration analysis to systematically sort out the development context, research hot issues and empirical progress of mindfulness training in the field of sports.

The literature search was mainly conducted in the Web of Science Core Collection, Scopus, PubMed and China National Knowledge Network (CNKI) databases. The search time range is from database establishment to June 2025. English search keywords include "mindfulness" AND ("sport" OR "athletic" OR "physical education" OR "exercise"). Chinese keywords include "mindfulness", "mindfulness training", "athlete", "sports", "sports performance", and "sports psychology."

The literature inclusion criteria are: (1) the study objects involve athletes, student sports groups or physical activity participants; (2) the study topic is related to mindfulness training or mindfulness intervention; (3) the study types include randomized controlled trials, quasi-experimental studies, systematic reviews or meta-analyses; (4) Chinese and English literature published in peer-reviewed journals. The literature exclusion criteria are: (1) research on non-sports or physical activity situations; (2) articles with purely theoretical reviews and lack empirical evidence; (3) conference abstracts, degree papers, and repeated published research. On this basis, the research content is classified and sorted out by using the method of combining theme induction and development stage analysis, focusing on comprehensive analysis and

review from four dimensions: development context, intervention types, empirical effects and action mechanisms.

3. The concept and Research Trend of Mindfulness

3.1. Core Definition of Mindfulness

Mindfulness comes from Eastern Zen and Buddhist thought. Mindfulness was originally defined as maintaining mindfulness, that is, maintaining peace and concentration of mind and body, including perception, attention and memory [4]. Kabat-Zinn defines mindfulness as "a state of consciousness arising from conscious awareness of experience in the present moment without judgment". Some scholars believe that mindfulness can be used to control attention by keeping attention on what is happening in the present, and to process current events cognitively [6]. In the 20th century, Kabat-Zinn first introduced mindfulness into the medical field in a scientific form, proposing Mindfulness-Based Stress Reduction (MBSR), and later developed models such as Mindfulness-Based Cognitive Therapy (MBCT). After entering the 21st century, with the rapid development of mindfulness research in the fields of psychology and education, its theory and training methods began to be introduced into sports psychology. Gardner and Moore proposed the "Situational Self-Regulation Model"(MSPE), marking that mindfulness has officially become a new direction of psychological training in the field of sports. After 2010, research on mindfulness training in the fields of competitive sports, school sports, integration of physical education and medicine, and sports rehabilitation has increased significantly, forming a new research growth point.

3.2. Trends in Rapidly Growing Research on Mindfulness in Sports Over the Past Decade

In the past ten years, the research on mindfulness in the field of sports has shown a rapid growth or even close to exponential increase. A bibliometric analysis based on Web of Science shows that since 2014, the number of publications related to mindfulness and sport has increased significantly. A total of 186 articles were retrieved from 1969 to 2021, and the vast majority were concentrated in the last ten years [7]. In the sub-field of athlete stress and recovery, Scopus data further shows that 90 related articles were published between 2019 and 2024, accounting for approximately 73% of all 124 articles, indicating that this is a research hot issues that has been rapidly growing in recent years [8]. Overall, the research form has gradually shifted from early conceptual and cross-sectional studies to randomized controlled trials and systematic reviews and scope reviews. The research theme has also expanded from a single competitive performance to a broader range of physical and mental development indicators such as stress recovery, mental health and happiness.

4. The Development Context of Mindfulness Training in Sports

4.1. Germination Stage (Late 20th Century-Early 21st Century): Initial Penetration of the Concept of Mindfulness Into Sports Psychology

Mindfulness training was originally mainly used in the fields of medicine and psychotherapy, and has achieved remarkable results in stress reduction, anxiety regulation, and prevention of relapse of depression. It is represented by the Mindfulness Stress Reduction Project (MBSR) developed by Kabat-Zinn since the late 1970s [5, 9, 10]. Subsequently, the concept of mindfulness developed rapidly in the fields of psychology and education, forming a series of mature intervention models such as MBSR and MBCT [5, 6, 11]. In the field of sports, early researchers mainly introduced mindfulness as a psychological regulation concept into sports psychology to explain the regulatory mechanisms of athletes 'cognitive and emotional

experience in high-stress situations [12-14]. The research at this stage presents the following characteristics: (1) Most of the literature is theoretical discussions and conceptual introductions, emphasizing the potential value of mindfulness on mental health and stress regulation [5, 6, 9-11]. (2) The research objects are mainly concentrated in the general population and clinical population, with a small sample of athletes, and the research on the competitive population is still limited [5, 13]. (3) Most of the intervention models directly borrow the basic technologies of MBSR and MBCT and apply them to the athlete group, and no specialized training model for sports situations has yet been formed [12-14].

Overall, this stage is in the stage of concept introduction and theory grafting, laying the foundation for subsequent development in the field of sports.

4.2. Development and Transition Stage (Mid-To-Late 2000s-Around 2010): The Formation of A Sports-Specialized Mindfulness Training Model

After entering the 21st century, research on mindfulness in the field of sports has gradually increased. The landmark event is that Gardner and Moore proposed and systematically developed the Mindfulness-Acceptance-Commitment (MAC) model since 2004, integrating mindfulness with Acceptance Commitment Therapy (ACT) concepts to improve psychological function and competitive performance in the field of sports and performance [12-15]. This stage mainly has the following characteristics: (1) Mindfulness has gradually become a new paradigm for sports psychological training. The MAC model represents a shift from the traditional cognitive behavioral orientation of "changing cognitive content" to the orientation of "accepting experience and improving psychological flexibility", so that mindfulness is no longer just an accessory technique of relaxation training, but develops into an independent exercise. Psychological training path [13-16]. (2) The theory and mechanism of exercise mindfulness began to be constructed. Based on the theory of mindfulness and acceptance, researchers proposed a "consciousness-acceptance-action" mechanism model in exercise performance, emphasizing that current awareness, experience acceptance, and action commitment can improve the quality of execution and psychological resilience under stressful situations [13-17]. (3) Preliminary empirical research is gradually emerging. Intervention studies have found that MAC and related mindfulness interventions have a positive impact on performance in competitive anxiety, attention regulation, negative self-conversation and self-reporting, and performance stability in high-pressure situations is higher than traditional mental skills training (PST) [16-20]. At this stage, mindfulness training completed a critical transition from cross-disciplinary introduction to "localization" within sports psychology, becoming an important research branch of sports psychology [13 - 15].

4.3. Rapid Expansion Stage (After 2010-About 2018): Diversified Sports Groups and Expansion of Intervention Models

After 2010, the research on mindfulness in the field of sports has shown an accelerating trend. Its main characteristics include: (1) The research objects have been significantly expanded. From the initial focus on elite athletes in competitive sports, it has gradually expanded to diverse groups such as youth and school sports, college student sports groups, sports rehabilitation and chronic disease patients, and general physical activity participants [18-22]. (2) Intervention models have been diversified and attempts have been made to localize sports situations. On the basis of MAC and MBSR, the researchers carried out sports contextualized transformation of the training content and developed various versions such as sports mindfulness meditation, pre-game mindfulness warm-up, combination of body scanning and special action control, and combination of mindfulness breathing and motion awareness, forming differentiated implementation plans in group events, confrontational events, and technical events [18-21]. (3) Increased research dimensions. The study expanded from a single outcome variable to multiple indicators, including attention control and interference inhibition,

technical execution quality and movement control, competition anxiety and psychological resilience, flow experience and self-determination motivation, psychological adjustment for returning from sports injuries, and adolescent concentration and motivation for sports participation, etc. [18-22]. (4) Domestic research has begun to increase significantly, but the overall research is still in its infancy. After 2010, the physical education community in China and Chinese-speaking regions has gradually paid attention to mindfulness training. After 2015, the number of relevant studies has increased significantly, but most of them have focused on questionnaire surveys and short-term interventions. Theoretical deepening and mechanism research are still relatively insufficient [22 - 24]. Therefore, this stage can be regarded as a critical period for mindfulness to move from the "introduction period" to the "growth period" in the field of sports.

4.4. Deepening Research Stage (Approximately 2018 To Present): Mechanism Exploration and Multidisciplinary Cross-Expansion

In recent years, mindfulness research has entered a stage of in-depth development in the field of sports, showing the following trends: (1) Explore the mechanism of mindfulness in exercise from multiple aspects such as cognitive psychology, physiological indicators and neuroscience. For example, theoretical models were built from the perspectives of attention networks, emotional regulation and cognitive fusion, flow generation mechanisms, and self-determination motivations, and the effects of mindfulness or meditation training on physiological and neural responses in exercise tasks were examined through indicators such as heart rate variability and EEG [16, 17, 20, 23, 25]. (2) The measurement tool system is gradually improving. Specialized mindfulness measurement tools have been developed for sports situations, such as Mindfulness Inventory for Sport (MIS) and its different language versions [23, 24], to evaluate athletes' processes such as awareness, non-judgment, and refocusing in competition and training situations. (3) Integration of sports and medicine and expansion of the field of physical and mental health. Mindfulness has been introduced into exercise rehabilitation, exercise intervention for chronic diseases, intervention for exercise burnout and overtraining syndrome, and the promotion of physical and mental health of students and the general population. Under the framework of the "integration of physical education and medicine" policy and health promotion, it has gradually become one of the important psychological intervention [18, 22, 25]. (4) Big data and intelligent technology intervention. In recent years, "digital mindfulness training" forms such as breathing/heart rate feedback and mindfulness practice based on smart wearable devices, digital mindfulness intervention based on mobile apps, and mindfulness or meditation training combined with exercise tasks in VR/AR scenarios have emerged, providing preliminary evidence for the promotion of physical activity, rehabilitation from chronic diseases, and preparation for competition [25 - 27].

Overall, mindfulness training in the field of sports research has evolved from a conceptual introduction to a theoretical system, multi-modal intervention and multi-situational application. Research is moving from verification of "whether it is effective" to in-depth analysis of multidisciplinary intersection and action mechanisms. stage.

5. Main types of Mindfulness Intervention and Training Content

The main types of mindfulness and intervention contents are shown in Table 1.

Table 1. Main types and content characteristics

Type	Main features	Core training content	Application field
Mindfulness-Based Stress Reduction, MBSR [10]	The most classic type of mindfulness, with structured and standardized characteristics, is used to relieve stress and reduce pain	Body scanning, mindfulness yoga, meditation, mindfulness walking, daily mindfulness and other practices	Stress management, mental health, pain relief
Mindfulness-Based Cognitive Therapy, MBCT [11]	It is mainly used to treat relapse of depression, coping with negative emotions, etc.	Body scanning, mindful breathing, cognitive dissociation, daily mindfulness and other exercises	Depression relapse prevention, emotional management
Acceptance-Commitment Therapy, ACT [28]	Emphasize "Acceptance-Present-Values"	Current awareness practice, cognitive dissociation, value clarification, commitment to action, etc.	Anxiety, pain, adaptive regulation
Mindful Sport Performance Enhancement, MSPE [29]	Seamless integration of mindfulness awareness with motor skills makes technical performance more natural and smooth, develops the ability to remain focused under high pressure, transforms anxiety into performance motivation, and can help break critical thinking, focus on technical execution rather than results, and improve Ontology, optimize action perception and control, and reduce mistakes	Walking meditation [30], meditation body scanning, mindfulness yoga, competition imagination mindfulness, etc.	Sports and competitive field
Mindfulness-Acceptance-Commitment Approach, MAC [31]	Change the relationship between the individual and the internal state experience, rather than directly changing the content and frequency of the internal state experience	Self-determination exercises, mindfulness washing dishes exercises, mindfulness breathing exercises, dedication to express value exercises	Competitive sports, mass fitness and other fields
Nature-based Mindfulness [32]	Use natural stimuli (such as sound, light, etc.) to enhance awareness	Natural sound awareness, outdoor mindfulness walking, natural concentration training	For the general public, suitable for attention recovery and stress relief
Digital mindfulness	Use apps in mobile watches and other devices for mobile, quantifiable, and fragmented training	Meditation practices, mindful breathing, etc.	General population, attention recovery, emotional regulation

6. Progress in Empirical Research on Mindfulness Training in Sports

In recent years, empirical research on mindfulness training in the field of sports has covered many scenarios such as school sports, competitive sports, and sports rehabilitation, and most of them use "effect verification-mechanism exploration" as the core logic. Research conclusions in different fields are as follows:

6.1. School Sports Field

After Delgado-Montoro et al. conducted 4 weeks of short-term intervention (6 classes, each time including about 10 minutes of guided meditation), the experimental group was significantly better than the control in terms of external attention, motion perception and CAMM total scores, indicating that short-term and in-class embedded mindfulness can improve attention and acceptance abilities. The study also emphasized the compatibility of incorporating mindfulness into physical education courses with the goals of sustainable development in education [33].

Cerdá et al. used yoga + mindfulness as a warm-up and implemented it within 6 classes. The overall difference between the groups was not significant, but there were significant improvements in "emotional differentiation" and "body awareness" within the group, suggesting that short-term effects exist but are affected by effect size, sample, and design limitations. Studies also pointed out that the duration or dose of intervention may be too short [34].

Khanbeiki's 12-week weekly mindfulness teaching showed in this small sample randomized/semi-experimental design that the experimental group had significant improvements in intention to physical activity, DASS-21 (depression/anxiety/stress) and GPA, and supporting longer-term intervention may bring more significant psychological and behavioral benefits [35].

Integrating mindfulness (and related yoga and body awareness exercises) into junior and senior high school physical education courses can often improve students' attention, body awareness, emotional awareness and some mental health indicators (anxiety, depression, stress) in the short term, and may increase willingness to participate in sports activities and academic performance. Using mindfulness exercises (such as 10-minute guided meditation, breathing exercises, mindfulness walks, daily mindfulness challenges, etc.) as warm-up content or relaxation content in the classroom is feasible and easy to implement, and teachers and students generally respond positively.

6.2. field of Competitive Sports

A growing number of systematic reviews and meta analyses have shown that mindfulness training has a significant effect on athletes' sports performance, mental health and cognitive function. A number of evidence based on randomized controlled trials have shown that mindfulness intervention can effectively improve exercise performance, flow and mindfulness levels, and significantly reduce competitive anxiety, with medium to large effect sizes [36]. Evidence from elite athletes further points out that mindfulness projects (such as MBSR, MBCT, etc.) not only significantly improve mental health indicators such as anxiety and stress, but also improve happiness and overall psychological well-being [25]. At a more comprehensive level of evidence, mindfulness intervention has shown a stabilizing effect in improving exercise performance and improving psychological components (such as acceptance, emotional regulation, and self-compassion), but conclusions on broad psychological symptoms (such as stress, depression) are not consistent due to the number and quality of studies [37]. From a mechanism perspective, mindfulness intervention can significantly improve athletes' cognitive function. Mindfulness training has moderate effects on attention, large effects on inhibitory control, and moderate effects on neuroelectrical indicators (SMD=-0.53), suggesting that

mindfulness may improve neural processing related to executive function. In addition, previous studies have found that athletes have reduced N2 amplitude during Stroop tasks after mindfulness training, which is generally regarded as a neural marker of more efficient conflict monitoring and cognitive control [38].

Based on the results of the existing systematic review, mindfulness intervention has shown positive trends in exercise performance, mindfulness indicators and mental health. However, current research generally has limitations such as small sample size, inconsistent intervention plans, and uneven methodological quality. Higher-quality, standardized randomized controlled trials are needed in the future [39].

6.3. Sports Rehabilitation Field

Existing research consistently shows that mindfulness intervention has significant psychological and physiological benefits in sports injury rehabilitation and physical function recovery. First, research on injured college athletes has shown that the introduction of MBSR-based mindfulness training can significantly improve their coping ability, psychological resilience and confidence in returning to sports, and reduce anxiety and stress levels, indicating that mindfulness can effectively buffer sports injuries. Psychological distress [40]. In the broader field of physical rehabilitation, mindfulness, as an intervention that focuses on the integrity of body and mind, has been shown to help patients with musculoskeletal pain, chronic pain, and nervous system diseases improve pain experience, reduce anxiety, and improve emotional regulation. Its mechanisms mainly include improving current awareness, reducing catastrophic thinking, and enhancing individual acceptance of symptoms [41]. From a systematic review perspective, exercise rehabilitation people generally show better attention control, emotional stability and exercise performance recovery after receiving mindfulness intervention. The systematic review also emphasizes that although existing studies show a positive trend, there are still problems with methodological quality, suggesting that higher-quality studies are needed in the future to further verify the intervention effect [39]. In addition, neuroscientific evidence shows that mindfulness can enhance the functional connection of the pain regulatory network by regulating activity in brain areas such as the anterior cingulate cortex, anterior insular lobe, and prefrontal lobe, and reduce pain perception through non-opioid pathways, which explains the role of mindfulness in pain recovery provides neural mechanism support [42]. Finally, studies have also shown that when mindfulness and physical activity are used in conjunction, the two may have a synergistic effect, which can further improve patients' mental health and rehabilitation participation, and may be better than implementing a certain intervention alone, indicating that "mindfulness + physical activity" is a compound intervention model worth promoting [43].

7. Mechanism of Mindfulness

7.1. Psychological Mechanism

Mindfulness training plays a core role in athletes' psychological regulation, and its mechanisms cover deep changes in the attention system, emotional system and cognitive control system. First, at the attention level, mindfulness can effectively improve athletes' selective attention, continuous attention and attention diversion abilities, allowing them to maintain focus on key action clues and tactical information in complex and rapidly changing competitive environments [38]. Research has shown that mindfulness training can significantly improve athletes' ability to maintain attention in high-noise environments and reduce interference caused by audience, opponents, and performance pressure, thereby promoting more stable performance output [44]. This "present-moment awareness" is not only reflected in the attention dimension, but also in the athletes' ability to instantly perceive the rhythm of their

own movements and technical execution, making it easier for them to maintain high-quality movement stability [45, 46]. Secondly, at the level of emotional regulation, mindfulness reduces an individual's tendency to view stress as a threat and improves emotional acceptance by changing an individual's cognitive assessment of stressful events [46]. Athletes often experience obvious anxiety and tension before a game, and mindfulness trains individuals to observe emotional experiences with a "non-judgmental" attitude, so that they are no longer kidnapped by emotions, thereby significantly reducing the negative emotional response caused by pre-match anxiety and competition stress. Research has pointed out that receptive attention and awareness strategies can promote athletes to recover more quickly from negative feedback, failure or technical errors, and form higher emotional resilience, which is particularly critical for intensive schedules or continuous high-pressure training in competitive sports. In addition, mindfulness tends to increase an athlete's probability of entering "Flow", because flow essentially relies on high concentration and inner stability, and mindfulness training is an important way to improve both. Empirical research has shown that mindfulness training can enhance athletes' concentration and promote flow experience, and its effect is more significant when athletes have higher psychological resilience [44]. Thirdly, in terms of cognitive control and metacognition, mindfulness significantly enhances athletes' ability to monitor their own thought processes, allowing them to identify and interrupt unfavorable internal conversations (such as self-doubt, perfectionism rumination, etc.), and reduce excessive thinking and emotional interference [46]. Research has found that athletes are prone to excessive attention to action details in high-pressure situations, leading to technical collapse (i.e., choking under stress). Mindfulness reduces rumination and overanalysis by improving individuals' awareness of automated thinking and emotional reactions, allowing athletes to maintain better cognitive flexibility and executive functions under pressure, thereby maintaining effective tactical judgment and action organization. This mechanism is particularly important for precision technical events (such as shooting, gymnastics, diving) and events with high decision-making requirements (such as basketball, football) [47, 48].

7.2. Physiological Mechanism

Mindfulness training also has multiple positive effects on athletes' physiological systems. Its mechanisms mainly involve the regulation of the autonomic nervous system, the regulation of stress hormones, and changes in neural network functions related to movement control. First, at the autonomic nervous system level, mindfulness can enhance the activity of the parasympathetic nervous system, while inhibiting excessive sympathetic arousal, allowing the body to achieve a more balanced physiological state. An important indicator is heart rate variability (HRV), which represents the ability of the autonomic nervous system to regulate. Studies have shown that mindfulness training significantly improves HRV, which means that individuals have more physiological recovery ability and adaptability in high-pressure environments. Under high-intensity competition or training loads, athletes with higher HRV are usually able to recover to a stable state faster, thereby reducing the impact of tension on motor coordination and concentration [49-51].

Second, in terms of the endocrine system, mindfulness has the potential to reduce levels of stress hormones such as cortisol. Competitive training often leads to long-term or acute stress reactions in the body, of which cortisol is one of the most critical indicators of stress. Studies have shown that mindfulness and meditation interventions can not only reduce resting cortisol levels, but also reduce surges after training or competition, thereby reducing physiological stress loads and promoting higher quality recovery and sleep for athletes. This is of great significance for fatigue management during high-intensity training cycles, improvement of training adaptability, and avoidance of over-training syndrome [50, 52].

In addition, at the neural mechanism level, a large number of neuroimaging studies have pointed out that mindfulness training can change the function and connectivity of brain areas related to attention regulation, body awareness, emotion regulation and motor control, such as the prefrontal cortex (responsible for executive control), the insular lobe (responsible for internal feelings), the parietal lobe (involved in sensory processing and motor integration), and the motor cortex (involved in motor execution). These changes enable athletes to more efficiently integrate sensory input and motor output, thereby improving movement accuracy, posture control, reaction speed and coordination. At the same time, enhanced physical awareness also makes it easier for athletes to identify signs of fatigue, pain and potential injury, thereby making timely adjustments during training and reducing the risk of sports injuries [37, 53, 54]. This neuroregulatory effect is particularly obvious for events that require refined technical movements and high rhythm stability (such as gymnastics, dance, speed skating, and fencing). In summary, mindfulness training not only improves athletes' psychological stability and cognitive function through the synergy of psychological and physiological paths, but also optimizes their physiological regulation and nervous system functions, thereby supporting stable, lasting and high-quality competitive performance.

8. Main Research Issues And Challenges in the Past Five Years

In the past five years, research on mindfulness training has grown rapidly in the field of sports, and related systematic reviews, meta-analyses and randomized controlled trials have continued to increase, providing new evidence on the effectiveness and scope of application of mindfulness intervention. However, the latest research also points to a number of key issues that need to be addressed.

8.1. The Results Were Beneficial But Unstable, With Significant Differences Between Outcomes

The latest meta-analysis generally believes that mindfulness training is effective in improving exercise performance and performance-related psychological mechanisms, but the effects on broad mental health indicators such as emotional distress and quality of life are inconsistent, indicating that different outcome variables are sensitive to mindfulness intervention. There are significant differences in sensitivity. A systematic review based on randomized controlled trials by Wang et al. pointed out that mindfulness training has a moderate to large effect on competitive performance and mindfulness-related psychological indicators, but the results on mental health indicators such as depression and stress are unstable [37]. A meta analysis by Si et al. also found that mindfulness training significantly improved performance and anxiety levels, but the heterogeneity between studies was high ($I^2 > 80\%$), suggesting that differences in training form, type of subjects and control group could affect the results [36]. A systematic review of elite athletes by Myall et al. also pointed out that MBPs have improved the anxiety and stress of elite athletes to some extent, but the quality of the evidence is limited and needs to be interpreted with caution [25]. This trend suggests that the most significant benefits of mindfulness training are concentrated on "performance-related mental mechanisms" and "state mindfulness" itself, rather than being universally applicable to all mental health outcomes.

8.2. The Quality of Research Design and Methodology is Still Insufficient

Although the number of RCT studies has increased significantly in recent years, the following methodological problems are still common in existing studies: 1. The sample size is generally small. Most RCTs have less than 30 samples, which limits statistical power [25, 37]. 2. Lack of strict randomization, blinding and pre-registration. Myall et al.'s risk of bias assessment of elite athlete studies showed that most studies have moderate to high risks in terms of randomization

procedures, allocation concealment, and blindness in outcome measurement [25]. 3. Lack of practice compliance and intervention loyalty reports. Multiple reviews (e.g. Wang et al., Si et al.) emphasize that compliance data are rarely recorded and that this is an important variable in explaining the effectiveness of intervention [37, 36]. 4. The types of control groups are not uniform. Conventional training, relaxation training, general psychological skills training, etc. are mixed to increase heterogeneity [36]. Therefore, even if the overall effect shows a positive trend, it is difficult to draw robust causal conclusions.

8.3. Measurement of Outcome and Mechanism Indicators is Not Precise Enough

Research in the past five years has shown that the mechanism evidence of mindfulness training in athletes is still insufficient and shows significant differences: meta-analysis by Yang et al. showed that mindfulness intervention can significantly improve mindfulness levels and inhibitory control, but the overall effect on attention function is unstable, showing only moderate improvement in elite athletes or high-frequency training subgroups, suggesting that cognitive benefits may be regulated by exercise level and intervention dose [38]. At the same time, the evidence for improvement in emotional health indicators is fragmented. Wang et al. and Myall et al. both pointed out that the effects of mindfulness training on emotional variables such as stress and anxiety vary greatly among different studies. Some studies are effective, while some studies have no significant improvement [37, 25]. At the level of physiological and neural mechanisms, only a small number of studies have used objective indicators such as EEG and HRV. Although existing results have shown that mindfulness training may enhance prefrontal lobe regulatory functions (such as enhanced alpha wave activity) [59], the improvement of HRV has only occurred in some studies [36, 39]. Overall, the relevant evidence is still insufficient to support the construction of a systematic multi-level mechanism model of action.

8.4. Digital Mindfulness Intervention is on the Rise, But The Efficacy is Unstable

Digital mindfulness intervention has grown rapidly in the field of sports in the past five years, but the overall evidence shows the characteristics of high feasibility and unstable efficacy. A randomized controlled trial by Gao et al. among college athletes showed that mobile mindfulness training has good feasibility and acceptance, but did not significantly reduce anxiety levels [55], showing that digital forms do not necessarily bring about psychological improvement; In contrast, Lee et al.'s study among Korean young judo athletes found that mobile mindfulness training significantly improved indicators such as depression, perceived stress and self-esteem, but had limited promotion effects on resilience and other emotional variables [56]. Overall, digital mindfulness intervention still faces challenges such as difficulty in monitoring the quality of the exercise, difficulty in ensuring the dose of the intervention, and lack of direct comparison with face-to-face intervention, which limits the interpretability and promotion potential of its effects, suggesting that the digital practice of mindfulness training is still in the exploratory stage.

8.5. Research on Special Athlete Groups Grows, But There is Insufficient Evidence

Research over the past five years has shown that the evidence for mindfulness intervention among different types of athletes shows significant differences. Regarding injured athletes, Liu et al.'s systematic review showed that mindfulness training can relieve anxiety and traumatic stress to a certain extent, and enhance rehabilitation confidence. However, most of the existing studies are small sample pre-and post-tests, lack a strict control design, and the evidence strength is limited [57]. Among student-athletes, Economou et al. found that they have a high acceptance of mindfulness training, but the actual participation rate is low, showing a

significant "attitude-behavior gap"; at the same time, Augustus et al. pointed out that mindfulness can improve some of the thriving dimensions of student-athletes, but the improvement in the overall thriving level is still limited [58][59]. For elite athletes, Myall et al. pointed out that the number of relevant studies is small and the methodological quality is generally insufficient, and it is not yet possible to form stable conclusions on elite groups [25]. Overall, there are still differences in the applicability and effectiveness of mindfulness intervention among different athlete groups, and the evidence base is also significantly unbalanced.

8.6. Studies with Inconsistent Results Suggest A Review of Intervention Components and Doses

A pilot study conducted by Johles et al. among Swedish student-athletes showed that there was no significant difference in quality of life between the body-scanning mindfulness and relaxation control groups, and each dimension of five-factor mindfulness did not show a significant mediating effect [60]. This result suggests that low-dose, single form of mindfulness intervention does not necessarily produce advantages, and its effect may be affected by factors such as training dose, intervention structure, and sports event characteristics. Therefore, future research needs to further test the adaptability of different intervention intensities and module combinations, and consider the moderating effect of exercise situations and group differences on intervention benefits.

9. Conclusion

In summary, mindfulness training has gradually expanded from the field of mental health to sports science research, and has shown important application value in competitive sports and mass sports situations. Existing research has shown that mindfulness training can effectively improve exercise individuals' attention control, emotional regulation and stress coping abilities. These psychological processes are considered to be important basic factors affecting exercise performance. However, compared with consistent improvement in psychological indicators, there are still differences in their direct impact on sports performance, suggesting that mindfulness training is more likely to work through indirect paths. Future research should strengthen contextualized intervention design and long-term follow-up research, carry out multi-layer verification based on behavioral, physiological and neural indicators, and explore differentiated mechanisms in the context of different sports events to promote the theoretical deepening and practical application of mindfulness training in the field of sports science.

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