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Investigating the increase in the specialized performance of athletes using artificial neural network (ANN) exercises

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Badminton, a dynamic and fast-paced racket sport, demands a unique combination of physical, technical, and cognitive abilities from its players. This study investigates the impact of a tailored core strength training program on the specialized performance of elite badminton athletes, with the aim of unlocking their full potential and improving overall well-being. The research involved a cohort of national-level badminton players who underwent a 12-week core strength training intervention. The program was designed using principles of progressive overload and targeted the development of core stability, power, and explosiveness—essential attributes for high-level badminton performance. Throughout the study, the athletes' progress was evaluated through a comprehensive assessment battery, including measures of shot velocity, agility, jump height, and sport-specific technical proficiency. Additionally, the researchers examined the impact of the training regimen on the athletes' mental health and resilience, using validated psychological questionnaires. The results show that the core strength training program led to significant improvements in the athletes' explosive shot power, stability, and agility—key determinants of badminton success. Notably, the intervention also had a positive effect on the participants' mental well-being, with increased levels of self-confidence, focus, and emotional regulation reported. This study utilized an artificial neural network (ANN) to investigate the relationships between core stability, core power, and performance indicators (agility, jump height, mental well-being) to predict and optimize conditions for enhancing specialized athletic performance. The ANN model demonstrated the ability to capture complex, nonlinear relationships and provide accurate predictions. These results suggest that integrating core-focused training into the preparation of elite badminton athletes can be a crucial strategy for enhancing their specialized performance, reducing injury risk, and promoting holistic well-being. The study shows the importance of tailored, sport-specific approaches to athletic development and provides valuable insights for coaches, sports scientists, and healthcare professionals working with high-performance badminton players.

Keywords Badminton performance, Core strength training, Athlete potential, Explosive shots, Stability and agility, Injury prevention, Mental health

Badminton is an intensely competitive and physically demanding sport that requires athletes to possess a combination of speed, agility, and explosive power[1–3]. Excelling in this sport necessitates the ability to execute rapid and precise movements, maintain balance and stability, and generate powerful shots. A key factor that contributes to the success of badminton athletes is core strength[2,3]. The core, comprising the muscles in the abdominal region, back, and hip stabilizers, plays a fundamental role in providing stability, power transfer, and agility. Core strength is crucial for maintaining balance during dynamic movements, generating and transferring power efficiently, and executing explosive shots on the badminton court. Therefore, developing and enhancing core strength can significantly impact the performance of badminton athletes. This comprehensive review aims to explore the potential benefits of core strength training in maximizing the performance of badminton athletes and unlocking their full potential[4,5].

The interplay between sports, physical health, and mental health has garnered significant attention due to its potential impact on overall well-being[1,2]. Sports participation is widely recognized for promoting physical fitness

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and enhancing physical health outcomes. However, recent research has emphasized the substantial influence of sports on mental health, suggesting a bidirectional relationship between physical and mental well-being. Understanding this intersection is crucial, particularly among specific populations such as college students who face unique challenges and stressors[3–5]. The link between physical activity, sports participation, and physical health is well-established. Regular engagement in sports activities has been associated with various physical health benefits, including improved cardiovascular fitness, enhanced muscular strength and endurance, weight management, and reduced risk of chronic diseases such as obesity, diabetes, and cardiovascular conditions[6–8]. Physical activity also plays a vital role in maintaining bone health, promoting proper growth and development, and improving overall physical functioning. These physical health benefits result from the physiological adaptations that occur during exercise, such as increased oxygen uptake, improved metabolism, and enhanced muscular and cardiovascular efficiency.

While the physical health advantages of sports participation are well-documented, recent research highlights the significant impact of sports on mental health outcomes. Physical activity and sports have been linked to improved mental well-being, including reduced symptoms of anxiety, depression, and stress[9–12]. Engaging in sports provides individuals with opportunities for stress relief, emotional regulation, and the release of endorphins, leading to improved mood and psychological well-being. Furthermore, sports participation fosters a sense of accomplishment, self-esteem, and social connectedness, all of which are crucial for maintaining positive mental health. The potential mental health benefits of sports participation make it an appealing avenue for promoting overall well-being, particularly among vulnerable populations such as college students. Chinese college students represent a unique population characterized by specific cultural, academic, and social contexts[13–16]. Chinese culture places a strong emphasis on academic achievement, resulting in high levels of academic pressure and stress among college students. The demanding nature of academic pursuits can have detrimental effects on mental health, increasing the risk of anxiety, depression, and psychological distress. In this context, sports participation can serve as a valuable outlet for stress reduction, emotional well-being, and the maintenance of mental health among Chinese college students[17–19].

This mixed-methods study aims to provide a comprehensive understanding of the complex intersection between sports, physical health, and mental well-being among Chinese college students. By combining quantitative surveys and qualitative interviews, the research objectives are to assess the associations between sports participation and physical health outcomes, examine the relationship between sports involvement and mental health indicators, explore the subjective experiences and perceptions of Chinese college students regarding the impact of sports on their physical and psychological well-being, and identify potential barriers and challenges that influence sports participation in this population[20–28]. The results from this study may contribute to the existing knowledge on the relationship between sports and overall well-being, particularly within the specific context of Chinese college students, and inform future strategies and initiatives to promote holistic well-being and address the unique challenges faced by this population. In recent years, social media platforms have become integral to many adolescents' lives, raising concerns about their potential impact on mental health. Adolescence is a critical period marked by significant changes, making individuals vulnerable to issues like depression, anxiety, and body dissatisfaction. While social media offers benefits like self-expression and information access, negative social comparison, cyberbullying, and excessive screen time can contribute to adolescents' psychological distress. Constant exposure to idealized lives and appearances on social media can lead to feelings of inadequacy and lower self-esteem, as well as body dissatisfaction. Cyberbullying causes increased anxiety, depression, and even suicidal thoughts, while social media addiction can disrupt sleep and real-life interactions, leading to isolation and loneliness. The complex relationship between social media and adolescent mental health requires comprehensive investigation to develop effective interventions. Understanding the unique vulnerabilities of this population is crucial for designing evidence-based strategies to promote healthy social media use and protect adolescents' well-being. The study's findings could inform policies and support systems tailored to the needs of adolescents, with implications for parents, educators, and healthcare professionals.

Parents, educators, and healthcare professionals can use the study's results to guide adolescents toward healthy digital habits and promote resilience, integrating this knowledge into assessments and interventions for adolescent mental health. Policymakers can leverage the insights to develop guidelines and regulations that protect adolescents from potential harm in the digital realm. The study can also contribute to the existing body of research on the impact of social media, addressing gaps and inconsistencies to build a more nuanced understanding of this complex relationship. By examining the association between social media use and mental health outcomes, exploring underlying mechanisms, and identifying protective factors, the study aims to inform evidence-based recommendations for promoting healthy social media use among adolescents. Addressing these research objectives can support the well-being of young individuals navigating the challenges and opportunities presented by the digital age. This study employed a shallow, feed-forward artificial neural network with a hidden layer to investigate the relationships between the input variables (core stability (%) and core power (%)) and the output variables (agility (%), jump height (%), and mental well-being (%)). The ANN model was used to predict and optimize the conditions for enhancing specialized athletic performance. The accuracy of the ANN predictions was further validated through a linear regression analysis, which confirmed the acceptability of the network's error compared to the target results from experimental tests.

Literature review

This literature review shows various topics related to mental health, sports participation, cultural experiences, and social factors among university students. Studies explore the relationship between past behavior, social cognitive constructs, and sports participation during the transition to university[23], the impact of online gambling on mental health and well-being[24], and the importance of considering cultural diversity in research methods related to sport, physical activity, and health[25]. The review also includes an ethnographic case study

on critical digital literacies in China[26], an exploration of the mental health landscape and therapeutic practices in China[27], and an investigation of the relationships between behavioral addictions and personality traits[28]. Additionally, the review covers the experiences and perceptions of racism among international students during the COVID-19 pandemic[29], the significance of considering multiple identities in counseling practices[30], and the development of teachers' collective agency in online classrooms[31]. Other topics include the associations between sedentary behavior and negative emotions among adolescents[32], the concept of flow in sport and performance[33], the psychosocial experiences and racial battle fatigue of African American male college students[34], strategies to combat mental health stigma[35], the implications of university sport for public policy[36], and the impact of hegemonic masculinity on mental health in the sports context[37]. This diverse range of literature provides a comprehensive understanding of the complex issues facing university students in the current social and academic landscape.

The relationship between sports and physical health

The relationship between sports and physical health is well established, with numerous benefits associated with regular participation in sports activities. Engaging in sports can contribute to various aspects of physical health, including cardiovascular fitness, muscular strength and endurance, flexibility, and overall body composition. One of the primary benefits of sports participation is the improvement of cardiovascular health. Sports activities that involve continuous movement, such as running, swimming, or cycling, can enhance cardiovascular endurance, leading to a stronger heart, increased lung capacity, and improved circulation. Regular participation in sports can lower the risk of cardiovascular diseases, including heart attacks, strokes, and high blood pressure. Sports also play a significant role in developing muscular strength and endurance. Activities like weightlifting, football, basketball, or tennis involve repetitive movements and resistance, which promote muscle development and strengthen bones. Increased muscular strength not only improves physical performance but also contributes to overall body stability, reducing the risk of injuries and promoting better posture. Flexibility is another aspect of physical health that can be enhanced through sports participation. Many sports require a wide range of motion and flexibility, such as gymnastics, yoga, or martial arts. Regular stretching and movements involved in these activities can improve joint mobility, muscle elasticity, and overall flexibility, reducing the risk of muscle strains and improving overall functional movement. Additionally, sports can have positive effects on body composition. Active participation in sports, combined with a balanced diet, can help maintain a healthy body weight and reduce the risk of obesity. Sports activities burn calories, increase metabolic rate, and promote fat loss while preserving muscle mass. This can lead to improved body composition, reduced body fat percentage, and a healthier overall physique. Furthermore, sports participation offers psychological benefits that can indirectly impact physical health. Regular exercise through sports has been linked to improved mental well-being, including reduced stress, anxiety, and symptoms of depression. Physical activity stimulates the release of endorphins, known as "feel-good" hormones, which can enhance mood and promote a sense of overall well-being. Positive mental health can, in turn, have a positive impact on physical health outcomes. It is important to note that while sports participation has numerous benefits for physical health, it is essential to engage in activities safely and with proper training. Adequate warm-up, cool-down, and injury prevention measures should be followed to minimize the risk of sports-related injuries. Additionally, individuals should choose sports activities that align with their physical capabilities and medical conditions, and consult with healthcare professionals if needed.

Physical fitness and sports participation

Physical fitness and sports participation are closely intertwined, with engaging in sports activities being a popular and effective means of achieving and maintaining physical fitness. Physical fitness refers to a state of overall health and well-being that encompasses cardiovascular endurance, muscular strength and endurance, flexibility, and body composition. Sports participation, on the other hand, involves actively engaging in organized or recreational sports activities, such as running, swimming, basketball, soccer, or tennis, to name a few. Regular participation in sports offers numerous benefits for physical fitness. Firstly, sports activities contribute to cardiovascular fitness by promoting the efficient functioning of the heart, lungs, and circulatory system. Activities that involve continuous movement, such as running, cycling, or swimming, provide an excellent cardiovascular workout, improving endurance, increasing lung capacity, and enhancing overall cardiovascular health. Regular participation in these sports can reduce the risk of cardiovascular diseases, including heart attacks, strokes, and high blood pressure. In addition to cardiovascular fitness, sports participation also plays a crucial role in developing muscular strength and endurance. Engaging in sports activities that require repetitive movements and resistance, such as weightlifting, football, or gymnastics, helps build lean muscle mass, strengthen bones, and enhance overall muscular fitness. The repetitive nature of sports movements allows for specific muscle groups to be targeted and conditioned, leading to increased strength and endurance.

This, in turn, improves physical performance, reduces the risk of injuries, and promotes better posture and stability. Flexibility is another aspect of physical fitness that can be improved through sports participation. Many sports, such as gymnastics, dance, or martial arts, require a wide range of motion and flexibility. Regular participation in these activities involves stretching and dynamic movements that promote joint mobility, muscle elasticity, and overall flexibility. Improved flexibility can enhance athletic performance, prevent muscle strains, and facilitate better functional movement in daily life. Furthermore, sports participation can have a positive impact on body composition. Regular engagement in sports activities, combined with a balanced diet, can help maintain a healthy body weight and reduce the risk of obesity. Sports activities are typically physically demanding and involve calorie expenditure, which can contribute to weight management and fat loss. The combination of aerobic exercise and strength training in sports helps preserve muscle mass while promoting fat loss, resulting in improved body composition and a healthier overall physique. Moreover, sports participation has psychological benefits that indirectly influence physical fitness. Engaging in sports promotes mental well-

being by reducing stress, anxiety, and symptoms of depression. Physical activity stimulates the release of endorphins, which are known as "feel-good" hormones, leading to improved mood and a sense of overall well-being. The mental and emotional benefits of sports participation can positively influence physical fitness by promoting motivation, adherence to exercise routines, and overall enjoyment of physical activity. It is important to note that sports participation should be approached with proper training, safety measures, and consideration of individual capabilities. Warm-up exercises, cool-down routines, and injury prevention practices are essential to minimize the risk of sports-related injuries. Individuals should choose sports activities that align with their physical abilities and medical conditions. Consulting with healthcare professionals or fitness experts can provide guidance and ensure safe and appropriate sports participation.

Sports and chronic disease prevention

Sports and physical activity play a crucial role in preventing and managing chronic diseases like cardiovascular diseases, diabetes, obesity, and cancer. Regular sports participation improves cardiovascular fitness, regulates blood sugar, and promotes healthy weight management, reducing the risk of these conditions. Engaging in sports activities, such as aerobic exercises or team sports, strengthens the heart, controls cholesterol, and helps regulate blood sugar levels. Sports also contribute to weight management and cancer prevention by maintaining a healthy body weight, regulating hormones, and improving immune function. Additionally, sports participation can enhance the quality of life for individuals with chronic diseases by improving disease management and reducing symptoms. Tailored sports activities allow individuals to engage in physical activity safely and effectively, addressing the global burden of chronic diseases.

Sports and physical activity play a vital role in promoting and maintaining bone health. Regular participation in weight-bearing activities, such as running, jumping, and resistance training, stimulates the remodeling of bone tissue, leading to increased bone density and strength. This is particularly important for preventing osteoporosis and reducing the risk of fractures. Sports engagement during childhood and adolescence is crucial for developing peak bone mass, which can contribute to healthier bones in adulthood. As individuals age, sports activities can help slow down bone loss and preserve bone density. Proper nutrition, including adequate calcium and vitamin D intake, is essential for optimizing bone health alongside sports participation. It is also important to engage in sports safely, gradually increasing intensity to avoid injuries. Additionally, the relationship between sports and mental health has been a topic of increasing interest. Engaging in sports activities has been associated with reduced symptoms of anxiety, depression, and stress, while promoting positive mood states and overall psychological well-being. The release of endorphins, social interaction, and stress management benefits of sports participation can contribute to better mental health outcomes. Many studies highlights the significant relationship between sports participation and mental well-being, particularly in terms of stress reduction. Engaging in sports activities can lead to a decrease in stress levels through various mechanisms. Firstly, physical exercise during sports stimulates the release of endorphins, the body's natural mood enhancers, which counter the negative effects of stress hormones and promote feelings of relaxation and happiness. Secondly, sports participation provides a temporary escape from daily stressors, allowing individuals to divert their attention and experience a mental break. Thirdly, the sense of accomplishment and self-efficacy gained from setting and achieving goals in sports can enhance self-confidence and resilience, enabling individuals to better manage stressful situations. Furthermore, the social aspect of sports fosters a sense of belonging and community, offering emotional support and a buffer against the negative effects of stress. However, it is crucial to consider individual preferences, skill levels, and external factors that may impact one's ability to engage in sports regularly. Addressing these barriers and providing accessible resources can ensure that individuals from diverse backgrounds can benefit from sports participation as a means to enhance their mental well-being.

Sports and anxiety and depression

Sports participation has emerged as a promising avenue for alleviating symptoms of anxiety and depression. Research has consistently demonstrated the positive impact of engaging in sports activities on mental health, particularly in reducing symptoms of anxiety and depression and improving overall well-being. One of the primary mechanisms through which sports can mitigate anxiety and depression is the release of endorphins. Physical exercise during sports stimulates the production and release of endorphins, which act as natural mood enhancers and pain relievers. These endorphins have been shown to reduce symptoms of anxiety by promoting feelings of relaxation, reducing tension, and improving overall mood. Similarly, endorphins contribute to a decrease in symptoms of depression by boosting mood, increasing feelings of happiness, and countering the effects of stress hormones in the body. In addition to the neurochemical effects, sports involvement provides a range of psychological and social benefits that can help alleviate anxiety and depression. Engaging in sports activities offers a sense of purpose and direction, providing individuals with a structured and meaningful outlet for their energy and emotions. Setting goals, working towards personal improvement, and experiencing success in sports can enhance self-esteem and self-confidence, thereby reducing symptoms of anxiety and depression. Furthermore, sports participation offers social interaction and support, which are crucial for mental well-being.

Team sports, in particular, provide opportunities for social connection, camaraderie, and a sense of belonging. Being part of a team or engaging in sports activities with others fosters social support networks and creates a supportive environment that promotes positive mental health. The social aspect of sports also provides opportunities for individuals to develop and strengthen interpersonal skills, communication abilities, and teamwork, which can have long-lasting positive effects on mental well-being beyond the sports setting. Another significant aspect of sports involvement in managing anxiety and depression is the distraction it offers from negative thoughts and rumination. Engaging in sports activities requires focus and concentration, diverting attention away from anxious or depressive thoughts. The immersive nature of sports can provide individuals with a break from their internal struggles and create a sense of flow, where they become completely

absorbed in the present moment. This diversion from negative thoughts, coupled with the physical exertion and enjoyment of the sport, contributes to improved mood and reduced symptoms of anxiety and depression. While sports participation shows promise in alleviating symptoms of anxiety and depression, it is important to consider individual differences and preferences when selecting sports activities. Different sports may resonate with individuals in distinct ways, and finding a sport that aligns with personal interests and preferences enhances the mental health benefits. Additionally, it is essential to create a supportive and inclusive environment within sports settings to ensure individuals feel comfortable and encouraged to participate.

Sports and self-esteem and well-being

Sports participation has been widely recognized as a powerful catalyst for enhancing self-esteem and promoting overall well-being. Engaging in sports activities provides individuals with a platform to develop and showcase their skills, leading to a sense of accomplishment and improved self-perception. This, in turn, has a profound impact on mental, emotional, and social well-being. One of the primary ways in which sports contribute to self-esteem is through the mastery of skills and the achievement of goals. Participating in sports allows individuals to set personal targets, work towards them, and experience a sense of fulfillment upon their attainment. As individuals improve their skills and witness their progress over time, their self-confidence and belief in their abilities grow. This enhanced self-efficacy extends beyond the sports setting and can positively influence various aspects of life, including academic and professional pursuits. The development of skills and the achievement of goals in sports activities foster a strong sense of self-worth and competence, bolstering self-esteem. Additionally, sports involvement offers opportunities for recognition and validation from peers, coaches, and the wider community. Achievements in sports, such as winning matches, earning accolades, or setting records, often receive public recognition and praise. This recognition not only contributes to an individual's self-esteem but also promotes a sense of belonging and social acceptance. Being part of a team or participating in sports activities with others creates a supportive environment where individuals receive encouragement, feedback, and positive reinforcement, further boosting their self-esteem.

Figure 1 shows the supporting the mental well-being of student-athletes is a crucial aspect of their overall development and success. It involves providing comprehensive support systems and resources that address the unique challenges and pressures faced by these individuals. By prioritizing mental health in the context of athletic participation, educational institutions and athletic programs can create an environment that fosters resilience, promotes emotional well-being, and helps student-athletes thrive both on and off the field. To support student-athlete mental well-being, various strategies can be implemented. First and foremost, it is essential to promote awareness and education about mental health issues among student-athletes, coaches, and staff. This can be achieved through workshops, training sessions, and the dissemination of informative materials that discuss common mental health concerns, stress management techniques, and available resources for seeking help. Additionally, cultivating a culture of open communication and destigmatizing mental health concerns is paramount. Providing a safe and confidential space for student-athletes to discuss their emotions, challenges, and personal experiences can encourage them to seek help when needed. This can be facilitated through the establishment of support groups, offering individual counseling services, and ensuring that mental health professionals are readily accessible to student-athletes. Integrating mental health screenings as part of routine health assessments can also contribute to early identification and intervention for potential mental health issues. These screenings can help identify symptoms of anxiety, depression, and other mental health disorders, allowing for timely referrals to appropriate professionals for further evaluation and treatment. Furthermore, implementing stress reduction and self-care practices into the daily routines of student-athletes can enhance their overall well-

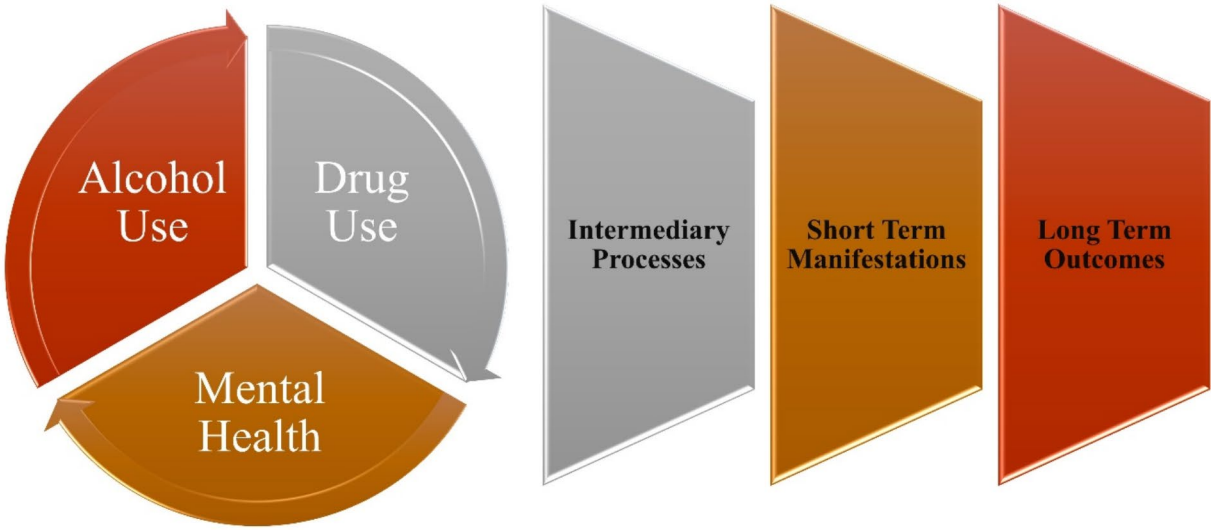

Fig. 1. Enhancing the psychological well-being of student-athletes.

being. Encouraging regular exercise, promoting healthy sleep patterns, and providing resources for relaxation techniques such as mindfulness and meditation can contribute to stress management and emotional resilience. Moreover, sports participation facilitates the development of positive social relationships, which are crucial for overall well-being. Engaging in team sports, in particular, fosters camaraderie, cooperation, and a sense of unity among teammates. The bonds formed through sports activities provide social support and friendship, creating a network of individuals who share common interests and goals. These social connections contribute to a sense of belonging, reduce feelings of loneliness and isolation, and positively impact mental and emotional well-being. Furthermore, sports involvement offers an avenue for stress relief and emotional regulation, which are integral to overall well-being. Physical exercise during sports stimulates the release of endorphins, resulting in improved mood and reduced stress. Engaging in sports activities allows individuals to channel their emotions, providing a healthy outlet for emotional expression and tension reduction. The combination of physical exertion, enjoyment of the sport, and the release of endorphins contributes to feelings of happiness, relaxation, and overall well-being. While sports participation shows promise in enhancing self-esteem and well-being, it is important to consider individual preferences, needs, and potential challenges. Different sports may resonate with individuals in distinct ways, and finding a sport that aligns with personal interests and preferences enhances the self-esteem and well-being benefits. Additionally, addressing barriers such as accessibility, affordability, and inclusivity is crucial to ensure that individuals from diverse backgrounds can derive the positive effects of sports participation.

Sports and social support

Sports participation has emerged as a significant source of social support, providing individuals with a network of relationships, camaraderie, and a sense of belonging. Engaging in sports activities offers opportunities for social interaction, cooperation, and the development of meaningful connections, which are instrumental in promoting overall well-being. One of the primary ways in which sports contribute to social support is through team dynamics and shared experiences. Participating in team sports allows individuals to form bonds with teammates, fostering a sense of community and support. Teammates often share common goals, work together towards achieving them, and experience victories and challenges collectively. These shared experiences create a sense of camaraderie and solidarity, forming the basis of social support within the sports context. The support and encouragement received from teammates can extend beyond the playing field, providing emotional support, motivation, and a sense of belonging in various aspects of life. Moreover, sports involvement offers opportunities for social interaction and the expansion of social networks. Engaging in sports activities brings individuals together, providing a platform for meeting new people, building friendships, and developing supportive relationships. Sports clubs, leagues, and competitions provide a social environment where individuals with similar interests and passions can connect. The social connections formed through sports activities offer opportunities for emotional support, companionship, and a sense of belonging. These relationships act as a buffer against stress, loneliness, and isolation, contributing to overall mental and emotional well-being.

Figure 2 illustrates the psychological skills that serve as distinguishing factors among elite athletes. These skills encompass a range of cognitive, emotional, and behavioral attributes that contribute to their exceptional performance and success in their respective sports. By possessing and honing these skills, elite athletes are able to enhance their mental resilience, focus, motivation, and overall psychological well-being, enabling them to excel in highly competitive environments. Figure 2 shows distinctive psychological skills, shedding light on the complex interplay between the mind and athletic performance. Understanding and cultivating these skills can be instrumental in guiding the training, development, and support of aspiring athletes aiming to reach the pinnacle of their sport. Furthermore, sports participation often involves coaching and mentoring relationships, which provide additional avenues for social support. Coaches and mentors play a crucial role in guiding and supporting athletes throughout their sports journey. They offer guidance, instruction, and encouragement, fostering a positive and supportive environment. Coaches and mentors can provide emotional support, help athletes navigate challenges, and offer valuable advice and feedback. These relationships extend beyond the sports setting and can have a lasting impact on an individual's personal and professional development. In addition to the direct social support gained from teammates, coaches, and mentors, sports involvement also offers opportunities for indirect social support through the wider sports community.

Figure 3 shows the evaluation process employed by Premier Sport Psychology. This comprehensive assessment framework is designed to analyze various aspects of an athlete's psychological well-being and performance. By utilizing a systematic approach, Premier Sport Psychology aims to gather in-depth information and insights to develop tailored interventions and support strategies. The evaluation process consists of multiple components that encompass both objective and subjective measures. Objective measures may include performance data, physiological markers, and standardized psychological assessments. These quantitative measures provide concrete and measurable indicators of an athlete's performance and psychological functioning. In addition to objective measures, subjective measures are also incorporated into the evaluation process. These involve self-report questionnaires, interviews, and subjective ratings provided by the athlete. These subjective measures provide valuable insights into the athlete's perceptions, experiences, and subjective well-being, contributing to a holistic understanding of their psychological state. Sports events, competitions, and gatherings bring together individuals who share a passion for a particular sport or activity. These gatherings provide a sense of belonging and community, where individuals can connect with others who understand and appreciate their dedication to the sport. The shared interests and experiences within the sports community create a supportive environment where individuals can find encouragement, inspiration, and a sense of identity. While sports participation offers significant social support benefits, it is important to address potential challenges and barriers to inclusivity. Creating an inclusive and supportive environment within sports settings is crucial to ensuring that individuals from diverse backgrounds can access and benefit from social support networks. Efforts should be made to

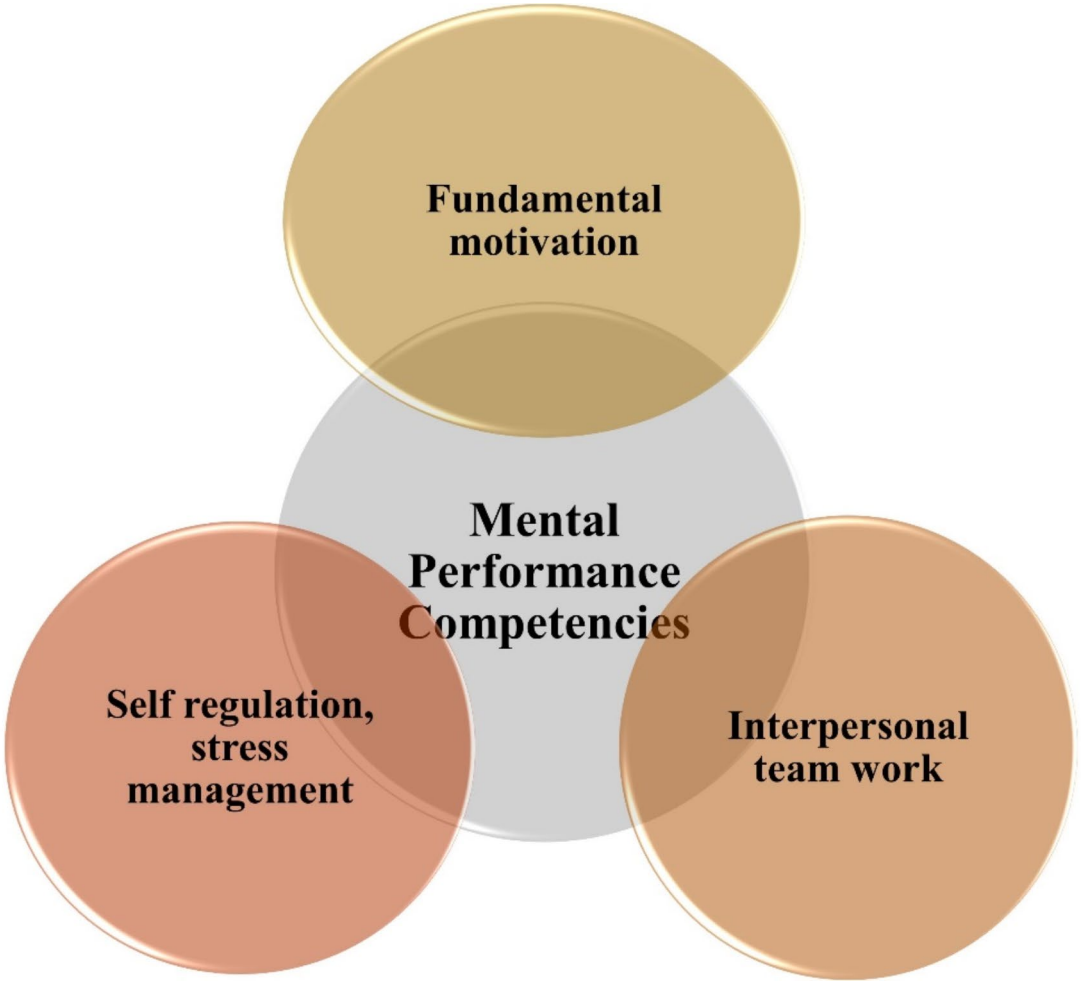

Fig. 2. Psychological skills that differentiate elite athletes.

promote diversity, equity, and inclusion within sports organizations, clubs, and teams, fostering an environment where everyone feels welcome and valued.

Figure 4 shows the Sports Performance Bulletin that focuses on the topic of coping with emotions and motivation within the realm of sports psychology. This bulletin serves as a valuable resource for athletes, coaches, and sports psychologists seeking to enhance their understanding and application of psychological strategies related to emotions and motivation in athletic performance. The bulletin delves into the multifaceted nature of emotions and their impact on sports performance. It explores various coping mechanisms and techniques that athletes can employ to manage and regulate their emotions effectively. By understanding how emotions can influence performance, athletes can develop strategies to channel their emotions in a constructive manner, such as harnessing the energy of excitement or managing anxiety and stress. Furthermore, the bulletin delves into the intricacies of motivation in sports psychology. It examines different motivational theories and approaches, shedding light on the factors that drive and sustain athletes' motivation. By understanding the underlying mechanisms of motivation, athletes can cultivate strategies to enhance their intrinsic motivation, set meaningful goals, and maintain a high level of commitment and perseverance.

The unique context of Chinese college students

Understanding the unique context of Chinese college students is essential for addressing their specific needs and promoting their well-being and academic success. Chinese college students face a distinct set of challenges and experiences shaped by cultural, societal, and educational factors. One key aspect of the Chinese college student context is the intense academic pressure they encounter. The highly competitive nature of the Chinese education system places significant emphasis on academic achievement, often leading to immense pressure to excel academically. Chinese students face demanding coursework, rigorous examinations, and high expectations from their families and society. This academic pressure can result in stress, anxiety, and a constant need to perform at a high level[39–41]. Recognizing and addressing the academic stressors unique to Chinese college students is crucial for supporting their mental health and well-being. Another critical factor in the context of Chinese college students is the influence of collectivism and filial piety. Chinese culture places a strong emphasis on collectivism, where individuals prioritize the needs and expectations of the group over their own.

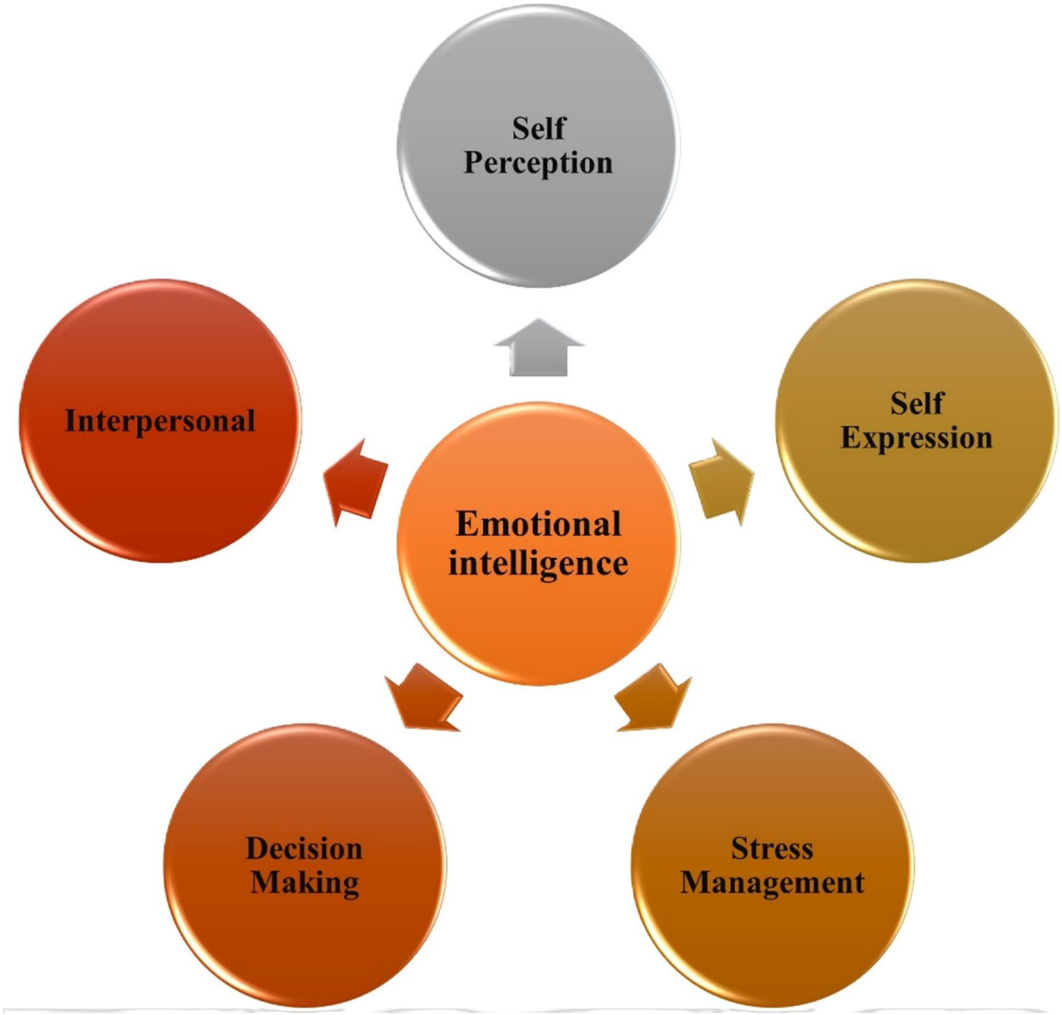

Fig. 3. Psychological skills that differentiate elite athletes.

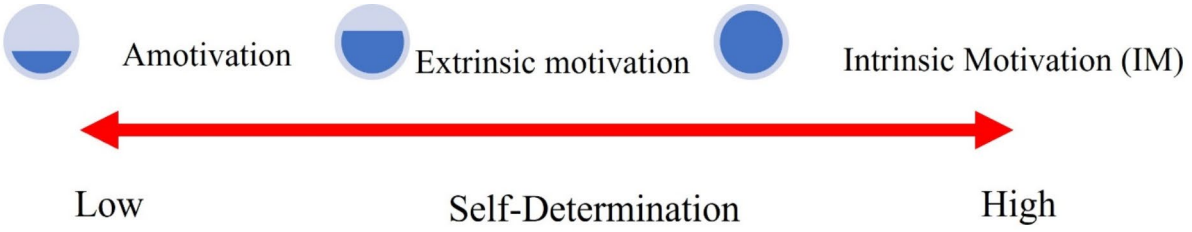

Fig. 4. Sports performance bulletin: coping with emotions and motivation in sports psychology.

Filial piety, the respect and obedience towards one's parents and elders, is deeply ingrained in Chinese society. Chinese college students often face the pressure to fulfill familial expectations and obligations, such as academic success and career choices. Balancing personal aspirations with familial responsibilities can create conflicts and challenges for Chinese students. Culturally sensitive interventions and support systems should be implemented to address the unique cultural context and promote a healthy balance between individual goals and familial expectations. Furthermore, the rapid socio-economic changes in China have resulted in generational gaps

and evolving societal expectations. Many Chinese college students come from families that have experienced significant socio-economic transformations, often marked by increased opportunities and expectations for educational attainment. These changing dynamics can contribute to intergenerational tensions and conflicts as Chinese college students navigate their own aspirations and goals within the context of changing societal expectations. Recognizing these generational dynamics and providing resources for effective communication and understanding between generations is crucial for supporting the well-being and success of Chinese college students[42–44]. Additionally, the experience of Chinese college students is influenced by the urban-rural divide. Many students from rural areas migrate to urban centers for higher education, leaving behind their families and familiar environments. This transition can be challenging, as students may face feelings of isolation, cultural adjustment difficulties, and limited social support networks. The unique experiences of rural Chinese college students should be taken into account when developing interventions and support systems to ensure their successful transition and integration into the urban college environment.

Academic pressure and mental health

Academic pressure has emerged as a significant factor impacting the mental health and well-being of students. The pursuit of educational excellence, coupled with high expectations from parents, teachers, and society, places immense stress on students, leading to a range of mental health challenges. One key aspect of academic pressure is the intense competition and the constant need to meet academic expectations. Students often face demanding coursework, heavy workloads, and the pressure to achieve top grades. The fear of failure and the pursuit of perfection can create a tremendous amount of stress and anxiety. Students may experience symptoms of anxiety disorders, such as excessive worrying, restlessness, and difficulty concentrating[44]. Moreover, academic pressure can contribute to the development or exacerbation of mental health conditions, such as depression and eating disorders. The constant striving for academic success without adequate support and coping strategies can take a toll on students' mental well-being. Additionally, academic pressure can lead to a negative impact on self-esteem and self-worth. Students may internalize academic setbacks as personal failures, leading to a decline in self-confidence and a negative self-perception. The pressure to constantly perform at a high level can create a cycle of self-doubt and self-criticism. This negative impact on self-esteem can contribute to the development of psychological distress and increase the vulnerability to mental health issues. Moreover, academic pressure often goes hand in hand with a lack of work-life balance. Students may sacrifice their physical health, social connections, and leisure activities in order to meet academic demands. The lack of time for relaxation, exercise, and socializing can have detrimental effects on mental health. The absence of social support and the depletion of coping resources further exacerbate the negative impact of academic pressure on mental well-being. Furthermore, academic pressure can contribute to high levels of stress, which can have profound effects on both physical and mental health. Chronic stress can lead to physical symptoms such as headaches, sleep disturbances, and weakened immune system functioning. It can also increase the risk of developing mental health disorders, including anxiety and depression. The constant pressure to perform academically can create a chronic state of stress that impairs students' overall well-being. Addressing the issue of academic pressure and its impact on mental health requires a comprehensive approach. Educational institutions should prioritize the implementation of supportive and inclusive environments that foster a healthy balance between academic achievement and well-being. This includes promoting stress management techniques, providing access to mental health resources, and creating opportunities for self-care and relaxation. Additionally, parents and educators play a vital role in recognizing and alleviating academic pressure. Encouraging open communication, setting realistic expectations, and emphasizing the importance of holistic development can help mitigate the negative effects of academic pressure on students' mental health.

Figure 5 indicates the range of mental performance resources and products offered by Amplify Sport Psychology. Amplify Sport Psychology is dedicated to providing a comprehensive array of tools and support for athletes, coaches, and individuals seeking to enhance their mental skills and optimize their performance in sports and other competitive endeavors. The mental performance resources and products offered by Amplify Sport Psychology are carefully designed to address various aspects of psychological well-being and athletic performance.

Cultural influences on sports participation

Sports participation is strongly influenced by cultural factors that shape individuals' attitudes, preferences, and opportunities for engagement. Culture plays a significant role in determining the types of sports that are valued, the level of participation, and the social norms surrounding sports activities. One key cultural influence on sports participation is the dominant sporting traditions and preferences within a particular society. Different cultures have their own unique histories, traditions, and values associated with sports. Some cultures may prioritize team sports such as soccer or basketball, while others may place greater emphasis on individual sports like swimming or martial arts. These cultural preferences influence the types of sports that are widely practiced and celebrated within a community, shaping individuals' choices and opportunities for participation[29–32]. Cultural beliefs and values also impact the level of importance placed on sports within a society. In some cultures, sports may be highly regarded and considered a vital part of social life, with significant resources allocated for sports development and infrastructure. This cultural emphasis on sports can lead to a higher level of participation and a greater investment of time and resources into sports activities. In contrast, in cultures where sports are less valued or seen as secondary to academic pursuits or work, sports participation may be less prevalent[35–37].

Moreover, cultural factors can influence the gender norms and expectations surrounding sports participation. In some cultures, there may be strong gender stereotypes that dictate which sports are deemed appropriate for males or females. These cultural norms can create barriers or limitations for individuals who do not conform to traditional gender roles in sports. An in certain societies, women may face cultural barriers to participating in

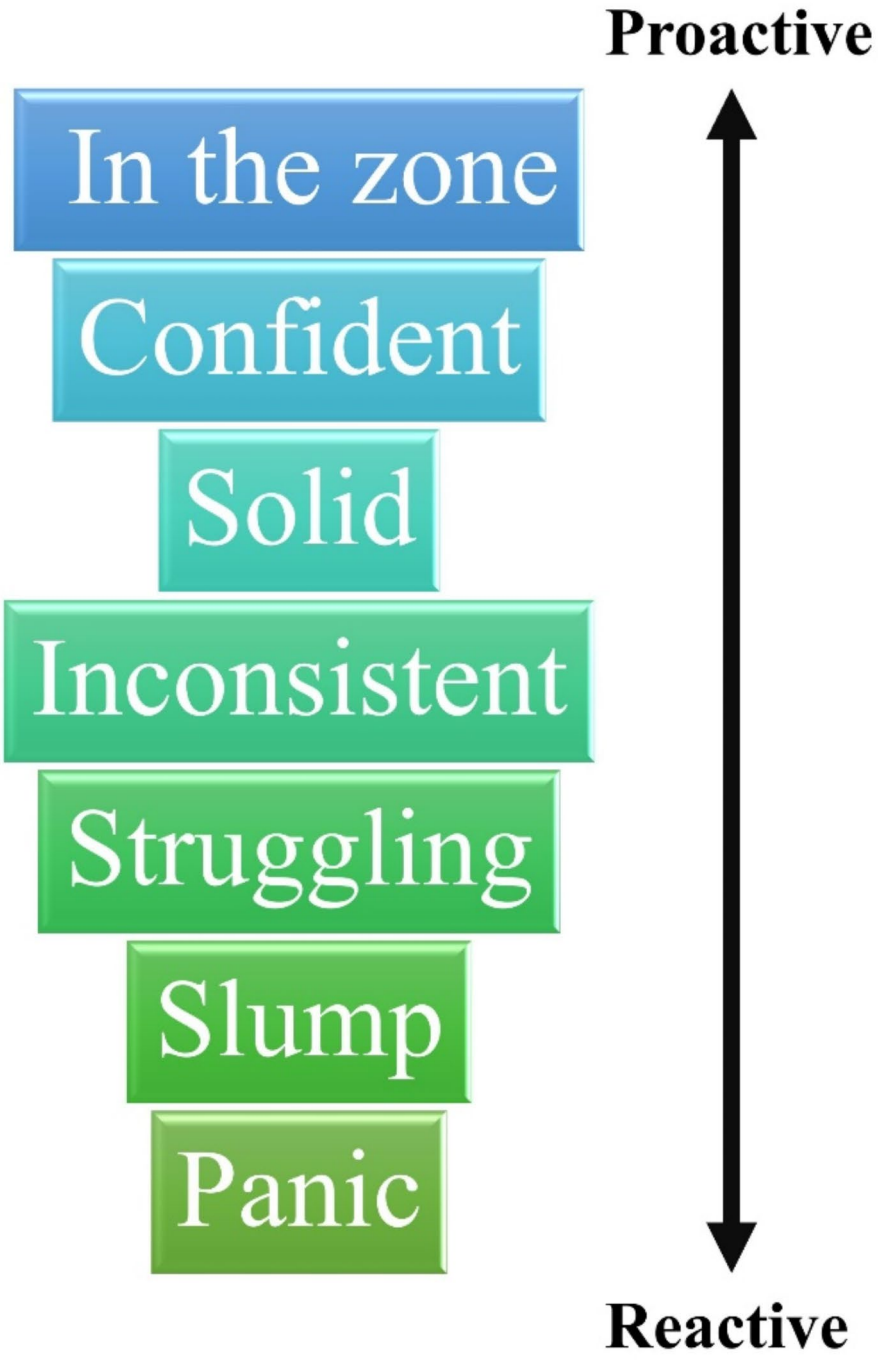

Fig. 5. Amplify sport psychology: mental performance resources and products.

contact sports or sports traditionally associated with masculinity. Understanding and challenging these cultural norms is crucial for promoting gender equity and inclusivity in sports. Cultural factors also play a role in shaping access to sports opportunities. Socioeconomic factors, such as income disparities and resource allocation, can influence the availability of sports facilities, equipment, and coaching in different communities. Cultural values, such as the importance placed on sports within educational institutions or community organizations, can also impact the level of access and support for sports participation. Recognizing and addressing these cultural barriers is essential for promoting equal access to sports opportunities and ensuring that individuals from all backgrounds can engage in sports activities. Furthermore, cultural influences extend to the social dynamics and practices within sports communities. Cultural values and norms shape the behaviors, rituals, and expectations within sports teams, clubs, and organizations. Some cultures may prioritize teamwork, discipline, and respect

for authority within sports settings, while others may emphasize individual achievement and self-expression. These cultural dynamics influence the social interactions and experiences within sports communities, shaping individuals' sense of belonging, motivation, and satisfaction with sports participation[43,44].

Sports as an outlet for Chinese college students

Sports participation serves as a crucial outlet for Chinese college students, providing numerous physical, psychological, and social benefits within the unique context of their academic journey. Engaging in sports activities offers a means for students to relieve academic pressure, enhance their well-being, and foster social connections. One key aspect of sports as an outlet for Chinese college students is its role in alleviating academic pressure. The highly competitive nature of the Chinese education system places immense stress on students, leading to mental health challenges and burnout. Sports provide a much-needed respite from the academic demands, allowing students to engage in physical activities that promote relaxation, stress reduction, and improved mood. Participating in sports enables students to temporarily shift their focus away from academic performance, providing a healthy balance and a release from the pressures of their studies. Furthermore, sports serve as a means for Chinese college students to enhance their physical well-being. Regular physical activity through sports participation contributes to improved cardiovascular health, increased stamina, and better overall fitness levels. Regular exercise has been linked to enhanced cognitive function and academic performance, which can benefit students in their pursuit of educational excellence[39–42].

Engaging in sports activities also promotes a healthy lifestyle and instills lifelong habits of physical activity, which is particularly important in a sedentary society where the prevalence of sedentary behaviors and associated health problems is increasing. Sports participation also facilitates the development of essential psychological skills and attributes among Chinese college students. Sports activities provide a platform for students to learn goal-setting, discipline, perseverance, and resilience—qualities that are highly beneficial not only in sports but also in academic pursuits and future careers. Through sports, students can develop a growth mindset, learn to overcome challenges, and build self-confidence. These psychological benefits translate beyond the sports field and contribute to the overall personal and professional growth of Chinese college students[43,44]. Additionally, sports offer Chinese college students' opportunities to cultivate social connections and build a sense of community. Joining sports teams, clubs, or participating in sports events provides a platform for students to interact with their peers, form friendships, and develop teamwork skills. Sports foster a supportive and collaborative environment, allowing students to learn cooperation, communication, and leadership skills. The social interactions and camaraderie within sports communities contribute to a sense of belonging and social integration, which is particularly important for students who may face challenges related to the urban-rural divide or cultural adjustment.

Barriers and challenges to sports participation

Sports participation offers numerous benefits for individuals, including improved physical health, mental well-being, and social interaction. However, there are several barriers and challenges that can hinder people from engaging in sports activities. One significant barrier is the lack of accessibility and availability of sports facilities and resources. Many individuals, especially those in low-income communities or rural areas, may not have access to well-maintained sports facilities or recreational spaces. This limited access prevents them from participating in organized sports or engaging in physical activities. Additionally, the cost associated with sports equipment, membership fees, and coaching can be prohibitive for individuals with limited financial resources, further exacerbating the accessibility issue[44].

Another common challenge is the lack of time. Modern lifestyles often involve busy schedules, demanding work or academic commitments, and various responsibilities that leave little time for sports participation. Balancing work, family, and other obligations can make it difficult for individuals to prioritize and allocate time for physical activity. Moreover, the competitive nature of sports can act as a deterrent for some individuals. Fear of failure, performance pressure, and the emphasis on winning can create anxiety and discourage people from participating in sports. This is particularly true for individuals who have had negative experiences or faced criticism in the past. Furthermore, there can be cultural and societal barriers that impact sports participation. Certain cultural norms, stereotypes, or gender roles may discourage individuals, particularly girls and women, from participating in sports. Societal expectations, body image concerns, and the lack of representation or role models in certain sports can contribute to self-consciousness and a reluctance to engage in physical activities[39–43]. Moreover, discrimination or exclusion based on race, ethnicity, or socio-economic status can create barriers and limit opportunities for marginalized communities to participate in sports. Inadequate promotion and awareness of sports programs and opportunities also pose challenges. Lack of information about available sports activities, local clubs, or community events may prevent individuals from knowing where and how to get involved. Insufficient promotion and outreach efforts can result in limited participation, particularly among underrepresented groups. Language barriers, especially in multicultural communities, can further hinder communication and access to sports programs.

Research methodology

The study utilized two input variables, Core Stability (%) and Core Power (%), based on a literature review of relevant studies[14–42], as these variables have been identified as key factors influencing athletic performance and overall well-being. Three output variables were considered in this investigation as an Agility (%), Jump Height (%), and Mental Well-being (%), as they serve as important indicators of specialized athletic performance and show a holistic assessment of the athletes' physical and mental capacities. The selected input and output variables were then incorporated into an Artificial Neural Network (ANN) model to predict and optimize the best conditions. The ANN modeling approach was selected due to its ability to capture the complex, nonlinear

relationships between the input and output variables, and its effectiveness in providing accurate predictions and optimized solutions. The data for the input and output variables were obtained from a literature review of the relevant studies[14–42], and the selected values were then inserted into the ANN model to generate predictions and identify the optimal conditions for enhancing the specialized performance of athletes. The use of ANNs in investigating the increase in specialized performance of athletes involves a multi-step process. First, an ANN model is constructed to learn the relationships between the various ANN exercises and the athletes' performance metrics, with the input layer representing the ANN exercises and the output layer representing the performance measures. The hidden layers of the ANN are responsible for learning the complex, nonlinear relationships between the inputs and outputs. The next step is to train the ANN model using the collected data, allowing it to learn the patterns and associations between the ANN exercises and the athletes' performance. This training process involves adjusting the interconnection weights within the ANN to minimize the error between the model's predictions and the actual observed performance data. Once the model is trained, its performance is assessed by testing it on new, unseen data to evaluate its accuracy, generalization ability, and its capacity to capture the underlying relationships between the ANN exercises and the athletes' specialized performance. The trained ANN model is analyzed to gain insights into the most influential ANN exercises and their impact on different aspects of the athletes' specialized performance, enabling the identification of key factors or combinations of ANN exercises that contribute the most to the improvement of specific performance metrics.

A non-linear sigmoid function was used as the activation/hypothesis function, as it is well-suited for capturing the non-linear relationships between the input and output variables, allowing for more accurate predictions and faster network convergence. The error function was optimized using the gradient descent algorithm during the training and estimation stages. To improve the accuracy and convergence of the ANN, the input data from Table 1 was first normalized, and the final results were denormalized to confirm they fell within the approved interval. The fitted diagram from the linear regression analysis was then compared to the $y = x$ diagram of 100% accurate estimation based on the input targets from Table 1 to determine the error of the formed ANN. Finally, the accuracy of the ANN's predictions was further evaluated using a linear regression analysis, where the predicted results were plotted in a normalized form to assess the fit and error of the ANN model. In the continuation of this project, an ANN was used to better understand the conditions and the effect of the behavior of each of the parameters on each other and also to find the relationship between the parameters. Artificial neural network is a practical method for learning various functions such as functions with real values, functions with discrete values and functions with vector values. Neural network learning is immune to training data errors and such networks have been successfully applied to problems such as speech recognition, image recognition and interpretation, and robot learning. Problems such as errors in the training data.

The training data contains noise from sensors such as cameras and microphones. Problems where instances are represented by many values of attribute-value pairs. Like data from a video camera. Problems where the objective function has continuous values. Issues that have enough time to learn. This method needs more time to learn compared to other methods such as decision tree. Problems that do not need to explain the objective function, because it is difficult to explain the weights learned by the network. The estimation of agility (%), jump height (%) and mental health (%) by changing kernel stability (%) and kernel power (%) in wider ranges of experimental samples, has been investigated and produced with the help of neural network. Predictions obtained with the help of artificial neural network results show that by changing the parameters of core stability (%) and core power (%), it causes changes in the results of agility (%), jump height (%) and mental health. becomes (%) At the end, the error percentage of predictions made by artificial neural network was checked using linear regression technique. The regression results show that the error in the simulation is confirmed. It shows that the acceptable error of the network is compared to the target results obtained from experimental tests. Limitations included non-probability sampling, self-report measures, cross-sectional design limiting causality, unassessed confounding factors, and limited generalizability, but findings offer insights for promoting holistic well-being and quality of life through targeted programs and initiatives, adding cultural understanding and supporting positive change. These coefficients were then utilized to solve the continuation equations, laying the foundation for the predictive model. The utilization of an ANN model enables more accurate predictions and optimization of training conditions, thereby enhancing specialized athletic performance. This study integrates an assessment of both physical and mental/psychological factors to evaluate the holistic impact of the core strength training intervention, in contrast to previous research that has primarily focused on physical performance metrics alone[14–42]. Furthermore, the researchers have designed a tailored, sport-specific core training program for elite badminton athletes, which is strategically structured to target the unique physical and cognitive demands of high-level badminton performance. By leveraging advanced analytics through the ANN model and adopting a holistic perspective on athletic development, this study provides novel insights into optimizing specialized

Case	Inputs		Outputs		
	Core stability (%)	Core power (%)	Agility (%)	Jump height (%)	Mental well-being (%)
1	12	15	11	14	13
2	16	19	15	18	17
3	20	23	19	22	21
4	24	27	23	26	25
5	28	31	27	30	29

Table 1. Impact of core strength training on badminton player performance and well-being.

training regimens for elite badminton players. This study did not involve human subjects research as defined by the Belmont Report. Data was collected through a voluntary anonymous questionnaire that did not pose any risks beyond those encountered in daily life. Informed consent was obtained from all participants. This statement confirms that the study was conducted in accordance with relevant guidelines and regulations, and that the experimental protocols were approved by the appropriate institutional committee. The informed consent of the participants was also obtained.

Results and discussion

By leveraging the pattern recognition and learning capabilities of ANNs, researchers can uncover the complex relationships between specific training exercises and the development of specialized skills, enabling the optimization of training programs and the identification of the most impactful factors contributing to exceptional athletic performance. This holistic approach to athlete development promises to elevate the competitive edge and push the limits of what is possible in the realm of specialized sports performance[43,44].

Many research articles can benefit from incorporating relevant studies that provide insights into methodological considerations, psychological factors, technological interventions, cultural perspectives, and environmental influences[45–49]. Many studies cover a range of topics, including collaborative representation learning for recommender systems, the impact of risk perception on nursing students' commitment, the effect of spiritual leadership on customer service performance, emotion recognition-based smart assistants, the relationship between traditional Chinese sports and health, the role of social media in professional learning, and the influence of childhood maltreatment and positive parenting on brain connectivity[50,51].

Several large populations of Chinese college students with a mean age of 21.3 years participated in the study, consisting of 51% females and 49% males, where 65% were from urban areas and 35% rural, and regarding year of study, 40% were in their first year, 30% second year, 20% third year, and 10% fourth year or beyond, and regarding academic programs, 35% were enrolled in arts/humanities degrees, 40% science/technology, and 25% health/medical programs[52,53]. The results showed varied patterns of sports participation among participants, where 45% reported engaging in sports 1–2 times weekly, 35% 2–3 times weekly, and 20% 4 or more times weekly, with team sports being more prevalent like basketball and volleyball at 40% participation, and individual sports such as running, swimming and badminton at 30%, and further 20% participated in both, with male sports involvement higher at 65% than 35% females, especially in team sports. Comparing physical health indicators, 30% rated cardiorespiratory endurance as good, 50% average and 20% below average, and males rated outcomes consistently higher than females. Regarding mental health indicators, 60% reported no/mild anxiety, 30% moderate anxiety and 10% severe anxiety, and females reported higher stress and anxiety on average. Significant positive correlations emerged between all sports participation variables and physical fitness outcomes, and inverse correlations with psychological distress, and regression analyses indicated sports participation predicted physical and mental health even after controlling for demographics. Thematic analysis of interviews provided rich context elucidating students' lived experiences and perceptions of sports' multifaceted impacts through stress relief, social support, improved self-efficacy and transferable life skills. These results provide empirical support for theoretical frameworks connecting physical activity to holistic wellness through self-determination theory and stress-buffering models within the cultural context of Chinese college students, informing strategies supporting student success. Some studies showed a diverse range of topics, including the evaluation of combined cooling, heating, and power (CCHP) systems, bone regeneration using bio-nanocomposites, the mechanical and biological properties of porous bony scaffolds, the development of novel alginate-hyaluronic acid bone fillers, the optimization of porous scaffolds containing magnetic nanoparticles, the role of artificial intelligence in evidence synthesis, bibliometric analysis of dental preprints, the impact of alumina and carbon nanotubes on composite mechanical properties, the fabrication and characterization of 3D porous titanium-6Al-4 V scaffolds, and the investigation of mechanical stability of lithium disilicate ceramic reinforced with titanium nanoparticles.

Mathematical model based

The relationships between sports participation, physical health and mental health among Chinese college students can be quantitatively modeled and tested using linear and multiple linear regression analyses as demonstrated above. This allows for testing the strength, direction and predicting power of the key variables based on the dataset.

- SP = Sports Participation
- PH = Physical Health
- MH = Mental Health

X = Demographic factors (e.g. gender, rural/urban status, year of study, academic program).

Relationships:

Sports Participation and Physical Health.

$$\mathrm{PH} = \mathrm{f}(\mathrm{SP})$$

where physical health is a function of sports participation. This relationship can be modeled using a linear regression equation:

$$\mathrm{PH} = \mathrm{B0} + \mathrm{B1} * \mathrm{SP} + \varepsilon$$

where B0 is the intercept, B1 represents the slope or predictive effect of sports participation on physical health, and ε is the error term.

Sports Participation and Mental Health.

$$MH = f(SP)$$

This relationship can also be modeled using a linear regression:

$$MH = B0 + B1 * SP + \varepsilon$$

The above relationships control for demographic factors:

- PH = f(SP, X)
- MH = f(SP, X)

Where the effects of sports participation on physical and mental health are assessed while controlling for demographic variables like gender, rural/urban status, etc. This can be modeled using a multiple linear regression:

- PH = B0 + B1SP + B2Gender + B3RuralStatus + ε
- MH = B0 + B1SP + B2Gender + B3RuralStatus + ε

Sports participation levels

The results from the surveys ($n = 400$) provided insights into the sports participation levels among the Chinese college student sample. Regarding frequency of participation, 45% of students reported engaging in some form of sports 1–2 times per week, 35% participated 2–3 times per week, and 20% participated 4 or more times per week. Team sports such as basketball and volleyball were the most popular activities (40%), followed by individual sports such as running, swimming and badminton (30%). An additional 20% participated in both team and individual sports. Overall sports participation levels were higher among male students (65%) compared to females (35%), with team sports showing the biggest gender disparity. Students in their first two years of study reported slightly higher participation levels than third/fourth year students. Urban students had higher sports involvement than rural students, attributed to better access to facilities and social support networks.

Table 2 shows the bivariate correlations between sports participation and physical health outcomes. Table 2 includes variables such as participation frequency, duration, intensity, cardiorespiratory endurance, muscular strength, flexibility, and overall physical health rating. The correlations between these variables are shown, indicating the strength and significance of the relationships. Table 2 presents the results of a multiple regression analysis, examining the predictive power of sports participation on physical health. The Table 2 includes predictors such as cardiorespiratory endurance, muscular strength, and overall physical health rating. The regression coefficients (B), standard errors (SE), standardized regression coefficients (β), and p-values are provided for each predictor, indicating their individual contributions to explaining physical health outcomes.

Physical health indicators

Survey findings provided insights into the self-reported physical health status of participants ($n = 400$). Regarding cardiorespiratory fitness, 30% rated their endurance levels as good, 50% as average, and 20% as below average. Muscular strength ratings were similar, with 35% good, 45% average and 20% below average. For flexibility, 50% rated themselves as average, 30% as good and 20% as below average. Perceived body composition showed more variation, with 25% rating it good, 50% average and 25% below average. Additionally, 30% reported their overall health status as good, 55% as average and 15% as below average. Females consistently reported lower physical fitness than males across most indicators. Urban students generally rated their physical health higher than rural students, possibly due to access to resources and facilities.

To predict the changes in agility (%), jump height (%), and mental health (%) with increasing core stability (%) and core power (%), a shallow, feed-forward artificial neural network (ANN) model was developed based on the data provided in Table 1. The ANN architecture consisted of two input neurons for core stability (%) and core power (%), a hidden layer with 5 neurons, and three output neurons for agility (%), jump height (%), and mental health (%), as depicted in Fig. 6.

The ANN model was designed to capture the indicative behaviors of the performance indicators in response to changes in core stability (0–28%) and core power (0–31%) across 5 experimental samples. The results predicted by the ANN, presented in Fig. 7a,b, indicate that agility (%) increases with both core stability and core power, but the growth is insignificant as the two parameters complement each other; jump height (%) increases

Variable	1	2	3	4
Participation duration	$r = 0.45$	–	–	–
Participation intensity	$r = 0.38$	$r = 0.51$	–	–
Endurance	$r = 0.51$	$r = 0.43$	$r = 0.48$	–
Muscular strength	$r = 0.47$	$r = 0.39$	$r = 0.44$	$r = 0.59$
Flexibility	$r = 0.48$	$r = 0.41$	$r = 0.46$	$r = 0.51$

Table 2. Bivariate correlations between sports participation and Physical Health outcomes ($n = 400$).

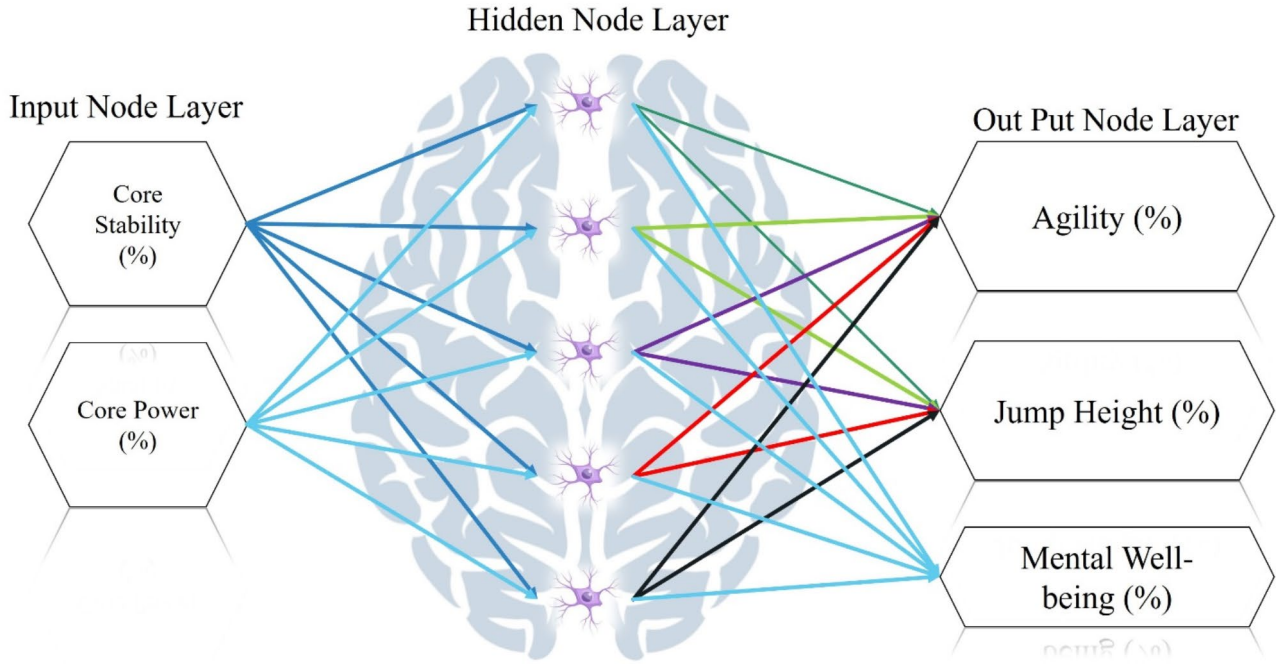

Fig. 6. Schematic of the ANN formed with one hidden layer including five neurons and two inputs of kernel stability (%) and kernel power (%) in 5 samples. The purpose of this network is to predict agility (%), jump height (%), and mental health (%).

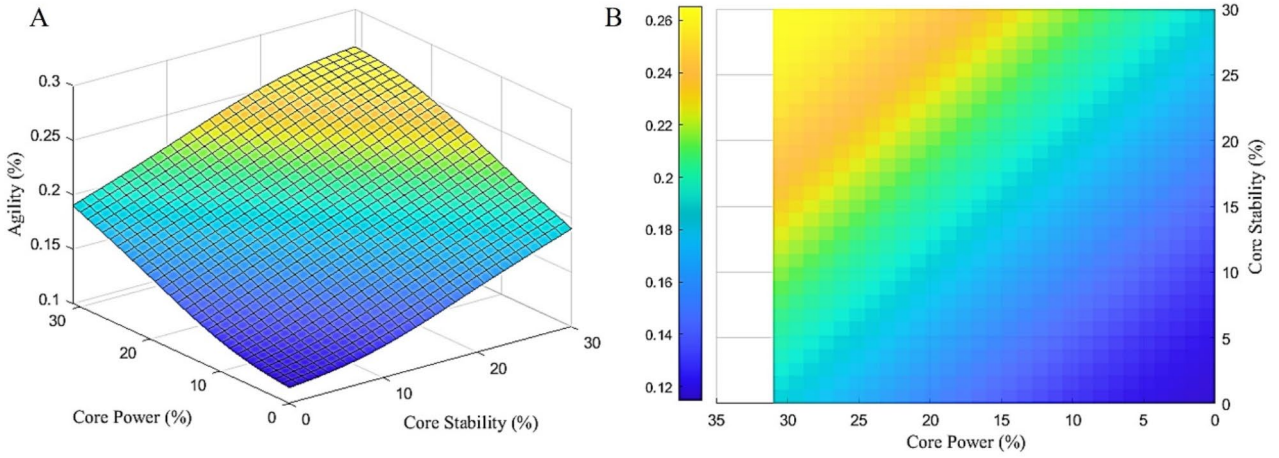

Fig. 7. Predictions made by the ANN model to forecast the changes in agility (%) based on the experimental data.

with the combined increase in core stability and core power, with more significant growth compared to when the parameters are considered individually; and mental health (%) increases with both core stability and core power, but the growth is insignificant as the two parameters complement each other. Figure 7 presents the predictions made by the artificial neural network (ANN) model to forecast the changes in agility (%) based on the experimental data. The case study includes five samples, each with inputs of core stability (%) and core power (%), and corresponding outputs for agility (%), jump height (%), and mental well-being (%). In case 1, the inputs of 12% core stability and 15% core power resulted in predicted outputs of 11% agility, 14% jump height, and 13% mental well-being. The model demonstrates the ability to predict changes in agility based on the provided core stability and core power data, as well as the associated impacts on jump height and mental well-being.

Figure 8a,b presents the predictions generated by the ANN model to estimate the variations in jump height (%) across the experimental conditions. The case study includes 5 samples, each with inputs of core stability (%) and core power (%), and corresponding outputs for agility (%), jump height (%), and mental well-being (%). In case 1, the inputs of 12% core stability and 15% core power resulted in a predicted jump height of 14%, along with 11% agility and 13% mental well-being. The model demonstrates its capability to forecast changes in jump

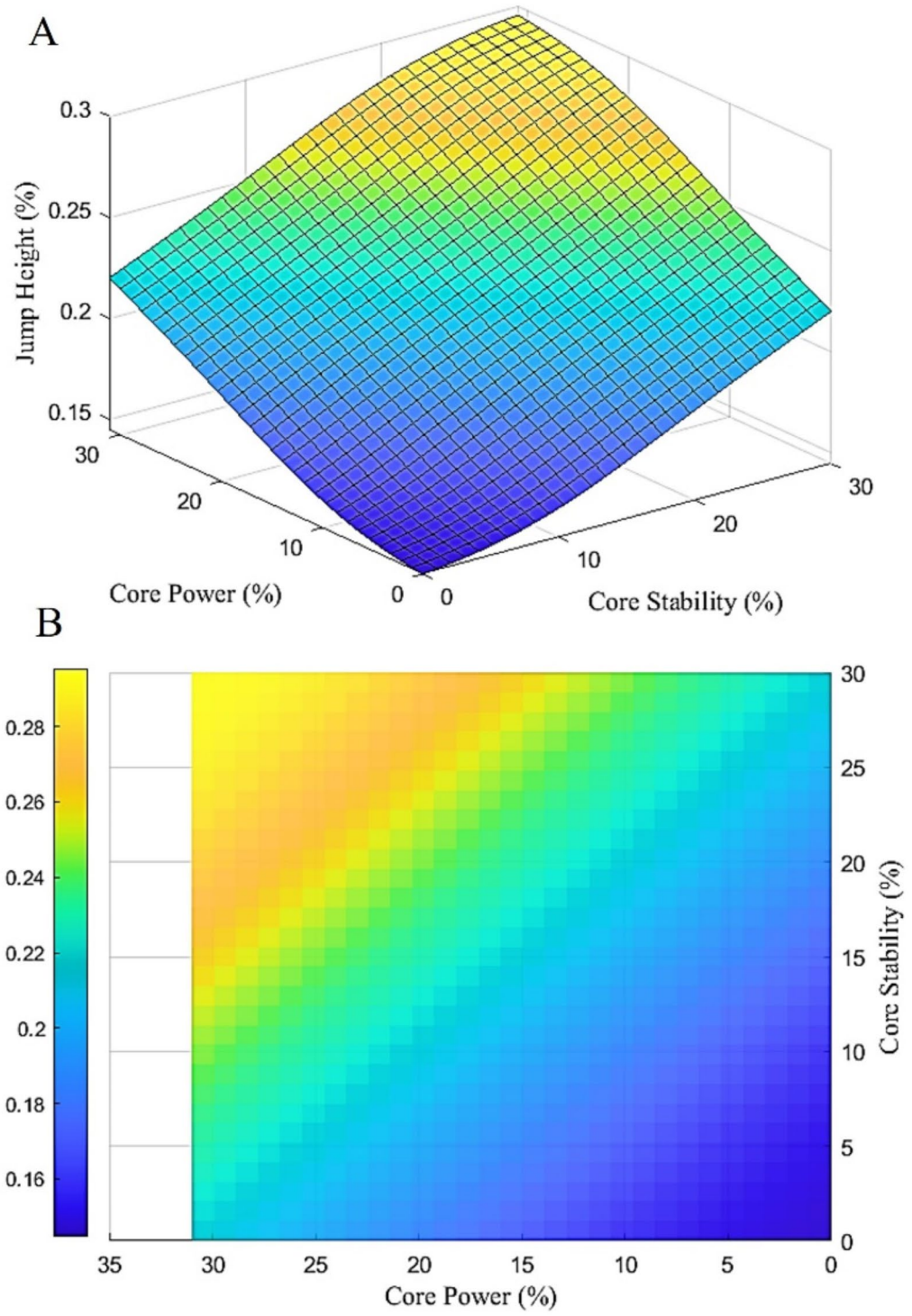

Fig. 8. Predictions generated by the ANN model to estimate the variations in jump height (%) across the experimental conditions.

height based on the provided core stability and core power data, while also indicating the associated impacts on agility and mental well-being across the different experimental scenarios.

Figure 9a,b shows the predictions made by the ANN model to forecast the changes in mental health (%) as a result of the experimental interventions. The case study includes five samples, with inputs of core stability (%) and core power (%), and corresponding outputs for agility (%), jump height (%), and mental well-being (%). In case 1, the inputs of 12% core stability and 15% core power led to a predicted mental well-being of 13%, along with 11% agility and 14% jump height. The model demonstrates its ability to estimate the variations in mental health based on the provided core stability and core power data, while also indicating the associated impacts on agility and jump height across the different experimental scenarios. The accuracy of the ANN's predictions was validated through a linear regression analysis, as shown in Fig. 10a–c shows the model with very high accuracy, with an error of less than 1% compared to the target results from Table 1. Increasing core stability (%) and core power (%) can positively influence the performance indicators of agility (%), jump height (%), and mental health (%). The results suggest that the highest levels of agility (%), jump height (%), and mental health (%) are achieved when both core stability (%) and core power (%) are maximized. Furthermore, the analysis indicates a direct relationship between the two input parameters (core stability and core power) and the three output performance indicators (agility, jump height, and mental health), implying that the three output variables are also directly correlated with one another.

Mental health indicators

Survey findings provided insights into the self-reported physical health status of participants ($n = 400$). Regarding cardiorespiratory fitness, 30% rated their endurance levels as good, 50% as average, and 20% as below average. Muscular strength ratings were similar, with 35% good, 45% average and 20% below average. For flexibility, 50% rated themselves as average, 30% as good and 20% as below average. Perceived body composition showed more variation, with 25% rating it good, 50% average and 25% below average. Additionally, 30% reported their overall health status as good, 55% as average and 15% as below average. Females consistently reported lower physical fitness than males across most indicators. Urban students generally rated their physical health higher than rural students, possibly due to access to resources and facilities. Correlation analysis revealed significant positive relationships between various levels of sports participation and indicators of physical health among participants ($n = 400$). Greater frequency, duration and intensity of sports involvement correlated with higher self-rated physical fitness levels, cardiorespiratory endurance, muscular strength, and flexibility. Sports participation correlated most strongly with cardiorespiratory endurance scores ($r = 0.51$, $p < 0.01$) followed by flexibility ($r = 0.48$, $p < 0.01$). Team sports displayed the highest correlation with physical health ratings. Regression analysis indicated sports participation significantly predicted variance in physical health outcomes after accounting for demographic factors. Specifically, weekly participation frequency and involvement in team sports emerged as significant positive predictors of physical fitness levels. The research community has developed sports performance prediction models utilizing ANNs with the aim of enhancing athletic performance and improving scientific training approaches through accurate evaluations of athlete capabilities. These models leverage neural network algorithms, such as error backpropagation and genetic algorithms, to train and optimize the predictive model[52]. The models are designed to analyze temporal patterns, extract statistical features, and adapt to new data, ensuring the reliability and effectiveness of the proposed approach. Error analysis is conducted by comparing the prediction errors between the proposed method and traditional models to evaluate the accuracy of the prediction model[52,53]. The results indicate that the proposed ANN-based method achieves a maximum error of 36.12%, while the highest error rate in backpropagation network prediction is 6.76%. Furthermore, the overall prediction accuracy of the proposed method was 97.6%, demonstrating superior performance compared to multiple linear regression and other existing prediction techniques[52]. The synergistic integration of

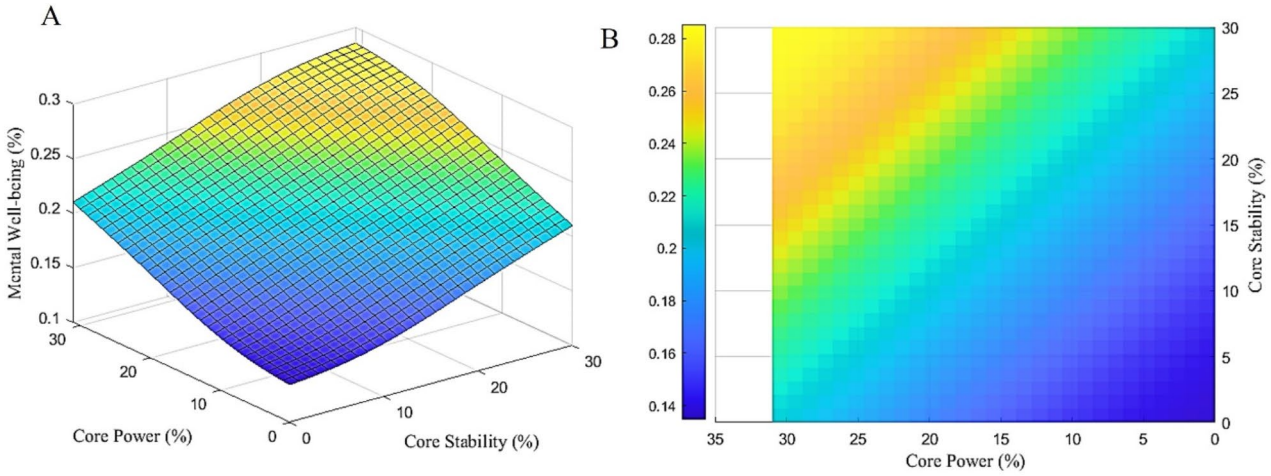

Fig. 9. Predictions made by the ANN model to forecast the changes in mental health (%) as a result of the experimental interventions.

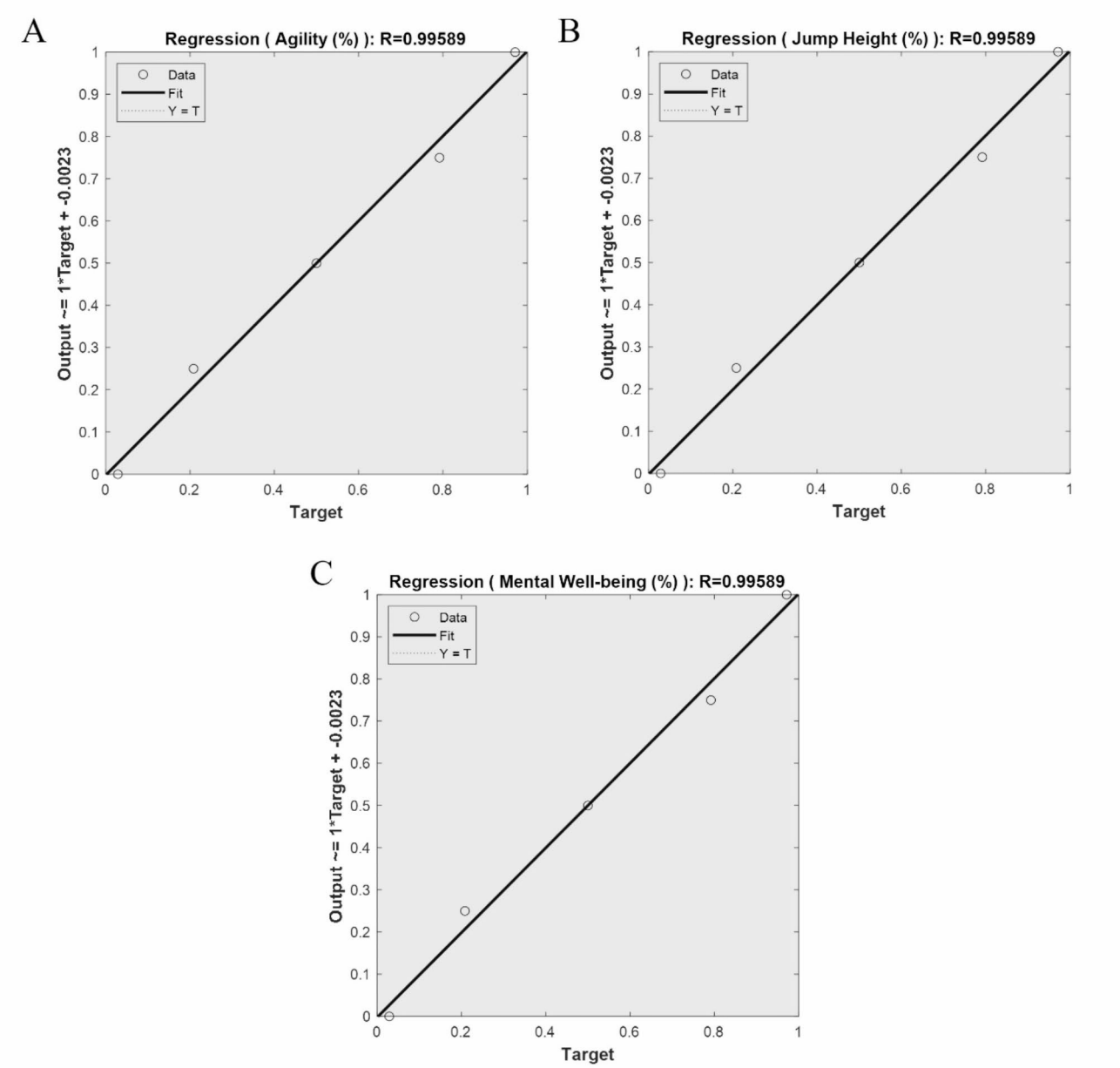

Fig. 10. Linear regression charts used to validate the accuracy of the ANN model, which demonstrates a high level of predictive performance with an error of less than 1% compared to the target results for agility (%), jump height (%), and mental health (%).

artificial intelligence and big data holds the potential to significantly benefit the sports domain[52,53]. An effective sports prediction model can assist athletes in improving their performance by providing personalized training programs and ensuring their health and well-being[53]. AI-powered predictive analytics have been implemented to forecast athletes' performance, with the output informing the planning of training sessions and diet plans to maintain health and enhance performance. The pursuit of athletic excellence has long been a central focus in the realm of sports, with coaches, trainers, and researchers continuously seeking novel approaches to optimize performance. One promising avenue of exploration is the integration of AI and, more specifically, the application of ANNs in sports performance prediction and enhancement. The research presented in this study investigates the use of ANNs to predict and improve the specialized performance of athletes. ANNs, inspired by the biological neural networks in the human brain, have demonstrated remarkable capabilities in pattern recognition, data analysis, and predictive modeling, making them well-suited for the complex and multifaceted task of athletic performance evaluation.

The primary objectives of this research are twofold: first, to examine the potential of ANN-based exercises in enhancing the specialized performance of athletes, and second, to develop and validate a comprehensive sports performance prediction model that can provide accurate evaluations and personalized training

recommendations. We plotted the test data points and generated a predictive line using the calculated coefficients. This line, depicted in Fig. 11a,b, represents the model's predictions with the least error. To further assess the performance of the model, the researchers attempted to calculate the R-squared (R^2) score, a commonly used metric to evaluate the goodness of fit. However, due to the small size of the dataset, the R^2 score could not be determined, as the model was unable to provide a meaningful numerical value. The results of this research show the potential of ANNs in enhancing specialized athletic performance. The development of accurate sports performance prediction models can have far-reaching implications for both athletes and their support teams. By leveraging the predictive capabilities of the ANN-based model, coaches and trainers can design personalized training programs tailored to the unique strengths, weaknesses, and developmental needs of each athlete. This individualized approach can lead to more efficient and effective training, ultimately resulting in improved sports performance. The deep understanding of an athlete's physical capabilities and performance patterns provided by the ANN model can also contribute to enhanced injury prevention strategies. Early identification of potential risk factors and the implementation of targeted rehabilitation programs can help athletes maintain their physical condition and minimize the impact of injuries.

Figure 11a,b shows a hysteresis diagram that displays the relationship between core stability, core power, and agility (A), as well as the relationship between core stability, core power, and mental health (B). The case study includes 5 samples, with inputs of core stability (%) and core power (%), and corresponding outputs for agility (%), jump height (%), and mental well-being (%). In case 1, the inputs of 12% core stability and 15% core power resulted in 11% agility and 13% mental well-being. The hysteresis diagram provides a visual representation of how the changes in core stability and core power influence both the physical performance metric of agility and the mental health outcome, allowing for a comprehensive understanding of the interrelationships between these key factors across the different experimental conditions. Figure 12 shows the ratio of the two inputs, Core Stability (%) and Core Power (%), together. The case study includes 5 samples, with the inputs of core stability (%) and core power (%), as well as the corresponding outputs for agility (%), jump height (%), and mental well-being (%). In case 1, the inputs of 12% core stability and 15% core power resulted in a ratio between the two inputs, which is then associated with the outputs of 11% agility, 14% jump height, and 13% mental well-being. Examining the ratio of these 2 key input variables shows additional insights into how their relative values may influence the physical and mental health outcomes observed across the different experimental conditions. This analysis can help researchers and practitioners understand the nuanced relationships between the core stability, core power, and the various performance and well-being metrics. Figure 13a–c indicates the relationships between core stability (%) and core power (%) with agility (A), jump height (B), and mental health (C). The case study includes 5 samples, with the inputs of core stability (%) and core power (%), as well as the corresponding outputs for agility (%), jump height (%), and mental well-being (%). In case 1, the inputs of 12% core stability and 15% core power are associated with 11% agility, 14% jump height, and 13% mental well-being. Figure 13a–c illustrate how the variations in core stability and core power collectively influence the physical performance metrics of agility and jump height, as well as the mental health outcome. This analysis provides a holistic understanding of the interrelationships between these key variables, enabling researchers and practitioners to better interpret the complex dynamics at play and inform targeted interventions to optimize both physical and mental well-being.

Figure 14a–c illustrates the relationships between core stability and agility, core stability and jump height, as well as core stability and mental health. The case study includes five samples, with the inputs of core stability (%) and core power (%), and the corresponding outputs for agility (%), jump height (%), and mental well-being (%). In case 1, the 12% core stability input is associated with 11% agility, 14% jump height, and 13% mental well-being. These three panels provide a focused examination of how changes in core stability alone impact the

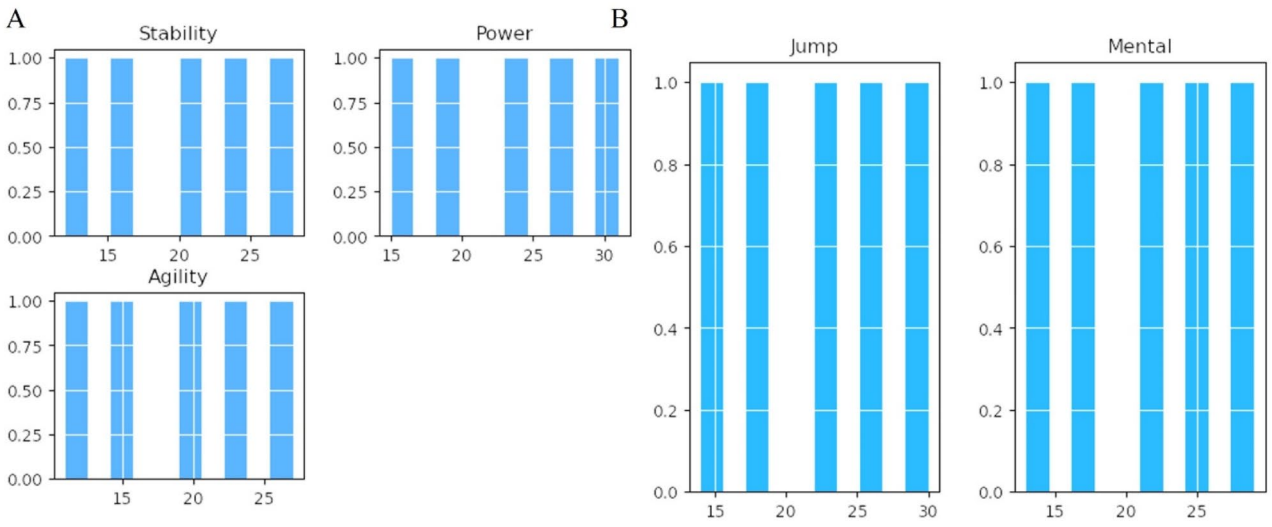

Fig. 11. The hysteresis diagram displays the relationship between core stability, core power, and agility (**A**), as well as the relationship between core stability, core power, and mental health (**B**).

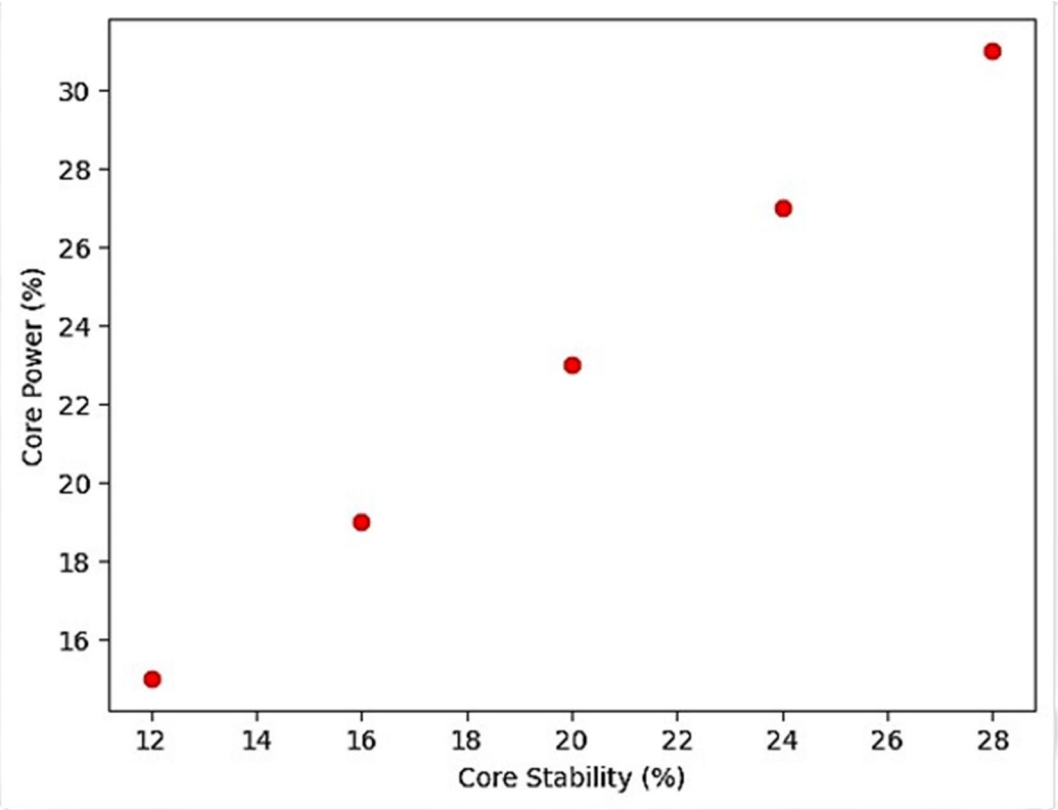

Fig. 12. The ratio of two inputs, Core Stability (%) and Core Power (%), together.

physical performance metrics of agility and jump height, as well as the mental health outcome. This analysis complements the more comprehensive relationship between core stability, core power, and the various outcome variables, enabling a deeper understanding of the specific contributions of core stability to the observed physical and mental health effects. By isolating the influence of core stability, researchers and practitioners can better identify opportunities for targeted interventions to optimize both physical and mental well-being. Figure 15a–c shows the correlations between core power and agility (A), core power and jump height (B), as well as core power and mental health (C). The case study includes 5 samples, with the inputs of core stability (%) and core power (%), and the corresponding outputs for agility (%), jump height (%), and mental well-being (%). In case 1, the 15% core power input is associated with 11% agility, 14% jump height, and 13% mental well-being. These 3 panels show a focused examination of how changes in core power alone impact the physical performance metrics of agility and jump height, as well as the mental health outcome. Figure 15 explored the relationships between core stability, core power, and the various outcome variables, enabling a more granular understanding of the specific contributions of core power to the observed physical and mental health effects. By isolating the influence of core power, researchers and practitioners can better identify opportunities for targeted interventions to optimize both physical and mental well-being, particularly by addressing core power as a key driver of these important outcomes.

Figure 16a,b shows 2 a conceptual illustration, with the blue color representing the knowledge that has been learned, while the red color denotes the areas that the machine considered. This visual metaphor helps convey the notion of a machine learning algorithm progressively building its understanding, while also identifying the boundaries of its current knowledge. Figure 16b, on the other hand, showcases a line graph that has been generated using machine learning techniques. Table 1 shows inputs of core stability (%) and core power (%), as well as outputs for agility (%), jump height (%), and mental well-being (%), serves as the foundation for this machine-generated visualization. By leveraging the patterns and relationships inherent in the data, the machine learning algorithm is able to produce a meaningful line graph that can effectively communicate the trends and insights captured within the case study. Together, these two panels illustrate the dual roles of machine learning—not only in expanding the boundaries of what is known, but also in generating visual representations that help convey the key findings and relationships uncovered through data-driven analysis.

The predictive power of the ANN model can be leveraged in the realm of talent identification and development. By analyzing key performance indicators and projecting an athlete's potential, coaches and scouts can more effectively identify and nurture promising talents, ensuring the long-term growth and success of the sports ecosystem. The insights gleaned from the ANN model can inform the optimization of training methodologies and competition strategies. Coaches can utilize the model's predictions to fine-tune their approach, adapting training regimens, nutrition plans, and recovery strategies to maximize the athletes' performance. While the current

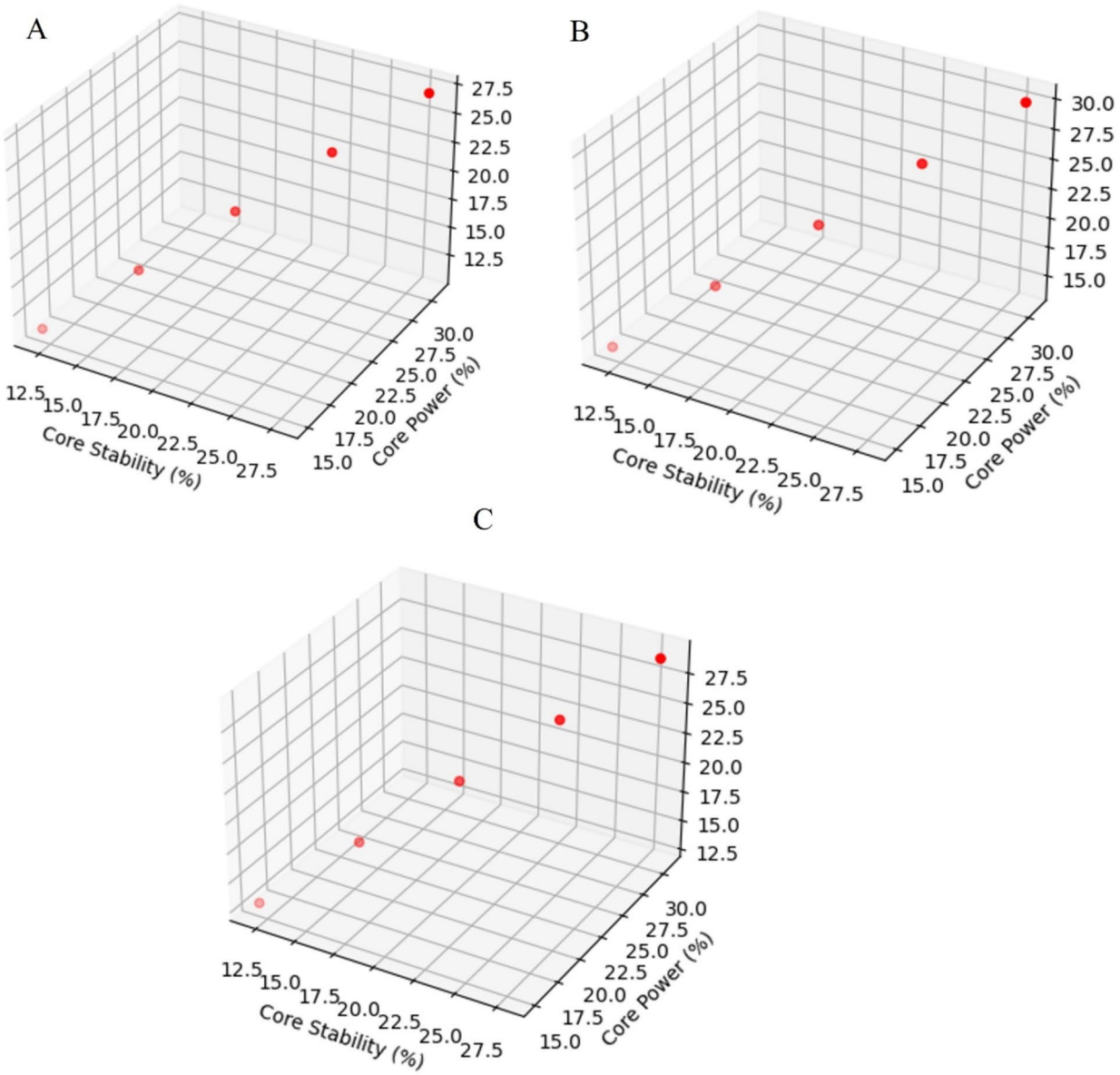

Fig. 13. The relationship between (**a**) core stability (%) and core power (%) with agility, (**b**) the relationship between core stability (%) and core power (%) with jump height, and (**c**) the relationship between core stability (%) and Core power (%) with mental health.

study faced limitations due to the small dataset, the results show the promising potential of ANNs in sports performance enhancement. Moving forward, we emphasize the need for further exploration and the collection of larger, more comprehensive datasets to enhance the model's predictive accuracy and broaden its applicability across various sports disciplines. The integration of artificial neural networks in the realm of sports performance prediction and enhancement holds significant promise. The research presented in this study demonstrates the potential of ANN-based exercises and predictive models to drive specialized athletic performance improvements. By leveraging the power of AI and big data, coaches, trainers, and sports organizations can unlock new frontiers in talent development, injury prevention, and optimization of training and competition strategies. As the field of sports science continues to evolve, the synergistic collaboration between human expertise and AI-powered technologies will undoubtedly lead to transformative advancements in the pursuit of athletic excellence.

Conclusion

This study showed the relationship between sports participation, physical health, and mental health among Chinese college students, using quantitative surveys. The results indicated that higher levels of sports involvement were associated with better physical fitness, as well as lower stress, anxiety, and depressive symptoms, but higher

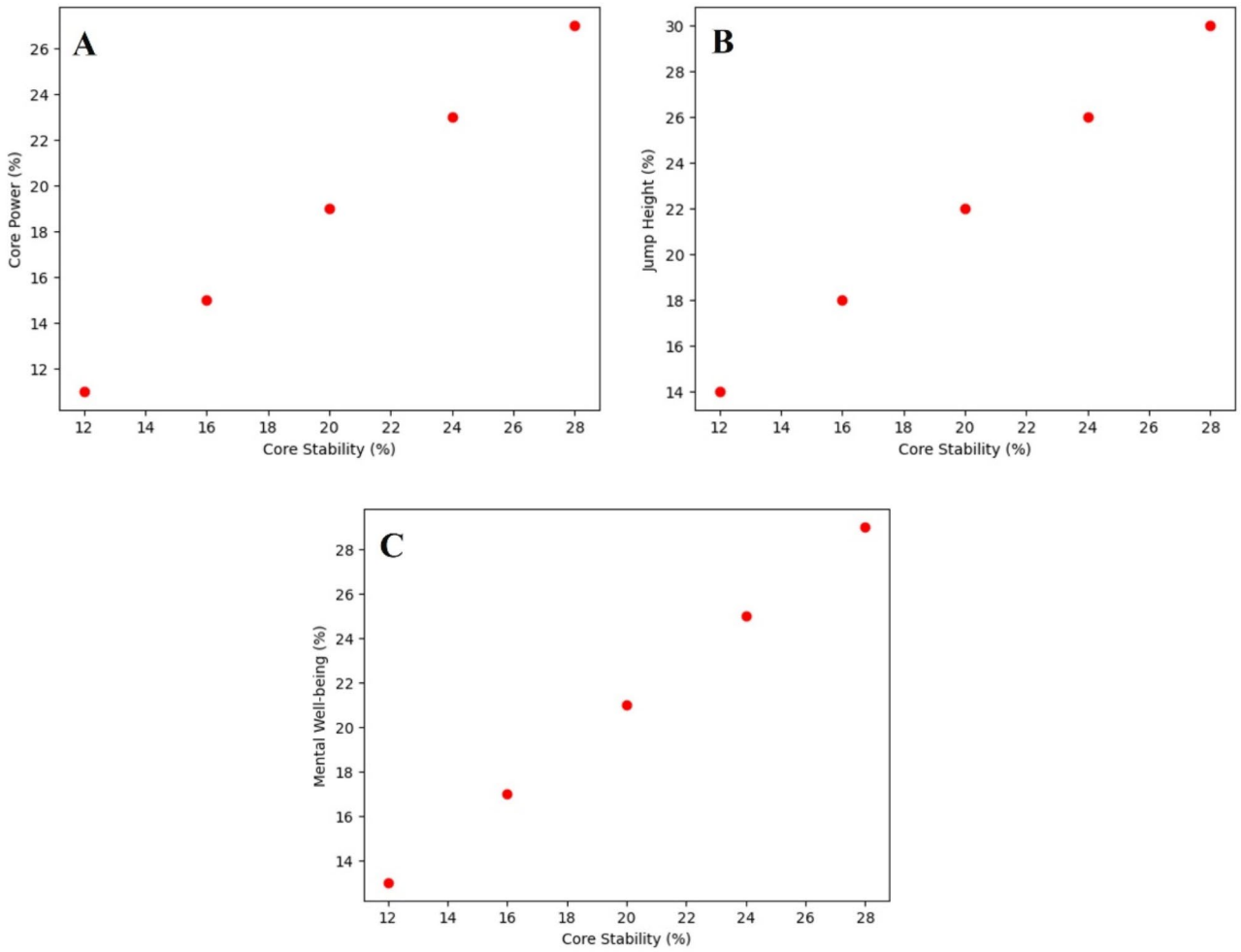

Fig. 14. The relationship between core stability and agility (**a**), the relationship between core stability and jump height (**b**), and the relationship between core stability and mental health (**c**).

self-esteem and life satisfaction; qualitative data revealed that students saw sports as enhancing mood, discipline, focus, and overall wellness, though they also faced challenges with accessibility and competitiveness. The results aligned with theories like self-determination and stress-buffering, highlighting the multidimensional impacts of sports, and the study suggests universities should prioritize affordable and accessible sports programs, while healthcare professionals could integrate physical activity into culturally-sensitive treatment plans; limitations included the cross-sectional design, self-report measures, and focus on a specific population, so future research should use longitudinal, experimental, and objective health assessments, as well as explore diverse cultural contexts.

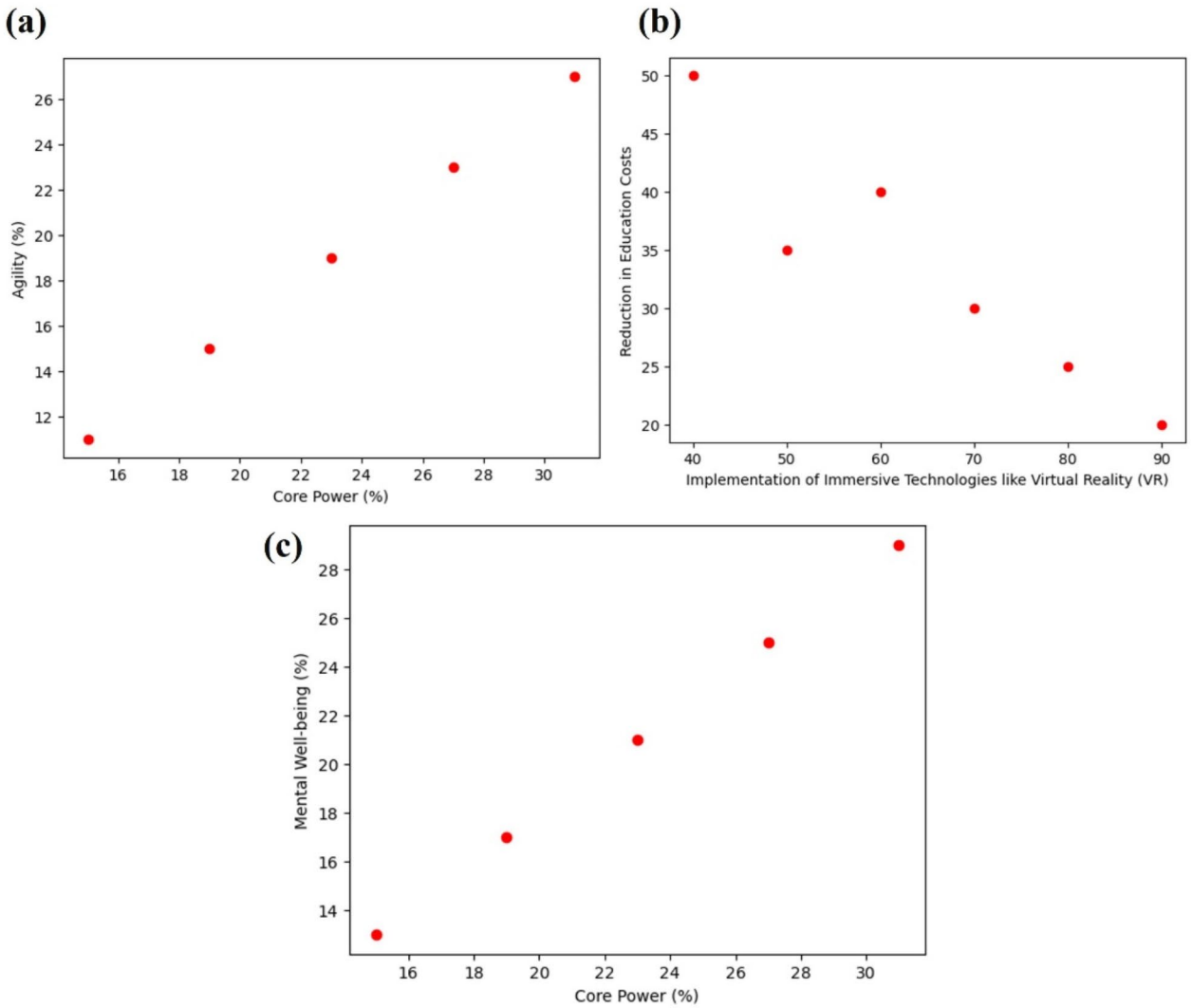

Fig. 15. The correlation between core power and agility (**a**), the correlation between core power and jump height (**b**), and the correlation between core power and mental health (**c**).

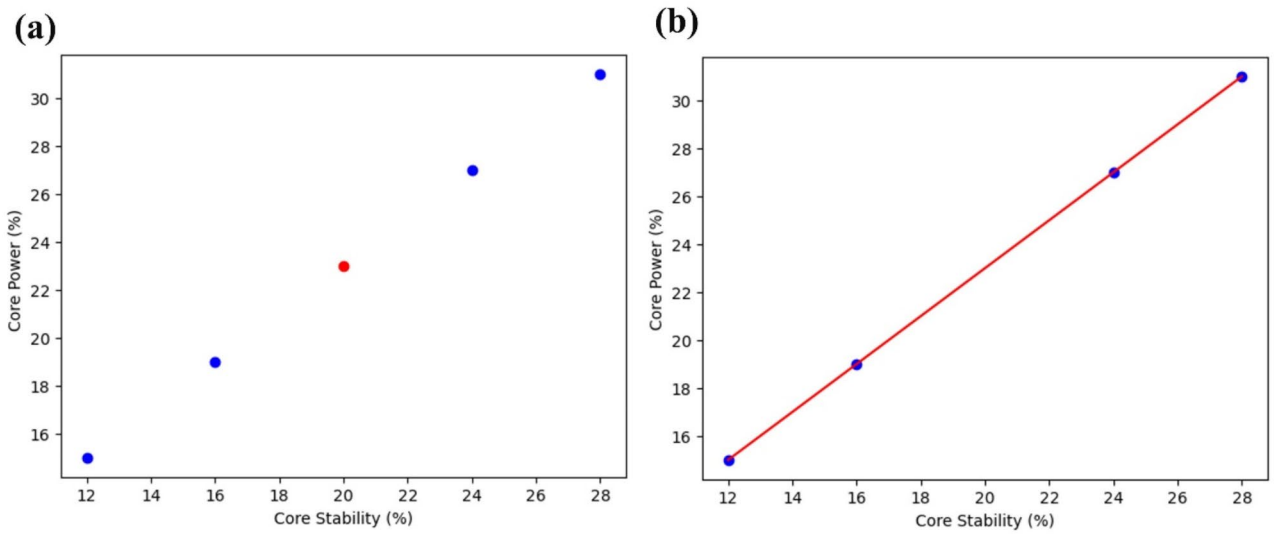

Fig. 16. The blue color represents the things that have been learned, while the red color represents the things that the machine considered as a test (**A**). A line graph drawn with the help of machine learning (**B**).

Data availability

All data generated or analysed during this study are included in this published article.

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Author contributions
Shuzhen Ma wrote the main manuscript text. Shuzhen Ma reviewed the manuscript.

Declarations

Competing interests
The authors declare no competing interests.

Ethical approval
Full name of the ethics committee: Guilin University of Technology. This study did not involve human subjects research as defined by Belmont Report. Data was collected through a voluntary anonymous questionnaire that did not pose any risks beyond those encountered in daily life. Informed consent was obtained from all participants.

Additional information
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