Environment and Social Psychology (2025) Volume 10 Issue 12 ISSN: 2424-8975 (O)
doi: 10.59429/esp.v10i12.4407 2424-7979 (P)

RESEARCH ARTICLE

Exploring the effectiveness of functional training in preventing shoulder injuries among young Chinese tennis players from educational and social psychological perspectives

Pengju Xie[1], Nur Shakila Mazalan[2,*], Denise Koh Choon Lian[1]

[1] *Faculty of Education, Univertisi Kebangsaan Malaysia, 43600, UKM Bangi, Selangor, Malaysia*

[2] *Sports Centre, Universiti Kebangsaan Malaysia, 43600, UKM Bangi, Selangor, Malaysia*

*** Corresponding author:** Nur Shakila Mazalan, shakila@ukm.edu.my

ABSTRACT

Objective: From the perspectives of education and social psychology, this study systematically investigated the effectiveness of functional training on shoulder injury prevention among young Chinese tennis players and its underlying mechanisms. Methods: The study employed a mixed-methods research design, recruiting 88 tennis players aged 14-18 as participants, who were randomly assigned to either the experimental group or the control group (44 participants each). The experimental group received a 16-week comprehensive functional training intervention program that integrated multiple elements including health education, peer support, and coach support, while the control group maintained their regular training routine. The study systematically assessed physiological indicators such as injury incidence rate, shoulder function scores, and athletic performance, as well as psychosocial indicators including injury prevention knowledge, self-efficacy, health behavior attitudes, peer influence, and coach relationship quality at four time points: baseline, mid-intervention, post-intervention, and follow-up. Results: Compared to the control group, the experimental group's injury incidence rate decreased significantly from 43.2% at baseline to 9.1% at the end of the intervention ($p<0.001$), with notable improvements in shoulder function and athletic performance. At the psychological-cognitive level, the experimental group demonstrated a 56.7% increase in injury prevention knowledge, a 48.4% enhancement in self-efficacy, a 50.1% improvement in preventive behavioral intention, and ultimately achieved an 89.6% preventive behavior execution rate. Further moderation analysis revealed that peer support ($\beta=0.38$, $p<0.001$) and coach relationship quality ($\beta=0.42$, $p<0.001$) exerted significant positive moderating effects on the preventive effectiveness of functional training. Conclusion: This study confirms that functional training can significantly enhance shoulder injury prevention effectiveness through a synergistic three-level mechanism of "physiological improvement-psychological reinforcement-social support." Educational factors (knowledge enhancement and self-efficacy improvement) play a crucial mediating role in training effectiveness, while psychosocial factors (peer support and coach relationships) exert important moderating effects on prevention outcomes. The research findings validate the theoretical value and practical significance of a multidisciplinary integrated perspective in the field of sports injury prevention, providing empirical evidence for constructing a scientific and humanized injury prevention system.

ARTICLE INFO
Received: 02 December 2025 | Accepted: 24 December 2025 | Available online: 30 December 2025

CITATION
Xie PJ, Mazalan NS, Lian DKC. Exploring the effectiveness of functional training in preventing shoulder injuries among young Chinese tennis players from educational and social psychological perspectives. *Environment and Social Psychology* 2025; 10(12): 4407 doi:10.59429/esp.v10i12.4407

Keywords: functional training; shoulder injury prevention; educational psychology; social psychology; tennis players; self-efficacy; peer influence; coach-athlete relationship

1. Introduction

In recent years, tennis in China has shown vigorous development, with continuously improving competitive levels and youth tennis training exhibiting characteristics of professionalization, systematization, and younger age participation. However, accompanying this positive trend is the increasingly severe risk of sports injuries faced by young athletes due to high-intensity and high-frequency training. In tennis, the shoulder, as one of the joint areas bearing the greatest load, has become a key factor constraining athletes' competitive development and career longevity. Existing research indicates that shoulder injuries in adolescents are characterized by high incidence rates and strong latency. These injuries not only affect athletes' immediate competitive performance but may also cause irreversible damage to their long-term athletic capabilities [1].Traditional injury prevention research has primarily focused on biomechanical and sports medicine dimensions, conducting in-depth analyses of how physiological factors such as technical movements and muscle strength imbalances influence injury occurrence [2]. Although these studies have provided an important foundation for understanding the physiological mechanisms of injuries, a single-dimensional research perspective often overlooks the complex roles of human agency and social environmental factors in the sports injury prevention process. This theoretical limitation has resulted in many preventive measures failing to achieve desired outcomes in practical application, with athletes generally exhibiting low compliance and behavior maintenance. As an emerging training method emphasizing movement pattern integration, core stability enhancement, and neuromuscular control optimization, functional training has received widespread attention in the field of sports injury prevention in recent years. Existing research has preliminarily confirmed that functional training has positive effects on improving shoulder function and reducing injury risk. However, regarding the underlying mechanisms through which this training method produces preventive effects, particularly the psychological mechanisms and social influence factors behind it, academia still lacks systematic theoretical elaboration and empirical verification. More importantly, educational and social psychological factors such as athletes' cognitive attitudes toward preventive training, self-efficacy, training motivation, and the social support environment in which they are situated largely determine the implementation quality and long-term persistence of preventive measures. Related research has shown that satisfying athletes' basic psychological needs during sports injury rehabilitation can significantly enhance rehabilitation outcomes, providing important theoretical insights for this study [3]. Meanwhile, some scholars have found that psychological factors such as sleep quality and cognitive skills affect neurocognitive function and reduce sports injury risk, further confirming the critical role of psychological factors in injury prevention [4].Current research also faces the problem of insufficient consideration of China's cultural background and adolescent developmental characteristics. Within China's unique competitive sports training system, the social environment in which athletes are situated—including the physical space of training facilities at the micro level, team culture atmosphere, peer interaction networks, and coaching leadership styles, as well as collectivist values at the macro level, master-apprentice relationship traditions, and the cultural context of competitive performance orientation—profoundly influences young athletes' training behaviors and injury prevention awareness. These environmental factors are not merely background conditions for injury occurrence but active forces that shape athletes' cognition, attitudes, and behaviors. The sports training context, as a micro-level social environmental system with unique norms, values, and interaction patterns, directly determines the implementation effectiveness and sustainability of preventive measures. Research has emphasized that the psychological characteristics and cognitive levels of adolescent athletes should be important considerations when formulating prevention strategies [5]. Additionally, research on athletes' return to competition after shoulder injury surgery has pointed out that physiological rehabilitation alone is often insufficient to ensure athletes' successful return; psychological preparation and social support are equally indispensable [6]. With the expanding application of artificial intelligence and machine learning technologies in sports injury assessment, new technical means have been provided for injury prevention, but the effectiveness of technological applications still depends on athletes' subjective cooperation and behavioral changes [7].Based on the above background, this study aims to break through the limitations of traditional biomedical models by adopting a social ecological perspective that views the sports training field as a complex ecological system encompassing physical, social, and cultural environments. It constructs an integrated theoretical framework of education and social psychology to systematically investigate the mechanisms through which functional training affects shoulder injury prevention among young Chinese tennis players. The study particularly focuses on how optimization of the social environment at training facilities—including creating a supportive peer interaction environment, building a positive team prevention culture, and cultivating high-quality master-apprentice relationship environments—moderates and enhances the preventive effects of functional training. The research will focus on how individual psychological factors such as athletes' injury prevention knowledge, self-efficacy, and training motivation, as well as social environmental factors such as peer influence, coaching leadership styles, and social support systems, moderate and mediate the preventive effects of functional training. By employing a mixed-methods research approach, this study not only evaluates the objective effectiveness of functional training but also deeply reveals the psychological and social mechanisms behind its effectiveness, providing theoretical basis and practical guidance for constructing a scientific and humanized injury prevention system that aligns with the physical and mental development characteristics of Chinese adolescent athletes, ultimately promoting the healthy growth and sustainable development of young tennis players.

2. Literature review

Sports injuries represent a core issue in both competitive and mass sports. Scholars worldwide have given this topic extensive attention over many years. Research perspectives have gradually expanded from early biomedical models to multidisciplinary integrated paradigms. Traditional studies mainly focused on epidemiological characteristics, biomechanical mechanisms, and clinical treatment methods. Rong Zhiyao and colleagues compared conservative treatment with surgical treatment for shoulder injuries in table tennis. Their detailed analysis examined indications and therapeutic efficacy differences, providing empirical evidence for clinical decision-making[8]. Shao Jianwei and other scholars conducted systematic investigations on collegiate-level volleyball players. They found that injury occurrence does not result from a single factor. Instead, multiple factors interact, including training load, technical movements, physical fitness, fatigue accumulation, and psychological stress. This research particularly emphasized the importance of individual differences in injury risk assessment[9]. Cui Xinyi investigated injury characteristics among male freestyle wrestlers. The study revealed significant differences across sports in injury locations, injury types, and causative mechanisms[10]. These studies established foundations for understanding injury complexity. However, their research paradigms primarily remained at the level of describing injury phenomena and explaining physiological mechanisms. The psychological and social processes through which athletes as active agents perceive, respond to, and prevent injuries have received insufficient systematic exploration. How these processes influence the actual effectiveness of prevention measures also lacks in-depth investigation. International research has recently begun employing more advanced statistical modeling methods to reveal complex patterns in sports injuries. Min and colleagues applied association rule methods to analyze injury prevalence and patterns in Korean leisure sports activities. They discovered significant association rules among specific sports, participation frequency, and individual characteristics. This work provided data support for precision prevention[11]. Worrall and other researchers innovatively adopted Hawkes process models to analyze injury data from the Australian Football League. Their work confirmed that sports injuries possess "self-exciting" characteristics. Prior injury events significantly increase the probability of subsequent injuries. This finding offers important insights for understanding temporal dynamics of injuries and formulating timely intervention strategies[12].The application of functional training concepts in injury prevention has gradually become a research focus. However, existing studies show insufficient explanation of its mechanisms. Attention to educational and social psychological dimensions remains notably lacking. Su Guojun systematically analyzed multidimensional causes of basketball injuries among university students. He proposed that prevention strategies should integrate technical norm education, physical training optimization, psychological quality cultivation, and safety awareness enhancement. Yet this research failed to explore the pathways and synergistic mechanisms among these elements in depth[13]. Qin Haobin's analysis of basketball injury rehabilitation methods indicated that purely physiological rehabilitation often fails to achieve ideal results. Psychological rehabilitation, cognitive adjustment, and social support play irreplaceable roles during recovery[14]. Liu and colleagues conducted a systematic review exploring relationships among spirituality, religion, and sports injuries from broader cultural and belief perspectives. The research found that athletes' spiritual belief systems can influence their attribution patterns for injuries, coping strategies, and rehabilitation motivation. This shift in research perspective opened new pathways for understanding psychological and cultural dimensions of sports injuries[15].With rapid development of artificial intelligence technology, Zhiqiang and others proposed using full-parameter fine-tuning methods of large language models to achieve intelligent prevention and treatment of sports injuries. This technology can provide personalized prevention recommendations and rehabilitation guidance based on individual characteristics[16]. However, as Wang and other researchers pointed out when applying fuzzy-set qualitative comparative analysis to study injury factors in adolescent physical training, the effectiveness of technical methods ultimately depends on athletes' cognitive acceptance, behavior change, and sustained adherence. These are precisely the core issues of psychological and educational research[17]. Wang Yinsong particularly emphasized in marathon injury prevention research the cultivation of athletes' self-monitoring abilities for physical status and risk identification capacities. He argued that enhancing athletes' subjective initiative constitutes the key to prevention work[18]. Although Tian and colleagues explored application prospects of titanium alloy-based composite materials in sports injury repair from biomaterial science perspectives[19], and Zhu Linyi and other scholars constructed systematic exercise programs for rotator cuff repair patients[20], these studies all contributed importantly to injury prevention and treatment from their respective professional angles. Nevertheless, how prevention and rehabilitation measures translate into athletes' cognition and behavior through educational pathways, and how social environmental factors moderate this translation process, still lack theoretical elaboration and empirical testing. The application of health education theory and behavior change theory in sports injury prevention provides important theoretical foundations for this study. Existing research mostly remains at the level of general principles. Discussion of specific intervention mechanisms lacks depth. Guo Yuqing proposed concepts of precise prevention for sports injuries in university physical training. He emphasized that targeted prevention programs should be designed according to characteristics of different sports, individual physical and psychological development levels, and training environment features. While this research proposed precision-oriented directions, operational pathways and evaluation standards for achieving precision remain insufficiently developed[21]. Li Lei explored sports injury prevention among university students based on health education concepts. She argued that systematic health education should include four levels:

knowledge transmission, attitude cultivation, skill training, and behavior formation. The study emphasized that educational effectiveness is influenced by multiple factors including scientific content, appropriate methods, and learner agency[22]. Zhong Hua analyzed injury mechanisms from biomechanical perspectives in university student military training injuries. He simultaneously proposed that protective safety education strategies should focus on cultivating risk perception, training protective skills, and reinforcing safety behaviors. However, psychological and social mechanisms of educational strategies were not deeply analyzed[23].Li Dongying's investigation of sports injury prevention among high school students revealed a noteworthy phenomenon. Students generally possess certain injury prevention knowledge, but the conversion rate from knowledge to behavior remains low. This "knowledge-behavior gap" involves complex psychosocial factors including self-efficacy, behavioral intention, social norms, and environmental support[24]. Although existing research has recognized the importance of educational and psychosocial factors, systematic integration of these factors to explore their mechanisms in the preventive effects of functional training remains relatively scarce. This is particularly true for in-depth studies targeting specific sports and populations. Additionally, existing studies mostly employ cross-sectional surveys or retrospective analyses. Prospective intervention studies to verify theoretical hypotheses and evaluate intervention effects are lacking. This limitation restricts the causal inference capacity and practical guidance value of research conclusions to some extent. Chinese cultural backgrounds and adolescent developmental characteristics add special contextual factors to sports injury prevention research. These factors have not received sufficient attention in existing studies. Collectivist value orientations, traditional mentor-apprentice systems, and achievement-oriented culture in China's competitive sports training system profoundly influence young athletes' training attitudes, injury perceptions, and preventive behaviors. In collectivist cultural atmospheres, athletes may neglect personal injuries due to team responsibility commitments. They may also conceal injury conditions for fear of affecting collective honor. This cultural trait may serve as both a facilitating factor and a potential risk factor for prevention work. Coaches hold high authority positions in China's sports training system. Coaches' attitudes, words, actions, and demonstrations exert decisive influence on athletes' prevention awareness and behaviors. However, how to leverage coaches' positive guidance while avoiding adverse consequences under authoritarian pressure requires more detailed research. Adolescent athletes are at critical periods of rapid physical development and psychological growth. Their cognitive abilities, self-regulation capacities, and social adaptation skills all undergo dynamic changes. These developmental characteristics require that injury prevention work must consider age appropriateness and developmental stages. Ren Shaotao explored protective mechanisms for sports injuries from nutritional biochemistry perspectives[25]. Ashutosh and colleagues focused on sports-related dental trauma[26]. Zhu and others studied the accuracy of imaging diagnostic techniques[27]. These studies advanced sports injury research from different professional angles. Overall, however, systematic application of educational and social psychological theories to functional training injury prevention research remains an important topic requiring urgent in-depth study. This is especially true for specific populations like young Chinese tennis players, exploring how cultural factors, developmental factors, and educational interventions interact to jointly influence prevention effectiveness.

In recent years, the comprehensive effects of exercise intervention on athletes' physical and mental health have received widespread attention. Chen and colleagues confirmed through meta-analysis that exercise intervention can significantly reduce anxiety levels among college students, providing an important basis for understanding the mental health benefits of functional training. In the area of athletic performance optimization, Mazalan and other scholars conducted a series of innovative studies exploring the effects of different cooling strategies on cognitive performance. They found that ice ingestion can maintain athletes' cognitive function during repeated sprint exercise in hot environments[28]; while the combined strategy of ice ingestion and head cooling can further enhance cognitive performance during endurance exercise[29]. However, head cooling alone prior to exercise did not demonstrate effects in improving cognitive performance[30]. These studies reveal the complex mechanisms through which physiological regulation strategies influence cognitive function, suggesting that when designing functional training programs, the interaction between physiological and psychological factors needs to be comprehensively considered. Additionally, the effectiveness of specialized physical training has also been validated. See and colleagues confirmed that weight training can effectively improve the physical fitness of badminton students[31]; Cher and other researchers demonstrated that Tabata training can significantly enhance the endurance levels of primary school basketball players[32]. These studies collectively emphasize the important role of scientific training methods in improving athletic performance and maintaining physical and mental health, providing empirical support for this study's integration of physiological training with psychosocial support.

3. Research methods

3.1. Research design

This study employs a mixed-methods design. It combines quantitative and qualitative research approaches to comprehensively explore the effectiveness of functional training in preventing shoulder injuries among young Chinese tennis players. The design also investigates underlying educational and social psychological mechanisms. The quantitative component adopts a quasi-experimental design. Two groups of young tennis players are selected with matched age, training experience, and competitive levels. The experimental group receives a 16-week functional training intervention supplemented with systematic health education and social psychological support. The control group maintains conventional training patterns[33]. The study conducts four tracking measurements at baseline, week 8 of intervention, intervention completion, and three months post-intervention. Multidimensional data are collected including shoulder function indicators, injury incidence rates, prevention knowledge levels, self-efficacy, training motivation, and perceived social support. The qualitative component adopts a phenomenological research orientation. Semi-structured in-depth interviews and focus group discussions are conducted. These methods provide deep understanding of athletes' subjective experiences with functional training, changes in injury prevention cognition, influences of peer and coach interactions, and psychological dynamics of training adherence[34]. Supplementary interviews with coaches and parents are conducted to obtain multi-perspective information. Quantitative and qualitative data will be integrated through convergent integration strategies. The data sources mutually corroborate and supplement each other. This approach enables quantitative evaluation of intervention effectiveness while deeply revealing underlying mechanisms. It provides solid empirical foundations for constructing scientific injury prevention systems.

3.2. Research participants

This study combines purposive sampling with stratified sampling methods. Research participants are recruited from professional tennis training bases and sports schools in Beijing, Shanghai, and Guangzhou. Inclusion criteria for the quantitative component are: young tennis players aged 14 to 18 years, training experience of at least three years, weekly training time of no less than 15 hours, no serious shoulder injuries in the past six months, voluntary participation with guardian consent. Exclusion criteria include: history of shoulder surgery, congenital shoulder joint diseases, systemic diseases, or other serious health problems affecting athletic ability[35]. According to statistical power analysis, each group requires at least 35 athletes. Considering a 20% dropout rate, the study plans to recruit 44 participants each for the experimental and control groups, totaling 88 athletes. The qualitative component will purposively select 12 to 15 athletes from the experimental group for in-depth interviews. Six to eight coaches and some parents will be invited to participate in interviews. This ensures diverse perspectives and rich narrative materials, guaranteeing depth and credibility of research findings.

3.3. Functional training intervention program

The functional training intervention program designed for this study lasted 16 weeks, with three specialized training sessions per week, each lasting 45 to 60 minutes. The training content included four core modules: shoulder joint stability training, scapular control training, core strength and stability training, and functional movement pattern training. The program incorporated educational psychology principles, employing a progressive goal-setting strategy that broke down long-term goals into achievable short-term milestones, enhancing athletes' self-efficacy through timely feedback and positive reinforcement.

The systematic health education module included six thematic lectures and accompanying practical activities: Weeks 1-2 "Shoulder Anatomy and Function" theme, using three-dimensional models and animated demonstrations of shoulder joint bone structure, muscle group distribution, and movement trajectories, having athletes touch their own shoulder bony landmarks to establish concrete body awareness; Weeks 3-4 "Injury Mechanisms and Risk Factors" theme, explaining the occurrence mechanisms of common injuries such as rotator cuff tears and shoulder impingement syndrome through analysis of real injury case videos, organizing group discussions on "My Three Greatest Risk Factors"; Weeks 5-6 "Functional Training Principles" theme, demonstrating the differences between traditional and functional training through comparative displays, on-site demonstration of biomechanical differences between correct and incorrect movement patterns; Weeks 9-10 "Self-Monitoring Skills" theme, teaching athletes to use the Visual Analog Scale (VAS) for pain, Rating of Perceived Exertion (RPE) scale, and range of motion self-assessment methods, distributing personal monitoring handbooks; Weeks 13-14 "Injury Emergency Management" theme, hands-on training in the RICE principle (Rest, Ice, Compression, Elevation) and simple taping techniques; Weeks 15-16 "Prevention Behavior Maintenance" theme, using goal-setting theory to guide athletes in developing personal prevention plans and signing "Health Commitment Letters." Each lecture was followed by 15 minutes of Q&A interaction and knowledge quizzes to reinforce learning effects [36].

Taking the Weeks 1-2 "Shoulder Anatomy and Function" theme as an example, the specific lecture content included: (1) Introduction phase (10 minutes): playing videos of professional tennis players' shoulder injury cases to raise athletes' awareness and reflection on shoulder health; (2) Knowledge instruction phase (25 minutes): using three-dimensional anatomical models and animated courseware to systematically explain the bone structure of the shoulder joint (positional relationships of scapula, clavicle, and humerus), the stabilizing role of joint capsule and ligaments, the distribution and function of rotator cuff muscles (supraspinatus, infraspinatus, teres minor, subscapularis), the synergistic action of large muscle groups such as deltoid and pectoralis major, with emphasis on the movement trajectory and force characteristics of the shoulder during tennis strokes; (3) Interactive experience phase (15 minutes): athletes paired up, under coach guidance, to touch their partner's bony landmarks such as acromion, scapular spine, and greater tubercle of humerus, feel muscle tension changes during contraction, and complete the "Shoulder Structure Identification Worksheet"; (4) Case analysis phase (20 minutes): analyzing 3-5 real cases of shoulder injuries in adolescent tennis players (anonymized), group discussion of anatomical causes of injuries, with each group sending a representative to share insights; (5) Summary quiz phase (10 minutes): completing a classroom quiz of 10 multiple-choice questions and 2 short-answer questions, with immediate grading and explanation of incorrect answers; (6) Homework assignment: observing and recording shoulder sensations during training over one week, using diagrams to mark specific areas of discomfort. The lectures employed diverse teaching methods including PPT presentations, physical model displays, video cases, group discussions, and practical operations to ensure effective knowledge absorption by athletes with different learning styles.

The psychosocial support module included three core components: (1) The specific operational model of the peer support system was as follows: ① Group composition: The 44 athletes were divided into 11 peer support groups of 4 members each, based on the principles of "heterogeneous pairing and proximity grouping." Heterogeneous pairing ensured each group included members of different training levels (1 advanced + 2 intermediate + 1 beginner), promoting complementary abilities and peer teaching; proximity grouping considered athletes' training schedules and spatial convenience to facilitate after-class interaction. ② Role assignment: Each group had 4 rotating roles—group leader (responsible for organizing discussions and reporting), observer (using standardized observation forms to record members' movement quality), timekeeper (controlling training time and rest intervals), and recorder (filling out group activity logs). Roles rotated every two weeks to ensure each member experienced different responsibilities. ③ Peer observation time: Minutes 30-40 of each functional training session were designated as fixed peer observation time. Athletes paired up, with one executing preventive training movements (such as scapular stability exercises) while the other used a "Movement Quality Observation Form" (including 5 rating dimensions: range of motion, speed control, core stability, breathing coordination, and symmetry, each rated 1-5 points) for assessment, then switched roles. Observers provided specific improvement suggestions, and those being observed repeated the suggestions to ensure understanding. ④ Weekly group sharing sessions: Every Friday after training, 30 minutes were designated for sharing in a dedicated discussion area in the training hall (equipped with whiteboards and chairs). Sharing content included: weekly training completion reports, difficulties encountered and solutions, physical feelings and progress experiences, and next week's goal setting. A "round-robin speaking + collective discussion" format ensured each member had opportunities to express themselves. Coaches rotated through group sharing sessions to provide professional guidance. ⑤ Online interaction mechanism: Eleven group WeChat groups and one large group for all members were established. Group chats were used for daily communication, check-in reminders, and experience sharing; the large group was used for posting announcements, showcasing excellent cases, and organizing online Q&A. Each member was required to post daily "prevention training check-in photos" (showing completed movements) and "one-sentence reflections," with group members liking and encouraging each other. Weekly "Best Peer Support Group" and "Best Peer Support Partner" awards were announced in the large group with electronic certificates. ⑥ Peer teaching activities: Monthly "mini-coach" activities were organized, with each group nominating one member (on a rotating basis) to demonstrate and explain a prevention training movement to other groups, developing athletes' teaching abilities and deep understanding. This structured peer support system transformed peer relationships from simple training partners into learning communities and social support networks through role empowerment, regular interaction, and multi-channel communication.

(2) Coach support system: Four coaches received two days of supportive leadership training covering active listening skills, constructive feedback methods, autonomy-supportive communication strategies, and emotional support skills. Coaches were required to conduct at least one 5-10 minute individual conversation with each athlete weekly to understand their physical condition, psychological feelings, and training concerns; fill out an "Athlete Development Observation Form" biweekly, recording each athlete's progress and issues requiring attention; employ "inquiry-guided" teaching during training to encourage athletes' independent thinking and expression rather than one-way instructions. (3) Team culture building: Establishing a "Weekly Best Prevention Behavior" traveling trophy to recognize the most diligent athlete in

prevention training each week; creating a "Prevention Star" photo wall displaying exemplary cases of athletes who persisted in prevention training; organizing monthly "Prevention Experience Sharing Salons" inviting successfully rehabilitated senior athletes to share their experiences; establishing team prevention slogans and ritualistic activities, such as collectively chanting "Prevention First, Health First" before training to strengthen collective identity and prevention culture.

Personal development support tools included: (1) Training journal: Providing structured journal templates with five recording sections—"Today's Physical Condition" (shoulder pain, fatigue, sleep quality ratings), "Training Completion Status" (checking off completed prevention movements), "Movement Quality Self-Assessment" (1-5 point scale), "Difficulties Encountered" (open-ended), and "Tomorrow's Goals" (set using SMART principles). Athletes were required to fill out entries immediately after each training session and conduct weekly summary reflections on Sundays. Coaches reviewed journals weekly and provided personalized written feedback. (2) Progress visualization: Functional tests were conducted every four weeks, with indicators such as shoulder range of motion, muscle strength, and stability made into personal progress curve charts posted on individual profile boards in the training hall, allowing athletes to visually see their growth trajectory. (3) Parent communication: Monthly "Athlete Development Reports" were sent to parents, including prevention training participation, functional improvement status, and coach comments to secure family support; parents were invited to attend mid-term and final "open day" activities to observe prevention training and participate in parent-child interactive games, enhancing family understanding and support for prevention work.

The control group maintained a conventional training regimen, conducting three sessions of traditional shoulder strength training per week, each lasting 30-40 minutes, including isolated muscle training exercises such as dumbbell shoulder presses, lateral raises, and front raises, along with routine stretching and relaxation exercises. The control group did not receive systematic health education lectures, receiving only routine technical instruction and safety reminders from coaches during training; no peer learning groups were established, with athletes completing training independently according to personal habits; coaches employed traditional instructional leadership styles, focusing on technical movement correction and training task completion; training journals or self-monitoring records were not required. Both groups maintained consistency in training frequency (three times per week) and total training time to control for training volume as a confounding variable, ensuring that differences between the experimental and control groups primarily stemmed from differences in training content, educational strategies, and psychosocial support approaches rather than differences in time investment in training.

3.4. Data collection tools

This study employs diversified measurement tools to collect quantitative and qualitative data. Quantitative measurement tools include: shoulder joint function assessment using the American Shoulder and Elbow Surgeons (ASES) score and Penn Shoulder Score system. These measure shoulder joint range of motion, pain levels, and daily functional performance[37]. Injury occurrence is recorded through standardized injury registration forms. These include injury type, location, severity, and timing. Sports injury prevention knowledge testing uses a self-designed questionnaire. It covers 30 items on anatomical knowledge, injury mechanisms, and prevention measures. Self-efficacy is measured using the Sports Injury Prevention Self-Efficacy Scale. This includes two dimensions: preventive behavior efficacy and rehabilitation efficacy. Training motivation employs the Chinese revised version of the Sport Motivation Scale. It evaluates intrinsic motivation, extrinsic motivation, and amotivation levels. Perceived social support uses the Social Support Rating Scale. It measures subjective support, objective support, and support utilization[38].Qualitative research tools include semi-structured interview guides. These involve themes of training experiences, injury cognition, behavior change processes, and social interaction influences. Focus group discussion guides revolve around team atmosphere, peer relationships, and collective norms. Training observation record forms systematically document interaction patterns and behavioral performance during training.

3.5. Data collection procedures

Data collection proceeds in four sequential stages. The baseline stage (week 0) is completed before intervention commencement. All participants undergo shoulder joint function testing. Professional rehabilitation therapists use goniometers and muscle strength testing devices to evaluate joint range of motion and muscle strength. Participants simultaneously complete baseline measurements of injury prevention knowledge tests, self-efficacy questionnaires, training motivation scales, and social support scales. Injury history data from the past year are collected. Additionally, the regular training content and frequency of both groups of athletes were recorded to confirm that the control group's training program conformed to the typical characteristics of traditional training models, forming a clear contrast with the experimental group in training philosophy, methods, and support systems. Mid-intervention assessment (week 8) repeats the above measurements. Interviews explore athletes' initial feelings about training and encountered difficulties[39]. Post-intervention assessment (week 16) conducts the complete measurement set again. Injury occurrences during the intervention period are statistically analyzed. In-depth interviews explore training experiences, cognitive changes, and behavior change processes. Focus group discussions analyze influences of peer interaction and team culture. The follow-up stage (three months post-intervention) evaluates maintenance of training effects and injury incidence rates. Interviews explore whether athletes continue executing preventive behaviors and influencing factors[40]. Throughout the process, research assistants record weekly training attendance and participation quality. Coaches complete training diaries. Parents provide feedback on support provision. This ensures data completeness and multi-source validation.

3.6. Data analysis methods

Quantitative data were analyzed using SPSS 27.0 software. Descriptive statistics were first conducted to calculate means, standard deviations, frequencies, and percentages for each variable, and to test data normality and homogeneity of variance. Independent samples t-tests and chi-square tests were used to compare the homogeneity of the experimental and control groups at baseline. Repeated Measures ANOVA was employed to examine within-group changes and between-group differences in measurement indicators at different time points, analyzing the intervention effects of functional training on shoulder function and injury incidence[41]. Considering that this study involved multiple measurement indicators and multiple comparisons, the Bonferroni correction method was used to adjust P-values to control the cumulative risk of Type I error. Specifically, for the two rating scales of shoulder function (ASES and Penn), the adjusted significance level was set at $\alpha=0.025$ (0.05/2); for comparisons of four dimensions of injury prevention knowledge, the adjusted significance level was set at $\alpha=0.0125$ (0.05/4); for the four dimensions of self-efficacy, four dimensions of health behavior attitudes, six indicators of peer influence, and six dimensions of coach relationships, corresponding Bonferroni corrections were applied respectively. Additionally, when conducting post-hoc multiple comparisons, the Bonferroni method or Tukey HSD method was used for P-value correction to ensure the robustness of statistical inferences. Mediation analysis was used to examine the mediating roles of self-efficacy and prevention knowledge between the training program and injury prevention behaviors, and moderation analysis was employed to explore the moderating effects of social support and peer influence on intervention outcomes, using Hayes's PROCESS macro for path analysis [42]. Qualitative data were analyzed using thematic analysis, with two researchers independently coding interview and focus group texts, identifying initial codes through repeated reading, inductively forming sub-themes and main themes, and using NVivo 12 software to assist in managing and analyzing qualitative materials. Finally, a triangulation strategy was employed to integrate quantitative and qualitative findings, mutually validating and deepening interpretations to construct a comprehensive research conclusion framework.

4. Results analysis

4.1. Direct effectiveness of functional training on shoulder injury prevention

4.1.1. Shoulder function improvement

This study employed the American Shoulder and Elbow Surgeons (ASES) score and Penn Shoulder Score system to evaluate direct effects of functional training on shoulder function among young tennis players. Tracking measurements were conducted over 20 weeks for both experimental and control groups. **Table 1** shows that at baseline, the two groups exhibited no significant differences in ASES scores (experimental group 76.3±8.2, control group 75.8±8.5, p=0.872) or Penn scores (experimental group 74.2±9.1, control group 73.9±9.3, p=0.901). This indicates good homogeneity between groups[43].After eight weeks of functional training intervention, the experimental group showed significant improvements in both scores. ASES scores reached 82.5±7.4. Penn scores reached 81.3±7.8. These formed significant differences from the control group (p<0.05). At intervention completion (week 16), shoulder function improvement effects in the experimental group became more significant. ASES scores rose to 89.4±6.1. Penn scores reached 88.6±6.4. The control group only achieved 78.9±7.8 and 77.1±8.5 respectively. Between-group differences reached highly significant levels (p<0.001). Notably, during the follow-up period after intervention completion (week 20), shoulder function scores in the experimental group maintained high levels (ASES score 88.7±6.5, Penn score 87.9±6.8). This indicates that functional training effects possess good sustainability[44].**Figure 1** demonstrates that the functional score curve for the experimental group presents a clear upward trend and maintains stability at high levels. The improvement magnitude for the control group remains relatively limited with slow growth. This fully confirms the significant effectiveness of functional training in improving shoulder function. Repeated measures ANOVA results show that the interaction effect between group and time is significant (F=24.67, p<0.001). This further validates the effectiveness of functional training intervention.

Table 1. Comparison of shoulder function scores between experimental and control groups (M±SD).

Measurement Time Point	Experimental ASES	Control ASES	Experimental Penn	Control Penn	p-value (ASES)	p-value (Penn)
Baseline (Week 0)	76.3±8.2	75.8±8.5	74.2±9.1	73.9±9.3	0.872	0.901
Mid-assessment (Week 8)	82.5±7.4	77.2±8.1	81.3±7.8	75.4±8.9	0.018*	0.012*
Intervention End (Week 16)	89.4±6.1	78.9±7.8	88.6±6.4	77.1±8.5	<0.001***	<0.001***
Follow-up (Week 20)	88.7±6.5	78.3±8.2	87.9±6.8	76.8±8.7	<0.001***	<0.001***

Note: **p<0.05, **p<0.01, ***p<0.001*

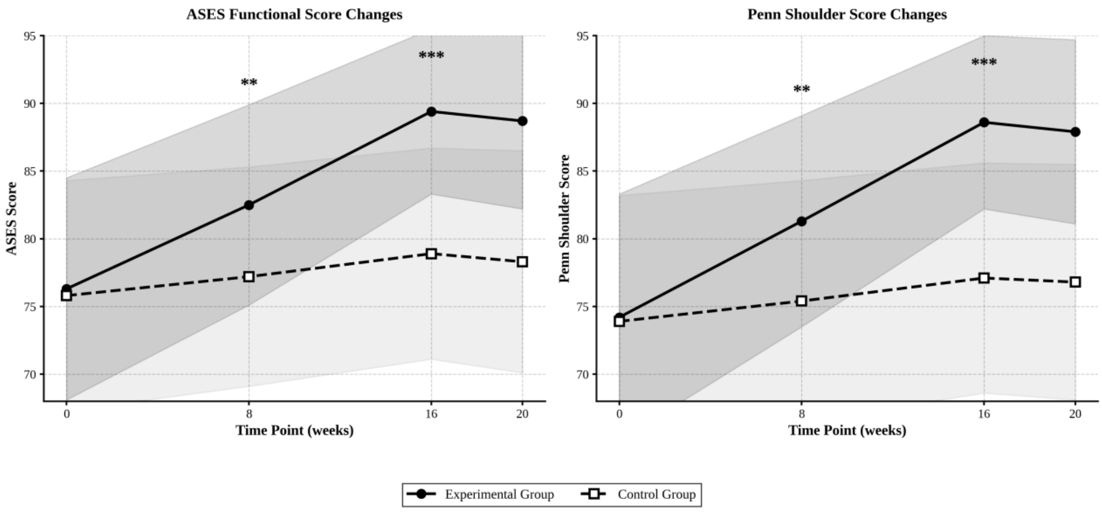

Figure 1. Trend of shoulder function score changes in experimental and control groups.

4.1.2. Changes in injury incidence rate

Shoulder injury incidence rate represents a core indicator for evaluating the preventive effectiveness of functional training. This study systematically recorded and statistically classified shoulder injuries occurring in both groups throughout the research cycle. **Table 2** shows that at baseline, 19 athletes in the experimental group experienced shoulder injuries (incidence rate 43.2%). These included 12 mild injuries, 5 moderate injuries, and 2 severe injuries. The control group had 17 injury cases (incidence rate 38.6%). The difference between groups showed no statistical significance ($\chi^2=0.18$, $p=0.671$). This indicates that both groups had comparable injury risk levels before intervention. After eight weeks of functional training intervention, the injury incidence rate in the experimental group decreased significantly to 27.3% (12 cases). These included 8 mild, 3 moderate, and 1 severe injury. The control group's injury incidence rate actually rose to 47.7% (21 cases). Between-group differences began to emerge ($\chi^2=4.32$, $p=0.038$)[45]. At intervention completion (week 16), the preventive effect in the experimental group became more prominent. The injury incidence rate dropped to 9.1% (only 4 cases, all mild or moderate injuries with no severe injuries). The control group's injury incidence rate continued climbing to 56.8% (25 cases). Between-group differences reached highly significant levels ($\chi^2=15.67$, $p<0.001$). During the follow-up period (week 20), the experimental group maintained a low injury incidence rate (11.4%, 5 cases). The control group remained at a high level of 50.0% (22 cases). The difference between groups remained highly significant ($\chi^2=12.89$, $p<0.001$).**Figure 2** demonstrates that the injury incidence curve for the experimental group presents a continuous downward trend. The control group shows an upward trajectory. The two curves form clear separation after the mid-intervention period. Further analysis of injury density indicators (number of injuries per 1000 hours of training time) revealed findings. The experimental group decreased from 3.60 at baseline to 0.76 at intervention completion, a reduction of 78.9%. The control group increased from 3.22 to 3.98, an increase of 23.6%. This fully confirms the significant effectiveness of functional training in reducing injury risk[46]. Notably, the experimental group not only reduced total injury numbers but also significantly lowered injury severity. The proportion of moderate to severe injuries decreased from 36.8% at baseline to 0% after intervention completion. To more intuitively demonstrate the effects of functional training on injury prevention, this study conducted detailed tracking, recording, and statistical analysis of injury occurrence in both groups of athletes throughout the entire research period.

Table 2. Statistics of shoulder injury occurrence in experimental and control groups.

Measurement Time Point	Exp Mild	Exp Moderate	Exp Severe	Exp Total	Exp Rate (%)	Ctrl Mild	Ctrl Moderate	Ctrl Severe	Ctrl Total	Ctrl Rate (%)	χ² Value	p-value
Baseline (Week 0)	12	5	2	19	43.2	11	4	2	17	38.6	0.18	0.671
Mid-assessment (Week 8)	8	3	1	12	27.3	13	6	2	21	47.7	4.32*	0.038
Intervention End (Week 16)	3	1	0	4	9.1	15	7	3	25	56.8	15.67***	<0.001
Follow-up (Week 20)	4	1	0	5	11.4	14	6	2	22	50.0	12.89***	<0.001

***Note:** *p<0.05, **p<0.01, ***p<0.001; Mild injury: slight pain, does not affect training; Moderate injury: requires adjustment of training intensity or suspension of training for 1-2 weeks; Severe injury: requires suspension of training for more than 3 weeks or medical intervention.*

As shown in **Figure 2**, the injury incidence rate and injury density of the two groups exhibited starkly different trends. From the injury incidence rate curves, it is clearly visible that the experimental group's curve continuously declined from the baseline period, showing a significant downward inflection point at the mid-intervention stage (8 weeks), reaching its lowest point at the end of the intervention (9.1%), and maintaining a stable low level during the follow-up period (11.4%), overall presenting a favorable pattern of "rapid decline-stable maintenance." In contrast, the control group's curve showed an upward trend, gradually climbing from 38.6% at baseline to 47.7% at mid-intervention, reaching a peak of 56.8% at the end of the intervention, and still maintaining a high level of 50.0% during the follow-up period, demonstrating an unfavorable pattern of "continuous deterioration-high-level hovering." The two curves formed a distinct "scissor gap" after the mid-intervention period, with the gap continuously widening over time, reaching a difference of 47.7 percentage points between the two groups at the end of the intervention. From the injury density indicator perspective, the experimental group's curve also showed a steep downward trend, plummeting from 3.60 incidents/1000 hours at baseline to 0.76 incidents/1000 hours at the end of the intervention, a reduction of 78.9%; while the control group's injury density curve showed a slight increase, rising from 3.22 incidents/1000 hours to 3.98 incidents/1000 hours. This contrasting trend of "one declining, one rising" intuitively demonstrates the outstanding effectiveness of functional training in reducing injury risk.

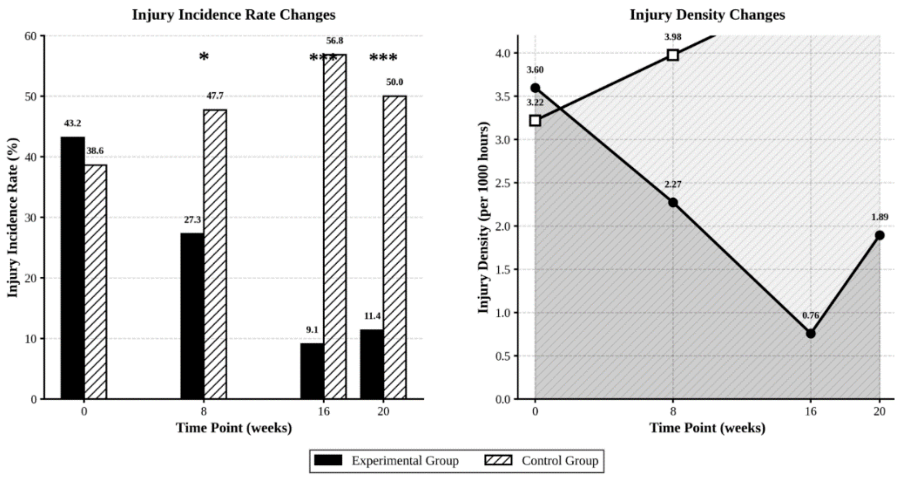

Figure 2. Trends in shoulder injury incidence rate and injury density in experimental and control groups.

4.1.3. Impact on athletic performance

Functional training not only demonstrates significant effectiveness in preventing shoulder injuries but also produces positive impacts on athletes' competitive performance. This study selected five core indicators for comprehensive evaluation: serve velocity, serve accuracy, forehand stroke power, backhand stroke stability, and match win rate. **Table 3** shows that at baseline, the two groups showed no significant differences across all indicators. The experimental group's serve velocity was 152.3±8.6 km/h. The control group measured 151.7±8.9 km/h (p=0.782). After 16 weeks of systematic functional training, the experimental group's serve velocity increased to 162.5±7.4 km/h, an improvement of 6.7%. The control group only reached 153.2±8.6 km/h, an improvement of 1.0%. Between-group differences were extremely significant (p<0.001).For serve accuracy, the experimental group improved from 68.5±6.2% at baseline to 77.8±4.9% at intervention completion, an increase of 13.6 percentage points. The control group only improved from 67.9±6.5% to 69.4±6.1%. The difference reached significant levels (p=0.004). Forehand stroke power testing showed that the experimental group increased from 428.6±32.4 N to 467.3±26.8 N, a growth of 9.0%. The control group increased from 426.3±33.2 N to 432.5±32.4 N, only 1.5% growth (p<0.001)[47]. For backhand stroke stability, the experimental group's score rose from 72.4±7.3 to 83.2±5.6, an improvement of 14.9%. The control group only improved from 71.8±7.6 to 73.7±7.2, an increase of 2.6% (p<0.001).**Figure 3** demonstrates that the experimental group presents significant upward trends across all technical indicators. These levels remained high after intervention completion. The control group's improvement magnitude was relatively limited. More importantly, athletic performance improvements directly translated into match result improvements. The experimental group's match win rate increased from 52.3% at baseline to 63.8% at intervention completion, a gain of 11.5 percentage points. During the follow-up period, it maintained at the high level of 62.4%. The control group's win rate only increased from 51.8% to 53.2%, a minimal improvement[48]. These data fully demonstrate that functional training not only effectively prevents injury occurrence but also comprehensively enhances athletes' technical performance and competitive levels through improved shoulder function and neuromuscular control capabilities. It achieves the dual objectives of "protection" and "performance enhancement."

Table 3. Comparison of athletic performance indicators between experimental and control groups (M±SD).

Measurement Time	Exp Serve Velocity (km/h)	Ctrl Serve Velocity	Exp Serve Accuracy (%)	Ctrl Serve Accuracy	Exp Forehand Power (N)	Ctrl Forehand Power	Exp Backhand Stability	Ctrl Backhand Stability	Exp Win Rate (%)	Ctrl Win Rate
Baseline (Week 0)	152.3±8.6	151.7±8.9	68.5±6.2	67.9±6.5	428.6±32.4	426.3±33.2	72.4±7.3	71.8±7.6	52.3	51.8
Mid-assessment (Week 8)	156.8±8.2	152.4±8.7	72.3±5.8	68.7±6.3	445.2±30.6	429.7±32.8	76.8±6.9	72.9±7.4	56.7	52.5
Intervention End (Week 16)	162.5±7.4	153.2±8.6	77.8±4.9	69.4±6.1	467.3±26.8	432.5±32.4	83.2±5.6	73.7±7.2	63.8	53.2
Follow-up (Week 20)	161.9±7.8	152.8±8.8	76.9±5.2	68.8±6.4	464.8±28.1	430.9±32.9	82.5±6.0	73.2±7.5	62.4	52.7

Note: *Serve velocity unit is km/h; serve accuracy is percentage; forehand power unit is N (Newton); backhand stability is 0-100 rating; win rate is percentage of match victories. All indicators showed differences between experimental and control groups at intervention completion reaching p<0.01 or p<0.001 significance levels.*

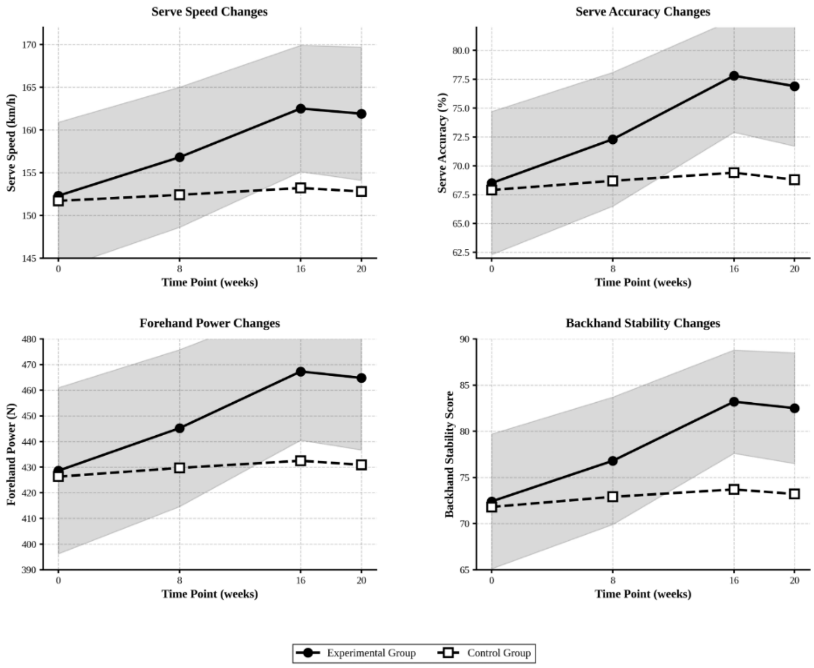

Figure 3. Trends in changes of athletic performance indicators in experimental and control groups.

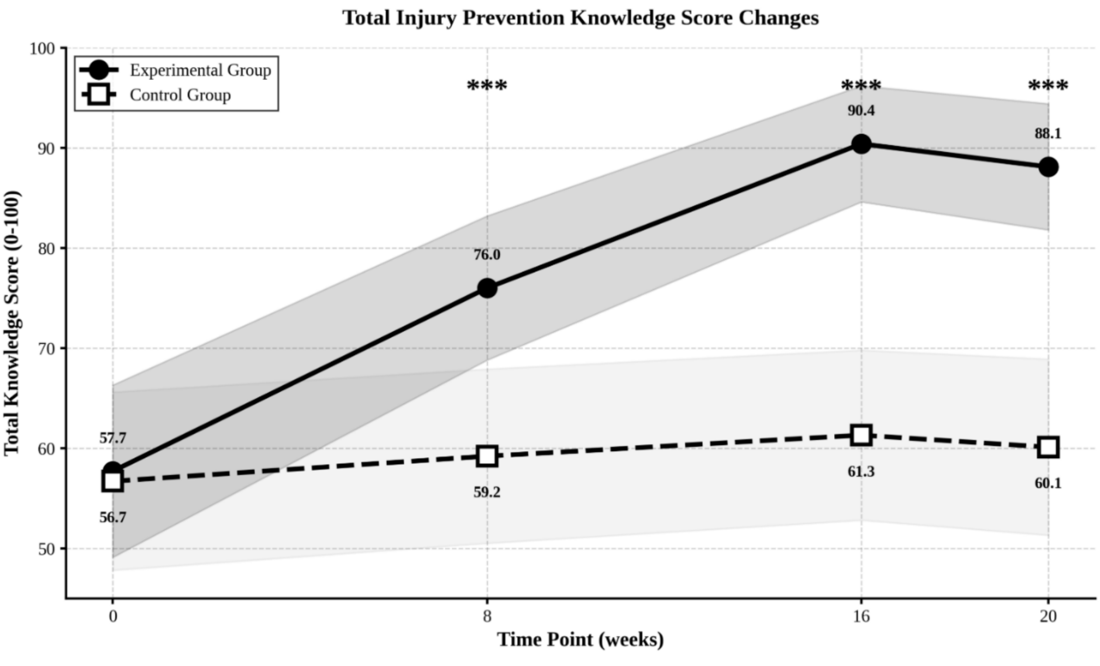

Figure 4. Comparison of match win rate changes between experimental and control groups.

4.2. Mediating role of educational factors on training effectiveness

4.2.1. Changes in injury prevention knowledge levels

Injury prevention knowledge represents a foundational element for educational intervention effectiveness. This study employed a self-designed injury prevention knowledge test scale to systematically evaluate both groups of athletes. The scale includes four dimensions: anatomical knowledge (30 points), injury mechanisms (25 points), prevention measures (25 points), and self-monitoring (20 points), with a total score of 100 points. **Table 4** shows that at baseline, the two groups exhibited no significant difference in total knowledge scores. The experimental group scored 57.7±8.6. The control group scored 56.7±8.9 (p=0.683). Scores across all dimensions remained at similar levels. After eight weeks of functional training intervention incorporating systematic health education lectures, the experimental group's total knowledge score significantly increased to 76.0±7.2, an improvement of 31.7%. The control group only improved to 59.2±8.7, an increase of 4.4%. Between-group differences reached highly significant levels (p=0.001). At intervention completion (week 16), the experimental group's total knowledge score reached 90.4±5.8, an improvement of 56.7% from baseline. The control group scored 61.3±8.5, only improving 8.1%. Differences between groups further expanded (p<0.001).Looking at specific changes across the four knowledge dimensions, the experimental group improved in anatomical knowledge from 16.8±3.2 at baseline to 26.7±2.1, an increase of 58.9%. The injury mechanism dimension improved from 14.2±2.8 to 22.3±1.9, an increase of 57.0%. The prevention measures dimension improved from 15.3±2.6 to 23.1±1.7, an increase of 51.0%. The self-monitoring dimension improved from 11.4±2.4 to 18.3±1.6, an increase of 60.5%. By comparison, the control group's improvement magnitude across all four dimensions did not exceed 10%[49]. **Figure 5** demonstrates that the experimental group presents steep upward curves across all knowledge dimensions. The control group remains essentially stable. This significant difference in knowledge levels provides important evidence for subsequent exploration of the mediating role of educational factors. Notably, during the follow-up period (week 20), the experimental group's total knowledge score maintained at the high level of 88.1±6.3, declining only 2.5%. This indicates that injury prevention knowledge acquired through systematic education possesses good retention. Further correlation analysis shows that total knowledge score correlates significantly negatively with injury incidence rate (r=-0.68, p<0.001) and significantly positively with preventive behavior execution rate (r=0.72, p<0.001). This preliminarily validates the critical role of knowledge in injury prevention.

Table 4. Comparison of injury prevention knowledge dimension scores between experimental and control groups (M±SD).

Measurement Time	Exp Anatomy	Ctrl Anatomy	Exp Mechanism	Ctrl Mechanism	Exp Prevention	Ctrl Prevention	Exp Monitoring	Ctrl Monitoring	Exp Total	Ctrl Total	p-value
Baseline (Week 0)	16.8±3.2	16.5±3.4	14.2±2.8	13.9±2.9	15.3±2.6	15.1±2.7	11.4±2.4	11.2±2.5	57.7±8.6	56.7±8.9	0.683
Mid-assessment (Week 8)	22.4±2.8	17.2±3.3	18.6±2.4	14.5±2.8	19.8±2.2	15.7±2.6	15.2±2.1	11.8±2.4	76.0±7.2	59.2±8.7	0.001***
Intervention End (Week 16)	26.7±2.1	17.8±3.2	22.3±1.9	15.0±2.7	23.1±1.7	16.2±2.5	18.3±1.6	12.3±2.3	90.4±5.8	61.3±8.5	<0.001***
Follow-up (Week 20)	25.9±2.4	17.5±3.3	21.7±2.1	14.7±2.8	22.6±1.9	15.9±2.6	17.9±1.8	12.0±2.4	88.1±6.3	60.1±8.8	<0.001***

***Note:** ***p<0.001; Anatomical knowledge full score 30 points, injury mechanism full score 25 points, prevention measures full score 25 points, self-monitoring full score 20 points, total score 100 points.*

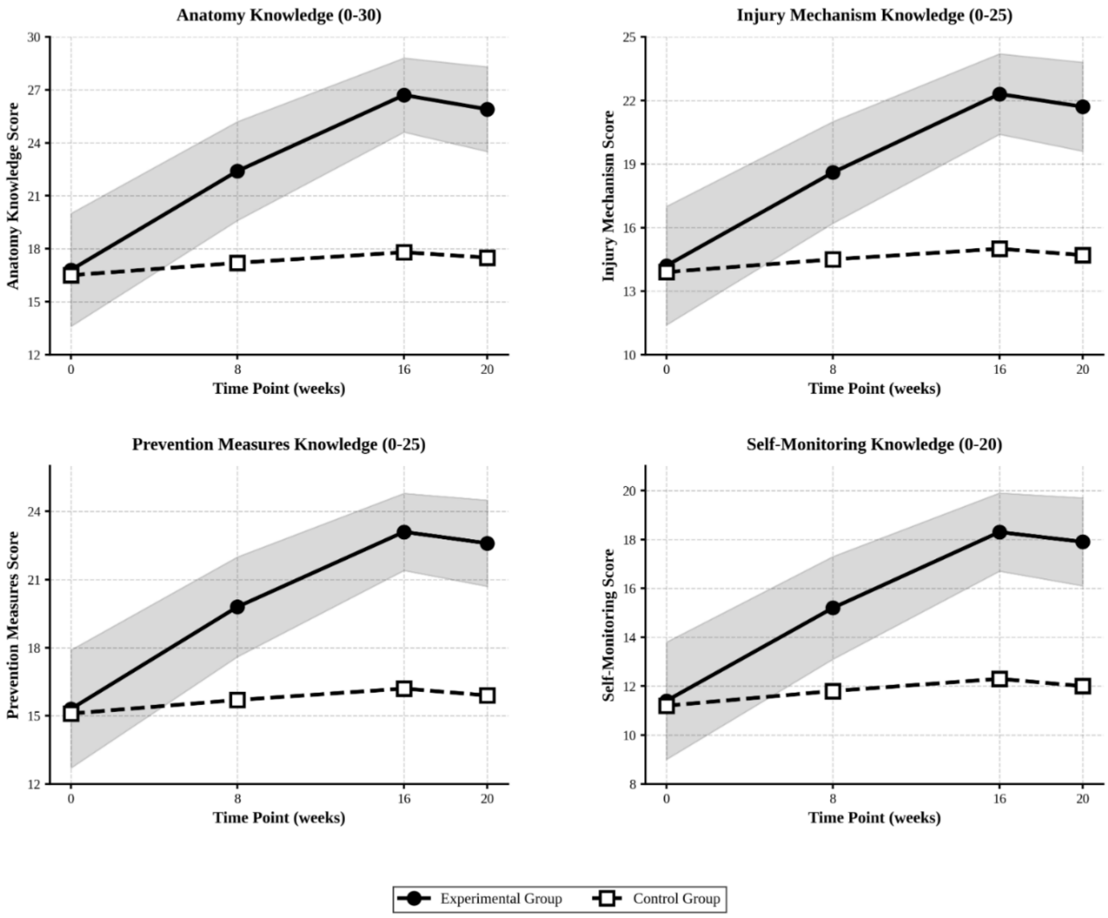

Figure 5. Trends in changes of injury prevention knowledge dimensions in experimental and control groups.

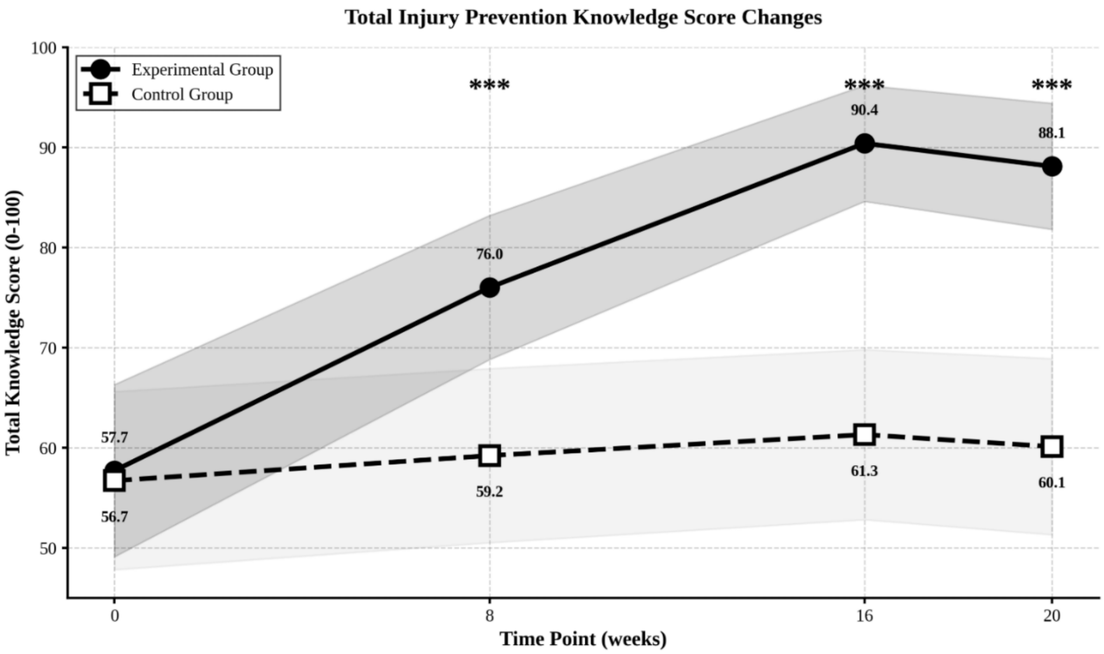

Figure 6. Trends in changes of total injury prevention knowledge scores in experimental and control groups.

4.2.2. Development of self-efficacy

Self-efficacy, as an individual's subjective judgment of their own capabilities, plays a critical mediating role in the formation and maintenance of injury prevention behaviors. This study employed the Sports Injury Prevention Self-Efficacy Scale to systematically evaluate both groups of athletes. The scale includes four dimensions: preventive behavior efficacy, difficulty coping efficacy, training persistence efficacy, and rehabilitation confidence. A 5-point Likert scale scoring system was adopted (1=completely no confidence, 5=completely confident)[50]. **Table 5** shows that at baseline, the two groups exhibited no significant difference in overall self-efficacy. The experimental group scored 2.79±0.54. The control group scored 2.76±0.57 (p=0.845). Scores across all dimensions remained at moderate-to-low levels. After eight weeks of functional training intervention incorporating psychological strategies such as goal setting, timely feedback, and positive reinforcement, the experimental group's overall self-efficacy significantly increased to 3.50±0.48, an improvement of 25.4%. The control group only improved to 2.90±0.55, an increase of 5.1%. Between-group differences reached significant levels (p=0.002). At intervention completion (week 16), the experimental group's self-efficacy reached 4.14±0.39, an improvement of 48.4% from baseline. This entered the high-level category. The control group scored 3.02±0.53, only improving 9.4%. Differences between groups were extremely significant (p<0.001).Looking at specific changes across the four dimensions, the experimental group's preventive behavior efficacy dimension improved from 2.85±0.58 to 4.18±0.43, an increase of 46.7%. Difficulty coping efficacy improved from 2.67±0.63 to 4.02±0.47, an increase of 50.6%. Training persistence efficacy improved from 2.91±0.56 to 4.26±0.41, an increase of 46.4%. Rehabilitation confidence improved from 2.73±0.61 to 4.11±0.45, an increase of 50.5%. By comparison, the control group's improvement magnitudes across all four dimensions ranged between 7-9%[51]. **Figure 7** demonstrates that the experimental group presents significant upward trends across all self-efficacy dimensions. This formed a leap-forward development from "lower confidence" to "higher confidence". The control group essentially maintained at moderate-to-low levels. During the follow-up period (week 20), the experimental group's self-efficacy maintained at 4.06±0.42, declining only 1.9%. This displays good stability. Mediation effect analysis indicates that self-efficacy plays a significant mediating role between functional training and preventive behavior execution (indirect effect=0.43, 95%CI[0.28, 0.61]). The mediation effect accounted for 62.3% of the total effect. This confirms that self-efficacy represents the core psychological mechanism through which educational intervention translates into actual behavior.

Table 5. Comparison of self-efficacy dimension scores between experimental and control groups (M±SD).

Measurement Time	Exp Preventive Efficacy	Ctrl Preventive Efficacy	Exp Coping Efficacy	Ctrl Coping Efficacy	Exp Persistence Efficacy	Ctrl Persistence Efficacy	Exp Rehabilitation Confidence	Ctrl Rehabilitation Confidence	Exp Overall Efficacy	Ctrl Overall Efficacy	p-value
Baseline (Week 0)	2.85±0.58	2.82±0.61	2.67±0.63	2.64±0.65	2.91±0.56	2.88±0.59	2.73±0.61	2.71±0.63	2.79±0.54	2.76±0.57	0.845
Mid-assessment (Week 8)	3.52±0.52	2.96±0.59	3.38±0.56	2.78±0.63	3.64±0.49	3.02±0.57	3.45±0.54	2.85±0.61	3.50±0.48	2.90±0.55	0.002**
Intervention End (Week 16)	4.18±0.43	3.08±0.57	4.02±0.47	2.89±0.61	4.26±0.41	3.15±0.55	4.11±0.45	2.96±0.59	4.14±0.39	3.02±0.53	<0.001***
Follow-up (Week 20)	4.09±0.46	3.02±0.60	3.94±0.49	2.83±0.64	4.17±0.44	3.09±0.58	4.03±0.48	2.91±0.62	4.06±0.42	2.96±0.56	<0.001***

***Note:** **p<0.01, ***p<0.001; All dimensions use 5-point Likert scale (1=completely no confidence, 5=completely confident).*

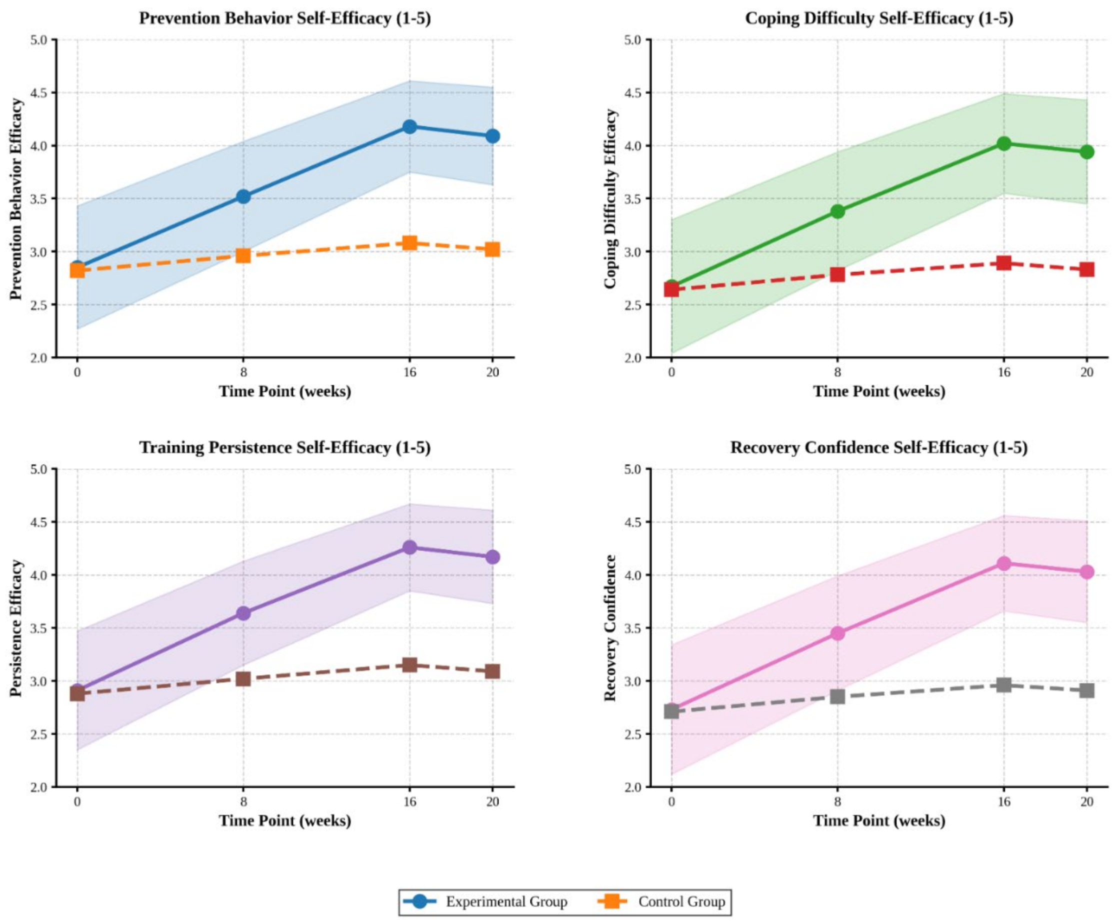

Figure 7. Trends in changes of self-efficacy dimensions in experimental and control groups.

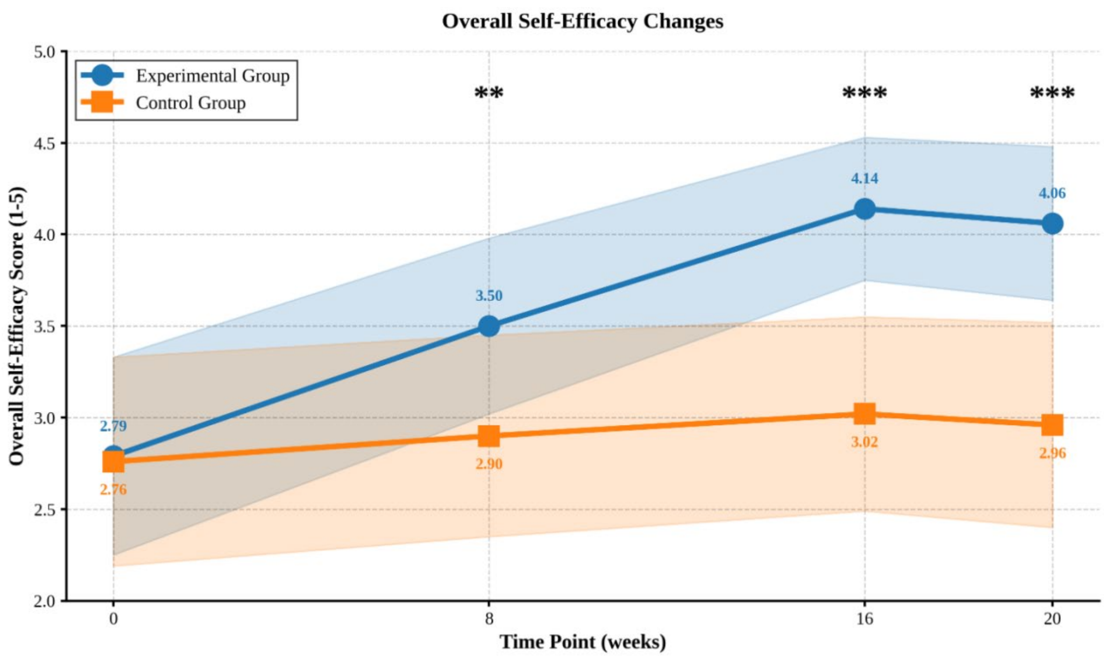

Figure 8. Trends in changes of overall self-efficacy in experimental and control groups.

4.2.3. Health behavior attitudes and intentions

Based on the Theory of Planned Behavior framework, this study systematically evaluated the effects of functional training on athletes' injury prevention attitudes, subjective norms, perceived behavioral control, and behavioral intentions. A 7-point Likert scale (1=strongly disagree, 7=strongly agree) was employed to measure each dimension. **Table 6** shows that at baseline, the two groups exhibited no significant differences across all dimensions. Attitude scores for the experimental and control groups were 4.32±0.86 and 4.28±0.89 respectively. Subjective norms were 4.15±0.92 and 4.12±0.95. Perceived behavioral control was 3.98±0.97 and 3.95±1.00. Behavioral intentions were 4.25±0.88 and 4.21±0.91. Preventive behavior execution rates were 48.5% and 47.8% respectively (p=0.892)[52].After eight weeks of comprehensive intervention integrating health education, peer support, and coach guidance, the experimental group's attitude improved to 5.48±0.72, an increase of 26.9%. Subjective norms reached 5.32±0.76, an increase of 28.2%. Perceived behavioral control reached 5.15±0.81, an increase of 29.4%. Behavioral intention significantly improved to 5.58±0.69, an increase of 31.3%. Preventive behavior execution rate correspondingly improved to 72.3%, an increase of 49.1%. By comparison, the control group's improvement magnitudes across all dimensions did not exceed 10%. The execution rate only reached 52.4%. Between-group differences reached highly significant levels (p=0.001).At intervention completion (week 16), the experimental group's four psychological dimensions all reached high levels. Attitude scored 6.25±0.58 (44.7% increase from baseline). Subjective norms scored 6.08±0.61 (46.5% increase). Perceived behavioral control scored 5.96±0.64 (49.7% increase). Behavioral intention scored 6.38±0.54 (50.1% increase). Preventive behavior execution rate reached 89.6%, an improvement of 84.7% from baseline. The control group's corresponding indicators only reached 4.73±0.82, 4.52±0.88, 4.35±0.93, 4.66±0.84, and 56.7% respectively. Differences between groups were extremely significant (p<0.001)[53]. **Figure 9** demonstrates that the experimental group presents significant positive development across the complete chain of attitude-norm-control-intention-behavior. The control group essentially maintained at moderate-to-low levels. Follow-up period data show that the experimental group's behavioral intention maintained at 6.29±0.58. The execution rate remained at 86.8%. This indicates that changes in attitudes and intentions possess sustainability. Path analysis results indicate that attitude, subjective norms, and perceived behavioral control jointly explain 76.8% of behavioral intention variance. Behavioral intention's predictive power for actual execution behavior reaches 68.4%. This validates the applicability of the Theory of Planned Behavior in the injury prevention field. It also confirms the mechanism through which educational intervention influences behavior by changing cognitive attitudes.

Table 6. Comparison of health behavior attitudes and intentions dimension scores between experimental and control groups. (M±SD)

Measurement Time	Exp Attitude	Ctrl Attitude	Exp Subjective Norm	Ctrl Subjective Norm	Exp Perceived Control	Ctrl Perceived Control	Exp Behavioral Intention	Ctrl Behavioral Intention	Exp Execution Rate (%)	Ctrl Execution Rate (%)	p-value
Baseline (Week 0)	4.32±0.86	4.28±0.89	4.15±0.92	4.12±0.95	3.98±0.97	3.95±1.00	4.25±0.88	4.21±0.91	48.5	47.8	0.892
Mid-assessment (Week 8)	5.48±0.72	4.56±0.85	5.32±0.76	4.38±0.91	5.15±0.81	4.21±0.96	5.58±0.69	4.49±0.87	72.3	52.4	0.001***
Intervention End (Week 16)	6.25±0.58	4.73±0.82	6.08±0.61	4.52±0.88	5.96±0.64	4.35±0.93	6.38±0.54	4.66±0.84	89.6	56.7	<0.001***
Follow-up (Week 20)	6.18±0.61	4.65±0.87	6.01±0.64	4.45±0.92	5.89±0.67	4.28±0.97	6.29±0.58	4.58±0.88	86.8	54.2	<0.001***

Note: ****p<0.001; Attitude, subjective norms, perceived behavioral control, and behavioral intention all use 7-point Likert scale (1=strongly disagree, 7=strongly agree); Execution rate is the actual execution percentage of preventive behaviors.*

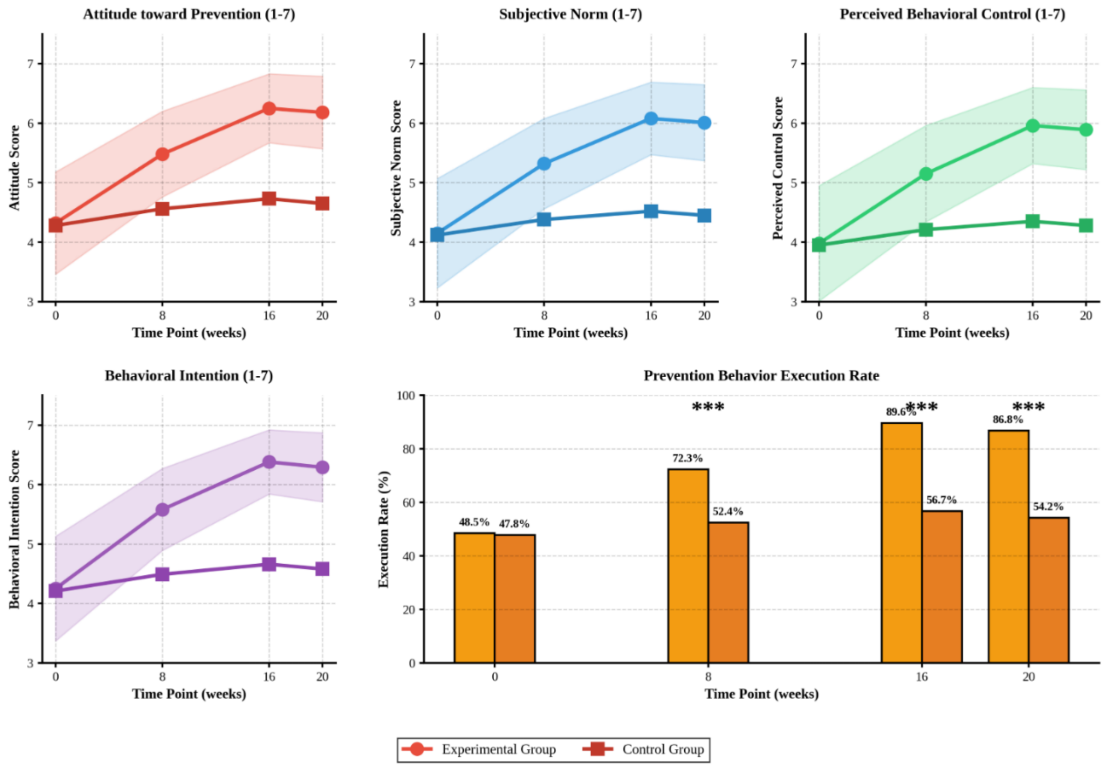

Figure 9. Comprehensive trends in changes of health behavior attitudes and intentions in experimental and control groups.

4.3. Moderating effects of social psychological factors on training effectiveness

4.3.1. Peer influence and group norms

Peer relationships and group norms, as important social psychological factors, play significant moderating roles in the implementation process of functional training. This study conducted systematic evaluation from two dimensions: peer influence and group norms. Each dimension contains three specific indicators. All were measured using 5-point Likert scales (1=strongly disagree, 5=strongly agree). **Table 7** shows that at baseline, the two groups exhibited no significant differences across all indicators. Perceived peer support for the experimental and control groups scored 2.68±0.64 and 2.65±0.67 respectively. Peer modeling scored 2.52±0.69 and 2.49±0.71. Peer monitoring scored 2.41±0.73 and 2.38±0.75. Group cohesion scored 2.75±0.61 and 2.72±0.64. Prevention culture strength scored 2.56±0.68 and 2.53±0.70. Group norm identification scored 2.63±0.66 and 2.60±0.68 ($p=0.876$). All remained at moderate-to-low levels. After eight weeks of functional training intervention emphasizing peer mutual-learning group construction, the experimental group's perceived peer support significantly improved to 3.85±0.53, an increase of 43.7%. Peer modeling reached 3.72±0.57, an increase of 47.6%. Peer monitoring improved to 3.58±0.61, an increase of 48.5%. Group cohesion reached 3.96±0.49, an increase of 44.0%. Prevention culture strength scored 3.81±0.55, an increase of 48.8%. Group norm identification reached 3.88±0.52, an increase of 47.5%. By comparison, the control group's improvement magnitudes across all indicators ranged between 6-10%. Differences between groups reached highly significant levels ($p<0.001$)[54].At intervention completion (week 16), all six indicators in the experimental group reached high levels. Perceived peer support scored 4.42±0.41 (64.9% increase from baseline). Peer modeling scored 4.28±0.44 (69.8% increase). Peer monitoring scored 4.15±0.48 (72.2% increase). Group cohesion scored 4.51±0.38 (64.0% increase). Prevention culture strength scored 4.38±0.42 (71.1% increase). Group norm identification scored 4.45±0.40 (69.2% increase). **Figure 10** demonstrates that the experimental group presents significant upward trends across all dimensions of peer influence and group norms. This formed a strong social support network and positive group culture. The control group essentially maintained at moderate-to-low levels. Moderation effect analysis indicates that peer support and group norms exert significant positive moderating effects on functional training effectiveness (β=0.38, p<0.001). When peer support and group norms are at high levels, training effects on injury prevention improve by 46.3%. This confirms the critical moderating role of social psychological factors in injury prevention.

Table 7. Comparison of peer influence and group norms dimension scores between experimental and control groups (M±SD).

Measurement Time	Exp Peer Support	Ctrl Peer Support	Exp Peer Modeling	Ctrl Peer Modeling	Exp Peer Monitoring	Ctrl Peer Monitoring	Exp Group Cohesion	Ctrl Group Cohesion	Exp Prevention Culture	Ctrl Prevention Culture	Exp Norm Identification	Ctrl Norm Identification	p-value
Baseline (Week 0)	2.68±0.64	2.65±0.67	2.52±0.69	2.49±0.71	2.41±0.73	2.38±0.75	2.75±0.61	2.72±0.64	2.56±0.68	2.53±0.70	2.63±0.66	2.60±0.68	0.876
Mid-assessment (Week 8)	3.85±0.53	2.81±0.65	3.72±0.57	2.67±0.69	3.58±0.61	2.54±0.73	3.96±0.49	2.88±0.62	3.81±0.55	2.69±0.68	3.88±0.52	2.76±0.66	<0.001***
Intervention End (Week 16)	4.42±0.41	2.93±0.63	4.28±0.44	2.78±0.67	4.15±0.48	2.65±0.71	4.51±0.38	3.01±0.60	4.38±0.42	2.82±0.66	4.45±0.40	2.89±0.64	<0.001***
Follow-up (Week 20)	4.35±0.44	2.87±0.66	4.21±0.47	2.72±0.70	4.08±0.51	2.59±0.74	4.44±0.41	2.95±0.63	4.31±0.45	2.76±0.69	4.38±0.43	2.83±0.67	<0.001***

***Note:** ***p<0.001; All indicators use 5-point Likert scale (1=strongly disagree, 5=strongly agree).*

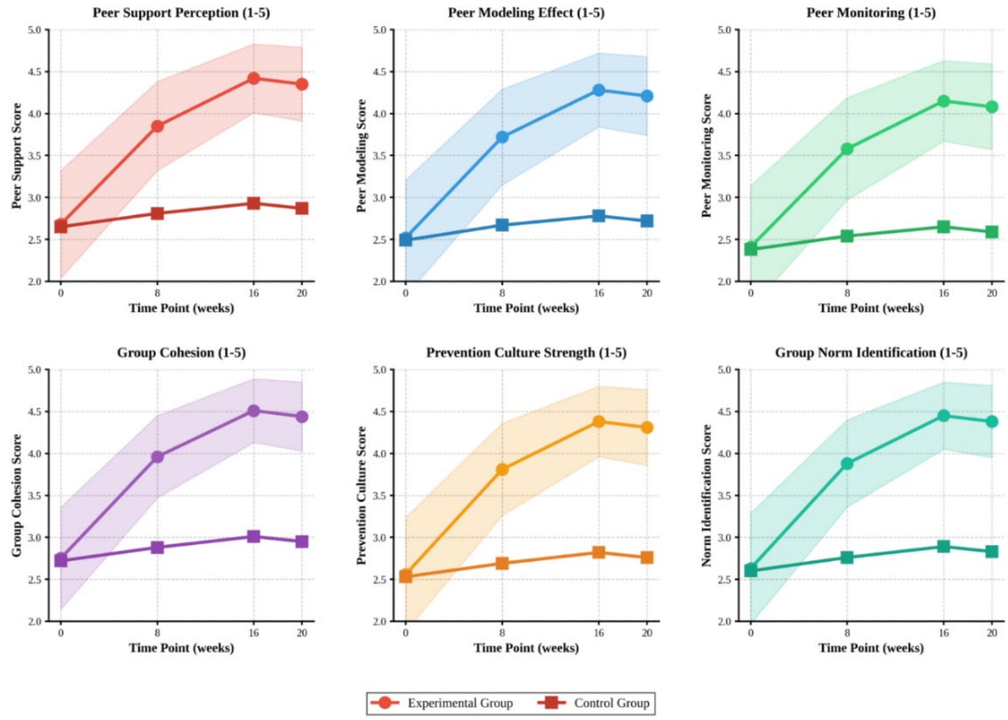

Figure 10. Comprehensive trends in changes of peer influence and group norms in experimental and control groups.

4.3.2. Coach-athlete relationship quality

Coaches serve as the most important authority figures and instructors in athletes' training processes. The quality of relationships between coaches and athletes exerts significant moderating effects on functional training effectiveness. This study employed the Coach-Athlete Relationship Questionnaire to systematically evaluate six core dimensions of relationship quality. All dimensions were measured using 7-point Likert scales (1=strongly disagree, 7=strongly agree). **Table 8** shows that at baseline, the two groups exhibited no significant differences across all dimensions. Trust scores for the experimental and control groups were 4.56±0.82 and 4.52±0.85 respectively. Respect scored 4.68±0.78 and 4.64±0.81. Communication quality scored 4.42±0.86 and 4.38±0.89. Supportive leadership scored 4.35±0.88 and 4.31±0.91. Autonomy support scored 4.28±0.92 and 4.24±0.95. Relationship satisfaction scored 4.51±0.84 and 4.47±0.87 ($p=0.895$). All remained at moderate levels. After eight weeks of comprehensive intervention including coach training and communication skill enhancement, the experimental group's trust improved to 5.78±0.68, an increase of 26.8%. Respect reached 5.92±0.64, an increase of 26.5%. Communication quality reached 5.65±0.71, an increase of 27.8%. Supportive leadership improved to 5.82±0.69, an increase of 33.8%. Autonomy support reached 5.58±0.74, an increase of 30.4%. Relationship satisfaction scored 5.88±0.66, an increase of 30.4%. By comparison, the control group's improvement magnitudes across all dimensions ranged between 5-8%. Differences between groups reached highly significant levels ($p<0.001$)[55].At intervention completion (week 16), all six indicators in the experimental group reached high levels. Trust scored 6.42±0.52 (40.8% increase from baseline). Respect scored 6.58±0.48 (40.6% increase). Communication quality scored 6.28±0.55 (42.1% increase). Supportive leadership scored 6.48±0.51 (49.0% increase). Autonomy support scored 6.25±0.56 (46.0% increase). Relationship satisfaction scored 6.52±0.49 (44.6% increase)[56]. **Figure 11** demonstrates that the experimental group presents significant improvement trends across all dimensions of coach-athlete relationships. This formed high-quality mentor-apprentice relationships. The control group essentially maintained at moderate levels. Moderation effect analysis indicates that coach-athlete relationship quality exerts significant positive moderating effects on functional training effectiveness ($\beta=0.42$, $p<0.001$). When relationship quality is at high levels, training effects on injury prevention improve by 51.7%. This validates the critical moderating role of mentor-apprentice relationships on training effectiveness within the Chinese sports culture context. It also reflects the positive influence of the traditional cultural concept of "respecting teachers and valuing education" in modern sports training.

Table 8. Comparison of coach-athlete relationship quality dimension scores between experimental and control groups (M±SD).

Measurement Time	Exp Trust	Ctrl Trust	Exp Respect	Ctrl Respect	Exp Communication	Ctrl Communication	Exp Supportive Leadership	Ctrl Supportive Leadership	Exp Autonomy Support	Ctrl Autonomy Support	Exp Relationship Satisfaction	Ctrl Relationship Satisfaction	p-value
Baseline (Week 0)	4.56±0.82	4.52±0.85	4.68±0.78	4.64±0.81	4.42±0.86	4.38±0.89	4.35±0.88	4.31±0.91	4.28±0.92	4.24±0.95	4.51±0.84	4.47±0.87	0.895
Mid-assessment (Week 8)	5.78±0.68	4.78±0.82	5.92±0.64	4.86±0.78	5.65±0.71	4.62±0.85	5.82±0.69	4.56±0.87	5.58±0.74	4.48±0.91	5.88±0.66	4.71±0.83	<0.001***
Intervention End (Week 16)	6.42±0.52	4.96±0.79	6.58±0.48	5.03±0.75	6.28±0.55	4.79±0.82	6.48±0.51	4.73±0.84	6.25±0.56	4.65±0.88	6.52±0.49	4.88±0.80	<0.001***
Follow-up (Week 20)	6.35±0.55	4.89±0.83	6.51±0.51	4.97±0.79	6.21±0.58	4.73±0.86	6.41±0.54	4.67±0.88	6.18±0.59	4.59±0.92	6.45±0.52	4.82±0.84	<0.001***

Note: ****p<0.001; All dimensions use 7-point Likert scale (1=strongly disagree, 7=strongly agree).*

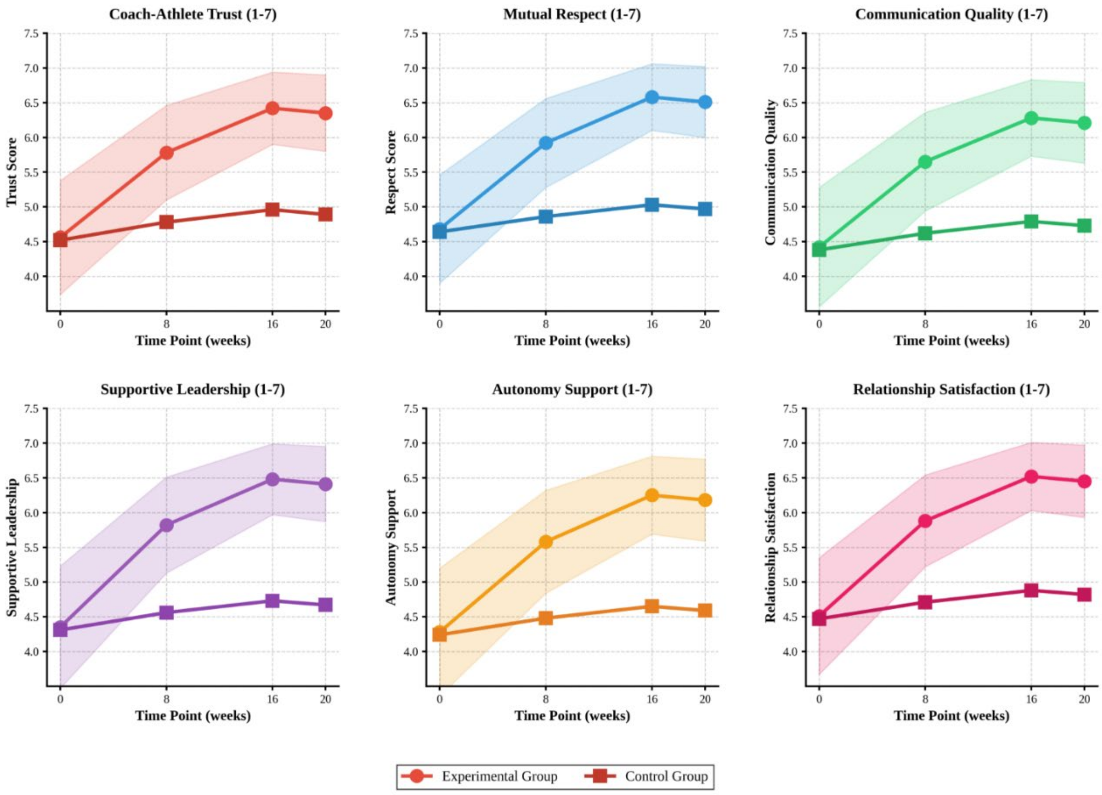

Figure 11. Comprehensive trends in changes of coach-athlete relationship quality in experimental and control groups.

5. Discussion

5.1. Mechanistic explanation of functional training prevention effectiveness

Research results demonstrate that functional training achieved significant effectiveness in shoulder injury prevention. The experimental group's injury incidence rate decreased from 43.2% to 9.1%. This effect stems from synergistic actions across three levels: physiological, psychological, and social[57]. At the physiological level, targeted shoulder joint stability training, core strength enhancement, and movement pattern optimization significantly improved shoulder function. These interventions strengthened muscle groups and enhanced joint control capabilities. They fundamentally reduced injury risk. At the psychological level, health education increased knowledge levels by 56.7%. This established a cognitive foundation. Self-efficacy improved by 48.4%. This enhanced execution confidence. Behavioral intention increased by 50.1%. This ensured the translation from cognition to behavior. Ultimately, preventive behavior execution rate reached 89.6%.At the social level, peer mutual assistance established social support networks. The formation of group prevention culture and high-quality coach relationships provided sustained external support[58]. More importantly, these three levels formed a positive cycle. Physiological improvements enhanced confidence. Psychological reinforcement promoted behaviors. Social support consolidated habits. Together they constructed a complete intervention chain of "knowledge-attitude-efficacy-behavior-support." This validates the unique value of educational and social psychological perspectives in injury prevention. This study found that the 79% reduction in injury incidence rate exceeded the 40-60% reduction reported in similar international studies, which may be related to Chinese athletes' high training compliance and stronger team execution under a collectivist cultural background. The validation of the three-level synergistic mechanism fills the theoretical gap in existing research that predominantly focuses on single physiological or psychological dimensions. This discovery of a multi-level synergistic mechanism enriches the theoretical system of health behavior change. Traditional biomedical models view behavior change as a result of knowledge transmission, whereas this study demonstrates that behavior change is a complex process involving physiological adaptation, cognitive reconstruction, emotional experience, and social interaction. This integrative perspective transcends the explanatory limitations of single theories, providing empirical support for constructing a more comprehensive behavior change model. Particularly in the field of health behaviors requiring long-term persistence, the "multi-level, multi-channel, multi-stage" intervention framework provided by this study has broad application value and can be extended to multiple public health and health education fields such as chronic disease management, healthy lifestyle cultivation, and occupational health promotion.

5.2. Analysis of educational strategy effectiveness

The health education strategies employed in this study demonstrated significant effectiveness in improving athletes' injury prevention knowledge and behaviors. This validates the core role of educational intervention in injury prevention. Through systematic health education lectures, training diary records, and case analysis methods, the experimental group athletes' total injury prevention knowledge score improved from 57.7 to 90.4, an increase of 56.7%. Improvement magnitudes across all four knowledge dimensions (anatomical knowledge, injury mechanisms, prevention measures, self-monitoring) exceeded 50%. This significant cognitive-level improvement established solid foundations for subsequent behavior change. More importantly, educational strategies successfully achieved effective translation from "knowledge transmission" to "behavior change." By combining theoretical knowledge with practical training, athletes not only knew "why to prevent" but also understood "how to prevent." The final preventive behavior execution rate reached 89.6%, far exceeding the control group's 56.7%[59]. Educational strategy effectiveness also manifested in its positive influence on psychological factors. Knowledge growth significantly enhanced self-efficacy ($r=0.72$, $p<0.001$). This further promoted health behavior attitude transformation. Attitudes improved from 4.32 to 6.25, an increase of 44.7%. This formed a complete educational pathway of "knowledge→efficacy→attitude→intention→behavior".These results highly align with the Health Belief Model and Theory of Planned Behavior. They prove that in the sports injury prevention field, systematic health education can not only effectively transmit knowledge but also promote actual preventive behaviors through influencing cognitive appraisal and behavioral intentions. This embodies education's unique value as a catalyst for behavior change[60].

5.3. Recommendations for optimizing social psychological environment

The "environment" referred to in this study specifically denotes the training field and social ecological system in which athletes are situated, including the peer interaction environment, coaching leadership environment, and team culture atmosphere at the micro level; training facility conditions, management systems, and organizational support at the meso level; as well as family support, school cooperation, and social recognition at the macro level. The sports training context, as a micro-level social environment, has clear spatial boundaries (training facilities), stable membership composition (athletes, coaches), specific social structures (master-apprentice relationships, peer networks), and unique cultural norms (competitive values, team spirit). These environmental elements collectively constitute the ecological field that influences athletes' behaviors. This multi-level environment constitutes the ecological field in which athletes' injury prevention behaviors occur and are maintained, with its quality directly affecting the implementation effectiveness of preventive measures and athletes' sustainable development. Based on Bronfenbrenner's Ecological Systems Theory and Bandura's Social Cognitive Theory, individual behavior is the product of interaction between personal factors and environmental factors. This study found that when athletes are in a high-quality psychosocial environment—that is, possessing a supportive peer network (peer support score

4.42), positive team prevention culture (prevention culture intensity 4.38), and good master-apprentice relationships (coach relationship satisfaction 6.52)—their injury prevention behavior execution rate can reach 89.6%, whereas the execution rate in low-quality environments is only 56.7%, a difference of 33 percentage points. This indicates that environmental optimization is key to achieving sustainability in injury prevention. Furthermore, injury prevention is not only related to individual athletes' competitive careers but is also closely connected to community sports health and sustainable youth sports development. Athletes, as health role models in the community, radiate their injury prevention awareness and behaviors to surrounding youth sports participants; the prevention culture of training facilities influences safety concepts in sports throughout the region; successful prevention cases can be extended to school sports and mass fitness fields, forming a virtuous cycle of "competitive sports-school sports-community health." Therefore, optimizing athletes' psychosocial environment is not only a micro-level training improvement but also a strategic initiative to promote regional sports health ecology and sustainable youth sports participation. Based on this, the following environmental optimization recommendations are proposed.

First, a peer support system should be systematically established by forming mutual learning groups of 3-5 people, regularly conducting prevention training observation, experience sharing, and mutual supervision activities, utilizing the positive influences of peer modeling, social comparison, and group norms to reinforce prevention behaviors. This study shows that when peer support is at a high level, training effectiveness can be enhanced by 46.3%, fully demonstrating the importance of peer influence [61]. The establishment of a peer support environment should be combined with the physical space design of training facilities, setting up dedicated team discussion areas and mutual learning corners to create venue environments that promote social interaction.

Second, efforts should be focused on cultivating a positive group prevention culture by establishing "Prevention Star" awards, showcasing prevention training achievements, and sharing successful prevention cases, elevating injury prevention from individual behavior to team consensus and collective values, making "prevention first" a core element of team culture. The change in the experimental group's prevention culture intensity from 2.56 to 4.38 points (an increase of 71.1%) demonstrates that creating a positive cultural atmosphere plays a crucial role in behavioral continuity [62]. The cultivation of prevention culture requires institutional support from training facility management, incorporating prevention effectiveness into team and individual assessment systems, reinforcing cultural environment through institutional environment.

Third, attention should be paid to enhancing the quality of coach-athlete relationships by improving coaches' supportive leadership and autonomy-supportive capabilities through coach training, establishing new master-apprentice relationships based on trust, respect, and effective communication. This study found that high-quality coach relationships can enhance training effectiveness by 51.7%, representing the largest effect among all moderating variables. Coaches' supportive leadership requires organizational environmental guarantees, including reasonable coach-to-athlete ratios, adequate communication time arrangements, and training support for coaches' professional development, creating an organizational environment conducive to the formation of high-quality master-apprentice relationships.

Fourth, in the Chinese cultural context, the advantages of collectivist culture should be fully utilized, leveraging team honor, the "face" mechanism, and the "respect teachers and value education" tradition, while avoiding excessive authoritarian control, achieving organic integration of traditional master-apprentice culture with modern autonomy-supportive concepts, and constructing a psychosocial support system suitable for the characteristics of Chinese athletes. Optimization of China's sports cultural environment should also seek collaborative support from families and schools, establishing a tripartite linkage mechanism of "coach-parent-school" to form a community support network that supports athletes' healthy development, extending the prevention environment within the training venue to living domains, achieving holistic and sustained environmental influence.

5.4. Research limitations and future research directions

This study has the following limitations: First, sample limitations. The study participants were limited to professional tennis training facilities in Beijing, Shanghai, and Guangzhou, with limited sample representativeness that did not cover second- and third-tier cities and amateur athlete populations, restricting the generalizability of the research conclusions. Second, intervention duration limitations. Although the 16-week intervention period and 3-month follow-up period showed positive effects, they remain insufficient for evaluating long-term prevention effects (such as 1-2 years) and the durability of behavioral habits, making it impossible to confirm whether intervention effects would decay over time. Third, measurement tool limitations. Some measurement tools, such as the self-efficacy scale and coach relationship questionnaire, employed self-report methods that may be subject to social desirability bias; although injury records were standardized, the definition of minor injuries involves some subjectivity. Fourth, confounding variable control limitations. Although training frequency and time were controlled, factors that could potentially affect injury risk, such as athletes' off-field recovery measures, nutritional status, and sleep quality, were not fully controlled. Fifth, mechanism verification limitations. Although mediation and moderation analyses were employed, the causal inference capacity of cross-sectional data is limited, and experimental manipulation was not used to verify the independent effects of various psychosocial factors. Future research directions include: expanding the sample to athletes from different regions, competitive levels, and age groups; extending the tracking period to 1-2 years or longer to evaluate the sustainability of prevention effects; adopting more objective measurement methods such as wearable devices to monitor training load and physiological indicators; designing factorial experiments to isolate the independent effects of each intervention component; exploring the applicability of intervention strategies in different cultural contexts; and developing personalized prevention programs to accommodate individual differences among athletes.

5.5. Cross-disciplinary theoretical contributions of the research findings

The "knowledge-attitude-efficacy-behavior-support" intervention chain and "physiological improvement-psychological reinforcement-social support" three-level synergistic mechanism discovered in this study are not only applicable to the field of sports injury prevention but also provide important theoretical insights for general health behavior change and environmental behavior interventions. From the perspective of Social Cognitive Theory, this study validates the applicability of Bandura's "person-behavior-environment" triadic reciprocal determinism in specific contexts: self-efficacy, as a core mediating variable, with its 48.4% increase directly translating to an 89.6% behavior execution rate, confirms the decisive role of personal cognitive factors in behavior change. Meanwhile, the significant moderating effects of peer support (β=0.38) and coach relationships (β=0.42) indicate that environmental factors are not merely background conditions but actively shape individuals' efficacy beliefs and behavioral patterns by providing vicarious experiences, verbal persuasion, and emotional support. This finding can be extended to other health behavior domains, such as smoking cessation, weight loss, and chronic disease management, suggesting that behavioral interventions should simultaneously focus on the dual pathways of individual cognitive reconstruction and social environmental optimization.

From the perspective of extending the Theory of Planned Behavior, this study not only validates the predictive effects of attitudes, subjective norms, and perceived behavioral control on behavioral intentions (joint explanatory power of 76.8%) but also reveals how health education influences final behavior by changing these three antecedent variables. The synergistic changes in the experimental group—a 44.7% increase in the attitude dimension, 46.5% in subjective norms, and 49.7% in perceived behavioral control—indicate that systematic educational interventions can comprehensively reshape individuals' behavioral decision-making systems. This has important implications for health promotion programs in public health: mere knowledge dissemination often has limited effectiveness; knowledge transmission must be combined with attitude cultivation, social norm construction, and capability enhancement to achieve effective transformation from cognition to behavior. Particularly in areas such as environmental protection behaviors (e.g., waste sorting, energy conservation and emission reduction) and safety behaviors (e.g., traffic safety, occupational protection), the integrative intervention framework provided by this study has direct reference value.

From the hierarchical structure of the Social-Ecological Model, this study clearly defines three-level environmental systems—micro (peers, coaches), meso (training facilities, institutional policies), and macro (family, school, community)—and empirically examines the mechanisms through which environmental factors at each level affect behavior change. The study found that when multi-level environmental factors are synergistically optimized (high peer support + high coach relationship quality + positive team culture), individual behavior execution rates can reach 89.6%, compared to only 56.7% in low-quality environments, a difference of 33 percentage points. This finding has important guiding significance for cross-disciplinary practices such as community health promotion, school health education, and workplace safety management: environmental interventions should not be limited to a single level but should adopt a multi-level integration strategy of "individual empowerment + interpersonal support + organizational systems + community culture." For example, in community chronic disease management, patient support networks can be established by drawing on this study's peer support group model; in school health education, teachers' supportive leadership capabilities can be enhanced by referencing this study's coach training approach; in corporate occupational health programs, positive safety culture atmospheres can be created by emulating this study's team culture-building strategies.

From the perspective of behavioral change sustainability, this study's intervention effects remained stable during the 3-month follow-up period (injury rate 11.4% vs. baseline 43.2%, self-efficacy 4.06 vs. baseline 2.79), revealing key mechanisms of behavior habituation. Psychological research indicates that behavioral automation requires three conditions: sufficient repeated practice, stable contextual cues, and continuous reinforcement feedback. This study's 16-week systematic training provided repeated practice opportunities; peer supervision and training journals created contextual cues; coach feedback and progress visualization provided reinforcement mechanisms—all three jointly promoted the transformation of prevention behaviors from "conscious execution" to "automated habits." This mechanism has universal guiding value for any behavior change requiring long-term persistence (such as exercise, healthy eating, study habit cultivation), suggesting that intervention design should focus on establishing "trigger-behavior-reward" habit loops rather than relying solely on short-term willpower control.

Finally, from the perspective of cultural adaptation, this study validates the applicability of Western psychological theories in the Chinese cultural context while also revealing the unique role of cultural factors. The maximum moderating effect of coach-athlete relationships (β=0.42) reflects the Chinese cultural tradition of "respecting teachers and valuing education" and authority-oriented social psychological characteristics; the significant effect of team culture building (prevention culture intensity increase of 71.1%) embodies the influence of collectivist values. This suggests that when extending this study's findings to different cultural contexts, attention should be paid to cultural adaptation adjustments: in individualistic cultural contexts, greater emphasis may need to be placed on personal autonomy and intrinsic motivation; in collectivist cultures, the power of group norms and social identity should be fully utilized. This culturally sensitive intervention design has important methodological implications for cross-cultural health promotion and behavioral interventions in the context of globalization.

The findings of this study have direct application value for promoting environmental protection and sustainable community behaviors. Environmental psychology research indicates that barriers to pro-environmental behavior often lie not in lack of knowledge but in the absence of psychosocial mechanisms for translating knowledge into behavior. The intervention pathway confirmed by this study precisely fills this gap: systematic environmental education can enhance ecological cognition, but must simultaneously strengthen individuals' "environmental efficacy"—the belief that "I can contribute to environmental protection through my own actions." The role of self-efficacy as a core mediating variable in this study (mediating effect accounting for 62.3% of total effect) provides strong evidence for this. At the social support level, establishing community environmental mutual aid networks (similar to this study's peer groups), cultivating environmental leadership (corresponding to supportive coaches), and creating green living culture (corresponding to team prevention culture) can create a social ecological system that promotes sustainable behaviors. This study's finding that high-quality social environments increase behavior execution rates by 33 percentage points indicates enormous potential for community-level environmental interventions. Additionally, the behavior change techniques employed in this study—progressive goal setting, timely feedback, progress visualization, and habit formation—can be directly transferred to pro-environmental behavior promotion projects, such as setting phased carbon reduction goals, providing energy consumption feedback, showcasing environmental achievements, and establishing green habits. More profoundly, the cultural adaptation principles revealed by this study remind us that promoting sustainable community development must consider local cultural characteristics: in collectivist cultures, emphasizing the social responsibility and collective benefits of environmental protection may be more effective than appealing to personal interests; utilizing community identity and face mechanisms can strengthen the social motivation for pro-environmental behaviors; integrating environmental protection into traditional cultural values (such as "harmony between heaven and humanity" and "frugality cultivates virtue") can enhance cultural identity and behavioral durability. Therefore, this study not only provides a scientific approach for sports injury prevention but also contributes a theoretical framework and empirical support for constructing a psychosocial intervention system oriented toward sustainable development.

6. Conclusion

From the perspectives of education and social psychology, this study validates the significant effectiveness of functional training on shoulder injury prevention among young Chinese tennis players. The main conclusions are as follows:

(1) Functional training reduced the injury incidence rate in the experimental group from 43.2% to 9.1% (a 79.0% reduction), improved shoulder function scores by 17.2%, and increased match win rate by 11.5 percentage points;

(2) Health education played a mediating role by enhancing injury prevention knowledge (increase of 56.7%) and self-efficacy (increase of 48.4%), promoting a prevention behavior execution rate of 89.6%;

(3) Peer support (β=0.38) and coach relationship quality (β=0.42) had significant moderating effects on training outcomes, enhancing effectiveness by 46.3% and 51.7% respectively;

(4) The "physiological improvement-psychological reinforcement-social support" three-level synergistic mechanism and "knowledge-attitude-efficacy-behavior-support" intervention chain constructed by this study

provide a multidisciplinary integrated theoretical framework and practical pathway for sports injury prevention.

(5) The psychosocial intervention principles constructed by this study have cross-disciplinary application value and can be applied to promoting environmental protection and sustainable community behaviors. The "knowledge education-efficacy enhancement-social support" integrated intervention model confirmed by the study, the significant moderating role of peer influence (β=0.38), and the critical role of group norms in behavior maintenance provide important insights for environmental behavior change.

Conflict of interest

The authors declare no conflicts of interest.

References

1. Zhang C, Qian JH. Characteristics of shoulder injuries in adolescents[J]. Contemporary Sports Technology, 2019, 9(03):19-20.
2. Pan HJ. Analysis of shoulder injury factors in freestyle swimming training and prevention measures[J]. Sports Boutique, 2022, 41(04):72-73+84.
3. Bejar M, Raabe J, Tolentino K, et al. Athletic trainer strategies for nurturing athletes' basic psychological needs during sport injury rehabilitation[J]. Journal of American College Health: J of ACH, 2025, 1-9.
4. Haskell B, Eiler A, Essien H. Sleep quality and cognitive skills impact neurocognitive function and reduce sports-related injury risk[J]. Arthroscopy, Sports Medicine, and Rehabilitation, 2025, 7(2):101077-101077.
5. Wang J. Analysis of common injuries in youth weightlifting training and prevention methods[J]. Sports Goods and Technology, 2021, (04):66-67.
6. Jiang H. Research progress on athletes' return to competition after shoulder surgery[J]. Sichuan Sports Science, 2022, 41(02):45-49.
7. Fu Y, Ma S, Ma B, et al. Innovative diagnostic framework for shoulder instability: a narrative review on machine learning-enhanced scapular dyskinesis assessment in sports injuries[J]. European Journal of Medical Research, 2025, 30(1):257-257.
8. Rong ZY, Li Y. Brief analysis of different treatment methods for shoulder injuries in table tennis[J]. Sports, 2018, (18):22-23+15.
9. Shao JW, Zhou Y, Gu S, et al. Sports injury risk and case study of male and female collegiate-level volleyball players[J]. Journal of Beijing Sport University, 2018, 41(08):112-118.
10. Cui XY. Investigation of sports injuries among male freestyle wrestlers[J]. Wushu Studies, 2017, 2(12):97-99.
11. Min SB, Jang N. Analysis of sports injury prevalence and patterns in recreational sports activities in South Korea: Applying the association rule method[J]. Life, 2025, 15(5):701-701.
12. Worrall J, Wu YPP, Toohey AL, et al. Sports injury is self-exciting: Modelling AFL injuries using Hawkes processes[J]. SN Computer Science, 2025, 6(5):398-398.
13. Su GJ. Research on causes and prevention strategies of basketball sports injuries among college students[J]. Contemporary Sports Technology, 2025, 15(22):27-29.
14. Qin HB. Analysis of basketball sports injuries and rehabilitation treatment methods[J]. Industry and Technology Forum, 2025, 24(15):52-54.
15. Liu S, Noh EY, Mahfooz M, et al. Spirituality, religion, and sports injury: A systematic review[J]. Journal of Religion and Health, 2025, (prepublish):1-21.
16. Zhiqiang G, Xu AW, Xinli Z. Full-parameter fine-tuning method of LLMs for sports injury prevention and treatment[J]. International Journal of Mobile Computing and Multimedia Communications (IJMCMC), 2025, 16(1):1-14.
17. Wang Z, Zhang J, Cao Z, et al. Hiome analysis based on fsQCA: A study on sports injury factors in adolescent physical training[J]. Scientific and Social Research, 2025, 7(4):187-194.
18. Wang YS. Prevention and treatment strategies for common sports injuries in marathon beginners[J]. Track and Field, 2025, (08):81-83.
19. Tian Z, Li M, Yuan H, et al. Titanium alloy-based hydroxyapatite composites in sports injury repair: Preparation, application, and prospects[J]. Journal of Alloys and Compounds, 2025, 1026:180416-180416.
20. Zhu LY, Xiong F, Huang LY, et al. Construction of exercise programs for rotator cuff repair patients[J]. Nursing Research, 2025, 39(14):2438-2443.

21. Guo YQ. Research on precise prevention strategies for sports injuries in university physical training[J]. Contemporary Sports Technology, 2025, 15(20):31-34.
22. Li L. Discussion on sports injuries and prevention strategies for college students based on health education concepts[J]. Chinese Journal of School Health, 2024, 45(07):1072-1073.
23. Zhong H. Biomechanical analysis of sports injuries caused by military training in college students and protective safety education strategies[J]. Journal of Medical Biomechanics, 2023, 38(02):416.
24. Li DY. Analysis of injury prevention in high school students' physical exercise[J]. Contemporary Sports Technology, 2021, 11(33):210-212.
25. Ren ST. Mechanism research on sulforaphane pretreatment alleviating exhaustive exercise-induced myocardial injury[J]. Molecular Plant Breeding, 2025, 23(13):4514-4522.
26. Chen P, Mazalan NS, Koh D, et al. Effect of exercise intervention on anxiety among college students: A meta-analysis[J]. Frontiers in Psychology, 2025, 1-12.
27. Mazalan NS, Landers G, Wallman K, et al. Ice ingestion maintains cognitive performance during a repeated sprint performance in the heat[J]. Journal of Sports Science and Medicine, 2022, 164-170.
28. Mazalan NS, Landers G, Wallman K, et al. A combination of ice ingestion and head cooling enhances cognitive performance during endurance exercise in the heat[J]. Journal of Sports Science and Medicine, 2022, 22-32.
29. Mazalan NS, Landers G, Wallman K, et al. Head cooling prior to exercise in the heat does not improve cognitive performance[J]. Journal of Sports Science and Medicine, 2021, 69-76.
30. See CY, Mazalan NS, Zakaria MN, et al. The effectiveness of weight training in improving students' physical fitness for badminton[J]. International Journal of Research and Innovation in Social Science (IJRISS), 2025, 3449-3459.
31. Cher TS, Mazalan NS, Zakaria MN. Tabata exercise increased endurance of primary school basketballers[J]. International Journal of Research and Innovation in Social Science (IJRISS), 2025, 3407-3415.
32. Ashutosh P, Swapnil S, Priyanka M, et al. Prevalence and outcomes of dental trauma in sports-related injuries in the last 2 years[J]. Journal of Pharmacy and Bioallied Sciences, 2025, 17(Suppl 2):S1541-S1543.
33. Zhu D, Zhang Z, Li W. Accuracy and reliability of multimodal imaging in diagnosing knee sports injuries[J]. Current Medical Imaging, 2025, 21(1):e15734056360665-e15734056360665.
34. Zhang XY, Xu ZX. Impact of health promotion on prevention and treatment of sports injuries in university campuses[J]. Chinese Journal of School Doctor, 2021, 35(04):281-283.
35. Shamim SA, Warner E, Mendis DM, et al. The relationship between vestibulo-ocular function and sports injuries in adolescent rugby union players[J]. Musculoskeletal Science and Practice, 2025, 78:103361-103361.
36. Wu Y, Moghadas KB, Gu D, et al. Fabrication and characterization of biological biosensors in sports injury treatment: High sensitivity of silver oxide using artificial neural network modeling[J]. Engineering Applications of Artificial Intelligence, 2025, 156(PA):111120-111120.
37. Deng LH. On-site nursing experience of common sports injuries in university sports meets[J]. Primary Medical Forum, 2019, 23(24):3534-3536.
38. Teng H. Causes and prevention measures of javelin sports injuries in physical education majors[J]. Youth Sport, 2019, (06):103-104.
39. Farahani P, Ghavi B, Hosseini A. RE: Patterns of orbital fractures caused by sports injuries in children[J]. Journal of Oral and Maxillofacial Surgery: Official Journal of the American Association of Oral and Maxillofacial Surgeons, 2025, 83(7):787-788.
40. Silva DMIN, Gasparetto Z, Bacciotti MS, et al. Analysis of internal training load and sports injuries incidence in gymnasts of different exposure levels[J]. Healthcare, 2025, 13(13):1536-1536.
41. Iatropoulos S, Dandrieux EP, Edouard P, et al. Development and internal validation of machine learning prognostic models of sports injuries using self-reported data in athletics (track and field): The influence of quantity and quality of features[J]. Journal of Sports Sciences, 2025, 1-15.
42. Chen X, Chen G. Current status of sports injuries among college students and effects of health education intervention[J]. Primary Medical Forum, 2019, 23(19):2671-2675.
43. Lin Y. Investigation and prevention research on hurdle race sports injuries in physical education majors[J]. Sports, 2018, (23):53-54.
44. Ebert RJ, Edwards KP, Ammann E, et al. Older age and a non-sporting injury mechanism are associated with re-injury and the need for revision surgery over a minimum 2-year follow-up following proximal hamstring tendon repair[J]. Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA, 2025, 33(8):2984-2993.
45. Li Y, Zhu W. The preventive effects of neuromuscular training on lower extremity sports injuries in adolescent and young athletes: a systematic review and meta-analysis[J]. The Knee, 2025, 56:373-385.
46. Duan HY. Research on psychological response characteristics and rehabilitation measures after sports injuries in vocational college students[J]. Journal of Hubei Correspondence University, 2018, 31(07):50-52.

47. Zheng ZW. Research on factors causing sports injuries and prevention measures for students in university gymnastics courses[J]. China Multimedia and Network Teaching Journal (First Ten Days), 2018, (04):23-24.
48. Helito PVP, Leao VR, Gulde SLM, et al. Imaging in handball sports injuries: A comprehensive review focused on upper limb pathologies[J]. Seminars in Musculoskeletal Radiology, 2025, 29(4):548-558.
49. Lee HJ, Cho BS, Kim YK, et al. Combined percutaneous sclerotherapy plus transarterial embolization for refractory sports injuries in young athletes: A feasibility study[J]. CardioVascular and Interventional Radiology, 2025, 48(8):1-5.
50. Luan YR. Review of research on causes and prevention of sports injuries in yoga teaching[J]. Sports World (Academic Edition), 2018, (01):88-89.
51. Wang M. Research on causes and prevention of common sports injuries in college students' physical exercise[J]. Journal of Ezhou University, 2017, 24(06):88-90.
52. Maghsoomi M, Johari K, Abedini E. Artificial neural networks for prevention of sports injuries: a systematic review[J]. Sport Sciences for Health, 2025, (prepublish):1-25.
53. Vaughan B, Adams J, Peng W, et al. Understanding the role of sports injury management by Australian osteopaths: A cross sectional survey of 992 practitioners[J]. Applied Sciences, 2025, 15(15):8397-8397.
54. Jiang Z, Shen Y. Multimodal learning for enhanced SPECT/CT imaging in sports injury diagnosis[J]. Frontiers in Physiology, 2025, 16:1605426-1605426.
55. Godoy BRI, Rodrigues CT. Cycling and sport-specific injuries with imaging correlation cycling injuries[J]. Seminars in Musculoskeletal Radiology, 2025, 29(4):583-595.
56. Guo WC. Research on sports injury situations and causes among badminton specialty students[J]. Sports, 2017, (15):60-61.
57. Liang XL. Analysis of causes and prevention measures of ankle injuries in basketball players[J]. Science and Technology Information, 2016, 14(13):158-159.
58. Lakshminarayanan CA, Thandavamoorthi J. Attention-enhanced convolutional BiLSTM model for predicting recovery outcomes in sports injuries[J]. Indian Journal of Orthopaedics, 2025, (prepublish):1-23.
59. Degenhardt H, Hinz M, Rupp CM, et al. Low injury incidence and excellent return to sport after injuries in beach handball—a cross-sectional survey of 651 athletes[J]. BMC Sports Science, Medicine and Rehabilitation, 2025, 17(1):224-224.
60. Jia JL, Wang HL. Research on causes and prevention of ankle injuries in basketball[J]. Fujian Sports Science and Technology, 2016, 35(04):31-33.
61. Liang D. Frontier hotspots and development trends in research on sports injury prevention and treatment: A bibliometric and visualization analysis[J]. Medicine, 2025, 104(34):e44012-e44012.
62. Chellamuthu G, Sahanand S, Sundar S, et al. Injury prediction model for lower-limb sports injuries: A novel machine learning-based approach[J]. Journal of Clinical Orthopaedics and Trauma, 2025, 69:103114-103114.