Vol.5 Iss.1 2025
https://doi.org/10.37420/j.ssp.2025.001

Scientific Analysis and Recommendations on the Impact of Core Strength Training on Badminton Performance

Yapeng Xie*, Huangbin Jin
School of Physical Education, Yunnan Normal University, Kunming , Yunnan, China
***Corresponding author, E-mail:13919058635@163.com**

Abstract

Research Objectives: Core strength training is widely applied in various sports, playing a critical role in enhancing athletic performance and preventing sports injuries. Badminton, as a physically demanding, net-based sport with extended match durations, imposes high technical and competitive demands on athletes, while also posing risks of sports injuries due to its high-intensity nature.Research Methods: The study employed methods such as literature review and logical analysis.Research Results and Conclusions: Existing domestic and international research primarily focuses on two aspects of core strength training in badminton: improving the quality of athletes' technical movements and preventing sports injuries. However, systematic analysis is lacking in areas such as the specific core muscle groups corresponding to fundamental badminton techniques, the types of injuries sustained, and their relationship to core muscles. This study systematically describes the core muscle groups involved in basic badminton technical movements and identifies common injury sites and types in badminton. Additionally, it provides valuable insights into how core strength training can enhance the quality of technical movements in badminton athletes and offers practical strategies for preventing specific injuries by strengthening targeted core muscle groups.

Keywords

Core Strength; Core Muscles; Badminton; Technical Movements; Sports Injuries

1 Introduction

Core strength training originated from core stability training, which was initially applied to spinal stability . Subsequently, it was widely adopted in sports rehabilitation in Western countries. After adjustments to certain training methods, core stability training evolved into core strength training and was integrated into the training regimens of competitive athletes. Since then, core strength training has become an essential component of athletic training. Badminton, as a non-contact sport, places high demands on athletes' reaction speed and movement speed. During matches and training, athletes are required to perform prolonged movements and jumps while maintaining coordination between the upper and lower limbs. The core, as the central region of the body, enhances badminton players' stability, coordination, and explosiveness, thereby reducing physical exertion during high-intensity competitions and preventing sports injuries. Therefore, core strength training holds significant importance in badminton. When engaging in core strength training, badminton players should start with simple bodyweight exercises. As their core strength improves, they can progress to more complex equipment-based training. Subsequently, players can tailor their training to the characteristics of badminton techniques and the involved core muscles, using comprehensive core strength training to enhance technical proficiency.Although previous studies have emphasized the importance of core strength in badminton, particularly its role in delaying fatigue and preventing injuries, they have not elaborated on the relationship between badminton techniques, core muscles, and common badminton-related injuries. This paper briefly describes the characteristics of core strength and core muscles, links them to fundamental badminton techniques, and explores how core strength training can enhance technical performance. Finally, it discusses the role of core strength training in preventing badminton-related injuries.

2 Characteristics and Significance of Core Strength Training

The core is located in the central region of the human body and primarily includes the muscles of the lumbopelvic-hip complex. This area comprises dozens of muscle groups, with 33 pairs + 1 individual muscles originating or inserting in the core region. The core can be vividly conceptualized as a box, with the anterior side composed of the abdominal muscles, the posterior side made up of the paraspinal and gluteal muscles, the diaphragm forming the top, the oblique abdominal muscles on the sides, and the pelvic floor and hip joint muscles at the bottom. The core region is crucial for maintaining body balance and ensuring the safety of the spine and vital organs during movement. Core strength, which originates from the continuous contraction of the muscles or muscle groups in the core, enables the coordination of force transmission between the upper and lower limbs, minimizes energy dissipation within the trunk, and maintains body balance during both static and dynamic tasks. Therefore, core strength can be regarded as the body's kinetic chain, responsible for facilitating the transfer of torque and force between the upper and lower limbs.

Core strength training enhances athletic qualities such as speed, agility, coordination, and endurance by strengthening the sagittal, frontal, and transverse plane muscles of the core region. The training methods primarily include bodyweight exercises and equipment-based training. Core strength training is characterized by its emphasis on multi-joint, multi-dimensional movements and muscle recruitment, with the core area of the body as the main focal point, preparing the body for various sports activities. The significance of core strength training lies in enhancing bodily stability and preventing sports injuries. First, balance training is often based on the strengthening of core muscle tissues to maintain balance during movement. For instance, rapid changes in movement can cause shifts in the body's center of gravity. To avoid losing balance and falling, the core muscles, such as the transversus abdominis, multifidus, rectus abdominis, gluteus maximus, psoas major, and diaphragm, need to be re-engaged. These muscle groups can be strengthened through core strength training exercises like single-leg standing on a balance ball, side plank, single-leg dumbbell squat, and half squat on a balance ball. Therefore, core strength training provides an essential foundation for stabilizing the connection between the upper and lower limbs of the body. Second, and most importantly, core strength training helps prevent injuries to the joints and muscles of athletes during competitions or training.

3 Badminton and Injuries

3.1 Characteristics of Badminton

Badminton is one of the most popular sports in the world, with an estimated 200 to 300 million followers. It originated in Japan and was formalized in the United Kingdom 20 21. As a racket sport played by either two or four players, badminton is characterized by its fast actions, short duration, and high intensity. The inclusion of badminton as an Olympic event in 1992 significantly increased participation in the sport 22. The sport comprises five events: men's singles, women's singles, men's doubles, women's doubles, and mixed doubles. Badminton tournaments typically involve 3 to 4 matches over a period of 4 to 5 days, with competitive matches lasting from 40 minutes to 1 hour. Therefore, each event demands a high level of technical and tactical proficiency as well as physical fitness from the athletes. Players are required to perform rapid, high-intensity, and short-duration repetitive movements within an 80-square-meter court, including quick directional changes, jumping, lunging forward, rapid arm movements, and swift transitions between the forecourt and backcourt. These characteristics highlight the significant physical demands placed on athletes during intense badminton matches.

3.2 Technical Movements in Badminton and Core Muscles

The application of technical movements by athletes plays a crucial role in the outcome of badminton matches. Core strength training can effectively enhance the competitive level of badminton players by strengthening the core muscles. Therefore, this paper summarizes the common technical movements in badminton and the corresponding core muscles as follows (Table 1):

Table 1 The fundamental technical movements in badminton and their corresponding core muscle groups.

Technical Movement	Corresponding Core Muscles
Smash	External oblique, diaphragm, gluteus maximus, rectus femoris, tensor fasciae latae, biceps femoris (long head), internal oblique, rectus abdominis, erector spinae, transversus abdominis, psoas major, quadratus lumborum, latissimus dorsi, pectineus, gracilis, sartorius
Clear	External oblique, diaphragm, gluteus maximus, rectus femoris, internal oblique, rectus abdominis, erector spinae, transversus abdominis, latissimus dorsi.
Drop Shot	External oblique, Diaphragm, Gluteus maximus, Rectus femoris, Internal oblique, Rectus abdominis, Erector spinae, Transversus abdominis, Latissimus dorsi.

Net Lift	External oblique, internal oblique, transversus abdominis, rectus abdominis, biceps femoris (long head), pectineus, sartorius, gracilis, latissimus dorsi, tensor fasciae latae, diaphragm, psoas major, quadratus lumborum, long head of the adductor, semitendinosus, semimembranosus, rectus femoris, gluteus maximus.
Crosscourt net shot	
Net spin	
Net push	

In badminton, the smash technique consists of four sequential movements: side-stepping, racquet preparation, jumping, and racquet swing. First, during the side-stepping and racquet preparation phase, the player must perform rightward trunk rotation and downward trunk flexion to generate power. Rightward trunk rotation primarily involves the external oblique, diaphragm, gluteus maximus, and rectus femoris, with coordinated movement between the legs and shoulders, resulting in a backward lean. Downward trunk flexion primarily involves the gluteus maximus, tensor fasciae latae, diaphragm, biceps femoris (long head), and rectus femoris, with coordinated movement in the back, resulting in elbow depression. Second, during the jumping and racquet swing phase, the player must perform backward racquet preparation and forward trunk flexion. Backward racquet preparation primarily involves the external oblique, internal oblique, rectus abdominis, gluteus maximus, and erector spinae, resulting in shoulder elevation, with coordinated movement between the waist and hips. Forward trunk flexion primarily involves the transversus abdominis, psoas major, quadratus lumborum, latissimus dorsi, iliacus, pectineus, gracilis, and sartorius, resulting in trunk curling, shoulder elevation, and elbow extension (see Figure 1).

In badminton, the clear shares nearly identical technical movements and core muscle engagement with the smash. However, high-level players execute the clear without a jumping motion. Instead, they rely on a sideways racket preparation and swing to complete the shot. During the sideways preparation, the body rotates to the right while swinging upward. This rightward rotation primarily engages the external oblique, diaphragm, gluteus maximus, and rectus femoris, supported by leg strength and manifested as a backward lean. The upward swing involves the internal oblique, rectus abdominis, and erector spinae, coordinated with shoulder extension to propel the racket forward. The forward swing requires trunk flexion, driven by the transversus abdominis and latissimus dorsi, supported by leg strength and back coordination (see Figure 2a-c).

The drop shot in badminton activates the same core muscle groups as the clear. The key difference lies in the wrist rotation and adjustments to the racket face angle, which alter the shuttlecock's trajectory height and landing point (see Figure 2d-f).

In badminton, the net lift is composed of two sequential actions: first, lunging forward with the right leg while flexing the torso diagonally to the right, engaging core muscles including the external oblique, internal oblique, transversus abdominis, rectus abdominis, biceps femoris (long head), pectineus, sartorius, and gracilis, with wrist abduction and leg stabilization, followed by the racket swing phase where the body leans forward, activating core muscles such as the latissimus dorsi, tensor fasciae latae, diaphragm, psoas major, quadratus lumborum, adductor longus, semitendinosus, semimembranosus, biceps femoris (long head), rectus femoris, and gluteus maximus, supported by pelvic stability and shoulder coordination, manifested through wrist adduction and arm extension (see Figure 3). Meanwhile, crosscourt net shots, net spins, and net pushes involve minimal core muscle engagement due to their limited range of motion, relying primarily on precise arm, wrist, and finger control; during crosscourt net shot drills, players maintain an upright upper body with a staggered stance, directing the shuttle to the opponent's opposite corner using muscles like the brachioradialis, flexor carpi radialis, and palmaris longus during racket extension, and the extensor pollicis longus, extensor digitorum, flexor carpi radialis, extensor carpi radialis longus, and flexor digitorum profundus during impact.

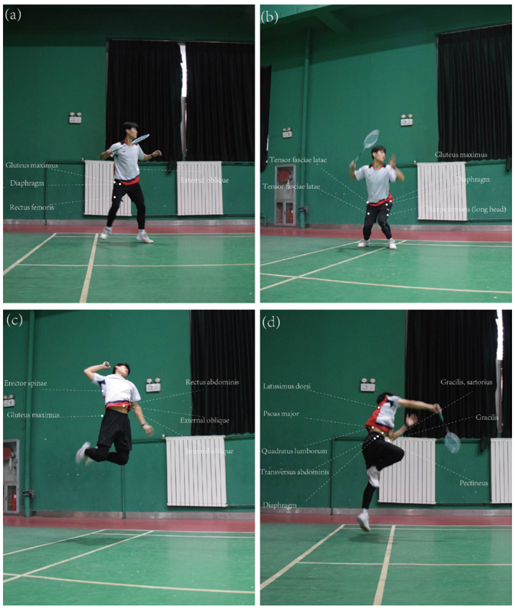

Figure 1 The technique for executing a badminton smash involves several sequential motions:

(a) leaning sideways and rotating the body to the right, (b) gripping the racket and pushing off with both feet to jump, (c) stretching the abdominal muscles, and (d) performing a forward bend and crunch before executing the smash.

Figure 2 The technique for executing a badminton high clear (a-c) and drop shot (d-f) involves several sequential motions:

(a) leaning sideways to position the racket, while shifting the body weight onto the right leg, (b) swinging the racket upwards and rotating the body forward, and (c) swinging the racket while leaning forward; (d) leaning sideways to position the racket, while shifting the body weight onto the right leg, (e) swinging the racket upwards and rotating the body forward, and (f) swinging the racket, while rotating the wrist to change the racket face.

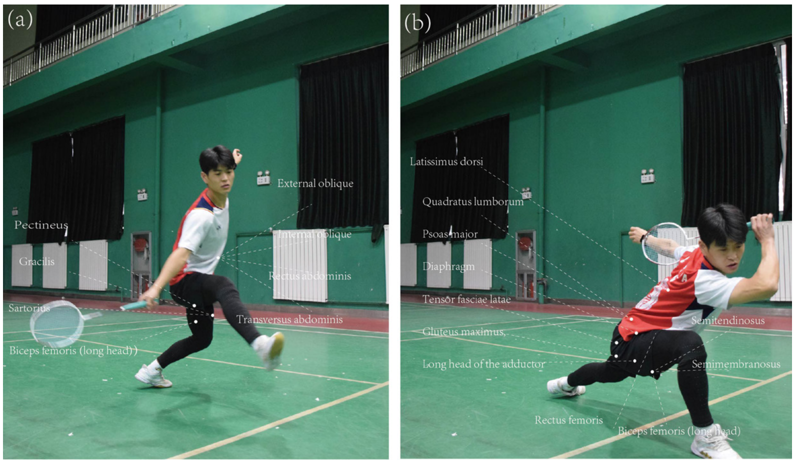

Figure 3 The technique for executing a badminton net shot involves several sequential motions:
(a) stepping forward to the right with a lunge, while abducting the wrist
(b) swinging the racket, leaning forward, and adducting the wrist.

3.3 Injuries and types of badminton

Existing research has demonstrated that in competitive badminton, athletes experience an injury rate of 0.85 injuries per year, 1.6 to 2.9 injuries per 1,000 hours of match play, and 2 to 5 injuries per 1,000 athletes. In a single competition, 1% to 5% of athletes sustain injuries. Among all badminton-related injuries, lower limb injuries account for 58% to 76%, upper limb injuries account for 19% to 32%, and back injuries account for 11% to 16%. Upper limb injuries primarily involve the wrist, elbow, and shoulder joints. A study in Sweden found that 52% of players experienced shoulder pain during badminton activities, with 16% exhibiting chronic pain. Lower limb injuries mainly include knee joint, ankle joint, Achilles tendon, and leg muscle strains. Due to the characteristics of badminton and individual differences in physical function, the causes and locations of injuries vary among athletes.

Upper limb injuries in badminton commonly involve the shoulder, elbow, and wrist. Shoulder injuries include tendinitis, tenosynovitis, bursitis, and rotator cuff tears, often caused by improper technique in overhead strokes, drop shots, and smashes, or by repetitive abduction, flexion, and external rotation during matches.Elbow injuries, such as tennis elbow (lateral epicondylitis) and golfer's elbow (medial epicondylitis), are common in beginners due to incorrect or overly tight gripping.Wrist injuries, including synovitis and ganglion cysts, are linked to actions like smashes, net play, and pushes. These result from the wrist's complex mechanics, where force transmission from the forearm to the fingers requires precise coordination. Over-repetition of wrist-twisting movements in net play can lead to joint and muscle strain. Most arm and wrist injuries stem from improper technique and excessive repetition. Lower back injuries, such as herniated discs and lumbar strain (lumbago-fasciitis), are associated with the high-intensity nature of badminton.

In terms of lower limb injuries, knee injuries include collateral ligament, cruciate ligament, meniscus injuries, knee sprains, and patellar tendonitis. Repeated lunges on the same leg can destabilize athletes, reduce knee load-bearing capacity, and increase anterior cruciate ligament (ACL) impact. Kimura et al. identified two main causes of ACL injuries in badminton: first, during single-leg landings for overhead shots, the knee opposite the racket-hand side is at risk, typically on the backhand side; second, the knee on the racket-hand side is prone to injury during forehand side-stepping or backpedaling.Ankle injuries involve the anterior talofibular and calcaneofibular ligaments of the lateral ankle, the deltoid ligament of the medial ankle, and the transverse tibiofibular ligament. Inversion or eversion can cause surrounding ligament tears and fractures, such as tibial spiral fractures or proximal fibula fractures. The most common in badminton are inversion and eversion, leading to ligament tears and fractures.Achilles tendon injuries include tendinopathy and rupture. Badminton places significant tensile stress on the Achilles tendon. Fahlström et al. investigated the prevalence and characteristics of Achilles tendon pain in elite Swedish badminton players, finding that 32% experienced pain over five years, with 17% having chronic pain. Causes are mainly linked to high-intensity play. Athletes often report a sudden "cramping" sensation in the Achilles tendon seconds before injury, followed by calf muscle contraction and tendon damage.Thigh muscle strains involve the hamstrings, rectus femoris, gracilis, and adductor magnus. Adequate warm-up can prevent such injuries. In badminton, passive lunges in the forecourt can strain the posterior hamstrings, while jumping smashes can strain the anterior rectus femoris, gracilis, and adductor magnus.

4 Scientific Recommendations for Core Strength Training in Badminton

In badminton, core training emphasizes high repetitions, coordination enhancement, and sport-specificity. Based on common badminton techniques, diverse core training methods and periodization are employed to strengthen athletes' core muscles, improve their badminton skills, and prevent sports-related injuries.

The entire training cycle consists of three phases, with core training methods adjusted according to the athletes' technical progression. The objective is to develop the core muscles of the abdomen, lower back, and hip region across different training stages, ensuring a foundation for advanced technical development. During the initial training phase, the focus is on mastering basic badminton techniques. Athletes can perform core exercises without equipment, such as planks, leg raises, side planks, glute bridges, dead bugs, bird-dogs, supine alternating leg lifts, and supine jump squats. These exercises progress from the upper limbs to the lower limbs and then to lateral movements. This phase lasts for 5 weeks, with 3 sessions per week, each lasting 25 minutes. The goal is to help athletes understand the proper force generation sequence for basic strokes like clears and smashes, avoid excessive body movements, and ensure consistency in techniques such as clears and drop shots.

During the mid-phase of training, incorporating sports equipment into core strength exercises has proven effective. For instance, Ma et al. implemented an 8-week core strength training program for tennis athletes, including equipment-based exercises such as V-sit ups, bicycle crunches, straight-leg crunches, long-arm crunches, and hanging leg raises, conducted four times weekly for 30–40 minutes per session. Each session involved 15 repetitions of equipment-based exercises and 30-second bodyweight drills, repeated for 3–5 sets, with 90-second rest intervals between cycles and 2–3 minutes between sets. Post-training assessments revealed significant improvements in the athletes' performance levels . Given that badminton and tennis belong to the same sport category and share similar biomechanical structures], tennis-inspired core training methods can be adapted for badminton. Specifically, after completing 15 repetitions of equipment-based exercises, the bodyweight training methods from the initial training phase (e.g., planks, side bridges) can be integrated as 30-second drills to enhance mid-phase technical proficiency in badminton players. This cross-disciplinary approach not only facilitates resource sharing (e.g., equipment, protocols) but also underscores the strategic value of complementary training advantages between the two sports, fostering collaborative innovation in future sport-specific conditioning programs.

In the late training phase, as athletes' overall technical proficiency and physical capabilities have been progressively refined, and their on-court movements predominantly rely on side steps, crossover steps, and lunge steps, it becomes critical to enhance reactive capabilities in scenarios such as passive net lifts, smash recoveries, diving saves, and midcourt directional changes, while preventing sports injuries common during advanced training. To address this, core strength training should prioritize badminton-specific adaptations. For instance, Liu Lancai et al. designed a 12-indicator specialized training program for badminton players, focusing on racket swing speed, basic endurance, core strength, and agility, comprehensively outlining the essential sport-specific competencies. Core strength was notably developed through 1-minute hanging leg raise exercises . Similarly, Jeong et al. conducted a 10-week core strength training trial with 48 participants, combining bodyweight exercises, equipment-based drills, and sport-specific conditioning. The program significantly strengthened hip and leg muscles, effectively reducing the risk of anterior cruciate ligament (ACL) injuries [46]. Therefore, during the late training phase, integrating speed endurance with sport-specific footwork and core strength with sport-specific movements is recommended. Training methodologies should emphasize comprehensiveness (e.g., multi-planar drills), systematic progression (phased intensity adjustments), and scientific rigor (biomechanical alignment) to optimize technical execution and injury prevention in elite badminton athletes.

5 Conclusion

In summary, there is a significant correlation between basic badminton techniques and the core muscle group. Core strength training, progressing from simple to complex, can enhance athletes' physical balance and facilitate the learning of badminton techniques, effectively improving competitive performance. Additionally, core strength training adjusts the body, reducing the risk of sports injuries caused by unskilled or uncoordinated muscle movements. Thus, it can prevent badminton-related injuries by strengthening the core muscles. Future core strength training in badminton should align with the sport's characteristics and laws.

It should combine traditional strength exercises with common badminton techniques and typical sports injuries for comprehensive, systematic, and scientific training. This ensures athletes' safety while enabling higher - level technical performance.

Reference

[1] POPE M H, PANJABI M. Biomechanical definitions of spinal instability [J]. Spine, 1985, 10(3): 255-6.

[2] 周冰 . 短跑运动员核心力量训练研究 —— 评《核心力量体能训练法》 [J]. 中国油脂 , 2021, 46(02): 168-9.

[3] KIBLER W B, PRESS J, SCIASCIA A. The role of core stability in athletic function [J]. Sports medicine, 2006, 36: 189-98.

[4] SHEDGE S S, RAMTEKE S U, JAISWAL P R. Optimizing Agility and Athletic Proficiency in Badminton Athletes Through Plyometric Training: A Review [J]. Cureus, 2024, 16(1): 1-8.

[5] 赵哲 , 金育强 , 常娟 . 核心区力量训练对提高大学生羽毛球运动员竞技能力的研究 [J]. 广州体育学院学报 , 2017, 37(03): 81-3.

[6] LIANG Y, TASNAINA N. Developing A Core Strength Training Program to Improve Badminton High Clear [J]. 2023: 163-70.

[7] ALLEN S, DUDLEY G A, IOSIA M, et al. Core strength training [J]. Sports Science Exchange Roundtable, 2002, 13(1): 27-9.

[8] FORCHIELLI A, STEINER M, HU S X, et al. Taphonomy of Cambrian (Stage 3/4) sponges from Yunnan (South China) [J]. Bulletin of Geosciences, 2012: 133-42.

[9] 黎涌明 , 于洪军 , 资薇 , et al. 论核心力量及其在竞技体育中的训练 —— 起源 · 问题 · 发展 [J]. 体育科学 , 2008, (04): 19-29.

[10] SHINKLE J, NESSER T W, DEMCHAK T J, et al. Effect of core strength on the measure of power in the extremities [J]. The Journal of Strength & Conditioning Research, 2012, 26(2): 373-80.

[11] HSU S-L, ODA H, SHIRAHATA S, et al. Effects of core strength training on core stability [J]. Journal of physical therapy science, 2018, 30(8): 1014-8.

[12] LEHMAN G J. Resistance training for performance and injury prevention in golf [J]. The Journal of the Canadian Chiropractic Association, 2006, 50(1): 27.

[13] CLARK A W, GOEDEKE M K, CUNNINGHAM S R, et al. Effects of pelvic and core strength training on high school cross-country race times [J]. The Journal of Strength & Conditioning Research, 2017, 31(8): 2289-95.

[14] 关亚军 , 马忠权 . 核心力量的定义及作用机制探讨 [J]. 北京体育大学学报 , 2010, 33(01): 106-8.

[15] PAN J, WEI M. Scientific physical core strength training of adolescent group [J]. Revista Brasileira de Medicina do Esporte, 2022, 28: 235-7.

[16] WILLARDSON J M. Core stability training: applications to sports conditioning programs [J]. The Journal of Strength & Conditioning Research, 2007, 21(3): 979-85.

[17] 刘耀荣 . 瑞士球训练为中心的组合力量训练与传统阻力训练对人体平衡能力作用的比较 [J].

中国运动医学杂志 , 2012, 31(10): 892-7.
[18] FREDERICSON M, MOORE T. Muscular balance, core stability, and injury prevention for middle-and long-distance runners [J]. Physical Medicine and Rehabilitation Clinics, 2005, 16(3): 669-89.
[19] RUIZ R, RICHARDSON M T. Functional balance training using a domed device [J]. Strength & Conditioning Journal, 2005, 27(1): 50-5.
[20] GUILLAIN J-Y. Histoire du badminton: du jeu de volant au sport olympique [M]. Editions Publibook, 2002.
[21] PHOMSOUPHA M, LAFFAYE G. Injuries in badminton: A review [J]. Science & Sports, 2020, 35(4): 189-99.
[22] PHOMSOUPHA M, LAFFAYE G. The science of badminton: game characteristics, anthropometry, physiology, visual fitness and biomechanics [J]. Sports medicine, 2015, 45: 473-95.
[23] BOESEN A P, BOESEN M I, KOENIG M J, et al. Evidence of accumulated stress in Achilles and anterior knee tendons in elite badminton players [J]. Knee Surgery, Sports Traumatology, Arthroscopy, 2011, 19: 30-7.
[24] SHARIFF A, GEORGE J, RAMLAN A. Musculoskeletal injuries among Malaysian badminton players [J]. Singapore medical journal, 2009, 50(11): 1095.
[25] FAHLSTRöM M, BJöRNSTIG U, LORENTZON R. Acut badminton injuries [J]. Scandinavian journal of medicine & science in sports, 1998, 8(3): 145-8.
[26] KRøNER K, SCHMIDT S, NIELSEN A, et al. Badminton injuries [J]. British journal of sports medicine, 1990, 24(3): 169-72.
[27] FAHLSTRöM M, SöDERMAN K. Decreased shoulder function and pain common in recreational badminton players [J]. Scandinavian journal of medicine & science in sports, 2007, 17(3): 246-51.
[28] 余长青 , 石鸿冰 . 羽毛球运动所引起常见的运动损伤及预防方法 [J]. 北京体育大学学报 , 2007, (S1): 227-9.
[29] WILK K E, OBMA P, SIMPSON C D, et al. Shoulder injuries in the overhead athlete [J]. Journal of orthopaedic & sports physical therapy, 2009, 39(2): 38-54.
[30] 周敬滨 , 马云 , 邹荣琪 , et al. 常见运动损伤的预防、评价与伤病运动员重返赛场 —— 基于第 64 届美国运动医学会年会报告综述 [J]. 北京体育大学学报 , 2017, 40(08): 48-52.
[31] CHARD M, LACHMANN S. Racquet sports--patterns of injury presenting to a sports injury clinic [J]. British journal of sports medicine, 1987, 21(4): 150.
[32] KARAHAN A Y, YESILYURT S, KAYDOK E, et al. Kienbock's disease that manifested in a badminton player: case report [J]. Int J Sport Sci, 2013, 3(4): 132-4.
[33] SENADHEERA V, MAYOORAN S, DISSANAYAKE J. Elbow, Wrist and Hand Tendinopathies in Badminton Players [J]. American Journal of Sports Science and Medicine, 2019, 7(1): 16-9.
[34] SHIN B-J. Risk factors for recurrent lumbar disc herniations [J]. Asian spine journal, 2014, 8(2): 211.
[35] KIMURA Y, ISHIBASHI Y, TSUDA E, et al. Mechanisms for anterior cruciate ligament injuries in badminton [J]. British journal of sports medicine, 2010: 1124-7.
[36] 薛博士 , 林昌瑞 , 郑亮亮 , et al. 核心稳定性训练降低落地动作前交叉韧带损伤的风险 [J]. 中国组织工程研究 , 2024, 28(16): 2467-72.

[37] GOOST H, WIMMER M D, BARG A, et al. Fractures of the ankle joint: investigation and treatment options [J]. Deutsches Ärzteblatt International, 2014, 111(21): 377.

[38] FONG D T-P, HONG Y, CHAN L-K, et al. A systematic review on ankle injury and ankle sprain in sports [J]. Sports medicine, 2007, 37: 73-94.

[39] HESS G W. Achilles tendon rupture: a review of etiology, population, anatomy, risk factors, and injury prevention [J]. Foot & ankle specialist, 2010, 3(1): 29-32.

[40] FAHLSTRöM M, LORENTZON R, ALFREDSON H. Painful conditions in the Achilles tendon region in elite badminton players [J]. The American Journal of Sports Medicine, 2002, 30(1): 51-4.

[41] GARRETT JR W E. Muscle strain injuries [J]. The American journal of sports medicine, 1996, 24(6_suppl): S2-S8.

[42] 魏小芳 , 刘勰 , 姜宏斌 . 核心力量训练的理论探析 —— 科学训练方法新视域 [J]. 成都体育学院学报 , 2013, 39(08): 47-51.

[43] MA Y. Strength training in the abdominal core of tennis players [J]. Revista Brasileira de Medicina do Esporte, 2023, 29: e2022_0595.

[44] 李克 . 羽毛球与网球高球下压技术差异性的运动学分析 [J]. 沈阳体育学院学报 , 2012, 31(02): 109-11.

[45] 刘兰财 , 肖杰 . 青少年男子羽毛球运动员专项运动能力评价指标研究 [J]. 首都体育学院学报 , 2019, 31(02): 182-6.

[46] JEONG J, CHOI D-H, SHIN C S. Core strength training can alter neuromuscular and biomechanical risk factors for anterior cruciate ligament injury [J]. The American journal of sports medicine, 2021, 49(1): 183-92.