Application and Potential Mechanism of Functional Training in Preventing Lower Limb Injuries of Adult Basketball Players: A Systematic Review

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Abstract. Research Objective: Functional training, as a method emphasizing multi-joint coordination and neuromuscular control, has gained significant attention in sports injury prevention in recent years. To clarify the practical effects and application characteristics of functional training in preventing lower limb injuries among adult basketball players, this study systematically reviews relevant research on functional training for lower limb injury prevention in adult basketball players. Research Methods: We searched the Web of Science, PubMed, and CNKI databases for literature on functional training interventions for lower limb injuries in adult basketball players. The methodological quality of the included studies was assessed using the PEDro scale, and training content, frequency, duration, outcome measures, and intervention effects were extracted for comprehensive analysis. Research Results: Eleven controlled experimental studies were included, involving 1,327 participants aged 18-40 from seven countries (Lithuania, the U.S., Germany, Japan, Iran, Belgium, and Italy). The studies were published in core journals of sports medicine, rehabilitation medicine, and sports science. Intervention types included neuromuscular training, proprioceptive training, jump and balance training, hip-focused training, and sport-specific functional training. Training content primarily featured single-leg jump stability exercises, dynamic balance, core anti-rotation control, and basketball-specific movement training. The intervention frequency was 2-4 sessions per week, lasting 10-120 minutes per session, over 6-22 weeks. Key outcome measures included increased hip, knee, and ankle flexion angles, improved vertical jump height (CMJ) and center of pressure (COP) control, optimized electromyography (EMG) metrics, enhanced toe strength, and a significant reduction in lower limb injury incidence. Conclusions: Functional training can effectively enhance lower limb joint mobility and dynamic stability in adult basketball players in the short term, reducing injury risks during sports activities. The intervention is flexible, practical, and adaptable, making it a valuable addition to daily training and pre-competition preparation.

Keywords: Functional training, Basketball players, Lower limb injuries, Adults, Injury prevention.

1. Introduction

Basketball is a high-intensity, highly confrontational sport, and its unique technical movements (e.g., sudden stops, pivots, jumps, and landings) make lower limb injuries extremely common among players [1], particularly in the ankles, knees, and anterior cruciate ligament (ACL). Authoritative studies have found that approximately 11,000 ankle sprains occur annually among U.S. college athletes, with basketball players exhibiting high rates of ankle injuries and sprains [2]. Each ankle injury can lead to significant athletic disruption, often requiring over a week of rest and, in severe cases, affecting an entire season—posing substantial challenges for professional or semi-professional teams [3,4]. Notably, lower limb injuries account for a significant proportion of sports injuries, with non-contact ACL injuries being particularly prevalent among adult athletes [5]. Such injuries not only impair performance but may also threaten long-term career development. Given the lengthy rehabilitation and high recurrence risk of ACL injuries, preventive measures are increasingly critical [6]. Thus, effective lower limb injury prevention for basketball players has become a focal point in sports injury research.

Functional training (FT) originated in rehabilitation medicine and was later adopted in competitive sports. The National Academy of Sports Medicine (NASM) defines it as dynamic, multi-planar training encompassing acceleration, stabilization, and deceleration [7]. Existing research demonstrates that FT effectively prevents lower limb injuries by addressing muscle imbalances and optimizing kinetic chain energy transfer. Systematic neuromuscular training programs can significantly reduce injury rates in basketball, volleyball, and other sports [8].

FT can be broadly categorized into neuromuscular training, proprioceptive training, jump and stability training, and balance training. A prospective cohort study found that FT as a warm-up effectively prevents lower limb injuries, with plyometric strength, stretching, proprioception, and sport-specific functional warm-ups proving more effective than traditional warm-ups in reducing ACL injuries in soccer players [8].

Notably, lower limb injury mechanisms involve multiple factors, and FT, as a key modifiable factor, has been widely applied in training and rehabilitation. Despite the growing body of research on FT, variations in intervention protocols, training duration, load, and outcome measures hinder systematic synthesis, particularly for adult basketball players. This study employs a systematic review to analyze the efficacy and mechanisms of FT in preventing lower limb injuries in adult basketball players, providing evidence-based guidance for coaches, rehabilitation specialists, and researchers while informing future studies.

2. Research Methods

2.1 PICO Framework

This study strictly adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to construct the PICO framework for the systematic review, using a systematic approach to evaluate the effectiveness and potential mechanisms of functional training in preventing lower limb injuries among basketball players. The specific PICO elements are detailed in Table 1.

Table 1 PICO Framework

Population	Intervenion	Comparison	Outcome
Amateur basketball players Professional basketball players Age: 18-40 years old Gender: Male, Female	Intervention types Functional training Neuromuscular training Balance and stability training Intervention contents: Training type, intensity, duration	Comparison between the intervention group and the control group (regular training, no intervention, other training forms) Self-comparison before and after the intervention Comparison among different training programs (intensity, duration, form)	Dynamic balance ability (e.g., Y Balance Test), joint range of motion (knee, ankle ROM), center of pressure (COP), functional sports performance (jump, Star Excursion Balance Test-SEBT, countermovement jump height-CMJ), EMG (electromyography) indicators, and injury incidence rate

2.2 Literature Search

Following the PRISMA statement, this study conducts a systematic literature search in databases including PubMed, Web of Science, Scopus, and CNKI. The search period ranges from the database inception date to April 2025. The search strategy is constructed based on three core themes: (1) For functional training: “functional training”, “neuromuscular training”; (2) For basketball athletes: “basketball players”, “amateur players”; (3) For lower limb injury prevention: “lower limb injury”, “knee injury”, “ankle injury”. Keywords within each theme are connected by the “AND” logic, and different expressions and synonyms within a group are connected by “OR” to form a complete logical search formula, enhancing the sensitivity and specificity of literature coverage.

2.3 Inclusion and Exclusion Criteria

Inclusion Criteria: ①Study subjects are amateur or professional basketball players; ②Interventions are clearly functional training, including but not limited to functional strength training, neuromuscular training, or core stability training; ③Study designs are randomized controlled trials, non-randomized controlled trials, before-after controlled trials, or prospective cohort studies; ④Report at least one quantitative outcome indicator related to lower limb injury prevention, functional improvement, or sports performance.

Exclusion Criteria: ①Duplicate-published studies or literatures with repeated data citations; ②Study subjects are athletes of non-basketball events or the general population; ③Interventions do not include specific functional training content; ④Only theoretical analyses, reviews, conference abstracts, or case reports; ⑤Incomplete data or lack of main outcome indicators.

2.4 Literature Screening and Data Extraction

Screening is carried out by two researchers using a double-blind independent review method. First, screening is done through titles and abstracts to exclude literatures that clearly do not meet the inclusion criteria. Then, full-text reading of the remaining literatures is conducted to further evaluate their compliance with inclusion and exclusion criteria. During the literature screening process, Zotero 7.0 literature management software is used for preliminary sorting and classification of search results, ensuring the systematicness and efficiency of the screening process. The screening strictly follows the PRISMA guidelines, and the PRISMA flow chart is used to intuitively show the specific quantities and exclusion reasons at each screening stage.

Data extraction is also independently completed by two researchers. The extracted content includes: first author’s name, publication year, research country/region, research subject characteristics (sample size, age, gender, competitive level), research design type, detailed intervention content (type, cycle, frequency), control group setting, follow-up duration, main outcome indicators, and main research findings. If there are disagreements during screening or data extraction, a third researcher participates in the discussion and makes a final ruling to ensure the scientificity and consistency of the entire process.

2.5 Literature Quality Assessment

This study uses the PEDro (Physiotherapy Evidence Database) scale to evaluate the methodological quality of included literatures. The PEDro scale has 10 scoring items, mainly including randomization, allocation concealment, baseline comparability, blinding, outcome completeness, statistical analysis, etc., with a total score of 10 points. The scoring criteria are: 0-3 points as poor, 4-5 points as moderate, 6-8 points as good, and 9-10 points as excellent. Scoring is independently completed by two researchers, and if there are disputes, a third researcher assists in ruling.

3. Research Results

3.1 Literature Search Results

A total of 842 records were retrieved from 3 databases, including 213 records from Web of Science, 478 records from PubMed, and 151 records from CNKI. Then, 416 duplicate literatures were removed. The remaining 426 literatures were screened by title and abstract, and 361 records that did not meet the criteria were excluded. Subsequently, 52 records were screened by downloading and reading the full texts according to the pre-determined exclusion criteria, and 41 records were excluded. Finally, a total of 11 controlled experimental studies were included.

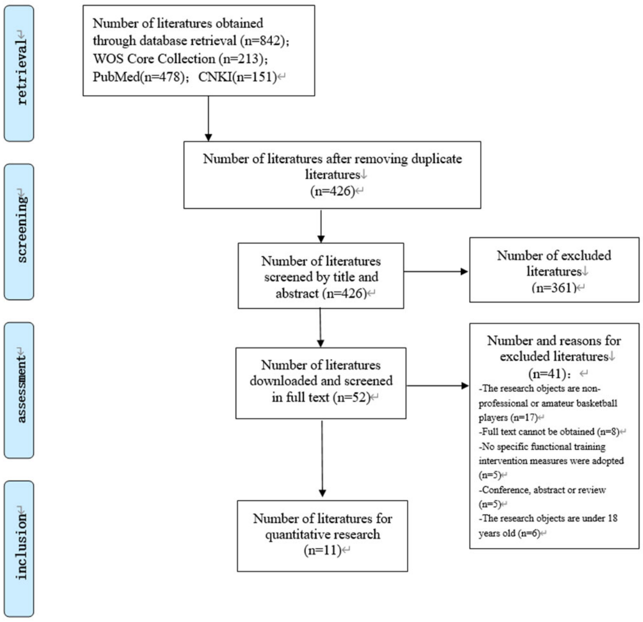

Figure 1 Literature Search Flowchart

3.2 Literature Quality Assessment

The PEDro scale scores of the 11 studies ranged from 5 to 10, with the overall research quality being moderate to good. Among them, 2 studies scored 5-6, 8 studies scored 7-9, and 1 study scored 10. Details are shown in Table 2.

Table 2 Literature Quality Assessment Table

Literature Involved	1	2	3	4	5	6	7	8	9	10	Total Score
Benis etc.[9]（2011）	√	√	√	√	√	√	√	√	√	√	10
Nagano etc.[6]（2016）	√		√			√	√	√			5
Domeika etc.[10]（2020）	√	√	√	√	√	√	√	√	√		9
Omi etc.[5]（2018）	√		√	√		√	√	√	√	√	8
Bonato etc.[11]（2017）	√	√	√		√		√	√			6
Kamikura etc.[12]（2018）	√	√	√		√	√	√	√	√		8
Cumps etc.[13]（2007）		√	√		√	√	√	√	√	√	8
Ardakani etc.[3]（2019）	√	√	√	√	√	√	√	√	√		9
Eils etc.[4]（2010）		√	√		√	√	√	√		√	7
Minoonejad etc.[14]（2019）		√	√	√	√	√	√	√	√		8
Pfile etc.[15]（2010）	√		√	√		√	√	√		√	7

Note: 1. Clear inclusion criteria; 2. Subjects randomly assigned to different groups; 3. Clear definition of interventions; 4. Baseline tests for similarity across groups; 5. Control group set up in the experiment; 6. Clear definition of outcome variables; 7. Assessments with practical significance; 8. Intervention duration with practical application; 9. Appropriate intergroup statistical analysis methods; 10. Indication of effect size.

3.3 Basic Characteristics of Literatures

The 11 literatures originated from 7 countries including Lithuania, the United States, Germany, Japan, Iran, Belgium, and Italy, published in journals of sports medicine, sports rehabilitation, and sports science fields between 2010 and 2024. The intervention types mainly focused on neuromuscular training (NMT), proprioceptive training, jump and balance stability training. The basic characteristics of the included literatures are shown in Table 3.

Table 3 Main Characteristics Table

Author	Year	Country	Sample Size	Age/ Gender	Subject Athletic Level	Intervention Type	Experimental Group Intervention	Intervention Frequency and Time	Main Test Indicator	Outcome Indicator Specific Results
Domeika et al [10]	2020	Lithuania	n=31	20.8-22 years/male	Collegiate basketball players	Proprioceptive training	Single-plane unstable balance board	Frequency: 3 times/week, 20 minutes each, 8 weeks	YBT composite score	YBT composite score increased (P<0.05), static balance improved
Minoonejad et al [24]	2019	Iran	n=28	19.7-25.5 years/gender not specified	Collegiate basketball players	Jump stability training	Single-leg jump stability training (e.g., lateral jumps)	Frequency: 3 times/week, 2 hours each, 6 weeks (18 sessions total)	EMG indicators	Lower limb muscle activation level increased from 1.10±0.20 mV to 1.65±0.25 mV (P<0.05), muscle activation time significantly shortened from 120±15 ms to 95±10 ms (P<0.05)
Ardakani et al [25]	2019	Iran	n=28	19.1-25.5 years/male	Collegiate basketball players	Jump stability training	Single-leg lateral jump, landing stability training	Frequency: 3 times/week, 2 hours each, 6 weeks (18 sessions total)	Sagittal plane joint angles (hip, knee, ankle)	Patellofemoral flexion angle increased from 6.24°±3.18° to 13.10°±3.19° (P<0.05)
Omi et al	2018	Jap	n=757	18.4-20.8 year	Collegiate basketball players	Hip-focused	Hip strength and stabili	Frequency: 1-2 times/week, 89% annual compliance;	ACL injury rate	ACL injury rate decreased from 0.25

[28]		an		s/female		training	ty training (e.g., lateral step squats)	Duration: not specified (8-year intervention period)		per 1000 to 0.10 per 1000 (RR=0.38), non-contact ACL injuries reduced by 63% (P=0.026)
Kamikura et al [31]	2018	Japan	n=33	18-22 years/male	Collegiate basketball players	Stretch balance stability training	Single-leg dynamic balance, COP control training	Frequency: daily training; Duration: 20 times daily, 2 weeks	Toe grip, COP distance	Toe grip increased from 16.6±3.5 kg to 17.8±4.8 kg (P<0.05), COP horizontal and forward distances decreased but not significant
Bonato et al. [11]	2018	USA	n=160	18-30/Female	Elite Athletes	NMT	Unstable surface training, reactive jumping	4 times/week, entire season (≈6 months), 30 minutes each	YBT scores, CMJ height, lower limb (ankle, ACL) injury rate	YBT scores significantly increased (right +3.7%, P=0.012; left +2.3%, P=0.007), CMJ height increased by 9.4% (P<0.001), lower limb (ankle, ACL) injury rate decreased by 60% (P=0.006)
Pfile et al. [15]	2016	USA	n=11	18-20.8/Female	Collegiate basketball players	NMT	Enhanced training + dynamic balance	3 times/week, 30 minutes each, 6 weeks	SEBT composite score	SEBT composite score increased (70.4%→74.2%, P=0.004)

							training			
Nagano et al. [6]	2016	Japan	n=8	20-30/Female	Collegiate basketball players	Jump and balance training	Single-leg landing stability training, anti-rotation balance exercises	3 times/week, 20 minutes each, 5 weeks	Knee joint flexion angle	Knee joint flexion angle increased from 19.3°±2.5° to 24.4°±2.1° (P<0.01)
Benis et al. [9]	2016	Italy	n=28	20-35/Female	Elite basketball players	NMT	Single-leg balance, jump landing control, core stability training	2 times/week, 20 minutes each, 8 weeks	YBT posterior medial/posterior lateral reach distance	YBT posterior medial/posterior lateral reach distance significantly increased (+3.5%~5.5%, P<0.05)
Eils et al. [4]	2010	Germany	n=232	20-35/Not specified	Not specified	Multistation proprioceptive training	Balance pad, Bosu ball, unstable surface circuit training	1-2 times/week, 20 minutes each, 6 months (entire season)	Postural sway parameters, joint position sense, ankle injury risk	Postural sway parameters significantly reduced (P<0.05), joint position sense reposition error significantly reduced (P<0.05), ankle injury risk reduced by 35% (P<0.05)
Cumps et al.	20	Belg	n=11	18-20.8/Not	Not specified	Balance stabilit	Basketball-specifi	3 times/week, 5-10 minutes	Ankle sprai	Ankle sprain incidence

al. [13]	07	ium	specified	y training	c movement training (e.g., direction change, sudden stop) using balance half-ball	each, 22 weeks	n incidence	decreased (IG injury risk ratio (RR) vs. CG: significantly reduced by 70%, RR=0.30, 95%CI: 0.11-0.84)

Note: NMT: Neuromuscular training: SEBT: Star Excursion Balance Test: YBT, Y-Balance Test: EMG, Electromyography: mV: millivolt: ms: millisecond: RR: Risk Ratio: ACL, Anterior Cruciate Ligament: COP, Center of Pressure: CMJ, Countermovement Jump; IG: intervention group: CG: control group.

3.4 Types of Functional Training

Functional training is a training method aimed at improving athletic performance and preventing injuries. When intervening in lower limb injuries of adult basketball players, multiple forms are often adopted, mainly including neuromuscular training, proprioceptive training, jump stability training, balance control training, and other functional training.

3.5 Application Effects of Functional Training in Lower Limb Injury Prevention

A total of 11 studies with outcome indicators related to lower limb injuries were included, including Y-Balance Test (YBT) composite scores, Star Excursion Balance Test (SEBT) composite scores, hip-knee joint flexion angles, lower limb (anterior cruciate ligament [ACL], ankle) injury rates, electromyography (EMG) indices, center of pressure (COP) distance, and lower limb muscle activation time. Among these, 4 studies reported lower limb (ACL, ankle) injury rates: 2 studies showed that proprioceptive and specialized balance training significantly reduced ankle injury rates in post-tests compared to pre-tests and/or control group post-tests, 1 study noted that proprioceptive training, despite negative effects on lower limb muscles, still decreased lower limb injury rates, and 1 study had no significant impact, with the overall longer duration indicating that long-term proprioceptive training could effectively reduce the risk of lower limb injuries; 3 studies reported YBT and SEBT scores, which significantly improved after neuromuscular and proprioceptive training, and the overall intervention intensity and frequency showed little variation, suggesting that sustained neuromuscular and proprioceptive training could effectively prevent lower limb injuries; 3 studies reported hip-knee joint flexion angles and toe grip strength, with significant increases in hip-knee flexion angles after jump balance and stability training (1 study had no significant effect); 1 study reported EMG indices, showing a decrease in lower limb muscle activation time with no significant impact; and 1 study reported COP horizontal and lateral distances with no significant effect.

4. Analysis and Discussion

The study results show that functional training can effectively prevent lower limb injuries in adult basketball players. It improves neuromuscular control, enhances core and lower limb muscle stability, thereby boosting muscle strength, coordination, and dynamic joint stability, optimizing movement patterns during exercise to prevent sports injuries [16,17]. Specifically, functional training demonstrates greater improvements in balance function compared to traditional strength training [18], with better effects in preventing lower limb injuries. It balances muscle strength development, avoiding joint instability and injuries caused by small muscle group imbalance during exercise [19].

4.1 Impacts of Different Training Methods on Outcome Indicators

4.1.1 Effects of Diverse Functional Training Approaches

The included studies adopted diverse forms of functional training interventions, including neuromuscular training, proprioceptive training, jump stability training, hip-focused training, and balance training.

Neuromuscular training minimizes the risk of lower limb injuries, immediately enhancing the strength, reaction speed, and coordination of target muscle groups, as well as improving balance and exercise-related performance indicators. It improves injury-related neuromuscular control and coordination skills, playing a positive role in reducing lower limb injuries. Similar results were also observed in studies by Fort (2016) and others [20,21]. Proprioceptive training primarily stimulates joint receptors through unstable support surfaces to improve postural control and balance, ensuring the safety of basic movements. By strengthening joint position sense and lower limb balance, it reduces injuries caused by unexpected movements [22,23]. Jump stability training improves the lower limb landing mechanism, increases flexion angles, and effectively reduces the peak value of ground reaction force, thereby reducing the impact load on the knee and ankle joints. It has a good effect on controlling knee valgus and ankle injuries [24-27]. Hip-focused training improves lower limb alignment and dynamic lower limb valgus angles by enhancing the strength and neuromuscular control of the hip muscles, significantly reducing the incidence of ACL injuries, especially in female athletes [28-30]. Balance training strengthens plantar stability and proprioceptive ability, improving toe grip and lateral pressure control. Specialized balance training based on basketball skills also plays an auxiliary role in preventing metatarsal fractures and ankle sprains [31,32].

In addition, the intensity of training intervention, reflected by indicators such as frequency, single-session duration, and cycle, is a main factor affecting intervention effects. There is no conclusive evidence regarding frequency and duration, but among the 11 studies included, 7 studies had a single-session duration of 10-30 minutes, a frequency of 2-3 times per week, and a cycle of 6-8 weeks or 22 weeks. The study by Bonato et al. (2017) recommended using neuromuscular training as a warm-up for each training session, with a duration of 30 minutes (depending on the number of training days per team), while the work by Omi et al. recommended a frequency of 3 times per week and a duration of 20 minutes [33-35]. Experiments with shorter durations all showed positive results. However, studies by Minoonejad and Ardakani et al. (2019) used a single-session duration of 2 hours [24,36], but there is no clear evidence that longer training durations have a better effect on preventing lower limb injuries in athletes.

In general, various types of functional training can improve neuromuscular control, thereby effectively reducing the risk of lower limb injuries. Although current studies have not reached a consensus on the optimal neuromuscular training program, some studies support the use of such programs to prevent injuries [37]. In future training interventions, different training forms can be combined, and more targeted intervention plans can be selected based on individual functional status and injury types.

4.1.2 Differences in Outcome Indicators

The 11 included studies reported diverse outcome indicators: lower limb (ACL, ankle) injury rates, YBT composite scores, SEBT composite scores, sagittal plane joint range of motion (hip/knee/ankle), CMJ height, EMG indices, COP distance, and toe grip strength. These indicators showed significant variations in reflecting the preventive effects of lower limb injuries:

In terms of injury rate indicators, Eils and Cumps used ankle injury rate as the primary outcome, demonstrating that functional training significantly reduced ankle sprain incidence by 34.8% and 70%, respectively—attributed to improved neuromuscular control [32,38]. Similarly, studies focusing on ACL injury rates showed reductions after intervention, though specific data varied due to individual differences in athletic level and physical fitness between university athletes (Omi's study) and elite athletes (Bonato's study) [28,34]. Among balance composite scores, Benis and Domeika both confirmed improved YBT scores, with Benis showing more significant gains (from 3.5% to 5.5%), indicating that training interventions enhance balance and prevent lower limb injuries [39,40]. Pfile's study further found a significant positive correlation between SEBT score improvements and YBT scores (from 70.4% to 74.2%), confirming the intervention's effect on dynamic balance [20]. As the research of joint range of motion indicators shown, intervention increased ankle/hip/knee flexion angles from 6.24°±3.18° to 13.10°±3.19° [24]. Notably, Nagano's kinematic analysis showed knee flexion angles at touchdown increased from 19.3° to 24.4°, a biomechanical change that may reduce ACL injury risks [26]. Among neuromuscular control and performance indicators, Minoonejad et al. found lower limb muscle reactive activation levels significantly increased from 1.10±0.20 mV to 1.65±0.25 mV (50% increase), and gluteus medius onset time shortened from 120±15 ms to 95±10 ms (20.8% faster), indicating enhanced muscle recruitment and neuromuscular coordination [25]. Bonato's study showed a 9.4% increase in countermovement jump (CMJ) height, reflecting improved lower limb explosive power [34]. Furthermore, from the toe grip and COP indicators, Kamikura's study showed toe grip strength in basketball players significantly increased from 16.6±3.5 kg to 17.8±4.8 kg after 2 weeks, while COP horizontal/forward distances trended downward (e.g., from 7.2 mm to 5.0 mm during turns) without statistical significance [31].

These outcome indicators reflect the preventive effects of functional training on lower limb injuries from multiple perspectives: injury rates and balance scores directly demonstrate intervention effects, joint range of motion and neuromuscular control indicators reveal improvements in movement patterns and joint strength, and increased CMJ height supports enhanced athletic performance. Although some indicators (e.g., COP stability) did not reach statistical significance, the overall trend suggests that functional training reduces injury risks through multiple pathways. Future research should combine long-term interventions, larger samples, and comprehensive assessments to clarify specific differences and synergies among indicators.

4.2 Individual Differences

4.2.1 Gender

The samples included in this study covered male and female basketball players. Except for some studies that did not specify gender, most studies showed positive intervention effects across different genders. However, there is a lack of research comparing the probability of injury prevention between males and females through functional training. Currently, Antoranz's (2024) study indicates that females have a higher incidence of overall, ankle, and knee injuries [41]. In contrast, a meta-analysis by Zech et al. (2022) suggests that except for anterior cruciate ligament (ACL) injuries, females do not have a higher overall injury risk than males, which may be related to individual differences in responses to training interventions [42,43]. Stojanovic (2023) further points out that the risk of ACL injury in female basketball players is approximately three times that in males, but the risk of ankle sprain is slightly lower, especially among amateur and intermediate-level athletes [44]. Caldemeyer's study reports that the difference in injury risk between genders may be related to innate physiological differences in females, such as anatomical structure, hormonal levels (e.g., estrogen affecting ligament laxity), and neuromuscular control ability [45]. However, there is currently no clear evidence showing that the effect of neuromuscular training-based prevention programs is superior or inferior to males. In the future, meta-analyses of literature and comparative experiments targeting gender differences should be conducted to clarify the adaptability and intervention effects of functional training in different genders.

4.2.2 Athletic Level

Based on the evidence of this study, functional training has been confirmed to be effective in injury prevention for both collegiate and elite athletes [28,34,39,40,46]. Stojanovic et al. (2023) showed that the incidence of anterior cruciate ligament (ACL) injuries among elite basketball players (0.25 injuries per 1,000 competitions/trainings) was higher than that among intermediate (0.16 injuries per 1,000) and amateur (0.06 injuries per 1,000) athletes when comparing different competition levels [44]. Integrated evidence analysis revealed similar trends in direct comparisons of ACL injury incidences across athletic levels [47]: professional basketball players had higher rates (males: 0.21 injuries per 1,000; females: 0.20 injuries per 1,000) than collegiate players (males: 0.08 injuries per 1,000; females: 0.29 injuries per 1,000). This is because basketball players at higher competition levels perform more movements involving direction changes than those at lower levels [48-50]. In higher-level basketball games, athletes face more frequent cutting, sudden stopping, rotation, and high-intensity landing actions—all of which contribute to lower limb injuries including ACL injuries during games [51]. Therefore, functional training interventions like neuromuscular and proprioceptive training can stimulate small muscles and deep muscle tissues not targeted by traditional strength training, thereby preventing injuries caused by difficult movements in high-intensity competitions. It should be noted that due to insufficient evidence (only two studies [34,39] examined lower limb injury incidences in elite basketball players), more research is needed on this population to clarify lower limb injury risks and establish effective functional training-based prevention programs for athletes at all competition levels (amateur, collegiate, elite).

4.3 Mechanistic Elaboration

Functional training fundamentally includes specific approaches such as neuromuscular training, proprioceptive training, jump & stability training, and balance training. It achieves injury prevention by enhancing athletes' dynamic stability and postural control through mechanisms like neuromuscular regulation and movement mechanics optimization. Neuromuscular training enhances athletic performance and reduces injury risks by improving muscle activation efficiency, contraction conduction speed, and nerve impulse transmission quality. Punt and McGowan (2015) indicated its physiological basis includes more efficient use of the phosphocreatine system, enhanced Type II muscle fiber activity, and induction of post-activation potentiation (PAPE), thereby improving joint stability and muscle coordination [34,52-54]. Omi (2018) emphasized that hip-focused training essentially prevents ACL injuries by reinforcing proximal neuromuscular control to reduce lower limb alignment deviations [28]. Proprioceptive training activates joint receptors through unstable support surfaces, improving the nervous system's feedback regulation of postural changes to enhance balance and joint control. Fort et al. (2016) added that training should emphasize correct flexion of the trunk-hip-knee-ankle complex to avoid potentially harmful movement patterns like knee valgus [37]. Domeika (2020) noted that proprioception, by stimulating joint receptors via unstable surfaces, enhances static/dynamic balance and postural control during exercise—serving as a key foundation for maintaining lower limb dynamic stability [40]. Jump & stability training primarily disperses impact loads by improving landing mechanics parameters, such as reducing peak ground reaction forces, increasing hip-knee flexion angles, and decreasing knee valgus/varus torque. Ardakani (2019) and Minoonejad (2019) both indicated this training modality improves postural control and neuromuscular feedback in chronic ankle instability patients, aiding in secondary injury prevention [24,25].

Overall, functional training provides comprehensive injury prevention strategies for basketball players by synergistically improving lower limb neuromuscular control, enhancing dynamic postural stability, and optimizing movement mechanics through multi-mechanistic actions.

5. Research Limitations

This study has the following limitations: ① Limited focus on intervention objectives and inconsistent outcome indicators: Outcome indicators vary across studies, with some literatures only focusing on single body parts (e.g., ankle or knee), leading to insufficient comprehensive assessment of overall lower limb function. ② Predominance of traditional training methods: Current literature primarily uses traditional tools like balance pads and Bosu balls for interventions, with limited involvement of emerging functional training approaches based on AI, wearable devices, or personalized modeling. ③ Wide time span of published literatures and uneven research design quality: Some studies published in the early period adopt relatively simple methodologies, leaving room for improvement in randomization design, blinding control, and compliance assessment.

6. Research Conclusions

Functional training effectively prevents lower limb injuries in basketball players. Warm-up activities before future training or competitions should prioritize body activation through functional training such as neuromuscular training, proprioceptive training, and jump-balance-stability training. The findings show that functional training activation can significantly increase hip/knee/ankle flexion angles, CMJ height, and COP distance, while improving EMG indices—thereby reducing injury risks during exercise. It is recommended to adopt short-duration, high-efficiency training with an intervention duration of 6 weeks, a frequency of 3 times per week, and 20-30 minutes per session. However, personalized and systematic training plans should also be arranged according to the training characteristics of athletes or teams.

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