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Research article

Training methods and evaluation of basketball players' agility quality: A systematic review

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A R T I C L E I N F O

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A B S T R A C T

Objective: Agility refers to the technical skills and abilities required by athletes to quickly react and adjust direction, speed, or movement patterns when faced with stimuli. This article provides a comprehensive review and evaluation of agility training methods for basketball players, offering valuable insights and references for scientifically enhancing their agility training. Method: Research literature published from January 1, 2000, to April 1, 2023, was searched in the Web of Science Core Collection, PubMed, and EBSCO databases with basketball, agility, and training as keywords. A total of 489 articles were initially identified. Based on predefined inclusion and exclusion criteria, including the removal of duplicate articles, non-English publications, and conference papers, a total of 463 articles were excluded. Ultimately, 26 articles that met the specified criteria were included for analysis in this study. The researchers utilized the PEDro quality evaluation screening scoring system to assess the quality of the final included literature. Result: 26 articles were included, with an average quality evaluation score of 4.5 points (3–7 points). Among them, the average training time for reaction ability (5 articles) is 5 weeks (ranging from 3 to 8 weeks), involving a total of 150 participantsa，nd the agility quality is improved by 7.2 %–19 %; The average training time for speed quality (5 articles) is 6 weeks (ranging from 4 to 8 weeks), involving a total of 151 participants，and the agility quality is improved by 1.2 %–14.4 %; The average training time for strength quality (4 articles) is 6 weeks (ranging from 4 to 8 weeks), involving a total of 57 participants， and the agility quality is improved by 1.41 %–10.33 %; The average training time for plyometrics (12 articles) is 6 weeks (ranging from 1 to 8 weeks), involving a total of 195 participants，with an increase in agility by 2.34 %–6.79 %. Conclusion: (1) The effect of simple reaction ability, speed, and strength training on improving the agility quality of basketball players is limited. In the actual process, the above training methods need to be combined to maximize the training effect, such as diversified speed training combined with different forms of reaction ability, strength training, etc. (2) Plyometric training has a high intensity of muscle stimulation, which can promote the agility quality of basketball players by improving the joint stability, neuromuscular adaptability as well as coordination and consistency

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between muscles. However, young basketball players must carefully consider exercise mode, load intensity, and other factors when implementing plyometric training.

1. Introduction

The essence of competitive sports is human movement driven by energy metabolism and neural control, manifested externally through muscle contractions. The core determinant of athletic performance is power, which directly correlates with an athlete's physical fitness [1]. With the rapid development of professional sports, physical fitness has become a barrier differentiating elite athletes from sub-elite athletes in team sports, ultimately influencing the outcome of competition [2]. Numerous studies have confirmed that physical fitness is one of the core factors determining basketball players' competitive performance [2,3]. With the rapid improvement of modern sports research, physical fitness training is becoming increasingly refined and scientific.

Agility has emerged as a prominent area of focus in the field of physical conditioning for basketball, garnering significant attention and research interest from both researchers and coaches. Executing quick changes of direction in sports can assist athletes in reducing interference from opponents and gaining advantages in both technical and tactical aspects [4]. In sports, high-speed human movement can be classified into linear and multidirectional movements. While linear speed is crucial in team sports, during actual basketball games, players need to continuously engage in multidirectional movements on the court. According to statistics, in a formal basketball game, adult males make 450 lateral movements, covering a total distance of 203–269 m; For women, the number is 63–298, with a coverage distance of 125 m [5]. Lateral movement accounts for 18–42 % of the competition time. A single action must be completed within 0.6–1.4 s, with appropriate time, height, and speed [3]. Relevant studies have indicated a positive correlation between lateral movement speed and shot-blocking ability for center players, as well as a positive correlation between lateral movement speed and steal ability for guard players [5]. Therefore, it can be inferred that fast lateral movements have become a key determinant of winning in sports competitions.

Agility quality is a important reflection of various qualities such as human strength, speed, flexibility, and balance. It serves as a vital physical foundation for basketball players to perform a series of high-difficulty technical actions on the court [6]. Agility is also defined as the body movement in which an athlete responds to "stimuli" and quickly changes speed or direction [7]. Researchers have pointed out that the agility qualities of excellent athletes have a technical characteristic, which is an important indicator to distinguish athletes of different sports levels [8]. Scanlan et al. [9]found a significant difference in reaction time test completion between starting and non-starting players. Spiteri et al. [10]discovered that players in the Women's National Basketball Association demonstrated better defensive agility performance compared to college-level female athletes in defensive agility tests. Furthermore, agility is important to recognize the positional demands on agility training for athletes [11]. Stojanovic et al. [12]found that perimeter players outperformed interior players in agility T-test and modified agility T-test. This is because perimeter players are involved in more multidirectional fast movements such as fast breaks, transition plays, and dribble penetration in half-court offense, resulting in higher frequencies of repeated sprints, distances, and movement pattern changes compared to interior players during games.

Thus, the agility quality of basketball players should be improved through scientific and reasonable training and evaluation to enhance their athletic performance. Although researchers have more and more training methods and means for basketball players' agility qualities, existing research primarily focuses on investigating the effects of different training methods or loads on agility performance, these training effects have not yet been systematically and comprehensively sorted out. Hence, the purpose of this systematic review is to describe the impact of agility training methods on the agility performance of basketball players.

2. Materials and methods

2.1. Literature retrieval methods

The authors wrote search formulas using Boolean logic methods to accurately search for corresponding literature in the Web of Science Core Collection database, PubMed (including MEDLINE), and EBSCO Publishing database. The search literature was published from January 1, 2000, to April 1, 2023. The written search formulas were: 1) Web of Science Core Collection, Topical Subject (TS)= ("agility" or "flexible" or "nimble" OR "agile" or "low limb flexible" or "dexterity") AND TS=("basketball") AND TS = training; 2) PubMed and EBSCO databases, ("agility" or "flexible" or "nimble" or "agile" OR "low limb flexible" OR "dexterity") and basketball and training.

Formulation and implementation of retrieval strategy: after the lead author initially formulated the retrieval scheme, the second author reviewed and revised it and determined the final retrieval scheme. The lead author carried out specific retrieval. Any queries arising during the search were resolved in consultation with the third author.

2.2. Inclusion and exclusion criteria for literature

Inclusion criteria for literature: 1) English is widely recognized as the international language of science, and its accessibility, standardization, and abundance of resources make it an essential platform for global researchers to communicate and collaborate. Therefore, the original literature selected for this study consists of publicly published English literature; 2) Intervention methods: including various factors such as different training content, intensity, duration, frequency, and period; 3) Experimental group and control group: the experimental group receives a regular training intervention for a certain period, while the control group differs from the experimental group in terms of training intervention or does not receive any training intervention; 4) Outcome measures: at least one sensitive physical fitness-related indicator is measured before and after the intervention; 5) Experimental design: adopting a randomized controlled trial with an exercise intervention plan.

Exclusion criteria for literature: 1) Participants are basketball players with health conditions; 2) Direct assessment of the effects of physical fitness training on basketball players has not been conducted; 3) Literature, conference abstracts, book chapters that are not based on direct experiments or rely on secondary sources of experimental data for review and analysis; 4) Insufficient clarity in the description of experimental protocols and procedures, data testing, statistical and analytical methods; 5) Randomized controlled trials were not employed in the experimental design.

2.3. Data extraction and analysis

After the literature retrieval was completed, the included literature catalog was obtained. Download the full text and extract the corresponding data. The extracted data specifically included: research identification information, research participants, demographic information (including gender, age, and athlete level), intervention time, training intensity and volume, training effectiveness, effect size, inter-group comparison, and Physiotherapy Evidence Database (PEDro) Scale. The purpose of extracting relevant data is to analyze the training effects of different agility training methods on athletes, as well as to examine whether the training outcomes are related to intervention duration, training intensity, and training volume. The tools used for this analysis include Endnote 20.0 and Excel 2019.

2.4. Methodology quality evaluation

After data extraction was completed, The methodological quality of the studies was independently assessed by the lead and second authors using the Physiotherapy Evidence Database (PEDro) Scale developed by Cashin et al. [13] (Table 1). The two researchers resolved any differences arising from the quality assessment through consultation, and the third author can decide if necessary. Methodological quality assessment is explained by management [14]: 3 points or lower than 3 represent low quality, 4–5 points represent medium quality, and 6–10 points represent high quality.

3. Results

3.1. Literature retrieval results

The search results for the Web of Science Core Collection database were 253, PubMed database 100, and EBSCO Publishing database 136, so a total of 489 search results. The screening process is shown in Fig. 1. Ultimately 26 experimental studies on the training methods of basketball players' agility quality were included in the system evaluation.

3.2. Basic input information of literature

Among the 26 articles ultimately included, 24 articles are long-term intervention experiments, and 2 articles are one-time intervention experiments. Intervention methods include reaction ability training (5 articles), involving 150 participants. The training methods included small-sided games training, fitlight agility testing training, repeated sprint training. Speed quality training (5 articles), involved 151 participants, with training methods such as speed sprint training, repeated sprint with change of direction training, and power and specific multidirectional repeated sprint training. Strength quality training (4 articles), involved 57 participants, with training methods including traditional resistance training, functional strength training, eccentric training. Plyometric training (12 articles), involved 195 participants, with training exercises focusing on horizontal, sagittal, and frontal axis jumps, and training environments including wooden floors, sand surfaces, grass fields.

The age range of the participants included in the literature ranged from 12 to 26 years old, and their competitive levels include

Table 1
Physiotherapy evidence database (PEDro) Scale.

Item	Yes	No
Eligibility criteria and source	1	0
Random allocation	1	0
Concealed allocation	1	0
Baseline comparability	1	0
Blinding of participants	1	0
Blinding of therapists	1	0
Blinding of assessors	1	0
Adequate follow-up (> 85 %)	1	0
Intention-to-treat analysis	1	0
Between-group statistical comparisons	1	0
Reporting of point measures and measures of variability	1	0

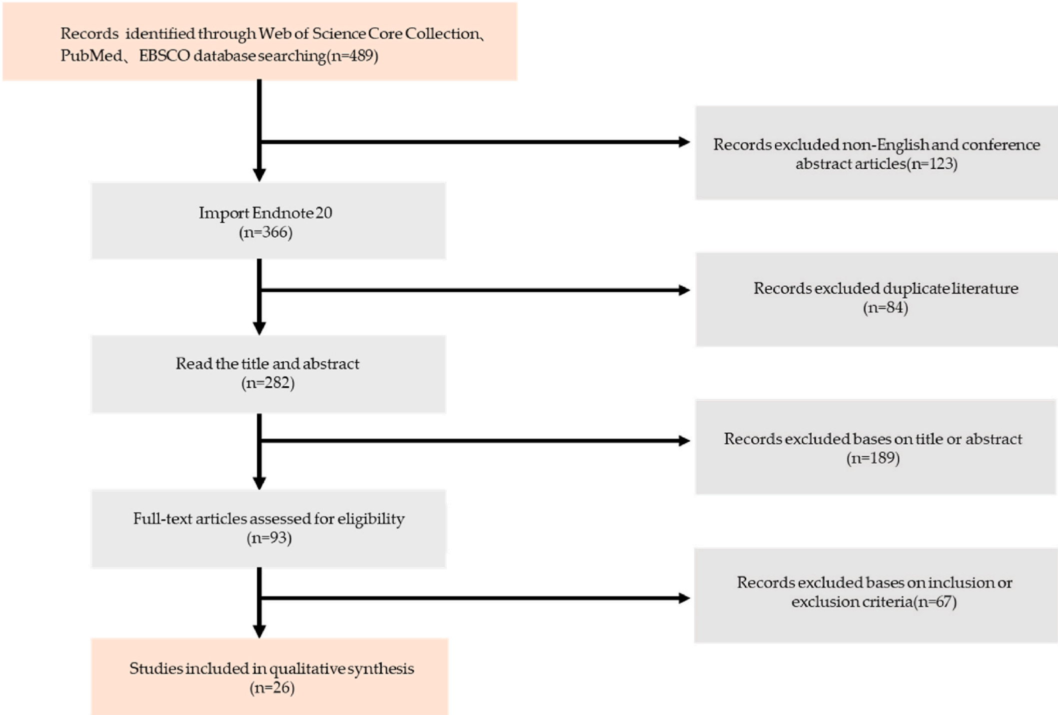

Fig. 1. Flow chart of literature retrieval and screening.

amateur, high-level, elite, and professional basketball players.

3.3. Methodology quality assessment results

The average quality evaluation score of 26 articles is 4.5 points (ranging from 3 to 7 points). Only 6 articles (23.1 %) were classified as high quality literature(≥6 points). There were 13 articles (50.0 %) classified as medium quality literature(4–5 points), indicating that the majority of studies provided detailed and replicable method descriptions, explicitly defined outcome variables, and correct statistical analysis methods. There were 7 articles (26.9 %) classified as low quality literature(≤3 points), suggesting the need for further improvement in experimental design and implementation procedures in the future. One of them is research on speed training using the same participants as the controls in the control experiment.

3.4. Results of included literature

By reading and analyzing the full text of 26 articles, and using training methods as classification criteria, the current methods for training basketball players' agility quality are classified into four types: reaction ability training, speed quality training, strength quality training, and plyometric training. All four types of training methods have been shown to effectively improve the agility performance of basketball players. This growth effect is also observed in athletes of different genders and competitive levels.Among them, the average training time for reaction ability (5 articles) is 5 weeks (ranging from 3 to 8 weeks), and the agility increases by 7.2 %–19 % (Table 2); The average training time for speed quality (5 articles) is 6 weeks (ranging from 4 to 8 weeks), and the agility quality increases by 1.2 %–14.4 % (Table 3); The average training time for strength quality (4 articles) is 6 weeks (ranging from 4 to 8 weeks), and the agility quality increases by 1.41 %–10.33 % (Table 4); The average training time for the plyometric training (12 articles) is 6 weeks (ranging from once to 8 weeks), with an increase in agility by 2.34 %–6.79 % (Table 5).

4. Discussion

Agility quality is crucial for basketball players. In competitions, athletes need to timely adjust all offensive and defensive movements according to the changes in their opponents [18]. These adjustments involve not only changing direction and speed but also quickly executing appropriate action responses based on external stimuli such as the movements of opponents and the situational context on the court [41].For instance, in a game, an offensive player does not know how the defensive player will guard them or what speed and angle the defensive player will take, so the offensive player must rely on quick reactions to external stimuli to make the next move. However, researchers have not yet formed a unified and precise definition of agility, mainly due to the association between agility and other physical qualities [6], such as speed and coordination [41]. Nevertheless, researchers have attempted to improve the

Table 2
Characteristics of reaction training studies.

Study	Nation	Research Object				Research Interventions		Relative Effects	Performance Improve (%) ES	PEDro
		Subjects	Sex	Age	AL	(W/S)	Intervention Project			
Zeng et al. [15]	China	19	F	19.9 ± 1.1	CBP	4/3	EG:SSG, 3 × (2 × 2min45), 2min recovery CG:HIT-COD,3 × (6min of 15″-15″at 90 of VIFT)	PostEG vs PreEG: MAT* PostCG vs PreCG: MAT* PostEG vs PostCG:MAT△	EG:7.2 %,ES = 1.7 CG:5.7 %,ES = 1.5	6
Arslan et al. [16]	Turkey	32	M	14.5 ± 0.5	RLP	6/3	EG:SSG, 2 × (2 × 2min30), 2min recovery CG:HIT,2 × (6min of 15″-15″at 90 of VIFT)	PostEG vs PreEG: ATT、MAT* PostCG vs PreCG: ATT、MAT*	EG-ATT-ES = 0.91 EG-MAT-ES = 0.39 CG-ATT-ES = 0.32 CG-MAT-ES = 0.09	4
Maggioni et al. [17]	Italy	30	M	19.0 ± 1.0	S-PLP	8/3	EG1:SSG, 4 × 4min, 4min recovery EG2:RST,3 × (6 × 20 m), 4min recovery CG:GBT	PostEG1 vs PreEG1:ATT* PostEG2 vs PreEG2:ATT* PostCG vs PreCG: ATT△	EG1-ES = 0.7 EG2-ES = 0.7 CG-ES = 0.2	5
Hassan et al. [18]	Saudi Arabia	20	M	14.8 ± 0.8	CP	8/4	EG:FITLIGHT training system CG:traditional method	PostEG vs PreEG: ATT、MAT*** PostCG vs PreCG: ATT、MAT*** PostEG vs PostCG: ATT、MAT**	EG-ATT:11 % EG-MAT:19 % CG-ATT:5 % CG-MAT:7.31 %	3
Silvestri et al. [19]	Italy	49	M	15.0 ± 1.5	CP	3/5	EG:FITLIGHT training system CG:shooting session	PostEG vs PreEG: ATT** PostCG vs PreCG: ATT**	NR	3

Abbreviations:ES:effect size; F:female; M:male; AL:activity level; (W/S):(Week/session); CBP:collegiate basketball player; EG:experimental group; SSG:Small-sides game; CG:control group; HIT-COD:High intensity interval training-change of direction; 15″-15″at 90 of VIFT:15s of High intensity running at a speed corresponding to 90 % of the speed attained in the last fully completed stage of the 30-15 intermittent fitness test; MAT:modified agility T-test; RLP:regional league player; ATT:agility T-test; S-PLP:semi-professional level player; GBT:general basketball training; CP:club player; NR:not repoeted; *:significant difference,***:P < 0.001,**:P < 0.01,*:P < 0.05; △:not significant difference.

agility performance of basketball players from various perspectives and in different methods.

4.1. The influence of reaction ability training on basketball players' agility quality

The agility quality of basketball players is mainly manifested in their ability to respond correctly and reasonably to random stimuli, that is, the ability to change direction and speed after receiving random stimuli. Generally speaking, the ultimate goal of the training program arranged by basketball coaches to change direction and speed is to improve athletes' ability to change direction and speed after they receive random stimuli [41]. Only randomly changing task stimuli can effectively enhance the agility quality of basketball players, and reaction ability training has become a commonly used method to improve athletes' random reaction speed because its training situation conforms more to the actual basketball games. From the effect size in Tables 2 and it can be seen that both Small Side Games Training (SSGT) and Fitlight agility testing training (FITL) can significantly improve the agility performance of basketball players, confirming that these training methods are effective ways to improve the agility quality of basketball players. The increase in agility performance ranges from 1.2 % to 19 %, among which FITL has the best effect, with the most remarkable improvement in athletes' Modified Agility T-test (MAT) scores, reaching 19 %. Spiteri et al. [42]pointed out that athletes with good agility performance often presented faster reaction time and decision-making time. In fact, through FITL, athletes' visual scanning, pattern recognition, and environmental cognition abilities are enhanced. At the same time, during training, athletes must continuously adjust their movement direction and speed to improve prediction, decision-making time, and accuracy. By using specific stimuli with multidirectional variations, FITL enhances the reaction ability of basketball players, thereby improving their agility performance. In terms of cognitive mechanisms, approximately 80 % of the relevant information surrounding athletes is conveyed through the eyes, as the visual sensory system rapidly transmits persistent signals and information to stimulate the nervous system [43]. This enhances the visual reaction speed and agility performance of basketball players [18]. SSGT has become a commonly used method in basketball training due to its adaptability to the requirements of athletes' technical movements and awareness in actual competitions and its ability to provide targeted training on athletes' reaction speed, action speed, and cognitive decision-making [16]. The training time of SSGT varies from 2 min to 4 min. The ratio of training time to rest time is mainly 1:1. Research has found that the short-term effect of SSGT application on young athletes is better than that of child athletes, possibly because young athletes have more mature skills and more stable thinking than child athletes. Although the numerous advantages of SSGT are already well known to coaches, it is crucial to recognize that SSGT is based on simulating real matches and is bound to inevitably increase the risk of sports injuries for athletes [44]. In

Table 3
Characteristics of speed training studies.

Study	Nation	Research Object				Research Interventions		Relative Effects	Performance Improve (%) ES	PEDro
		Subjects	Sex	Age	AL	(W/S)	Intervention Project			
Sanchez-Sanchez et al. [20]	Spain	12	F	17.2 ± 1.1	NLLP	6/2	EG1:HIT-COD1 EG2:HIT-COD3 HIT = 2 × (6min of 10″-10″at 90 of VIFT)	PostEG1 vs PreEG1: MAT△ PostEG2 vs PreEG2: MAT***	EG1:2.5 %,ES = 0.45 EG2:3.1 %,ES = 0.39	5
Aschendorf et al. [21]	Germany	24	F	15.1 ± 1.1	NLLP	5/2	EG:basketball-specific HIT CG:traditional method	PostEG vs PreEG: CODS-HB、CODS-NB△ PostCG vs PreCG: CODS- HB*、CODS- NB△	EG- CODS-HB:1.2 % EG- CODS-NB:1.5 % CG- CODS-HB: 2.8 % CG- CODS-HB: 2.1 %	4
Arede et al. [22]	Portugal	9	F	19.0 ± 2.4	ASLP	4/2	EG:RST with COD1 CG: RST RST = 2 × (10 × 20 m)	PostEG vs PreEG:505T-R、505T-L△ PostCG vs PreCG:505T-R、505T-L△	EG-505T-R-ES = 1.03 EG-505T-L-ES = 0.22 CG-505T-R-ES = −0.18 CG-505T-L-ES = 0.10	4
Ersoy et al. [23]	Turkey	54	NR	12.5 ± 0.5	NR	8/3	EG1:functional sprint training EG2:GBT CG:no training	PostEG1 vs PreEG1: ATT***、IAT**、505T* PostEG2 vs PreEG2: ATT**、IAT**、505T* PostCG vs PreCG: ATT、IAT、505T△	EG1-ATT:14.41 % EG1-IAT:10.27 % EG1-505T:4.97 % EG2-ATT:5.27 % EG2-IAT:4.82 % EG2-505T:7.25 % CG-ATT:3.28 % CG-IAT:0.74 % CG-505T:0.04 %	3
Brini et al. [24]	Tunisian	52	M	EG1:26.0 ± 2.4 EG2:25.8 ± 1.8 EG3:26.1 ± 1.8 CG:26.4 ± 2.0	PP	8/2	EG1:DJP,3 × 10, 3min recovery EG2: MRST,3 × (10 × 30 m), 4min recovery EG3: DJP + MRST CG: no training	PostEG1 vs PreEG1: ATT*** PostEG2 vs PreEG2: ATT*** PostEG3 vs PreEG3: ATT*** PostCG vs PreCG: ATT*	EG1:0.96 % EG2:1.98 % EG3:2.49 % CG:0.32 %	5

Abbreviations:NLLP:national league-level player; HIT-COD1/3:High intensity interval training-one/three change of direction; CODS:20 m change of direction sprint test; HB:have ball; NB:not ball; ASLP:amateur senior level player; RST:repeated sprint training; 505T:505 Test; R:right; L:lift; IAT: illinois agility test; NR:not repoeted; PP:professional player; DJP:drop jump training; MRST:multidirectional repeated sprint.

addition, previous studies have shown that not all players in different positions are subjected to the same exercise load in SSGT [45]. Therefore, coaches should comprehensively consider factors including athletes' positions on the field, training status, and training cycle when using SSGT, and reasonably arrange the training time of SSGT.

In formal basketball games, players need to perceive the surrounding situations of both offensive and defensive players, make rapid and accurate decisions, and change their directions and speeds accordingly. Therefore, training that enhances players' agility performance should focus on developing their perceptual and decision-making abilities [46]. Reaction ability training is characterized by scenarios that closely resemble the dynamic nature of basketball games, helping players to quickly and accurately identify task-relevant cues, process incoming information, and select appropriate responses within the training environment.

4.2. The impact of speed training on basketball players' agility quality

In basketball games, athletes must perform many fast forward, backward, and lateral movements [24]. For example, if a defensive player completes a steal in the backcourt, he needs to hold the ball and quickly advance to the frontcourt to score. From this process, it can be seen that speed is an essential quality for basketball players. Theoretically, agility, movement speed, coordination, and power have the same mechanism effect at the physiological and biomechanical levels [47]. Therefore, specialized speed training for basketball players can also improve their agility performance [23]. Table 3 shows that the improvement in agility performance ranges

Table 4
Characteristics of strength training studies.

Study	Nation	Research Object				Research Interventions		Relative Effects	Performance Improve (%) ES	PEDro
		Subjects	Sex	Age	AL	(W/S)	Intervention Project			
Arede et al. [25]	Portugal	16	M	EG:14.24 ± 0.35 CG:14.89 ± 0.42	S-EP	8/4	EG: GBT + SCT(ST 5min + NMST 15min + PT 15min) CG:GBT	PostEG vs PreEG:505T△ PostCG vs PreCG:505T△	EG-ES = 0.15 CG-ES = 0.13	4
Zhang et al. [26]	China	15	F	EG:22.0 ± 1.2 CG:21.7 ± 2.3	CBP	6/2	EG:VBRT(BS + BP) CG:PBRT(BS + BP) Increase from 65 % to 90 % of 1RM	PostEG vs PreEG:505T* PostCG vs PreCG:505T△	EG-ES = 0.87 CG-ES = 0.09	6
Yilmaz et al. [27]	Turkey	16	NR	13.29 ± 1.96	NR	4/2	EG: GBT + ICST(6 × 2min) CG:GBT	PostEG vs PreEG:505T*	EG:10.33 %	4
Hernandez Davo et al. [28]	Spain	10	NR	21.6 ± 2.41	AP	6/2	EG:EOT(flywheel training)(4 × 8, 2min recovery) EG1: bilateral EG2: unilateral	PostEG1 vs PreEG1: ATT-D、ATT-ND * PostEG2 vs PreEG2: ATT-D *、ATT-ND△	EG1- ATT-D-ES = 1.41 EG1- ATT-ND-ES = 1.57 EG2- ATT-D-ES = 0.87 EG2- ATT-ND-ES = 0.64	5

Abbreviations:S-EP:sub-elite player; SCT:strength and conditioning training; ST: stability training; NMST: neuromuscular strength training; PT: power training; VBRT:velocity-based resistance training; PBRT:percentage-based resistance training; BS: back squat; BP:bench press; 1RM:1 repetition maximum; NR:not repoeted; ICST:isometric core strength training; EOT:eccentric overload training; D:dominant leg; ND:non-dominant leg.

from 1.2 % to 14.41 %. The five articles included in this study include three different training schemes: Speed sprint training, Repeated Sprint Training with Changes-of-Direction, and Power and Specific Multichange-of-direction Repeated Sprint Training. Among them, Speed sprint training shows an improvement in agility performance ranging from 1.2 % to 14.41 %, repeated sprint training with changes-of-direction shows an improvement ranging from 2.5 % to 3.1 %, and power and specific multidirectional-of-repeated sprint training shows a 2.49 % improvement. These findings confirm that these training methods are effective approaches to enhance the agility performance of basketball players. Ersoy et al. [23]pointed out that the development of speed and agility is crucial for the success of basketball players. Speed sprint training can improve athletes' coordination, mechanical smoothness, and speed. As a particular physical skill, agility enables athletes to complete deceleration, turning quickly, and acceleration movements, closely related to speed quality [48]. Repeated sprint training can improve the efficiency of aerobic and anaerobic training for athletes while adding change-of-direction training during the sprint process to meet the specific adaptation of athletes to the competition. With the same training time and load, athletes perform better agility in repeated sprints combined with change-of-direction training than in basketball-specialized technical and tactical training [22]. In addition, this study finds that after 6 weeks of training, repeated sprint training with multiple changes of direction shows a more significant improvement in agility than only one change of direction [20]. It is worth noting that the combination of power and repeated sprint change-of-direction training achieves better results than simple repeated sprint change-of-direction training. Brini et al. [24]believe that this combined training method can improve the control ability of the athlete's neuromuscular system over the lower limb muscles and increase the centrifugal force of the leg muscles, which are the ability required for the deceleration stage in the change-of-direction process. Therefore, the effect of joint training on improving athletes' agility will exceed that of repeated sprint combined with change-of-direction change training.

4.3. The impact of strength training on basketball players' agility quality

The level of agility quality of basketball players is closely related to their muscle mass. Spiteri et al. [42]In multi-change-of-direction agility tests, athletes with better test results exhibit higher relative peak strength in their muscle cross-sectional area and a higher rate of strength development. Therefore, strength training has become an important method to improve basketball players' agility. It can be seen from Table 4 that strength quality training can effectively improve the athletes' agility test results. However, the actual effects of different strength training schemes are different. The percentage-based resistance training (PBRT), represented by bench press and squat, has the characteristics of convenience and practicality, making it the best strategy for improving strength quality [49]. Zhang et al. [26]recruited 15 adult female basketball players and randomly divided them into PBRT and velocity-based resistance training (VBRT) groups. After 6 weeks, the 505 Test results showed that both training methods could improve the athletes' test scores. Although the experimental results showed that the VBRT group had a more remarkable improvement, no significant differences were found between the groups ($P > 0.05$). Arede et al. [25]conducted functional strength training for young elite basketball players for 8 weeks. Although there was no significant change in the athletes' agility test scores after the experiment compared with that before the experiment ($P > 0.05$), they found that functional strength training could improve the athletes' ability to change directions in offensive and defensive techniques, such as the speed of changing direction when the players broke through with the ball. Bagherian et al. [50]believe that core strength can improve athletes' functional movement patterns and

Table 5
Characteristics of plyometric training studies.

Study	Nation	Research Object				Research Interventions		Relative Effects	Performance Improve (%) ES	PEDro
		Subjects	Sex	Age	AL	(W/S)	Intervention Project			
Poomsalood et al. [29]	Thailand	10	M	EG:19.60 ± 1.34 CG:19.20 ± 0.84	CBP	4/2	EG:PJT, increase from 100 to 140, 2min recovery CG:no training	PostEG vs PreEG:ATT*** PostCG vs PreCG:ATT△ PostEG vs PostCG*	NR	3
Cherni et al. [30]	Tunisia	25	F	EG:20.9 ± 2.6 CG:21.0 ± 3.0	NLLP	8/4	EG:PJT,(BJ + HJ + DJ),4 × 6,2 min recovry add 1 set every 2 weeks CG:no training	PostEG vs PreEG:ATT* PostCG vs PreCG:ATT△	EG:4 % CG:NR	6
Huang et al. [31]	Taiwan	15	M	22.16 ± 0.85	CBP	8/3	EG:PJT(VJ + HJ)	PostEG vs PreEG:ATT*	NR	3
Alp [32]	Turkey	24	M	EG:20.16 ± 1.47 CG:21.16 ± 1.94	PP	8/3	EG: GBT + PT(30 min) CG: GBT	PostEG vs PreEG:ATT△ PostCG vs PreCG:ATT△ PostEG vs PostCG△	NR	3
Cherni et al. [33]	Tunisia	27	F	21.0 ± 2.6	EP	8/2	EG:GBT + PJT, (BJ + HJ + DJ),4 × 6,2 min recovry add 1 set every 2 weeks CG:GBT	PostEG vs PreEG:ATT* PostCG vs PreCG:ATT△	EG-ES = 0.60 CG-ES = 0.25	7
Meszler et al. [34]	Hungary	18	F	EG:15.8 ± 1.2 CG:15.7 ± 1.3	YAP	7/2	EG:GBT + PJT, (HJ + DJ) 20min CG:GBT	PostEG vs PreEG:ATT、IAT△ PostCG vs PreCG:ATT、IAT△	NR	6
Palma-Munoz et al. [35]	Chile	22	M	13.5 ± 2.0	RLP	6/2	EG1:PPT(1152 jump repetition per leg) EG2:non PPT(960 jump repetition per leg) EG:SLHJ + SLVJ + HJ + VJ	PostEG1 vs PreEG2: CODS* PostEG2 vs PreEG2: CODS* PostEG1 vs PostEG2△	NR	5
Paktas [36]	Turkey	30	F	19–24	CBP	4/2	EG1: PT EG2: RST CG:GBT	PostEG1 vs PreEG1: IAT* PostEG2 vs PreEG2: IAT△ PostCG vs PreCG: IAT*	NR	3
Munshi et al. [37]	India	24	M	20.8 ± 2.02	CBP	1	EG1: PT EG2: W-BVT	PostEG1 vs PreEG1:ATT* PostEG2 vs PreEG2:ATT*	EG1:2.34 % EG2:1.21 %	4
de Villarreal et al. [38]	Spain	40	M	14.2 ± 1.3	NR	7/2	EG1: PT EG2: RST EG3:CODT CG:GBT	PostEG1 vs PreEG1:ZZT* PostEG2 vs PreEG2:ZZT△ PostEG3 vs PreEG3:ZZT* PostCG vs PreCG:ZZT*	EG1:6.79 %,ES = 0.39 EG2:0.52 %, ES = 0.04 EG3:9.02 %, ES = 0.91 CG:0.63 %, ES = 0.07	5
Bouteraa et al. [39]	Tunisia	26	F	EG:16.4 ± 0.5 CG:16.5 ± 0.4	RLP	8/2	EG: PT + BT CG:GBT	PostEG vs PreEG: MICODT* PostCG vs PreCG: MICODT*	EG:6.7 % CG:0.71 %	6
Ozen et al. [40]	Turkey	12	M	17.58 ± 0.5	RLP	6/3	EG:PT EG1:WPS EG2:SS EG:(VJ + DJ + CMJ),3 × 8, add 2 set every 2 weeks	PostEG1 vs PreEG1:ATT* PostEG2 vs PreEG2:ATT* PostEG1 vs PostEG2*	EG1 < EG2	5

Abbreviations:PJT:plyometric jump training; BJ:bounding jumps; HJ:hurdle jumps; DJ:drop jumps; VJ:vertical jumps; NR:not repoeted; PT:plyometric training; PPT:progressed plyometric training; SLHJ: single leg horizontal jumps; SLVJ: single leg vertical jump; CODS:change of direction speed; RST:resistance strength training; W-BVT:whole-body vibration training; CODT:change of direction training; ZZT:zig-zag test; BT:balance training; MICODT:Modified Illinois Change of Direction Test; WPS:wooden parquet surface; SS:sand surface.

dynamic posture control. Yilmaz et al. [27]the study further confirmed this result. Through 4 weeks of core strength training, the MAT performance of 8 young basketball players increased by 10.33 %, and there was a significant change ($P < 0.05$). Spiteri et al. [51] pointed out that centrifugal force is one factor that affects athletes' agility. This is because, during the braking phase, agility requires a greater centrifugal force of lower limb muscles and the ability of muscles to stretch and shorten the cycle. Hernandez Davo et al. [28] conducted centrifugal training, represented by flywheel training, on 10 adult amateur basketball players. A 6-week ATT test indicated flywheel centrifugal training could significantly improve athletes' agility test scores ($P < 0.05$). In addition, whether it was the performance of superior or inferior legs, the effect size of the bilateral training group was greater than that of the unilateral training group. At present, there is limited research literature regarding the impact of strength training on the agility performance of basketball players, and the influence of strength training on the agility performance of basketball players remains unclear. Spiteri et al. [51] pointed out that athletes with better agility performance exhibit greater impulse, isometric strength, and relative muscle mass compared to slower athletes. Rouissi et al. [52]suggested that the movement patterns and muscle contraction modes of lower limb strength tests are similar to those of agility performance tests, which may explain why players with stronger lower limb strength perform better in agility tests. Acceleration running and 'cutting' change-of-direction movements in agility tests essentially involve the stretch-shortening cycle (SSC) action, with lower limb movements ultimately reflecting the movement pattern of the SSC. However, in contrast, some studies found no significant correlation between 1RM squat, lower limb eccentric strength, isometric strength, concentric strength, and agility test performance in female basketball players. Spiteri et al. [53]proposed that unlike change-of-direction movements, agility tests have an unknown final direction before the decision-making process takes place, and the presence of cognitive decision-making processes reduces the importance of the interaction between lower limb strength and agility performance. This also suggests that different studies may yield different results due to variations in the agility test methods used. Future research could focus on refining the impact of strength training on different forms of agility test performance to clarify the mechanisms between strength and agility qualities.

4.4. The impact of plyometric training on basketball players' agility quality

From the perspective of exercise physiology, the human body requires two different forms of muscles to quickly complete deceleration (centrifugal) and acceleration (centripetal) actions when completing change-of-direction or variable speeds [54]. During the process of change-of-direction or variable speed movements, the working state of the athletes' centrifugal muscles significantly impacts the efficiency and effectiveness of change-of-direction or variable speed movements. This is because the centrifugal muscles mainly play a role in the deceleration process of athletes, and deceleration is an essential prerequisite for the body to complete subsequent acceleration and change-of-direction movements. Plyometric training is a composite exercise in which muscles make centrifugal stretching followed by centripetal contraction [35]. The effect of plyometric training on muscles is relatively significant compared to other methods, mainly because the intensity of the plyometric training mode is relatively high, which produces more obvious stimulation on the human nerves, muscles (primarily centrifugal muscles), and joints, thereby improving joint stability, neuromuscular adaptability, and coordination and consistency between muscles. According to Table 5, 12 studies on plyometric training were included in this study, with a quality score of 3–7 points, an average of 4.7 points, and an improvement in performance of 2.34 %–6.79 %. Cherni et al. [30]randomly divided 25 female basketball players from the Tunisian national team into a plyometric training group and a control group. The experimental group underwent plyometric training for 8 weeks, 4 times a week, with different jumping movement combinations. The study found that the ATT test scores of the plyometric training group were significantly improved compared to those before the experiment ($P < 0.05$). In contrast, the test scores of the control group did not show significant changes compared to those before the experiment ($P > 0.05$). The plyometric training content of Poomsalood et al. [29]was also composed of jumping movements. After four weeks of training twice a week, five male college basketball players found a significant difference in ATT scores compared to the control group ($P < 0.05$). In addition, the researchers also compared plyometric training with other training methods. De Villarreal et al. [38]randomly recruited 40 high school basketball players and randomly divided them into the plyometric training group, the strength training group, the change-of-direction training group, and the control group. The study found that the ZZT (zag Zig test) score of the plyometric training group was 6.79 % higher than that before the experiment ($P < 0.05$), which was significantly better than that of the strength training group (0.52 %) and the control group (0.63 %), and lower than that of the particular change-of-direction training group (9.02 %). Munshi et al. [37]also, plyometric training had a better acute impact on athletes' ATT performance than vibration training.

Although plyometric training has sound training effects, its stimulation intensity and mode are not necessarily applicable to all basketball players. Meszler et al. [34]randomly divided 18 adolescent amateur female basketball players into experimental and control groups. The experimental group conducted two horizontal jump training sessions per week. After 7 weeks, the ATT and IAT scores of the experimental and control groups did not significantly improve ($P > 0.05$). The study of Alp [32]also found that there was no significant difference ($P > 0.05$) in the ATT performance of adult male basketball players compared to the control group and that before the experiment, during an 8-week, three times a-week plyometric training. Therefore, it can be seen that plyometric training is not entirely manifested as improving the agility of basketball players, and their adaptive reaction is influenced by factors such as participants' training level, gender, and maturity status [33]. Ozen et al. [40]randomly divided 12 adolescent elite athletes into a wooden floor training group and a sand floor training group. Both groups received the same jumping training. After 6 weeks, it was found that the ATT scores of both groups of athletes showed significant changes ($P < 0.05$), and the improvement rate of the sand floor training group was significantly higher than that of the wooden floor training group ($P < 0.05$). Bouteraa et al. [39]conducted plyometric and balance training for adolescent female elite athletes twice a week. After 8 weeks, they found that their agility test scores increased by 6.7 %, with an effect size of up to 2.91, much higher than the control group's 0.71. To sum up, plyometric training has an intense stimulation of muscles, which can effectively improve joint stability, neuromuscular adaptation, and coordination and consistency between muscles, thereby improving the agility quality of athletes. In plyometric training, the amount and intensity of training should be scientifically and reasonably arranged. If the plyometric training can be conducted on an unstable surface or be combined with balance ability training, it will greatly improve training efficiency. In addition, due to the fact that young basketball players are in a prime period of physical development, they may struggle to withstand excessive training intensity and may not adapt to the plyometric training mode, so the implementation of plyometric training needs to be carefully arranged.

4.5. Summary

(1)FITL and SSGT can improve basketball players' reaction speed, accuracy, and neuromuscular connections, improving their agility quality. The effect of FITL is better than that of SSGT. (2) Simple speed and strength training do not conform to the actual situation in the process of basketball matches, and the benefits obtained from the training are limited. The combination of speed training, reaction ability training, resistance training, and change-of-direction training can improve the specialized agility performance of basketball players more effectively, and the combination of strength training has the best training effect. (3) Plyometric training has more muscular muscle stimulation and apparent training effects. However, child basketball players are in the stage of physical development, so factors including exercise mode and load intensity must be carefully considered in plyometric training.

5. Conclusions

(1) The effect of single reaction ability, speed, and strength training on improving the agility quality of basketball players is limited. In the actual process, organically combining the above training methods can achieve the maximum training effect, such as diversified speed training combined with different forms of reaction ability, strength training, etc. (2) Plyometric training has a high intensity of muscle stimulation, which can improve the agility of basketball players by improving joint stability, neuromuscular adaptability as well as coordination and consistency between muscles.

6. Research Limitations

(1) Only published English literature was included, and literature in other languages was not considered, which may introduce selection bias. (2)Some studies did not provide detailed information on the agility performance testing protocols, which may result in lower levels of evidence for the research findings. (3)The studies did not differentiate the gender and skill level of the athletes in the analysis, which may potentially influence the research outcomes. (4)The classification of strength training, speed training, reaction training, and plyometric training was performed by the lead and second authors, which may introduce bias.

Declarations

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6.1. Informed consent statement

Not applicable.

6.2. Conflicts of interest

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Pukui Wang: Writing - original draft, Funding acquisition. **Chenge Shi:** Writing - original draft, Software, Resources. **Jun Chen:** Resources, Project administration, Conceptualization. **Xiang Gao:** Software, Resources, Methodology, Investigation. **Zenwen Wang:** Validation, Supervision, Software, Resources, Methodology. **Yongzhao Fan:** Writing - review & editing, Resources, Investigation.

Yongqiang Mao: Writing - review & editing, Visualization, Software, Resources, Project administration, Conceptualization.

Declaration of competing interest

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