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# Effects of functional training on physical and technical performance among the athletic population: a systematic review and narrative synthesis

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## Abstract

**Background** The evidence indicates that functional training is beneficial for athletes' physical and technical performance. However, a systematic review of the effects of functional training on athletes' physical and technical performance is lacking. Therefore, this study uses a literature synthesis approach to evaluate the impact of functional training on the physical and technical performance of the athletic population and to extend and deepen the existing body of knowledge.

**Methods** This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, and the researchers performed a systematic search of five international electronic databases using the predefined terms "functional training" and "athletes" on 15th November 2023: Web of Science, CINAHL PLUS, PubMed, Scopus, and SPORTDiscus. A PICOS approach was used to identify the following inclusion criteria: (1) athletes, (2) a functional training program, (3) an active control group, (4) a measure of physical and/or technical performance, and (5) randomized controlled studies. A methodological quality assessment of the original research was conducted using the Physiotherapy Evidence Database (Pedro) scale. The review was performed using the PRIMSA guidelines and registered in PROSPERO (ID: CRD42022347943).

**Results** Of the 1059 potentially eligible studies identified, 28 studies met the inclusion criteria. The studies included were conducted on 819 athletes from 12 different countries and were published between 2011 and 2023. The assessment was performed on the Pedro scale, and the mean Pedro score for the included studies was 5.57 (moderate quality, ranging from 4 to 10). The eligibility study reported on 14 different types of sports, with 22 studies focusing on physical performance and 11 studies focusing on technical performance. These studies have shown that functional training can significantly improve the physical and technical performance of athlete populations, but in some studies, no significant difference in the data was observed between groups.

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**Conclusion** Functional training is an effective training method for enhancing the physical and technical performance of athlete populations. However, no significant difference in the data was observed between the functional training groups and the regular training group, which may be due to the duration of the training program, the different training experiences of the athletes, and the different focuses of the training regimens. Therefore, future studies should focus on the physical and technical performance of different sports groups with different types and durations of functional training programs to expand the current evidence base.

**Keywords** Functional exercise, Physical fitness, Skills, Performance, Players

## Introduction

Sports performance is the demonstration of an athlete's competitive ability during training or competition [1]; it relies on several factors, such as an individual's talent level, fitness level, technical ability, tactical level, and psychological qualities [2, 3]. A comprehensive assessment of these complex factors can identify and address the specific needs of an athlete for all practitioners to optimize sports performance. Among the many factors that influence sports performance, an athlete's physical fitness and skill level are the most central [4–6]. Physical fitness can be defined as either health-related or skill-related, health-related physical fitness (body composition, muscular strength, muscular endurance, flexibility, and cardiorespiratory endurance) related to one's day-to-day activities, and skill-related physical fitness (agility, balance, coordination, reaction time, power, and speed) refers to your ability to perform physical tasks efficiently as it relates to a particular sport [7]. Technical performance refers to sport-specific technical skills (i.e., tennis forehand and backhand), movements involving specific goals or objectives, and the need to coordinate several motor abilities within a specific environment and time frame [8]. Additionally, recognizing the interplay between physical fitness and technical performance, as physical fitness is the prerequisite and foundation of technical performance is important, and technical performance is the highest expression of physical fitness [6, 9].

Sports scientists use modern science and technology and scientific training methods to optimize sports performance; the effectiveness of different training methods to improve sports performance has become a focus of attention, and many empirical studies have been conducted using various types of training methods, such as resistance training [10], core strength training [9], plyometric training [11], and functional training [12]. Targeted training can realize the organic connection and transformation of physical fitness and technical performance and improve athletes' performance [13], which is mainly because these methods are based on the characteristics and laws of the sports program, from which weak links are identified, and targeted training strategies are developed. Second, these methods focus on the totality of human movement, thus highlighting the overall effects of multiple joints; the overall coordination of the human movement chain; the dynamics of human movement, stability and balance; the ability of the nervous system to coordinate human movement; and the ability of the nervous system to coordinate human movement [14–16]. The American College of Sports Medicine (ACSM) supports the use of traditional resistance training to enhance athletic performance, which is accomplished by gradually increasing the exercise load during training [17]. Most traditional resistance training lacks multijoint and multiplanar exercises, which are believed to be the cornerstones of peak athletic performance [18, 19]. The training components included in the training program should be consistent with the athlete's needs and the program's characteristics to ensure maximum transfer to the sport [1]. In other words, the principle of specificity should be followed by the selection of exercises that reflect the type of activity involved in the sport. Nevertheless, functional training is a training strategy that has garnered significant attention [17]. The fundamental principle is the specificity of training, namely, the specific training for an individual's specific function or needs, to achieve the goal of improving or enhancing his or her functional ability [20]. Although a number of studies have described the efficacy of functional training, convincing athletes and coaches that functional training can improve athletes' physical [12, 21, 22] and technical performance [23–25], current studies do not fully understand the impact of functional training on the physical and technical performance of athletes, mainly due to significant differences in the study design and study populations. Confounding factors, such as combination with other training interventions, were also included. These inconsistencies make it challenging to draw firm conclusions. However, to the authors' knowledge, several systematic reviews of functional training have been published recently, and most reviews on this topic have focused on athlete fitness [26–28], and athletes' technical performance [29, 30]; however, a gap exists in the literature that specifically examines the effects of functional training on athletes' physical and technical performance. The physical and technical performance of athletes are the key factors in their comprehensive competitive ability [4–6]. As a result, a systematic review and summary of the literature on the effects of functional training on athletes' physical and technical performance can not only identify potential advantages of functional training on the physical and technical performance of various athlete types but also provide insightful recommendations for future research directions for practitioners or academics in the field. Consequently, the purpose of the current systematic review was to evaluate the available data on the impact of functional training on athletes' physical and technical performance.

## Methods

The research was registered under the CRD42022347943 designation in the International Prospective Systematic Evaluation Registry and adhered to the Preferred Reporting in Systematic Evaluation and Meta-Analysis (PRISMA) criteria [31]. Since individual subject data were not included in this study, no further ethical approval was needed.

### Search strategy

Researchers systematically searched potential literature in five international electronic databases (Scopus, PubMed, CINAHL PLUS, SPORT Discus, and Web of Science) in November 2023 using predetermined keyword combinations of "functional training" and "athlete". Additionally, researchers performed an updated search in November 2024 to incorporate more recent studies that may not have been included in the synthesis papers. The predetermined keyword combinations were as follows: (("functional training" OR "functional exercise" OR "functional skill*" OR "functional task training" OR "therapeutic exercise" OR "functional balance training" OR "functional strength training" OR "functional movement training" OR "functional movement screen training" OR "functional correction training" OR "functional fitness training" OR "functional fitness training") AND ("player ∗ " OR "athlete ∗ " OR "sportsman ∗ " OR "sportswoman ∗ " OR "sportsperson ∗ ")). Moreover, a thorough manual search was conducted on both Google Scholar and the reference lists of all the selected papers to ensure that no relevant publications were missed.

### Eligibility criteria

The following inclusion criteria were created using the Population, Intervention, Comparison, and Outcome (PICOS) framework: (1) subjects were athletes, regardless of age, training experience (refers to an individual's past experiences and practices in sports), or competitive level; (2) the intervention was a planned, organized study of the effects of functional training on athlete performance; in addition, studies using a combination of functional training and other types of exercise (e.g., resistance training) were included; (3) the outcomes included at least one physical or technical performance component; (4) the experimental design was a randomized controlled trial (RCT); and (5) the length of the intervention, the experimental site, and the sample size were all unrestricted.

The following studies were excluded: (1) case reports, short communications, reviews, conference abstracts, published and unpublished articles written in languages other than English; (2) duplicate studies; and (3) studies that included nonexercise interventions (e.g., psychological interventions and, nutritional supplements) in addition to functional training.

### Screening and data extraction

Three steps composed the literature screening process: (1) a skilled librarian conducted the literature search; (2) duplicates were eliminated from the list of retrieved literature by importing it into the Mendeley Literature Manager; and (3) independent researchers (XWS and BXR) perused the titles and abstracts of the identified studies to find relevant articles. The whole texts of all eligible studies had to be available for inclusion in the qualitative synthesis analysis; those without the full texts were disqualified. If any disagreements occurred, a third reviewer (SKG) was consulted until a consensus was reached.

Two independent reviewers (XWS and BXR) extracted data relevant to the aims of this review from the included studies, with the accuracy validated by a third reviewer (SKG). Following screening, the following information was obtained in a predefined format: (1) authors and publication year; (2) participant characteristics (type of athletes, gender, age, training experience, and sample size); (3) intervention program characteristics (type, duration, time, and frequency); and (4) measures and outcomes.

### Quality assessment and risk of bias

Four aspects of research methodology are evaluated by the Physiotherapy Evidence Database (Pedro) scale: the randomization process, blinding, group comparison, and data analysis. The Pedro scale has a maximum value of 10, and higher scores indicate higher methodological quality. The eligibility criteria are not included in the total score because they are connected to external validity [32]. More precisely, scores between 6 and 10 indicate high quality, scores between 4 and 5 indicate moderate quality, and scores less than 3 indicate low quality. Any disagreements regarding the methodological quality of the studies between the two authors (XWS and BXR) were first discussed, and a consensus was sought. If no agreement was reached, a third reviewer (SKG) made the final decision. In the assessment of methodological quality and risk of bias, inter-rater reliability was quantitatively evaluated using the Cohen kappa coefficient. The kappa value obtained was 1.00.

### Data synthesis and analysis

Due to the insufficient homogeneity of the included studies in terms of the type of athlete, training programs (i.e., functional balance training, and functional strength training), and methods used to measure the outcomes, a meta-analysis could not be conducted, and a qualitative analysis of the studies was instead conducted. Additionally, the researchers used a qualitative assessment of best evidence synthesis (BES) to reach their conclusions, a method that has been used in other systematic reviews in the past [1, 33], which considers the quantity of studies, methodological quality, and consistency at five levels of evidence, to evaluate the overall level of scientific evidence: (1) strong evidence, provided by generally consistent results from multiple (≥ 2) high-quality studies; (2) moderate evidence, provided by one high-quality study and one or more low-quality studies or generally consistent results from multiple low-quality studies; (3) limited evidence, when only one study is available or multiple (≥ 2) studies have inconsistent results; (4) conflicting evidence, for conflicting results from case–control studies (75% of studies reported consistent results); and (5) no evidence, when no case–control studies were found [34].

## Results

The review included 28 randomized controlled trials (RCTs) that were published between 2011 and 2024. Nineteen studies were conducted in Europe (two in Germany and one each in Croatia, Switzerland, Russia, and Spain), seventeen in Asia (seven in China, six in Turkey, two in Korea and Iran, and one each in Italy, Iraq, and Pakistan), and two in Africa (Egypt).

### Study section

A total of 1059 potentially eligible publications were obtained from the five international electronic databases using predetermined keyword combinations (Scopus: $n=504$; PubMed: $n=74$; CINAHL PLUS: $n=32$; SPORTDicus: $n=253$; Web of Science: $n=141$). Furthermore, 55 potentially eligible studies were identified via manual searches of the reference lists ($n=24$) and Google Scholar ($n=31$). Following deduplication, 738 studies were included for title and abstract screening. A total of 267 studies were subsequently eliminated because of their non-English publication or review format. Furthermore, 443 studies were excluded based on the eligibility criteria. Ultimately, 28 studies met all the eligibility criteria. Figure 1 presents the PRISMA flowchart.

### Quality assessment

The mean Pedro score for the included studies was 5.57 (moderate quality), with a range of 4 to −10; 19 studies were rated as moderate quality, with a score of 4 or 5; nine studies were rated as high-quality, with a score of 6 to −10; and three studies met all the criteria of the Pedro checklist [12, 35, 36]. Table 1 display the methodological quality assessment scores.

### Characteristics of the participant

The included studies focused on 14 different types of sports, including soccer [32, 43, 58], basketball [23, 44, 48, 58, 59], tennis [12, 21, 35, 47, 53], taekwondo [52, 57], handball [39, 43], shot put [40], wushu [41], judo [42], dance [51], baseball [54], badminton [55], dragon boat racing [56], hammer ball [24], and hockey [36], with one study focusing on collegiate athletes who did not report sport categories [37]. This review included 903 participants (463 males and 111 females), 329 of whom were from a mixed population or did not specify their gender. The age ranged from 8.9 years [21] to 32.5 years [44], and eight studies did not report the age of the participants [23, 41, 42, 51, 53–55, 58]. At the professional level, eight studies focused on collegiate athletes, eight studies focused on professional or elite athletes, four studies focused on club athletes, and one study focused on athletes from soccer schools. Additionally, 14 studies reported that subjects' training experience ranged from 2 years [21] to more than 12 years [37, 38], and 14 studies did not report subjects' training experience. Table 2 display the population demographic characteristics.

### Characteristics of the intervention

The study's experimental group, which fulfilled the eligibility criteria, followed a different exercise regimen with an emphasis on functional strength training. The following were the intervention program characteristics: (1) training duration—the shortest duration of the intervention was 8 days [38], and the longest duration was 10 months [50]; (2) time—nine studies did not report the duration of a single intervention [37, 38, 41, 52, 53, 55, 58, 59], and in the remaining studies, the duration of a single intervention ranged from 10 min [43] to 90 min [42, 47, 49, 57]; (3) frequency—three studies did not report the intervention frequency [38, 41, 52], and in the remaining studies, the intervention frequency ranged from 2 times/week [42, 43, 45, 46, 49, 50, 56] to 4 times/week [48]. Table 3 display the interventions and outcomes characteristics.

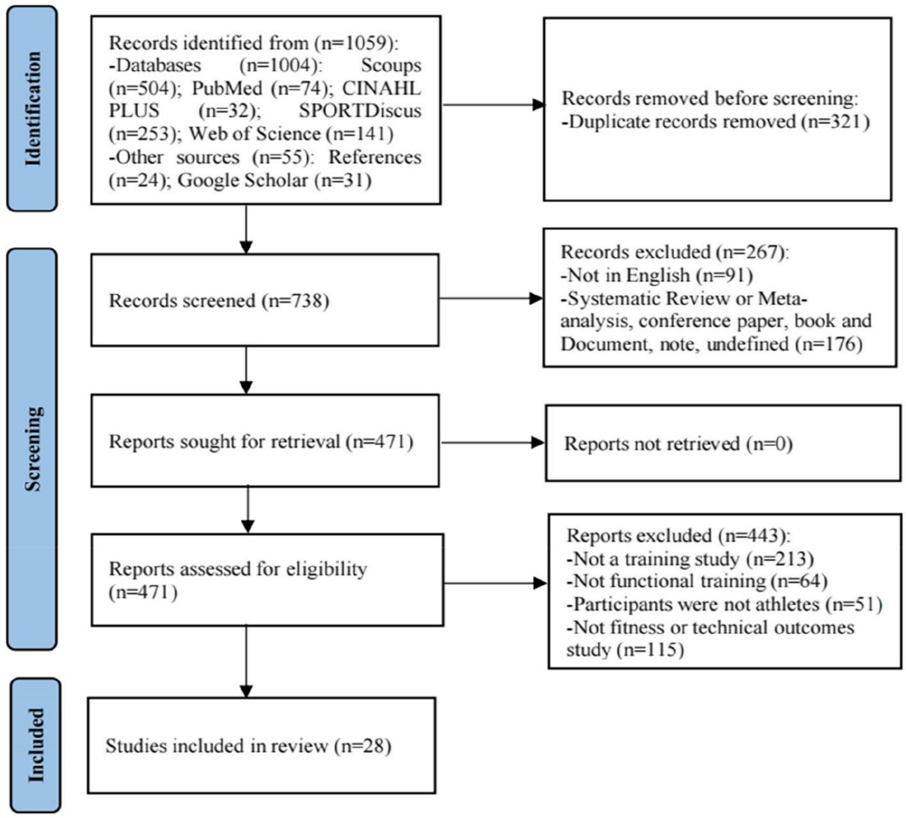


**Fig. 1** PRISMA flow chart was used to identify of the include studies

## Outcome characteristics

### *Effects of functional training on physical performance*

This review included 22 studies that reported physical performance, and the outcomes were categorized into health-related physical performance and skill-related physical performance.

*Effects of functional training on health-related physical performance* The core components of health-related fitness include body composition, muscular strength, muscular endurance, flexibility, and cardiorespiratory endurance. Meanwhile, since keeping track of individuals' food and calorie consumption during the intervention—a characteristic that significantly affects body composition [60]—is more difficult, body composition was temporarily excluded from use as an outcome indicator in this study.

(1) Muscular strength. Thirteen studies focused on strength performance, using medicine ball throws [37, 41], grip strength [24, 39, 54, 56], 1RM [39, 44, 46, 50, 52], static strength tests [24], push-ups [12, 41, 56, 58], sit-ups [57], and wall squat tests [12] to assess strength performance. The subjects participated in soccer [46, 50], taekwondo [52, 57], basketball [44, 58], baseball [54], tennis [12], handball [39], hammer ball [24], wushu [41], and dragon boat racing [56]. One study did not report on the type of athletes and only reported results for college athletes [37]. The results of the study indicated how much functional training enhanced athletes' strength performance. Furthermore, following the trial, six investigations reported no significant difference between groups [44, 46, 54, 56–58].

(2) Muscular endurance. Three studies focused on muscular endurance, using the Taekwondo core endurance test [52] and the push-up test [36, 57] to assess muscular endurance performance. The participants were Taekwondo [52, 57] and hockey players [36]. The subjects' muscular endurance performance was significantly enhanced by functional training. Following the trial, Khazaei et al. (2023) and Bashir et al. (2024) documented statistically significant differences between the groups after the intervention.

(3) Flexibility. Ten studies focused on flexibility performance, which was assessed using the sit and reach [21, 35, 36, 44, 46, 47, 54, 56, 57], the trunk forwards

**Table 1** Summary of methodological quality assessment scores

| Study | Item 1 | Item 2 | Item 3 | Item 4 | Item 5 | Item 6 | Item 7 | Item 8 | Item 9 | Item 10 | Item 11 | TS | SQ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tomljanović et al. (2011) [37] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 5 | M |
| Sander et al. (2013) [38] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 5 | M |
| Song et al. (2014) [39] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 4 | M |
| Elbadry (2014) [24] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 5 | M |
| Kamal (2016) [40] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 5 | M |
| Cherepov & Shaikhetdinov (2016) [41] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 5 | M |
| Osipov et al. (2017) [42] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 5 | M |
| Alonso-Fernández et al. (2017) [43] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 5 | M |
| Yildiz et al. (2019) [21] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 4 | M |
| Usgu et al. (2020) [44, 45] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 4 | M |
| Turna & Alp (2020) [46] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 4 | M |
| Zirhli & Demirci (2020) [47] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 5 | M |
| Turker & Yuksel (2021) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 5 | M |
| Hovsepian et al. (2021) [48] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 | H |
| Carvutto et al. (2021) [49] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 5 | M |
| Keiner et al. (2022) [50] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 | H |
| Zheng (2022) [51] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 5 | M |
| Abood et al. (2022) [23] | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 4 | M |
| Zou & Ma (2022) [52] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 4 | M |
| Liu & Yi (2023) [53] | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 4 | M |
| Lee et al. (2023) [54] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 5 | M |
| Chen (2023) [55] | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 6 | H |
| Wu et al. (2023) [56] | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 | H |
| Khazaei & Amani-Shalamzari (2023) [57] | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 8 | H |
| Xiao et al. (2023) [12] | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | H |
| Shang et al. (2023) [58] | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 6 | H |
| Xiao et al. (2024) [35] | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | H |
| Bashir et al. (2024) [36] | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 | H |

Item 1: Eligibility criteria; Item 2: Random allocation; Item 3: allocation concealment; Item 4: baseline comparability; Item 5: blind participants; Item 6: blind therapist; Item 7: blind assessor; Item 8: follow-up; Item 9: intention to treat analysis; Item 10: between group comparisons; Item 11: point measure and variability; P: poor quality; M: moderate quality; H: high quality; TS: total score; SQ: study quality

flexion test, the trunk back extension test, the split test [39], and the side-step test [54], with subjects such as tennis players [21, 35, 47], handball players [39], basketball players [44], soccer players [46], baseball players [54], dragon boat racers [56], taekwondo players [57], and hockey players [36]. Most of the studies confirmed a significant improvement in subjects' flexibility performance after the intervention, and two studies reported no significant difference in subjects' ability to sit and reach after the intervention [54, 56]. Furthermore, four investigations showed significant differences between groups after the intervention [21, 35, 36, 47].

(4) Cardiorespiratory endurance. Seven studies focused on cardiorespiratory endurance and used the Wingate anaerobic power test [46, 47], VO2max test [43], Bruce test [57], 3200 m, sideline 17-repetition run [58], dedicated endurance test [42], and multistage fitness test [35] to assess cardiorespiratory endurance performance. The participants were tennis players [35, 47], judo players [42], handball players [43], basketball players [46, 58], and taekwondo players [57]. The study findings indicated that functional training greatly increased participants' cardiorespiratory endurance. Moreover, two investigations revealed significant differences between the groups after the intervention [57].

### *Effects of functional training on skill-related physical performance*

(1) Agility. Twelve studies focused on agility performance, which was assessed using the t-test [21, 36, 44, 47–49, 57], shuttle run test [41, 48, 56], hexagonal agility test [35, 37], limited area body acuity detection [58], planned agility test [35], and Illinois

**Table 2** Summary of population demographic characteristics

| Study | Country | Type of Athletes | Level/training experience | Population Characteristics |
|---|---|---|---|---|
| Tomljanović et al. (2011) [37] | Croatia | NR | Moderately trained collegiate athlete/ > 12 yr | EG: *n* = 11, CG: *n* = 12, Gender: M, Age: 22–25 yr |
| Sander et al. (2013) [38] | Germany | Soccer | Professional/ > 12 yr | EG1: *n* = 65, EG2: *n* = 56, Gender: NR, age: 15.1 yr |
| Song et al. (2014) [39] | Korea | Handball | Elite/NR | EG: *n* = 31, Gender: M, age: 17.0 ± 1.06 yr.; CG: *n* = 31, Gender: M, Age: 16.62 ± 0.94 yr |
| Elbadry (2014) [24] | Egypt | Hammer throw | Collegiate/NR | EG: *n* = 10, Gender: F, Age: 18.33 ± 0.5 yr.; CG: *n* = 10, Gender: F, Age: 18.29 ± 0.8 yr |
| Kamal (2016) [40] | Egypt | Shot put | Collegiate/NR | EG: *n* = 10, Gender: F, Age: 18.33 ± 0.5 yr.; CG: *n* = 10, Gender: F, Age: 18.29 ± 0.8 yr |
| Cherepov & Shaikhetdinov (2016) [41] | Switzerland | Martial artists | Elite/NR | EG: *n* = 15, CG: *n* = 15, Gender: NR, Age: NR |
| Osipov et al. (2017) [42] | Russia | Judo | Collegiate/7–8 yr | EG = 30, CG = 30, Gender: NR, Age: 20–30 yr |
| Alonso-Fernández et al. (2017) [43] | Spain | Handball | Club/60 months | EG = 7, CG = 7, Gender: F, Age: 15.2 ± 0.6 yr |
| Yildiz et al. (2019) [21] | Turkey | Tennis | Prepubertal players/3.1 ± 1.1 yr | EG1 = 10, EG2 = 10, CG = 8, Gender: NR, Age: 9.6 ± 0.7 yr |
| Usgu et al. (2020) [44, 45] | Turkey | Basketball | Professional/NR | EG: *n* = 14, Gender: M, Age: 26.6 ± 5.9 yr.; CG: *n* = 14, Gender: M, Age: 22.4 ± 4.2 yr |
| Turna & Alp (2020) [46] | Turkey | Soccer | Professional/6.4 ± 3.09 yr., 4.4 ± 2.71 yr | EG: *n* = 10, Gender: M, Age: 25.2 ± 3.36 yr.; CG: *n* = 15, Gender: M, Age: 22.90 ± 2.02 yr |
| Zirhli & Demirci (2020) [47] | Turkey | Tennis | Club/ ≥ 2 yr | EG = 10, CG = 10, Gender: F, Age: 11.20 ± 0.834 yr |
| Turker & Yuksel (2021) | Turkey | Basketball | Elite/NR | EG: *n* = 15, Gender: M, Age: 20.8 ± 1.7 yr.; CG: *n* = 15, Gender: M, Age: 21.06 ± 1.9 yr |
| Hovsepian et al. (2021) [48] | Iran | Basketball | Professional/7.5 ± 2.5 yr., 6.5 ± 1.5 yr | EG: *n* = 10, Gender: F, Age: 23.5 ± 3.0 yr.; CG: *n* = 10, Gender: F, Age: 21.0 ± 1.5 yr |
| Carvutto et al. (2021) [49] | Italy | Soccer | Soccer school/NR | EG: *n* = 14, Gender: M, Age: NR; CG: *n* = 10, Gender: M, Age: NR |
| Keiner et al. (2022) [50] | Germany | Soccer | Professional/NR | EG1: *n* = 11, EG2: *n* = 11, EG3: *n* = 14, CG: n = 12, Gender: NR, Age: 17.45 ± 0.52 yr |
| Zheng (2022) [51] | China | Dance | Collegiate/NR | EG: *n* = 30, Gender: M, Age: NR; CG: *n* = 30, Gender: M, Age: NR |
| Abood et al. (2022) [23] | Iraq | Basketball | Clubs/NR | EG: *n* = 7, Gender: NR, Age: NR; CG: *n* = 7, Gender: NR, Age: NR |
| Zou & Ma (2022) [52] | China | Taekwondo | National second-level athlete/ ≥ 2 yr | EG1 = 8, CG = 8, Gender: M, Age: 22 yr |
| Liu & Yi (2023) [53] | China | Tennis | Clubs/ NR | EG: *n* = 9, Gender: M, Age: NR; CG: *n* = 9, Gender: M, Age: NR |
| Lee et al. (2023) [54] | Korea | Baseball | Collegiate/TB: > 10 yr | EG: *n* = 5, Gender: NR, Age: NR; CG: *n* = 5, Gender: NR, Age: NR |
| Chen (2023) [55] | China | Badminton | National level/NR | EG: *n* = 6, Gender: M, Age: NR; CG: *n* = 6, Gender: M, Age: NR |
| Wu et al. (2023) [56] | China | Dragon Boat | Collegiate/NR | EG: *n* = 21, Gender: M, Age: 21 ± 1.47 yr.; CG: *n* = 21, Gender: M, Age: 22 ± 1.50 yr |
| Khazaei & Amani-Shalamzari (2023) [57] | Iran | Taekwondo | Elite/NR | EG: *n* = 9, Gender: F, Age: 21.1 ± 2.9 yr.; CG: *n* = 8, Gender: F, Age: 22.3 ± 3.1 yr |
| Xiao et al. (2023) [12] | China | Tennis | Elite/ > 4.5 yr | EG: *n* = 20, Gender: M, Age: 16.7 ± 0.4 yr.; CG: *n* = 20, Gender: M, Age: 16.5 ± 0.6 yr |
| Shang et al. (2023) [58] | China | Basketball | Collegiate/NR | EG: *n* = 9, CG: *n* = 9, Gender: NR, Age: NR |
| Xiao et al. (2024) [35] | China | Tennis | Elite/4.5 yr | EG: *n* = 20, Gender: M, Age: 16.7 ± 0.4 yr.; CG: *n* = 20, Gender: M, Age: 16.5 ± 0.6 yr |
| Bashir et al. (2024) [36] | Pakistan | Hockey | Elite/ > 3.8 yr | EG = 22, CG = 22, Gender: M, Age: 21.5 ± 0.8 yr |

*NR* not reported, *M* male, *F* female, *yr*: year, *EG* functional training group, *CG* control group, *Freq* frequency, time: single intervention time; Length: total time of the intervention; ↑: significant difference between pre- and post-experimental group data; ↔: no significant difference between pre-and post-experimental group data; #: significant difference between post-experimental group data; *NWP* normal soccer warm-up, *WPS* warm-up program supplemented with functional training

**Table 3** Summary of interventions and outcomes characteristics

| Study | Interventions | Type of Exercise | Measuring instruments and main outcomes |
|---|---|---|---|
| Tomljanović et al. (2011) [37] | Freq.: 3 times/week, time: NR, Length: 5 weeks | EG: Functional training; CG: Traditional resistance training | Agility (5–10-5 test ↔, HEX↑#); Power (CMJ: AT ↔, PEAKPWR↑#, JH↑#, GCT↑#); Strength (SMB↑#, LMB ↔); Speed (10 m ↔, 20 m ↔, 10–20 m ↔) |
| Sander et al. (2013) [38] | Freq.: NR, time: NR, Length: 8 days | EG1: Completed the NWP first and the WPS 4 days later; EG2: Completed the WPS first and the NWP 4 days later | Speed: linear sprint: 5 m↑#, 10 m↑#, 15 m↑#, 20 m↑#, 25 m↑#, 30 m↑#; CDS: 5 m left↑ and right↑#, 10 m left↑# and right↑# |
| Song et al. (2014) [39] | Freq.: 3 times/week, time: NR., Length: 16 Weeks | EG: Functional training (EG1); CG: Regular training | Strength (hand grip strength↑#, back muscle strength↑#, bench-press 1 RM↑#, squat 1 RM↑#); Flexibility (trunk flexion forward↑, trunk extension backward↑, the splits↑#) |
| Elbadry (2014) [24] | Freq.: 3 times/week, time: 60 min, Length: 8 weeks | EG: Functional strength training; CG: Regular training | Balance (dynamic balance↑#); Strength (core strength↑#, handgrip strength↑, static strength test↑#); Performance level test↑# |
| Kamal (2016) [40] | Freq.: 3 times/week, time: 60 min, Length: 8 weeks | EG: Functional training; CG: Regular training | Performance level test↑ |
| Cherepov & Shaikhetdinov (2016) [41] | Freq.: NR, time: NR, Length: 6 months | EG: Functional training; CG: Regular training | Strength (PU↑#, OMBT↑#); Agility (SHR↑#) |
| Osipov et al. (2017) [42] | Freq.: 2 times/week, time: 90 min, Length: 32 weeks | EG: Functional training; CG: Regular training | Judo fitness test↑#; Test with punching↑# |
| Alonso-Fernández et al. (2017) [43] | Freq.: 2 times/week, time: 10 min, Length: 8 weeks | EG: Combining strength, coordination and plyometric exercises; CG: Regular training | Cardiorespiratory endurance (VO2max); Speed (RSA↑); Power (CMJ: AT ↔, JH ↔, GCT ↔, PEAKPWR ↔) |
| Yildiz et al. (2019) [21] | Freq.: 3 times/week, time: 65–70 min, Length: 8 weeks | EG1: Functional training group; EG2: Traditional training group; CG: Regular training | Flexibility (Sit and reach↑#); Power (CMJ↑#); Speed (10 m↑#); Agility (T-test↑#); Balance (RDB↑#, LDB↑#, SB↑#) |
| Usgu et al. (2020) [44, 45] | Freq.: 2 times/week, time: 75–85 min, Length: 20 weeks | EG: Functional training; CG: Regular training | Strength (1 RM bench press↑ and leg press tests↑#); Flexibility (sit and reach↑); Agility (T-drill↑, Lane-Agility tests↑#); Speed (20 m↑#); Power (Vertical jump↑#) |
| Turna & Alp (2020) [46] | Freq.: 2 times/week, time: 20 min, Length: 8 weeks | EG: Functional training; CG: Regular training | Strength (Vertical jump↑, hand grip↑, back-leg strength↑); Flexibility (sit and reach↑); Speed (30 m↑) |
| Zirhli & Demirci (2020) [47] | Freq.: 2 times/week, time: 90 min, Length: 8 weeks | EG: Functional training; CG: Regular training | Speed (10 m↑#); Power (vatical leap test↑#); Flexibility (sit and reach↑#); Agility (T-test↑#); Anaerobic capacity (Wingate Anaerobic Power Test↑#) |
| Turker & Yuksel (2021) | Freq.: 3 times/week, time: NR, Length: 8 weeks | EG: Functional + strength training; CG: Regular training | Aerobic capacity (Watt bike Pro Ramp Test↑#); Body Composition (Fat Measurement↑#); Dynamic Balance Test (Libra see saw balancing board test↑#) |
| Hovsepian et al. (2021) [48] | Freq.: 4 times/week, time: in average of 80–150 and 180–240 min per week respectively, Length: 10 weeks | EG: High intensity functional training; CG: Regular training | Basketball simulated performance↑#; Agility (t-test↑); lateral shuffle test ↔, vertical jump ↔, average power↑# |
| Carvutto et al. (2021) [49] | Freq.: 3 times/week, time: 90 min, Length: 8 weeks | EG: High intensity functional training; CG: Regular training | Agility (t-test↑#); Speed (20 m↑#) |
| Keiner et al. (2022) [50] | Freq.: 2 times/week, time: 60 min, Length: 10 months | EG1: Traditional strength training; EG2: Plyometrics and sprint training; EG3: Functional training; CG: Regular training | Speed (20 m↑#, CDS: CODSR↑#, CODSL↑#); Power (SJ: AT↑#, JH↑#); Strength (1RM↑#) |

**Table 3** (continued)

| Study | Interventions | Type of Exercise | Measuring instruments and main outcomes |
|---|---|---|---|
| Zheng (2022) [51] | Freq.: 3 times/week, time: 45 min, Length: 10 weeks | EG: Functional training; CG: Regular training | Difficulty scores of specific actions (time to pan 360↑#, turn 360 whip time↑#, balance and flexibility difficulty score↑#, total difficulty score↑#), fitness (plank high-five↑#, pulley support↑#, Russian swivel↑#, fast sit-ups turn↑#, backbend↑#, back up↑#) |
| Abood et al. (2022) [23] | Freq.: 3 times/week, time: 20–25 min, Length: 8 weeks | EG: Functional training; CG: Regular training | Accuracy of shooting skill from outside the three-point arc↑ |
| Zou & Ma (2022) [52] | Freq.: NR, time: NR., Length: 16 weeks | EG: Functional training; CG: Regular training | Core endurance↑#, core strength↑# |
| Liu & Yi (2023) [53] | Freq.: 3 times/week, time: NR, Length: 12 weeks | EG: Functional training; CG: Regular training | Hit accuracy test↑, depth test↑ |
| Lee et al. (2023) [54] | Freq.: 3 times/week, time: 60 min, Length: 6 weeks | EG: Functional training; CG: Weight training | Strength (handgrip, L↑# and R↑), sit up↔side-step↔, 30 m↔#, standing long jump↔pitching speed↔#, Batting speed↔# |
| Chen (2023) [55] | Freq.: 3 times/week, time: NR, Length: 8 weeks | EG: Functional training; CG: Regular training | Depth test↑, hit accuracy test↑ |
| Wu et al. (2023) [56] | Freq.: 2 times/week, time: 40 min, Length: 8 weeks | EG: Functional training; CG: Regular training | Rowing speed (200 m rowing↑#); Strength (hand grip↔, pull-up↑, push-up↑); Agility (4 × 10 m shuttle run↔#); Speed (30 m↔); Flexibility (sit and reach↔); Power (standing long jump↔#) |
| Khazaei & Amani-Shalamzari (2023) [57] | Freq.: 3 times/week, time: 75–90 min, Length: 8 weeks | EG: Functional strength training; CG: Regular training | Flexibility (sit and reach↑); Balance (Y-balance test↑); Power (Sargent test↑#); Speed (30 m↑); Agility (t-test↑); Reaction time(8-direction reaction time test↑); Aerobic endurance (Bruce test↑); Strength (sit-up↑); Muscular endurance (push-ups↑) |
| Xiao et al. (2023) [12] | Freq.: 3 times/week, time: 60 min, Length: 12 weeks | EG: Functional training; CG: Regular training | Strength (push-ups↑#, wall squat test↑#); Power (over medicine ball throw↑#, standing long jump↑#) |
| Shang et al. (2023) [58] | Freq.: 3 times/week, time: NR, Length: 8 weeks | EG: Functional training; CG: Regular training | Push-ups↑, touch high↔, 3200 m↑, limited area body acuity detection↑#, four times the basketball court sideline 17 turns back↑#, Run-up touch↑# |
| Xiao et al. (2024) [35] | Freq.: 3 times/week, time: 60 min, Length: 12 weeks | EG: Functional training; CG: Regular training | Cardiorespiratory endurance (multistage fitness test↑#); Agility (the hexagon test↑#, planned agility↑#); Speed (20 m↔#); Flexibility (sit and reach↑#) |
| Bashir et al. (2024) [36] | Freq.: 3 times/week, time: 60 min, Length: 12 weeks | EG: Functional training; CG: Regular training | Flexibility (sit and reach↑#); Agility (t-test↑#, Illinois agility test↑#); Speed (30 m↔#); Muscular endurance (push-ups↑#) |

*NR* not reported, *M* male, *F* female, *yr* year, *EG* functional training group, *CG* control group, *Freq* frequency; time: single intervention time; Length: total time of the intervention; ↑: significant difference between pre- and post-experimental group data; ↔: no significant difference between pre- and post-experimental group data; #: significant difference between post-experimental group data, *NWP* normal soccer warm-up, *WPS* warm-up program supplemented with functional training agility test [36]. The participants were martial arts players [41], tennis players [21, 35, 47], basketball players [44, 48, 58], soccer players [49], dragon boat racers [36], taekwondo players [51], and hockey players. The results of most studies showed that functional training significantly improved athletes' agility performance [21, 35, 36, 41, 44, 47–49, 57, 58], whereas Tomljanović et al. (2011) reported a significant improvement in the hexagonal test and no significant change in the 5–10-5 test. Additionally, only one study showed no statistically significant differences in shuttle run test results [56]. Furthermore, five studies revealed a significant difference in the between-group outcomes after the intervention [35, 36, 44, 48, 57].

(2) Balance. Four studies focused on balance performance, which was assessed using the dynamic balance test [21, 24, 59], the static balance test [21], and the Y-balance test [57]. The participants were hammer throw players [24], tennis players [21], basketball players [59], and taekwondo players [57]. These studies' data revealed that functional training greatly enhanced participants' balance abilities. Furthermore, three investigations showed significant differences between groups after the intervention [21, 24, 59].

(3) Reaction time. One of the included studies focused on response time [57], and used 8-way reaction time test to examine reaction time performance in professional taekwondo athletes; a significant difference was observed within groups but not between groups.

(4) Power. Thirteen studies focused on power performance, which was assessed using the vertical long jump [21, 37, 43, 44, 46–48, 50], standing long jump [12, 54, 56], over medicine ball throw [12], Sargent test [57], and assisted running with touching the ground with a jump in place [58]. The participants included tennis players [12, 21, 47], soccer players [46, 50], basketball players [44, 48, 58], dragon boat racers [56], taekwondo players [57], handball players [43], and baseball players [54], with one study reporting only the results for college athletes [37]. The results of most studies confirmed that functional training improved subjects' power performance, whereas the results of five studies showed that functional training did not significantly improve subjects' power performance [43, 48, 54, 56, 58]. Nine studies reported significant differences between the groups after the intervention [12, 21, 37, 44, 47, 50, 56–58].

(5) Speed. Fourteen studies focused on speed performance; speed was assessed with a linear speed test, a multidirectional speed test, and a repetitive sprinting ability test, and most studies used linear speed tests at distances of 5 m, 10 m, 15 m, 20 m, 25 m, and 30 m [21, 35–38, 44, 46, 47, 49, 50, 54, 56, 57]. Two studies used both linear speed and multidirectional directional speed tests [38, 50]; multidirectional speed was assessed using change-of-direction sprints (5 m left and right turns, 10 m left and right turns), and only one study evaluated the benefits of an intervention using the repetitive sprinting ability test [43]. The participants included college athletes [37], soccer players [38, 46, 50], handball players [43], tennis players [21, 35, 47], basketball players [44], taekwondo players [57], baseball players [57], dragon boat racers [56], and hockey players [36]. Most studies confirmed that functional training significantly improved athletes' speed performance [21, 35, 36, 38, 43, 44, 46, 47, 49, 50, 54, 57], whereas three studies reported no significant improvement in subjects' straight-line sprint speed performance after functional training [37, 54, 56]. Furthermore, seven studies revealed a significant difference in the between-group outcomes after the intervention [21, 38, 44, 47, 49, 50, 54].

#### *Effect of functional training on technical performance*

The dominant factors of athletes' athletic ability and its manifestations or characteristics were used to categorize the technical performance results in this study [61]. These factors allowed for the following classifications: (1) same-court confrontational item groups (basketball) [23, 48]; (2) across-net confrontational item groups (tennis, badminton) [53, 55]; (3) fighting confrontational item groups (judo) [42]; (4) fast power item groups (shot put) [24, 40]; (5) difficult aesthetic item groups (dance) [51]; (6) endurance item groups (dragon boat racing) [56]; and (7) rotational offensive and defensive confrontational item groups (baseball) [54].

(1) Same-court confrontational item groups. Two studies examined the same-court confrontational item groups and measured basketball technical performance. According to Hovsepian et al. (2021), professional basketball players' performance in simulated games was greatly improved after 10 weeks of functional training, and a significant difference in the between-group outcomes was observed after the intervention. After eight weeks of functional training, collegiate basketball players presented significantly increased three-point shooting accuracy, according to another study. However, no significant differences were observed between the groups after the intervention [21].

(2) Across-net confrontational item groups. Two of the included investigations evaluated the technical performance of tennis and badminton players, focusing on across-net confrontational item groups. Chen (2023) reported significant improvements in the hitting depth and accuracy of national badminton players following 8 weeks of functional training, but no significant difference in the data was observed between the groups after the experiment. Another study provided club tennis players with 12 weeks of functional training, which significantly improved their stroke depth and accuracy, but no significant differences were observed between the groups after the intervention [53].
(3) Fighting confrontational item groups. Only one study examined fighting confrontational item groups. In this study, 32 weeks of functional training for college judo athletes significantly improved the punching speed, but a significant difference was not observed between the groups [42].
(4) Fast power item groups. Two studies focused on the fast power item groups of shot put and hammer throw athletes. Elbadry (2014) documented significantly improved performance levels in tests of collegiate hammer throw athletes through 8 weeks of functional training, and a significant difference was observed between groups after the intervention. Another study revealed that 8 weeks of functional training significantly improved the performance of college shot put athletes, but no significant difference was observed between groups after the intervention [40].
(5) Difficult aesthetic item groups. One study examined difficult aesthetic item groups (dancing) and evaluated technical performance using difficulty scores for specific actions (time to pan 360, turn 360 whip time, balance and flexibility difficulty score, and total difficulty score). A significant difference was not observed between the groups following the intervention, and after 10 weeks of functional training, individuals demonstrated considerable improvements in difficulty scores for specific actions [51].
(6) Endurance item groups. One study examined endurance item groups and reported that college dragon boat athletes who completed eight weeks of functional training experienced significant improvement in their 200-m rowing speed, but no significant difference was observed between the groups after the intervention [56].
(7) Rotational offensive and defensive adversarial item groups. One investigation examined rotational offensive and defensive adversarial item groups. After six weeks of functional training, collegiate baseball players' pitching and batting speeds were significantly improved, and a significant difference was observed between the groups after the intervention [54].

## Discussion

This systematic review provides a comprehensive overview of the impact of functional training on physical and technical performance among athlete's and the relevant knowledge for improving their physical and technical performance. Of the 28 studies included, 22 studies focused on physical performance (no studies focused on coordination), and 11 studies reported on technical performance. The results show that functional training can significantly improve the physical and technical performance of the athlete population. Additionally, the mean Pedro score of the included studies was 5.57 (moderate quality, ranging from 4 to 10).

### Effect of functional training on physical performance

This study offers a comprehensive overview of the impact of functional training on athletes' physical performance, drawing on 20 studies that specifically examined athletes' physical performance and concluded that functional training improves it.

#### *Effects of functional training on health-related physical performance*

(1) Muscular strength. Strong evidence supports the suggestion that functional training improves athletes' strength performance. Strength performance can be classified as either upper or lower extremity strength; ten studies [12, 24, 37, 39, 41, 46, 54, 56–58] focused on the strength of the upper limbs, four focused on the lower limbs [12, 44, 50, 52], and only one focused on the combined strength of both limbs [12]. These studies confirmed that functional training improved athletes' muscle strength significantly. The most recent results are supported by similar benefits reported in other investigations. Oliver (2019) observed that following 13 weeks of functional training, female volleyball players' strength (single-legged deep squats) increased significantly [22]. Consistent with Ju-sik's (2019) findings, the back strength of experienced taekwondo players was significantly improved after six weeks of functional training [62]. During an 8-week neuromuscular warm-up before and following tennis-specific training, Fernandez-Fernandez et al. (2020) reported significant improvements in shoulder strength and solid ball throwing [19]. Furthermore,

five studies fulfilling the criteria for inclusion in the literature review reported no significant differences in the data between groups following the experiment [46, 54, 56–58], which strengthened the suggestion that athletes' upper-limb muscle strength can be enhanced by regular exercise. This conclusion can be understood by the simple fact that different types of regular target athletes' strength indicators, as shown by an analysis of the intervention protocols in these five investigations. In addition, five studies [12, 24, 37, 39, 41] documented significant within-group and between-group differences in the data, indicating that functional training is better than standard training in terms of improving athletes' upper limb strength.

(2) Muscular endurance. Two studies that examined the impact of functional training on muscular endurance demonstrated that Taekwondo athletes' muscle endurance performance can be significantly improved through functional training. One high-quality study and one moderate-quality study that used the Pedro scale to measure methodological quality confirmed this conclusion. Therefore, the effects of functional training on muscle endurance seem to be supported by moderate-quality evidence on muscle endurance performance. Zou et al. (2022) documented significantly improved muscular endurance (taekwondo core endurance test) of taekwondo athletes through 16 weeks of functional training [52]. Khazaei et al. (2023) observed significantly improved muscular endurance (push-ups) in elite taekwondo athletes through 8 weeks of functional strength training, with no between-group differences [57]. This study suggested that both functional and conventional training can significantly improve muscular endurance in taekwondo athletes and that both provide additional benefits to specific components of endurance [63]. However, push-ups are used to assess muscular endurance in the pectoralis major, deltoids, and triceps rather than in the deep core [64], which may account for the lack of significant differences between groups. Notably, other studies have confirmed that functional training significantly improves endurance performance in nonathlete populations; Menz et al. (2019) reported significantly improved muscular endurance performance in college students with 12 weeks of functional training [63]. Wibowo et al. (2021) and Fathir et al. (2021) reported significantly improved endurance performance in recreational runners after 6 weeks of functional training [65, 66].

(3) Flexibility. Functional training significantly improved flexibility performance in six of the investigations, whereas two studies reported no significant improvement in flexibility performance [54, 56]. Functional training exercises the subjects' hips and improves their lumbar–pelvic–hip mobility; it also changes physiological conditions such as neuromuscular excitability and elevated rates of neurotransmission, which could decrease soft tissue viscosity [67, 68]. Dynamic and multiplanar movement patterns that promote muscle activation and core activation may also have contributed to this significant improvement [69, 70]. The results of the other investigations may be associated with the intervention program created in the various investigations, which is an unknown factor, considering that Lee et al. (2023) and Wu et al. (2023) could not identify significant improvements in the subjects' flexibility performance. For the benefit of a thorough examination of the results, future research should provide specifics on the intervention program.

(4) Cardiorespiratory endurance. Six studies investigating this aspect revealed that functional training significantly enhanced athletes' cardiorespiratory endurance performance; however, one study reported no significant difference in the postintervention outcomes between groups [57]. This results may be because long term elite athletes or individuals participating continuous organized exercise programs (lasting more than three years) have notably achieved significant physiological modifications [71], and enhancements in cardiorespiratory endurance have a direct impact on sports performance [72]. Previous investigations have confirmed this result, showing that taekwondo athletes' cardiorespiratory endurance performance (VO2max) improved after 6 weeks [73] and 4 weeks [74] of functional training. Furthermore, Khazaei et al. (2023) did not observed a significant difference in the cardiorespiratory endurance (Bruce test) of professional taekwondo players after 8 weeks of functional strength training [57]. This results further demonstrated that both interventions significantly improved the subjects' cardiorespiratory endurance performance, with the experimental group exhibiting significantly greater levels of cardiorespiratory endurance performance (10.8% vs. 5.6%) than the control group. The observed difference might be addressed by the athletes' initial higher baseline in cardiorespiratory endurance, necessitating a more extended duration of the intervention to significantly strengthen their performance in this domain [72].

#### *Effects of functional training on skill-related physical performance*

(1) Agility. Ten investigations examined subjects' agility performance, and eight of the investigations found that functional training significantly improved participants' agility. This significant improvement could be attributed to the neuromuscular changes generated by functional training and the increased energy produced by increased skeletal muscle synchrony, which enhances individuals' agility. However, after eight weeks of functional training, Wu et al. (2023) did not observe find any significant increases in shuttle running ability. Furthermore, Tomljanović et al. (2011) reported that after five weeks of functional training, moderately trained male athletes' agility performance (hexagonal test) was significantly improved, with a strength capacity and postural control that dominated across speeds (agility 5–10-5 test) [37]. This result suggests that the athletes followed a functional training program that focused mainly on upper-body unstable resistance movement exercises and lacked a whole-body movement exercises [37].

(2) Balance. The results of four studies demonstrated that functional training can lead to significant improvements in the following areas: the dynamic balance performance of hammer throw athletes [24], the dynamic balance performance of basketball players [59], the dynamic and static balance performance of tennis players [21], and the performance on the Y-balance test of taekwondo athletes [57]. Furthermore, one high-quality study and three moderate-quality studies that used the Pedro scale to measure methodological quality confirmed this conclusion. Therefore, the effects of functional training on balance seem to be supported by moderate-quality evidence on balance performance. These results are consistent with those reported in a previous systematic review [1]. Xiao et al. (2021) reported that functional training improves the adaptations that occur in all the sensory systems assisting with postural control, such as the vestibular, visual, and somatosensory and motor systems controlling muscular output. Additionally, some studies have confirmed significant positive correlation between balance, muscle strength and flexibility [75, 76]. A reasonable explanation for this result may be that functional training improves the core strength of the subjects, thereby improving the stability of the individual's control of the spine and pelvis, coordinating the shift in the centre of gravity and posture adjustment during movement, and improving the balance ability of the athlete [77, 78].

(3) Reaction time. One study examined reaction time and used an 8-way reaction time test. This study evaluated the impact of functional training on professional taekwondo athletes. The functional training group improved by 17.7%, whereas the control group improved by 11.2%, with significant differences in the data between the groups. This difference could be a result of improved neuromuscular function and increased recruitment of fast muscle fibers after the intervention, both of which increase the athletes' reaction times [57]. Nevertheless, additional studies did not support this conclusion. After 12 weeks of functional training, Redondo et al. (2014) did not find a statistically significant improvement in the reaction times of elite fencers. The findings of these two studies could be explained by the fact that top athletes have initial response times that are naturally high and that this metric needs much time to develop [79].

(4) Power. Eight investigations reported that functional training significantly improved the performance of power, whereas five additional studies reported no significant differences in this aspect [43, 48, 54, 56, 58]. This notable improvement might be attributed to the fact that functional training increases the kinetic chain's movement of energy transfer and strengthens the athletes' struts, producing a powerful and productive movement pattern [80]. Functional training also improved subjects' lower limb power performance by strengthening their hip, knee, and ankle extension muscles [45]. Research has shown that functional training can strengthen the interaction between upper and lower limb movements, leading to a more regulated transfer of power, and that upper body swing (arms) increases athletes' lower limb leaping performance [81]. Some explanations for the lack of noticeable improvements in the subjects' explosive ability following functional training are provided below. First, most the studies' intervention protocols used in these studies revolved around upper-body exercises and did not include a design for lower-body movements. Second, the maximum intervention period was 10 weeks, which may have been insufficient to significantly increase the subjects' power performance. Furthermore, most studies have overlooked upper-body explosive performance and rather focused on lower-body power performance.

(5) Speed. Twelve trials examined speed performance; most of the trials documented statistically significant improvements in linear, multidirectional, and

repeated sprint speed tests. This conclusion could be explained by the evidence that functional training enhances athletes' patterns of motion. Athletes' speed performance is improved when functional movement patterns are optimized, as shown by Campa et al. (2019). In contrast, compensatory movement patterns, such as joint hypermobility or inadequate muscle strength, can reduce an athlete's movement efficiency and increase the risk of sports injuries [82, 83]. Functional training looks at athletes' movements as a whole movement chain, emphasizing the flexibility and stability of body joints to enable coordinated and smooth motions. Weak links in the chain are identified through examination, and then specific training is implemented to maximize the movement's performance [12, 84]. Three investigations reported no improvements in linear sprinting speed [37, 54, 56], and Lee et al. (2023) observed that after six weeks of functional training, collegiate baseball players' speed (30 m) performance did not significantly improve; nevertheless, posttest outcomes were significantly difference between groups [54]. These results suggest that functional training requires a longer intervention time for lasting improvements in speed performance, and the intervention time may have been sufficient to transfer the training effects to actual movements. The absence of increased stimulation practice movements in the intervention protocol, which had the most beneficial effect on speed performance, was identified by an examination of the functional training programs in this study [85]. Future studies might focus on whether an 8-week functional training program may significantly increase athletes' speed performance, considering that this period was the most frequently used intervention time in the included studies.

#### Effect of functional training on technical performance

The effects of functional training on athletes' technical performance were the subject of a thorough and systematic review by this study, which categorized the research according to the primary manifestations or attributes of athletes' athletic ability as well as the dominant factors influencing athletes' athletic ability [86].

(1) Same-court confrontational item groups. Moderate-quality evidence seems to be available for this cluster because both studies on the same-court confrontational item groups found that functional training significantly improved basketball players' technical performance. The findings were further confirmed through the analysis of one high-quality study and one moderate-quality study combined with the Pedro scale. According to studies by Hovsepian et al. (2021) and Abood et al. (2022), basketball players' technical performance increases significantly following the application of functional training for 10 and 8 weeks, respectively [23, 48]. While attempting to use offensive or defensive techniques, basketball players must continuously shift their body positions and maintain balance and control. This process calls for the coordinated movement of several core-stimulated muscles. Conversely, sagittal, coronal (or frontal), and transverse plane motions are all part of functional training [87]. In basketball, the muscles collaborate in all dimensions to maximize the effectiveness of each unique move. The entire basketball shooting, dribbling, and other technology power chain starts at the sole of the foot; travels through the ankle, knee, hip, upper body, arm, and wrist, and ends with the fingers when the ball is thrown. For the entire power chain to transfer energy more effectively, the core area must stimulate the coordinated activity of several muscles [14].

(2) Across-net confrontational item groups. Functional training was found to significantly enhance performance in across-net confrontational item groups, as shown by two studies that focused on badminton and tennis players. Medium-quality evidence is available for investigations on the technical performance of a-cross-net confrontational item groups, as indicated by the methodological quality assessment of the Pedro scale, which included one high quality study and one medium quality study. Across-net confrontational item groups require an accurate and aggressive technique [61]. Players must simultaneously and accurately control the racket to achieve accuracy and accurate control of the shot depth [86]. The participants' shot-accuracy and shot depth were assessed in both trials. Functional training interventions will likely improve performance. This improvement could be explained by the athletes' enhanced ability for accurate motor nerve control of the racket, increased power transmission effectiveness in the power chain, and improved control over body posture and technical movements during exercise as a result of the functional training [1]. The muscles in the back and abdomen tighten considerably when a tennis player serves, which aids in the player's ability to keep their waist stable while striking the ball. Athletes' athletic ability and the trunk muscle group are closely linked. Athletes' trunk muscle group performance can be enhanced by strengthening their body mus-

cles through exercise. Tennis hitting, or the swing action, is viewed as a dynamic chain in functional training. In addition to improving the subjects' core strength, functional training can accelerate the transfer of leg energy and enhance the quality of their swings, ultimately leading to the development of core control abilities.

(3) Fighting confrontational item groups. Limited evidence is available showing that functional training might improve the technical performance of fighting confrontational item groups. A study revealed that 32 weeks of functional training can significantly increase the punching speed of judo athletes [42]. The Pedro methodological quality assessment of the study also indicated medium quality. Judokas frequently use single-leg support, rotation, or torsion as the primary action when performing offensive techniques. This technique calls for a strong core muscle group to preserve the stability of the spine. Judokas possess a wide range of explosive power movements during training and competition, including pushing, pulling, and turning [88]. Functional training seems to considerably increases the punching speed of judo athletes because it strengthens motor control and improves spine flexibility and stability.

(4) Fast power item groups. In two of the fast power item group investigations, college students participating in shot put and hammer throw received functional training for eight weeks, three times a week. The results showed that functional training could significantly improve participants' distance throw performance. These two studies were provided a medium methodological quality evaluation from Pedro. Therefore, a moderate amount of information confirms the idea that functional training may improve the fast power item groups' technical performance. Throwing sports require the coordination of upper and lower limb joints and muscles to perform sophisticated movements [89]. Consequently, throwing athletes' athletic performance is directly impacted by the transmission efficiency of the human power chain. Functional training enhances the nervous system innervation and control ability of throwers, increases the core muscle participation rate; enhances muscle strength, coordination ability, and proprioception of the motor cluster; and ultimately enhances the technical performance of throwers. These properties could explain the notable improvement in athletes' technical performance in the two studies.

(5) Difficult aesthetic item groups. The difficult aesthetic item groups were the focus of only one study [55], which reported that dancers' difficulty scores for specific actions (time to pan 360, turn 360 whip time, balance and flexibility difficulty score, and total difficulty score) were significantly improved after 10 weeks of functional training three times a week [51]. The study's methodology was evaluated as medium quality by the Pedro methodological quality assessment. The evidence that functional training improves the technical performance of the difficult aesthetic item group seems to be insufficient. Dancers need to have a strong core and possess the capacity to execute movements with great strength. Balance, stability, dynamics, and proprioception are all emphasized in functional training, with a particular focus on the coordination of small and core muscle groups [90]. This finding has also been confirmed in gymnasts [91]. Athletes' technical performance can become better-organized, coordinated, and consistent through functional training, which can also effectively strengthen the core muscle group and improve the body's control and coordination.

(6) Endurance item groups. In one study, which emphasized endurance events, 8 weeks of functional training significantly improved the technical performance of dragon boat athletes [56]. The study's Pedro methodological quality was assessed as good. Consequently, evidence indicates that functional training may improve the technical performance of endurance event groups. The main force used in dragon boat racing is one-sided, resulting in difficulties consisting of action compensation, trunk instability, and deviations in the symmetry of the right and left sides of the body. These challenges not only limit sports performance but also increase the risk of sports injuries [92, 93]. According to this study, functional training improved the athletes' capacity in the Y-balance and functional movement test, enhanced the movement mode for dragon boat athletes, decreased energy expenditure during movement completion, and enhanced the power chain's transmission efficiency [94]. Therefore, functional paddling training can help dragon boat competitors transmit power more effectively, regulate their body movement, and paddle faster.

(7) Rotational offensive and defensive confrontational item groups. One study, which emphasized the opposing group of rotation and attack, demonstrated that six weeks of functional training three times a week might significantly improve baseball players' batting and pitching speeds [54]. Little evidence indicates that functional training promotes endurance item group technical performance, as

indicated by the study's medium-quality Pedro methodological rating. An analysis of the study's intervention plan might be needed to understand this finding. The intervention plans for the control group involved routine training with a focus on isolated muscles or muscle groups, leading to reduced muscle elasticity and limited joint flexibility. In contrast, the functional training plan employed unilateral movements as the foundation for comprehensive movement training, incorporating baseball-specific characteristics. Action pattern optimization is given more consideration [54].

### Strengths and limitations

This study gas several strengths. First, the methodological strengths of this review include adherence to the PRIMSA statement and a rigorous assessment of the quality of evidence using the Pedro guidelines. Second, three independent and blinded evaluators conducted the literature screen data extraction, and methodological quality assessment, which can reduce the influence of subjective bias and ensure the objectivity and accuracy of the evaluation process.

This review presents the latest evidence of the effects of functional training on the physical and technical performance of athletes, which can provide novel and noteworthy value to the current body of knowledge on the effects of functional training on the physical and technical performance of athletic populations. Nevertheless, this evaluation has several limitations. First, one of the key variables influencing athletes' performance in sports is their training experience [95]. However, the results of 16 of the included studies may have been impacted by the respondents' lack of information regarding their training experience. Future research should thus disclose the training experience of its respondents. Second, the accuracy of the findings might be affected by an inadequate or large sample size, as it depends on a number of factors including the study aims and target population [96, 97]. The sample size calculation procedure was explained in detail in only three of the research projects that satisfied the eligibility requirements. Consequently, the sample size for subsequent research should be determined scientifically. Third, forecasting the long-term effects of functional training on athletic performance is challenging because this research lacked any type of short- or long-term follow-up. Fourth, future studies should focus on how functional training influences the athletic performance of a wider variety of athletes, as only 14 sports were examined in the included studies. Last, despite a rigorous attempt to include all suitable studies, only English studies were included in this review to avoid misunderstandings and confusion caused by language differences and to ensure the accuracy of the findings.

### Practical implications

This study has certain practical significance for coaches, athletes and other practitioners, which are described below. First, this study confirms that functional training can improve the physical and technical performance of athletes, thus, functional training should be included in the daily training of athletes as a training method to improve physical and technical performance. Second, this review does not provide sufficient evidence of a clear dose correlation to recommend the best training program for improving athletes' physical and technical performance. In general, functional training lasting more than 20 min two to four times per week for at least 5 weeks is likely to be more successful than training involving various other exercise types, durations, frequencies, and sessions. Thus, therapies with these specific characteristics may represent fruitful areas for future research and therapeutic applications. Third, the included studies focused on 14 different types of sports, and the methodological quality of the studies varied greatly (ranging from 4 to 10). Therefore, future studies should focus on more high-quality studies of different types of athletes.

## Conclusions

This systematic review included 28 published studies, and the results revealed that functional training can enhance the physical and technical performance of the athlete population. The results also support the principle of specificity in training Xiao et al. (2023) studied the training contents of functional training, including strength and power, and the results revealed significant improvements in tennis players' strength and power performance. Additionally, most studies documented significant differences between groups, whereas other studies reported no significant differences, which may be due to factors such as the athletes' training experience and the duration of the training program. Therefore, in the future, more high-quality studies of different types of athletes are needed to provide more reliable evidence for practical applications in this field.

## Supplementary Information

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Supplementary Material 1.

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**Authors' contributions**
Conceptualization, WSX, XRB, and JLZ; methodology, WSX, XRB, and SKG; writing—original draft preparation, WSX, XRB and SKG; writing—review and editing, TB, HGC, LZ, WYZ and JLZ. All authors contributed to manuscript revision, read, and approved the submitted version.

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**Data availability**
The data set supporting the conclusions of this article is included within the article.

## Declarations

**Ethics approval and consent to participate**
Not applicable.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

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