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Impact of circuit training on physical fitness among team sports athletes: A systematic review

Wpływ treningu obwodowego na sprawność fizyczną wśród sportowców uprawiających dyscypliny zespołowe: Przegląd systematyczny

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Abstract
Background of the Study. Physical fitness is crucial for athletes, enabling them to endure rigorous training and meet competitive demands effectively. It encompasses both health-related attributes, such as cardiovascular endurance and muscular strength, and skill-related components like agility and speed. Various training methods, including circuit training (CT), have been explored to enhance fitness levels among athletes. Despite the growing popularity of CT in various sports, comprehensive research on its effects on athletes' physical fitness has been limited.
Aim. The present review aims to clarify the effects of CT on physical fitness among team sports Athletes.
Material and Methods. In accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyzes (PRISMA) Statement guidelines, the systematic search of PubMed and Google Scholar databases was undertaken on the 28th of August, 2023, to identify the reported studies, using a combination of keywords related to CT, physical fitness, and athletes. Of the 566 studies, only 18 articles met all eligibility criteria and were included in the systematic review. The assessment was performed on the Pedro scale, and the study quality included in the eighteen studies was fair (ranging from 5 to 6).
Results. The results showed that speed (n = 12) was the aspect of physical fitness studied in CT interventions, followed by muscular strength (n = 10), power (n = 13), balance (n = 2), body composition (n = 2), agility (n = 14), flexibility (n = 5), muscular endurance (n = 7), and cardiovascular endurance (n = 8). Existing evidence concludes that CT significantly impacts speed, muscular strength, power, balance, flexibility, agility, body composition, and cardiovascular endurance.
Conclusions: The CT method is one of the ways of physical fitness training aiming at general development, which includes all the physical aspects. Furthermore, there is still limited numbers of evidence showing the effect of CT on agility, body composition, and speed.

Keywords
circuit training, physical fitness, team sport, athletes

Streszczenie
Wprowadzenie. Sprawność fizyczna jest kluczowa dla sportowców, umożliwiając im wytrzymać intensywne treningi i skutecznie sprostać wymaganiom zawodów. Obejmuje ona zarówno atrybuty związane ze zdrowiem, jak wytrzymałość sercowo-naczyniowa i siła mięśniowa, jak i składowe związane z umiejętnościami, takie jak zwinność i szybkość. Różnorodne metody treningowe, w tym trening obwodowy (CT), były badane pod kątem poprawy poziomu sprawności fizycznej wśród sportowców. Pomimo rosnącej popularności CT w różnych dyscyplinach sportowych, kompleksowe badania nad jego wpływem na sprawność fizyczną sportowców były ograniczone.
Cel. Celem niniejszego przeglądu jest wyjaśnienie wpływu CT na sprawność fizyczną wśród sportowców uprawiających dyscypliny zespołowe.
Materiał i metody. Zgodnie z wytycznymi Deklaracji PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), 28 sierpnia 2023 roku przeprowadzono systematyczne wyszukiwanie w bazach danych PubMed i Google Scholar, aby zidentyfikować opublikowane badania, używając kombinacji słów kluczowych związanych z CT, sprawnością fizyczną i sportowcami. Spośród 566 badań, tylko 18 artykułów spełniło wszystkie kryteria kwalifikacyjne i zostało włączonych do systematycznego przeglądu. Ocena została przeprowadzona na skali Pedro, a jakość badań włączonych do osiemnastu studiów była zadowalająca (wahała się od 5 do 6).
Wyniki. Wyniki wykazały, że szybkość (n = 12) była aspektem sprawności fizycznej badanym w interwencjach CT, po niej następowały: siła mięśniowa (n = 10), moc (n = 13), równowaga (n = 2), skład ciała (n = 2), zwinność (n = 14), elastyczność (n = 5), wytrzymałość mięśniowa (n = 7) i wytrzymałość sercowo-naczyniowa (n = 8). Istniejące dowody wskazują, że CT ma znaczący wpływ na szybkość, siłę mięśniową, moc, równowagę, elastyczność, zwinność, skład ciała i wytrzymałość sercowo-naczyniową.
Wnioski: Metoda CT jest jednym ze sposobów treningu sprawności fizycznej mającego na celu ogólny rozwój, który obejmuje wszystkie aspekty fizyczne. Ponadto, wciąż jest ograniczona liczba dowodów na wpływ CT na zwinność, skład ciała i szybkość.

Słowa kluczowe
trening obwodowy, sprawność fizyczna, sporty zespołowe, sportowcy

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Introduction

Physical fitness is a current topic of interest for physical educationists and researchers and is of great importance to sportspeople. For a sportsperson, physical fitness is the ability to bear a load of strenuous training exercises and to meet the demands of competition without undue fatigue [1]. For sports performance development, numerous factors are important, usually talent, tactical, technical, and psychological qualities. Physical fitness is essential for assessing athletes' competitive capability [2]. A high general fitness level is essential for developing high sports performance [3]. Experts are conducting various field experiments to develop new methods that can enhance players' physical abilities. A frequently asked question concerns the amount of exercise that is sufficient. Furthermore, what type of exercise and method is best for developing and maintaining fitness? Before initiating training, coaches or physical education teachers should clearly understand the specific methods to be used with the athletes. Various training procedures are in practice to improve physical and physiological qualities at different levels. Each type of training has its unique effect on fitness. Various training methods include weight training, continuous training, interval training, fartlek training, and circuit training. Among these training methods, circuit training (CT) is particularly effective in improving physical fitness among athletes. Previously, there has been no detailed research showing the effects of the CT method on athletes' physical fitness levels. The term 'physical fitness' encompasses a variety of characteristics, including those in the broad categories of health-related aspects, such as cardiovascular endurance, muscular strength, muscular endurance, flexibility, and body composition, as well asance, coordination, agility, power, speed, and reaction time [4].

Many training models can help athletes to improve their physical condition. The CT model is one of the most complex exercise models [2]. This popular training method is designed to improve general or basic fitness, which is a prerequisite for every sport [4, 5]. The unique contribution to sports training called the CT emerged in England and was developed by R.E. Morgan and G.T. Adamson in 1953 at the University of Leeds [6]. The term 'circuit' refers to several carefully selected exercises arranged in a planned sequence. A conditioning training method, the 'circuit,' typically includes several exercises and can consist of anywhere from six to fifteen stations, depending on the goals and pre-training levels of the participants. Exercise protocols were arranged in different stations where participants performed exercises at each station [7]. When developing a CT routine, various exercises and equipment are used. Most of the equipment is inexpensive and includes surgical tubing, jump rope, body weight, physio balls, dumbbells, kettlebells, resistance bands, medicine balls, and weight training machines [8]. Upon completing a circuit, participants start with the first exercise again for the next circuit [9]. A circuit includes various exercises that come in succession at a specific time related to the adaptation to the relevant exercises [10]. The initial routines were arranged in a circle, alternating between muscle groups. CT stations are generally sequenced to alternate between muscle groups, allowing for adequate recovery. Each exercise should be general or sport-related and can involve the whole body or just a specific body compartment [10, 11]. Several studies have confirmed that modern CT is one of the most used methods in many sports, including football [7]. The CT is a popular, effective methodology in fitness and wellness programs, as well as in sports, and this training combines a number of different components of training. Thus, total fitness is emphasized. It is an effective organizational form of doing physical exercises for improving all physical fitness components because it allows the development of muscle endurance [9, 10], muscle strength [10, 12], agility [7,13], power [7,9], balance [10], body composition [14], speed [7, 13] and cardio-vascular–respiratory endurance adaptations in a time-efficient manner [15, 16]. Sportsmen and women can use it during the closed season and early pre-season to help develop a solid fitness base and prepare the body for more stressful subsequent training. A participant should always consult with a physician before beginning a fitness program.

Additionally, other research has discovered positive effects of CT on physical fitness in footballers [12], handballers [17], basketballers [4], volleyballers [18]. Despite the significance of CT for improving the physical fitness components among the players, no study summarized crucial information on the effectiveness of CT programs on the development of physical fitness among team sport athletes. The findings of this study will provide valuable insights into the effectiveness of CT programs on physical fitness development among team sport athletes. The results of this study can inform the development of evidence-based training programs that can help players improve their physical fitness and, ultimately, their performance on the field. The results presented by the different studies on CT effects on physical fitness components among team sport athletes are encouraging, but limited scientific information is available to determine its possible benefits on the different physical fitness components of performance. Therefore, this systematic review aimed to clarify the effects of CT on physical fitness among team sport athletes.

Methodology

Search strategies

The lead investigator and a co-author conducted the electronic searches for relevant literature. The literature search was undertaken in Pub-Med and Google Scholar databases, conforming to the guidelines set by the "Preferred Reported Items for Systematic Reviews and Meta-Analysis" (PRISMA) [19]. Articles published up to the 28th of August, 2023, were considered. In each database, keywords were selected through experts' opinions and a systematic Boolean Logic, the following combination of keywords was used in the search databases: "circuit training" OR "varied intensity circuit training" OR "circuit resistant training" OR "resistant circuit training" OR "game specific circuit training" AND "physical fitness" OR "physical endurance" OR "cardiorespiratory fitness" OR "physical conditioning" OR "health-related physical fitness" OR "health-related physical" OR "health-related fitness" OR "aerobic endurance" OR "muscular strength" OR "muscular endurance" OR "body composition" OR "flexibility" OR "speed" OR "power" OR "reaction time" OR "agility" OR "balance" OR "coordination" OR "skill-related fitness" OR "skill related

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physical" OR "skill-related physical fitness" AND "players*" OR "athlete*" OR "sportsman*" OR "sportswomen*" OR "sportsperson*". We also explored other relevant articles in the reference lists of the studies included in the review and examined the reference lists of previous related reviews. All titles were manually searched for potential inclusion. Reference lists of retrieved papers, authors' names, and review articles were retrieved manually for additional relevant citations.

Table 1 Inclusion criteria according to the PICOS conditions

Items	Detail inclusion criteria
Population	Athletes (Male/Female)
Intervention	Circuit training
Comparison	Two or more groups and single group trails
Outcome	Physical fitness (Speed, Power, Reaction time, Agility, Balance, Coordination, Aerobic endurance, Muscle strength, Muscle endurance, Body composition, Flexibility)
Study designs	RCT or Non-RCT

Inclusion criteria

(1) A full-text, peer-reviewed study published in English describing the use of healthy Athletes (male and female) to explore the effects of CT interventions on physical fitness, randomized controlled trial (RCT), non-randomized controlled trial (non-RCT) with two or more groups, and single-group trials with pretest and post-test design; (2) In this study, only included studies on planned and organized CT intervention to improve or maintain physical fitness. Notably, studies using varied intensity CT or combinations of CT and other exercise training interventions (e.g., Low, Moderate, and High-intensity CT) were also included in this review; (3) Investigate the effects of CT on physical fitness among sports Athletes and assess at least one physical fitness component outcome; (4) There were no restrictions on the sample size and study location for the included studies; (5) Examined healthy adult athletes aged between (10–23 years); (6) Involved an intervention of ≥ 4 weeks in duration.

Exclusion criteria

(1) Studies that combined CT interventions with additional non-exercise training (e.g., psychological interventions) and interventions including unsupervised training courses were not included in the study; (2) Studies published articles, meeting abstracts, case reports, and short communications in languages other than English were excluded; (3) Not looking of other variables only selected variables which is part of inclusive; and (4) Subject not included whose age group more than 23 or less than 10.

Study selection

The retrieved studies were imported into Zotero reference management software to remove any duplicates. Firstly, the search strategies were assisted by an experienced researcher. Secondly, two independent reviewers (Saibya, and Pandey) screened the titles and abstracts of all the identified articles in the initial screening phase to identify relevant studies. Irrelevant materials were removed from the database before assessing all other titles and abstracts using our predetermined inclusion and exclusion criteria. Articles that remain at the end and enter a qualitative synthesis must have the whole text, and the whole text must be read. Items for which full text is not available are dropped. If there were any disagreements, a third reviewer (Gogoi) was consulted until a consensus was achieved.

Data extraction and quality assessment

After the data search was complete, data were obtained from eligible studies in a predetermined extraction form [including: (1) Author, publication year; (2) Research design; (3) Sample size, experimental group, control group; (4) Participant characteristics (age, gender, etc.); (5) Intervention features (type, length, and frequency); (6) Measures index, and research outcomes. One author abstracted information into the standard form, and the other author checked it. The PEDro scale [20] has been proven to be a useful measure of the quality of experimental methodology in developing a systematic review and has good validity and reliability [21]. The PEDro scale is designed to evaluate a study's four fundamental methodological aspects, such as random process, blind technique, group comparison, and data analysis. The assessment of the 11 items in the PEDro scale was performed by two well-trained, independent raters using a yes (1 point) or No (0 points) response rating scale and disagreements were resolved by a third rater. However, the eligibility criteria were not considered in the total score since this was related to external validity. The total PEDro score ranges from 0 to 10 points, and higher scores reflect

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a better methodological quality. The higher the PEDro score, the higher the quality of the corresponding method. Studies scoring 8 to 10 were considered to be methodologically excellent in quality, those ranging from 5 to 7 to be good in quality, while a score between 3 and 4 is fair in quality, and those scoring below 3 to be poor in quality [21]. The judgment of overall scientific evidence was based on the number, methodological quality, and consistency of outcomes of the studies in three levels of evidence: (1) strong evidence, provided by generally consistent findings in multiple (≥2) number and results studies, (2) moderate evidence, when only one study is available, or findings are inconsistent in multiple (≥2) studies, (3) no evidence when no case-control studies are found.

Results

The search results were screened and read by formulating literature inclusion and exclusion criteria. This systematic review contains eighteen articles involving RCT and Non-RCT on the effects of CT on physical fitness among athletes. They were published between the years of 2013–2023. In Table 2, the characteristics of the studies are presented.

Table 2. Characteristics of the studies examined in the study

Authors	Design	Types of athletes	Population characteristic	Interventions	Types of exercise training	Measures index	Outcome
Hermassi et al. [22]	Pretest-post-test design	Elite handball players	Sex: M, CT EG: N:12, Age: 20.3 ± 0.5 years, WT: 84.8± 7.6 kg, HT: 1.83 ± 0.07 m, BMI:NR, CG: N = 10, Age: 20.1± 0.5 years, WT: 80.0 ± 8.5 Kg, HT: 1.84± 0.07 m, BMI:NR	Freq:2 Times/ Weeks, Time: 30–35 minutes, Length: 10 weeks	CRT: 8 exercises - Frontal sprint, Hurdle jumps, Pull-overs, Bench press, Barrier jumps, Half-squats, 110° Zig zag sprint, Box-to-box jumps. 20 sessions; 2-3 sets, 8-12 reps; 180s rest/set & exercise.	Upper extremity max strength (1 RM Bench press), Upper body strength (1 RM pullover), Lower extremity max strength (1 RM Half squats), Power (CMJ, SJ: Height, max force, avg power), Speed (RSA: six 2×15-m sprints, best trial time), Agility (T-Half Test).	EG: 1 RM Half squats↑, 1 RM Bench press↑, 1 RM Pullover↑, Jump height↑, Maximal force before take-off↑, Average power↑, RSA (six 2×15-m shuttle sprints with a recording of the best time for a single trial) ↔, T-Half Test↑
Hermassi et al. [17]	Pretest-post-test design	Elite handball players	Sex: M, EG: N:10, Age: 18.5 ± 0.85 years, WT: 88.01 ± 14.56 kg, HT: 1.81 ± 0.06 m, BMI:NR, CG: N = 9, Age: 18.5 ± 0.85 years, WT: 88.01 ± 14.56 kg, HT: 1.81 ± 0.06 m, BMI:NR	Freq:2 Times/ Weeks, Time: NR, Length: 12 weeks	12-week CT: 6 exercises - Zig zag sprint, Half back-squat, Medicine ball throw, Multiple diagonals, CMJ box jumps, 1RM Pull-over. 24 sessions; 2 sets, 6-16 reps; 180s rest/set & exercise.	Upper extremity max strength (1 RM bench press), Upper body strength (1 RM pullover), Lower extremity max strength (1 RM half back-squat), Power (CMJ, SJ: Height, max force, avg power), Agility (T-half Test), Sprint (15m & 30m).	EG: 1 RM Bench press↑, 1 RM Pullover↑, 1 RM half back squat ↑, Jump height↑, Maximal force before take-off↑, Average power↑, T-half Test ↔, Sprint 15 m↑, Sprint 30 m↑
Annasai et al. [23]	Pretest-post-test design	Basketball athletes	Sex: M, EG N = 15, Age: 15-17, WT:NR, HT:NR, BMI:NR	Freq:3 Times/ Weeks, Time: NR, Length: 8 weeks	CT study: 10 posts - Lunge, Reverse Crunch, Hindu Push Up, High Knee, Jumping Jack Tuck Jump, Squat Trust, Plank, Kneeling Hip Extension, Shuttle Run 10m. 2-3 sets; 30s/post, 10-20s rest/post, 60-180s rest/set.	Leg muscle strength (leg dynamometer), Back muscle strength (back dynamometer), Hand muscle strength (hand dynamometer)	LD↑, BD↑, HD↑
Annasai et al. [24]	Pretest-post-test design	Basketball athletes	Sex: M, EG N = 28, Age: 15-18, HT:NR, BMI:NR, CG: 28, Age: 15-18, HT:NR, BMI:NR	Freq: NR Times/ Weeks, Time: NR, Length: 8 weeks	CT program: S1 (Ickey shuffle, push-ups, rope jump, shuttle runs), S2 (Jump squats, x-drills, triangle drills, triceps dips), S3 (Lateral squats, 4-corner drills, biceps curls, high knees), S4 (Lunges, triceps curls, m-drills, high knees), S5 (Band walks, zig-zag runs, Hindu push-ups, heel kicks), S6 (Triceps band exercises, hexagon drills, hurdle hops, kicks).	Speed, (20-meter run test), Arm power (med ball toss), Leg power (counter Movement Jump Test)	20-meter test↑, MBT↑, CMJ↑

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Authors	Design	Types of athletes	Population characteristic	Interventions	Types of exercise training	Measures index	Outcome
Strelnikowa & Polevoy [25]	Pretest-post-test design	Basketball player	Sex: M, EG N = 16, Age: 18-19, HT:NR, BMI:NR, CG N = 16, Age: 18-19, HT:NR, BMI:NR	Freq:2 Times/ Weeks; in the competitive period- once a week; Time: NR, Length: 28 weeks	CT program: S1 (High vs. low bar squat, Single-leg barrier jumps, Vertical jumps, Rope jumps), S2 (Seated military press, Calf raises, Incline bench press, Close grip bench press), S3 (Shots, Box down jumps + vertical, Single-leg barrier jumps), S4 (Parallel bar dips, Euro sit-up, Lateral barrier jump).	Explosive leg strength (standing long jump test), Leg muscle Power (vertical jump test), Strength Arms muscles (pull-up bars), Abdominal muscles strength and endurance (hanging leg raises)	EG: SLJ (cm)↑, VJ (cm)↑, Pull-up bars (times)↑, HLR (times)↑
Zein et al. [12]	Pretest-post-test design	Young football players	Sex: M, CT EG: N:14, Age: 15.71 ± 0.72 years, WT: 55.93 ± 9.44 kg, HT: 1.65 ± 8.03 m, BMI:20.36 ± 1.8, CG: N = 13, Age: 14.92 ± 0.76 years, WT: 55.23 ± 9.62 Kg, HT: 1.64 ± 0.06 m, BMI:20.42 ± 2.72	Freq:3 Times/ Weeks, Time: 60-90 minutes, Length: 4 weeks	HICT program: Planks, Side plank, Nordic hamstring, Single leg stance, Squat, Vertical jump - 30-40s/ exercise with 10s rest. Two sets of CT.	Core strength (plank test), Leg muscle strength (Leg dynamometer), Agility (IIIinosi test)	EG: Plank↑, LD↑, IIIinosi test↑, CG: Plank↑, LD↑, IIIinosi test↑
Tsegay et al. [7]	Pretest-post-test design	Young football players	Sex: M, HICT EG1: N = 20, Age: 16.20 ± 0.69, WT:51.70 ± 2.90, HT: 1.62 ± 0.041, BMI: 19.55 ± 0.93, MECT EG2: N = 20, Age: 16.30 ± 0.73 WT: 50.55 ± 4.01, HT: 1.64 ± 0.049, BMI: 19.42 ± 1.15, CG3: N = 20, Age:15.95 ± 0.68, WT:49.75 ± 4.03, HT:1.60 ± 0.064, BMI:19.14 ± 1.73	Freq:3 Times/ Weeks, Time: NR, Length: 16 weeks	HICT EG1 (85% to 90% of HRmax), MICT EG2 (75% to 85% of HRmax)	Agility (zig-zag run), Explosive strength (standing long jump), Speed (30-m sprint)	EG1: ZZR↑, SLJ↑, 30-m test↑, EG2: ZZR↑, SLJ↑, 30-m test↑
Kumar [5]	Pretest-post-test design	Football players	Sex: M, EG: N = 20, Age: 18-23 years, WT: NR, HT: NR, BMI: NR Sex: M, CG: N = 20, Age: 18-23 years, WT: NR, HT: NR, BMI: NR	Freq:3 Times/ Weeks, Time: NR, Length: 6 weeks	CT programs, modified from Don Schmidt's original, include: Burpees Squat jumps Sit ups High knees Single leg kickbacks Bicycle kicks.	Speed (50 m sprint test), Agility (shuttle run), Cardiovascular endurance (12 minutes run and walk)	EG: 50 m test ↔, SEMO shuttle ↔, 12 minutes run and walk↑
Sunarto et al. [2]	Pretest-post-test design	Football athletes	Sex: M, HICT EG1: N = 20, Age: 12-16 years, WT: 51.70 ± 2.90, HT: 1.62 ± 0.041, BMI: 19.55 ± 0.93	Freq: 3 Times/ Weeks, Time: 30-60 minutes, Length: 8 weeks	CT intensity in this study ranged from 60% to 90%. The study utilized 7 programs: Shuttle run 100-meter run 400-meter run Skipping Throwing and catching the ball Zig-zag run.	Muscle Strength and power (vertical jump test), Flexibility (sit and reach), Speed (40-meter run), Abdominal muscle endurance (sit ups), Agility (shuttle run), Cardiovascular endurance (400-meter run)	EG: VJ↑, SR↑, 40-m test↑, SU↑, SR↑, 400-meter run↑

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Authors	Design	Types of athletes	Population characteristic	Interventions	Types of exercise training	Measures index	Outcome
Belli et al. [10]	Pretest-post-test design	Adult amateur soccer players	Sex: M, CT EG: N:11, Age: 22 years, WT:71.2 ± 4.8 kg, HT:174 ± 5.8 cm, BMI:NR CG: N = 8, Age: 22 years, WT: 73.2 ± 4.1 Kg, HT: 176 ± 6.3 cm, BMI:NR	Freq:2 Times/ Weeks: Time: 21 to 28 min, Length: 8 weeks	CT core exercises: Four exercises - crunch, plank, supine bridge, side plank. Three upper body movements - press, pull, push; and three lower body - squat, deadlift, lunge. Work: rest ratio 1:1, 30 seconds each.	Lower body explosive Strength and power (standing long jump), Upper body strength and Power (medicine ball Chest press right and left side), Strength and endurance of Core (Curl-up), Agility (Illinois Agility Test), Right and left lower limbs Balance (Y-Balance Test),	EG: SLJ↑, MBCr↑, MBCl↑, CU↑, IAT↑, YBr↑, YBl↑,
Vianna et al. [26]	Pretest-post-test design	Football athletes	Sex: M, EG: N = 20, Age: 13.3 ± 0.5 years, WT: 52.2 ± 10.6 kg, HT: 1.63 ± 0.1 m, BMI: NR	Freq:3 Times/ Weeks, Time: 90 minutes, Length: 6 weeks	CT involved direction changes, slow runs, sprints, jumps, trotting, and skippings without a ball. It was repeated thrice: post-circuit 1, 10 squats; post-circuit 2, 5 maximal CMJ; and post-circuit 3, 30 sit-ups. There was a 2-min rest between sets, totaling ~15-min for the CT.	Lower body explosive strength and power (Countermovement jump height), Speed (RSA), Agility (change of direction Speed), Cardiovascular endurance (Yo-Yo Intermittent Recovery Test Level 1)	EG: CMJ↑, RSA↔, CODS↑ Yo-Yo Intermittent Recovery Test Level 1↑
Boraczyński et al. [27]	Pretest-post-test design	Youth soccer players	HICT EG1: N = 22, Age:11.2 ± 0.4, WT:37.3 ± 7.9, HT:144.7 ± 7.5, (cm), BMI:17.3 ± 2.1, MICT EG2: N = 24, Age:11.1±0.2, WT:36.6 ±7.3, HT:143.1±7.2(cm), BMI:17.5 ±1.9, CG3: N = 21, Age: 11.0 ± 0.3 WT: 38.1 ± 7.6, HT: 144.9 ± 6.5 (cm), BMI: 17.8 ± 1.8	Freq:3 Times/ Week, Time: HICT EG1:19 minutes, MICT EG2: 28 minutes, Length: 24 weeks	HICT (85%-95% HRmax): Mon/Wed/Fri: Sets ex.1, ex.2, ex.3 respectively. MICT (75%-85% HRmax): Mon/ Wed/Fri: Sets ex.1, ex.2, ex.3 respectively. Indoor CT: Mon (Set 1): High knee, Box jump, Russian twist, Burpee, Mountain climber, 40-m sprints. Wed (Set 2): Back squat, Sit-ups, Jumping jacks, Line jumps, Split squat, 40-m sprints. Fri (Set 3): Triceps dips, Incline push-ups, Jump squats, Standing calf raises, 40-m sprints.	Flamingo balance (one minute on one leg on a 3 cm beam), Flexibility (SAR), Lower body muscular power (SBJ), Forearm strength (hand grip), Abdominal muscular strength and endurance (sit-ups), Upper body muscular strength and endurance (BAH), Agility (10 ×5 m SHR)	EG1: one minute on one leg on a 3 cm beam↑, SAR↑, SBJ↑, HG↑, SU↑, BAH↑, 10 ×5 m SHR↑, EG2: one minute on one leg on a 3 cm beam↑, SAR↑, SBJ↑, HG↑, SUP↑, BAH↑, 10 ×5 m SHR↑
Indris [4]	Pretest-post-test design	Basketball players	Sex: M, EG: N:16, Age: 15 years, WT: 44.00 kg, HT: 1.515 m, BMI:19.2012	Freq:3 Times/ Weeks, Time: 60 minutes, Length: 8 weeks	CT exercises five stations to train the trainees.	Flexibility, Power for the lower extremities (vertical Jump), Agility (Illinois agility sprint), Speed (50m run test), Cardiovascular endurance (Harvard step test)	EG: SR↑, VJ↑, Illinois agility↑, 50m test↑, Harvard step test↑
Arjuna et al. [18]	Pretest-post-test design	Volleyball athletes	Sex: F, N: 36, Age 15 – 23 years, WT: NR, HT: NR, BMI: NR	Freq:3 Times/ Weeks, Time: 30-45 minutes, Length: 8 weeks	CT with Fixed and Decreasing Rest Intervals 60 - 80% of RM (Maximum Reps) 9 stations (half squat jump, shuttle run, frog jump, jumping jack, squat trust, step up, side plank	Muscle Strength (hand and leg digital dynamometer),Muscle Endurance (sit up), Speed (50-meter run test), flexibility (flexometer), Lower body Muscle Power (vertical Jump), Agility (T-test), Cardiovascular endurance (multistage Fitness Test)	EG: HGDD ↑, LGDD↑, SU↑, 50-meter test↑, Flexometer↑, VJ↑, T-test ↑ Multistage Fitness Test↑

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Authors	Design	Types of athletes	Population characteristic	Interventions	Types of exercise training	Measures index	Outcome
Sumaryanti & Tomoliyus [28]	Pretest-post-test design	Basketball players	Sex: M, CT EG1: N = 30, Age: 16-18, WT: NR, HT:NR, BMI:NR	Freq:3 Time/ weeks, Time: NR, Length: 6 Weeks	CT Program - 8 Stations: Exercises: Push-up, Sit-up, Jump rope, Backs up, Plank, Side defence, Shuttle run, Squat trust. Circuits: 3 with 3 mins rest between. Activity & Rest Duration: Weeks 1-2: 30s activity, 60s rest. Weeks 3-4: 40s activity, 70s rest. Weeks 5-6: 50s activity, 90s rest.	Speed (20 meters sprint), Legs muscle power (vertical jump), Agility (Illinoise test), Cardiovascular endurance (multistage fitness test)	20 meters sprint↑, Illinoise↑, VJ↑, multistage fitness test↑
Francis & Lohar [29]	Pretest-post-test design	Football Players	Sex: M, EG: N = 20, Age: 14 and 18 years (Mean 16.5), WT:NR, HT: NR, BMI:NR Sex: M, CG: N = 20, Age: 14 and 18 years (Mean 16.5), WT:NR, HT: NR, BMI:NR	Freq:5 Time/ weeks, Time: 90 minutes, Length: 8 Weeks	CT Program - 10 Stations (3 sets each): On-the-spot high knee Single-leg lateral broad Skipping Front hops Squat jumps Lateral jump over cones Zigzag run Step up Passing ball 10m Dribbling cone 10m.	Muscular Strength (bent Knee Sit – Ups), Agility (shuttle Run), Explosive Power (Standing Broad Jump), Speed (50 Meters Dash)	EG: SU↑, SHR↑, SBJ↔, 50 Meters Dash↑, CG: Sit – Ups ↔, SHR↑, SBJ↔, 50 Meters Dash↑
Akilan [30]	Pretest-post-test design	Basketball players	Sex: M, EG: N = 12, Age: 16.85 ± 0.67. years, WT:NR, HT: NR, BMI:NR Sex: M, CG: N = 12, Age: 16.85 ± 0.67. years, WT:NR, HT: NR, BMI:NR	Freq:3 Time/ weeks, Time: NR, Length: 6 Weeks	CTG Protocol: Intensity: 2 mins at 90-95% target heart rate. Reps: Weeks 1-2: 8 Weeks 3-4: 10 Weeks 5-6: 12 Rest: 2 mins at 70-80% target heart rate. Work-Rest Ratio: 1:1 Circuit Details (59s per lap, 153m/lap): Actions: Forward sprinting (60.2%), Side shuffling (39.8%) Offense (55.6%): Dribbling Defense (44.4%): Without ball Per Lap: 3 layups, 3 rebounds, 7 jumps, 1 pivot, 20 direction changes.	Percent body fat, lean body mass, Fat mass (skinfold calliper), Cardiovascular endurance (Multistage fitness test)	SC↔, Multistage fitness test↑
Subramaniam et al. [31]	Pretest-post-test design	Athletes (Track & Field, Netball, Field Hockey, Basketball, Squash, and Cricket)	Sex: M and F: 32, EG: N: 32, Age: 14.49 ± 0.78, HT:1.70 ± 8.17, WT: 60.23 ± 1.10, BMI: NR, Sex: M and F, CG: 32, N:32, Age: 14.37 ± 0.81, HT: 1.67 ± 5.34, WT: 57.28 ±9.90, BMI: NR,	Freq:2 Time/ weeks, Time: 90 minutes, Length: 12 Weeks	Progressive CRT Protocol: Equipment: Medicine ball. Stations (10): Reverse Lunges, Pelvic Thrust, Split Squat, Front Raise, Chest Press, Lying Trunk Twist, Toe Touch, Overhead Toss, Lunges, Squat, Toss, Bounce and Catch. Sets: 1-3 Reps: Based on prior 1RM test, adjusted for upper body, core, and lower body exercises.	Body composition (Skinfold calliper), Speed (50-yards Dash), Flexibility (Sit & Reach), Agility (T-Drills), Power (medicine Ball Put), Muscular strength (half Squat Jump), Abdominal strength (modified Sit Ups), Cardiovascular endurance (Multistage 20m Shuttle Run)	SC↑, 50-yards Dash↑, SR↑, T-Drills↑, MBP↑, HSJ↑, MSU↑, Multistage 20m Shuttle Run↑

Note: ↔,non-significant within-group change from pretest to post-test; ↑, significant within-group improvement from pretest to post-test; WT, weight; BMI, body mass index, N, Number of participation; HT, height; F, Female; M, Male; NR, not reported; Freq., frequency; EG, experimental group; CG, control group; 1RM,1 repetition maximum; S, Station; CMJ, Counter Movement jump; SBJ, Standing Broad Jump; SLJ, Standing long jump; SHR, Shuttle Run; CRT, Circuit Resistant Training; HICT, high intensity circuit training; MICT, moderate intensity circuit training; BAH, Bent Arm Hang; ZZR, zig zag run; HSJ, Half Squat Jump; VJ, vertical jump; BD, back dynamometer; LDD, Leg digital dynamometer; HDD, Hand digital Dynamometer; SC, skinfold calliper; VJ, Vertical jump; SR, Sit and reach; MBP, Medicine Ball Put; MBT, Med ball toss; TCB, Throwing and catching the ball; HLR, Hanging leg raises; SU, Sit up; MSU, Modified Sit Ups

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Study selection

Figure 1 shows the flow chart of records selection. A total of 566 potential articles were identified through the electronic database search (16 from PubMed and 540 from Google Scholar), and additional relevant articles in screening the reference lists of studies that were included in the review and reference lists of previous related reviews (n = 10). After the exclusion of the duplicates (436), the title and abstract of 130 were assessed for eligibility. After elimination at the title and abstract level of 40 articles, the remaining 90 articles were subsequently read. After reading, another 72 articles were eliminated, leaving eighteen relevant articles that satisfied the inclusion criteria and were included in the qualitative synthesis.

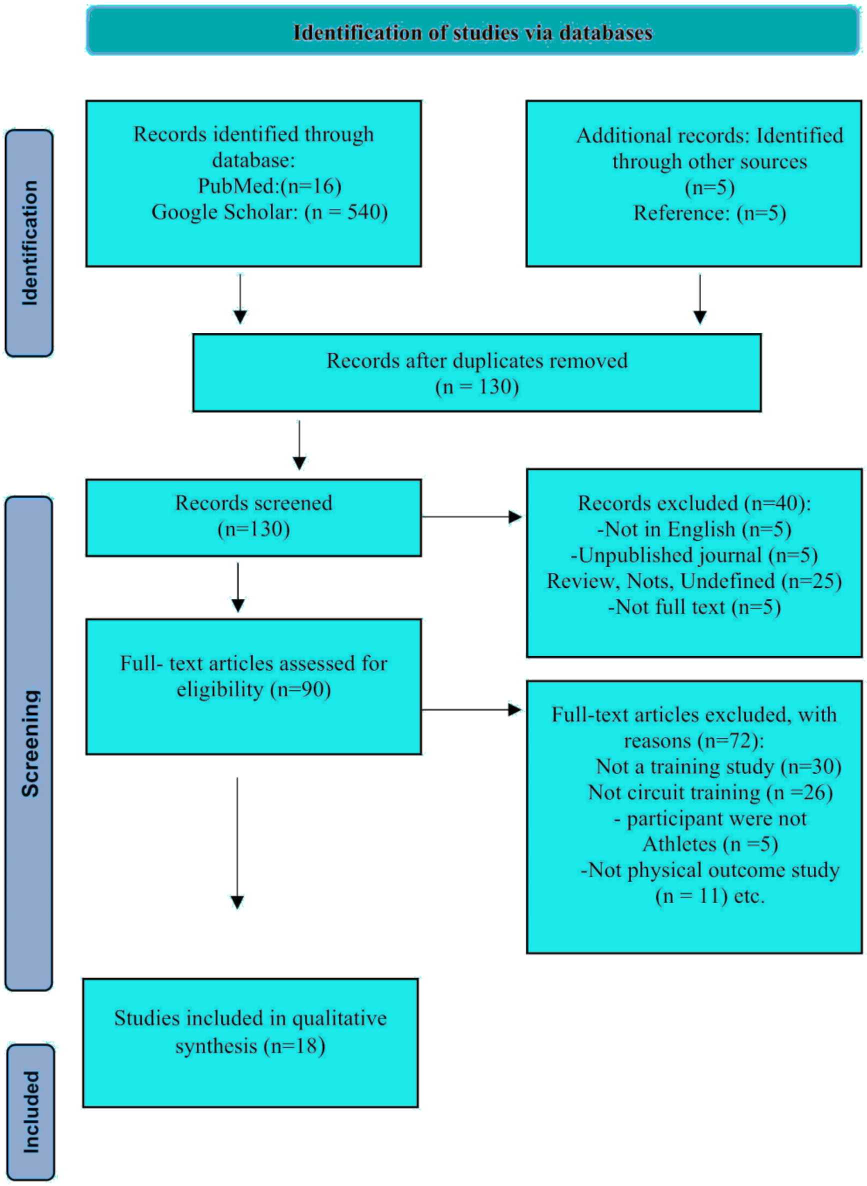

Figure 1. PRISMA flow chart of the study selection process

Study quality assessment

An assessment of the study quality, according to the PEDro list, is presented in Table 3. The mean PEDro score of the included studies was 5.05 (range 5-6), which indicates that the included studies were of fair quality, and none of the studies met all the PEDro list quality criteria. All studies specified their eligibility criteria, similar baseline group, point estimated variability between-group comparisons, and point measure and variability. None of the studies reported on allocation concealment, blind assessors, blind therapists, or blind subjects, with the exception of nine studies that described random allocation [5, 7, 12, 24, 28, 30–33]. Additionally, only one study failed to report on follow-ups [12]. Nevertheless, including blind subjects, therapists, and assessors is challenging in exercise training intervention studies. This situation calls for higher quality and better evidence-level studies to be conducted in the future.

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Table 3. Summary of methodological quality assessment scores

References	1 [7]	2 [5]	3 [12]	4 [10]	5 [27]	6 [22]	7 [17]	8 [2]	9 [26]	10 [4]	11 [18]	12 [23]	13 [24]	14 [25]	15 [28]	16 [29]	17 [30]	18 [31]
Eligibility criteria	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Random allocation	1	1	1	0	1	0	1	0	0	0	0	0	1	0	1	0	1	1
Concealed allocation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseline similarity	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Blind subjects	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blind therapists	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blind assessors	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Adequate follow-up	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Intention to treat analysis	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Between-group comparisons	1	1	1	1	1	1	1	0	0	0	0	0	1	1	0	1	1	1
Point estimated variability	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
PEDro score	6/10 Good	6/10 Good	4/10 Fair	5/10 Fair	6/10 Good	5/10 Fair	6/10 Good	4/10 Fair	4/10 Fair	4/10 Fair	4/10 Fair	4/10 High	6/10 Good	5/10 Fair	5/10 Fair	5/10 Fair	6/10 Good	6/10 Good

Note: The PEDro scale is an 11-item scale designed for rating the methodological quality of RCTs. PEDro score is obtained by adding points describing the quality of papers, for example, 9–10 (excellent), 6–8 (good), 4–5 (fair), and ≤ 3 (poor), Yes (Y/1); No (N/0) (Maher et al., 2008)

Tsegay et al. [7]; Kumar [5]; Zein et al. [12]; Belli et al. [10]; Boraczyński, Boraczynski, et al. [27]; Hermassi et al. [22]; Hermassi et al. [17]; Sunarto et al. [2]; Vianna et al. [26]; Indris [4]; Arjuna et al. [18]; Annasai et al. [23]; Annasai et al. [24]; Strelnikowa & Polevoy [25]; Sumaryanti & Tomoliyus [28]; Francis & Lohar [29]; Akilan [30]; Subramaniam et al. [31];

Population characteristics

The population characteristics of the eighteen included studies were reported based on aspects such as: (1) Athlete classification. In the included literature, eighteen articles reported the type of athlete, including eight on football/soccer players [2, 5, 7, 10, 26, 29, 32], handball players [22, 33], basketball players [4, 23–25, 28, 30], volleyball players [18]; Among the eighteen studies, one study included a group of athletes from various sports such as Track & Field, Netball, Field Hockey, Basketball, Squash, and Crickett [31]. (2) Sample size. The eighteen studies included a total of 607 subjects, with participant numbers ranging from 15 [23] to 67 [27], a median of 28.5 [12, 28] and a mean of 33.72. (3) Gender. Of the eighteen studies, one focused on female athletes [18], one on a mixed-gender group [31], and the remaining sixteen on male athletes [2,4,5,7,10,22–26,28–30,32]. (4) Age. All studies report the subjects' age, and only eleven studies reported the age range of the subjects [2, 4, 5, 10, 18, 23–25, 28, 29]. An analysis of age reports in seven studies found that the age range of the subjects ranged from 11.2 years to 23 years [7, 12, 22, 26, 31–33]. (5) Body Mass Index. Most studies reported the height and weight of the subjects [2, 4, 7, 10, 12, 22, 26, 31–33], only four studies reported the BMI of the subjects [2, 4, 12, 32], and only eight study did not state the weight, height, BMI of the subjects [5, 18, 23–25, 28–30]. For the consistency of literature analysis, the following formula was used to calculate the BMI of the subjects in the relevant studies: BMI = weight (kg)/height^2 (m^2). The participants' BMI ranged from 17.3 ± 2.1 to 26.93 kg/m^2. (6) Training background. Among the eighteen studies, four studies reported the training background of athletes [18, 26, 30, 32], while the other fourteen studies did not describe the training background [2, 4, 5, 7, 10, 22–25, 28, 29, 31, 33]. For the consistency of literature analysis, the training background of the athletes was recorded in years. The training background of the subjects ranged from 3.1 ± 06 years to 6.3 ± 2.5 years.

Interventions characteristics

The intervention characteristics of the eighteen included studies were reported based on aspects such as: (1) Training length. The shortest intervention length is four weeks [12], and the longest is seven months [25]. (2) Duration of each training session. Most studies reported the duration of each training session [2, 4, 10, 12, 18, 22, 26, 29, 31, 32], only nine studies did not state the duration [5, 7, 12, 23–25, 28, 30, 33]. The analysis of the duration of each training session, based on 9 research reports, found that it ranged from 19 minutes [27] to 90 minutes [29, 31]. (3) Training frequency. Among the eighteen studies included, 17 studies reported frequency of training [2, 4, 5, 7, 10, 12, 18, 22, 23, 25, 26, 28–33]. while only one study did not [24]. The frequency analysis of seventeen research reports found that the frequency ranged from 2 times/week [10, 22, 25, 31, 33] to 5 times/week [29].

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Outcome and measures
The outcomes of this study were categorized based on the effects of CT on various components of physical fitness in athletes. All authors of this study independently classified the papers according to other research components. Disagreements were resolved through discussion among all authors until a consensus was reached.

Effect of CT on speed
Twelve of the eighteen studies included in this systematic review presented inferences about the effect of CT on speed performance [2, 4, 5, 7, 18, 22, 24, 26, 28, 29, 31, 33]. The speed tests used in these studies included linear sprint test of 15 m [17], 20 m [24, 28], 30 m [7, 33], 50 m [5], 40-m [2, 4, 18, 29, 31], and repeated sprint ability test [22, 26]. The subjects included young football players [2, 5, 7, 10, 26, 29, 32], handball players [17, 22], basketball players [4, 23–25, 28, 30], volleyball female players [18], and athletes from different game (Track & Field, Netball, Field Hockey, Basketball, Squash, and Cricket) [31]. Nine studies observed a significant improvement for 15 m test [17], 20 m test [23, 28], 30 m test [7, 33], 50 m test [4, 18, 29, 31], 100 m test [2]. However, only three studies did not observe any significant change in the 50 m test [5] and repeated sprint ability test [22, 26]. However, HICT group showed significant differences from even the MICT group on speed [7].

Effect of CT on muscular strength
Muscular strength was evaluated in ten of the studies that were included in this review. The aspects valued and assessment tools used were half squat jump [31], pull-up bars [25], leg digital dynamometer [18, 23], back dynamometer [23], hand digital dynamometer [18, 23, 32], standing long jump [7, 10, 25], plank test [12], 1 RM bench press [22, 33], 1 RM pull over [22, 33], 1 RM half back-squat [22, 33]. The subjects include young handballers [22, 33], volleyballers [18], basketballers [23, 25], soccer players [7, 10, 12, 32]. Furthermore, one study included young athletes from different games like Track and field, Netball, Field Hockey, Basketball, Squash, and Cricket [31]. All ten studies observed a significant improvement in muscular strength after the CT intervention.

Effect of CT on power
Among the eighteen studies included in this review, thirteen studies reported on power [2, 4, 10, 18, 22, 24–26, 28, 29, 31–33]; and five studies did not report on it [5, 7, 12, 23, 30]. The 6 assessment tools used involved medicine ball put [10, 31], medicine ball toss [24]; standing broad jump [27, 29], vertical jump [2, 4, 18, 25, 28], counter movement jump test [24, 26, 33]. The subjects include female volleyballers [18], footballers [2, 10, 26, 27, 29], handballers [22, 33] elite adolescent basketballers [4, 24, 25, 28] and one study included young athletes from different game like Track & Field, Netball, Field Hockey, Basketball, Squash, and Cricket [31]. The results of these studies reveal that CT can improve power and observed a significant improvement in the countermovement jump test [17, 24, 26], vertical jump test [2, 4, 18, 25, 28], medicine ball put [10, 31], medicine ball toss [24], standing broad jump [29, 32]. However, only one study reported that the CT did not yield significant results in the explosive power (standing broad jump) [29].

Effect of CT on balance
Balance (dynamic balance) was valued only in two of the eighteen studies included in this review. The measurement tools were the dynamic balance (right and left), flamingo balance test (one minute on one leg on a 3 cm beam) [27], and Y-balance test (right and left lower limbs balance) [10]. The subjects include football players [10, 27]. One study reported an 8-week intervention period [10], while the other had an intervention period of 28 weeks [27]. The results of these studies reveal that CT can improve balance [10, 32].

Effect of CT on body composition
The body composition aspect appeared to be undervalued by the studies included in this review. Only two of the studies assessed this aspect by using different measurement tools like percentage of body fat [30], lean body mass [30], fat mass [30], body composition [31]. The subjects include moderately trained athletes (Track & Field, Netball, Field Hockey, Basketball, Squash, and Cricket) [31], and basketball players [30]. Studies observed a significant effect of CT on Percent body fat [30], lean body mass [30], Fat mass [30], Body composition [31].

Effect of CT on agility
Agility was the main aspect in many of the studies included in this review. Fourteen studies valued this criterion through difference exercises: T- drills test [18, 31], shuttle run test [2, 29], IIlinosis agility sprint test [4, 10, 12, 28], change of direction speed [26], T half test [17, 22], 10×5 m SHR [27], SEMO shuttle run test [5] and zigzag run [7]. The subjects include footballers [2, 7, 10, 26, 29, 32], basketballers [4, 28], handballers [17, 22], volleyballers [18]. One study moderately trained athletes (Track & Field, Netball, Field Hockey, Basketball, Squash, and Cricket) [31]. Studies conducted by [2, 4, 7, 10, 12, 18, 22, 26, 28, 29, 31, 32] revealed significant increases in agility after the CT intervention. In contrast, Hermassi et al. [17] and Kumar [5] found no significant change in the agility test (T half test and SEMO agility test).

Effect of CT on flexibility
Only five studies included in this systematic review presented inferences about the effect of CT on flexibility. The flexibility was measured based on the sit and reach test and flexometer commonly used in health-related and physical fitness test batteries to evaluate the hamstring and lower back flexibility [2, 4, 18, 31, 32]. The participants of this study were volleyballers [18], footballers [2, 32], basketballers [4], moderately trained athletes (Track & Field, Netball, Field Hockey, Basketball, Squash, and Cricket) [31]. This study revealed a highly significant improvement in flexibility after 8 weeks of CT [2, 4, 18, 31, 32].

Effect of CT on muscle endurance
Muscular endurance was assessed in seven out of the eighteen studies included in this review [2, 10, 25, 29, 31, 32, 34]. This study uses the one-minute sit-up test [18], curl-up [10], bent arm hand [27], hanging leg raise [25], bent knee sit-up [29],

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modified sit-ups [31] to evaluate muscular endurance. The study subjects included young footballers [2, 10, 29, 32], basketballers [25], female volleyballers [18] and moderately trained athletes (Track & Field, Netball, Field Hockey, Basketball, Squash, and Cricket) [31]. All studies reported positive results in this aspect after the intervention.

Effect of CT on cardiovascular endurance
Eight of the eighteen studies included in this systematic review presented inferences about the effect of CT on Cardiovascular Endurance [2, 4, 5, 18, 26, 28, 30, 31]. The Cardiovascular Endurance tests used in these studies included 12-minute run and walk [5], 400-meter run [2], Yo-Yo intermittent recovery test level 1 [26], Harvard step test [4], Multistage fitness test [18, 28, 30, 31]. The study subjects included young footballers [2, 5, 26], basketballers [4, 28, 30], volleyballers [18]. Another study on moderately trained athletes found significant CT effects on Cardiovascular Endurance (Track & Field, Netball, Field Hockey, Basketball, Squash, and Cricket) [31]. All studies reported positive results in this aspect after the intervention.

Discussion
This systematic review provides a comprehensive overview of the impact of CT on physical fitness among athletes and the relevant knowledge for athletes to improve their physical fitness. This review intends to be different from other published studies on using the CT intervention among athletes. The main findings indicated that CT could increase physical fitness (speed, strength, power, flexibility, agility, balance, aerobic, and muscular endurance) among athletes. The reviewed papers varied significantly regarding the participants (type of athletes, age, and gender) and the physical fitness components studied. Nonetheless, CT may be an effective physical fitness intervention among athletes based on positive findings in these studies. Following the framework in the "Results" section, the physical fitness components of the studies were analyzed in detail.

Effect of CT on speed
The comprehensive analysis of circuit training's impact on speed performance, conducted through an exhaustive review of twelve studies, provides valuable insights into its multifaceted effects. This collective consensus highlights the effectiveness of CT in enhancing speed among athletes with varying backgrounds and training methods. Nevertheless, it's noteworthy that three studies did not observe significant changes in speed performance, particularly in the 50-meter and repeated sprint ability tests. These variations in outcomes could be attributed to diverse training methodologies, individual participant characteristics, or potential limitations in the duration or intensity of the CT interventions. Further research is warranted to explore the specific factors contributing to these discrepancies and to optimize the application of CT for enhancing speed performance within specific athletic contexts. The HICT is better training to improve speed due to the more repetitive activities as well as relatively more strenuous exercises [7]. One study on handball players showed no significant change in RSA parameters in response to RCT despite an improvement in sprint performance. One possible reason for this result could be that the RCT program did not include exercises at the intensity range demanded by the RSA test [22].

Effect of CT on muscular strength
The examination of the effect of CT on muscular strength, as scrutinized across ten studies within this systematic review, illuminates a compelling pattern of enhancement. These investigations employed a diverse array of assessment tools to evaluate muscular strength, including half squat jump [31], pull-up bars [25], leg digital dynamometer [23, 35], back dynamometer [23], hand digital dynamometer [23, 32, 36], standing long jump [7, 10, 25], plank test [12], 1 RM Bench press [17, 22], 1 RM pull over [17, 37] and 1 RM half back-squat [17, 37]. The study populations were equally diverse, comprising young handballers [17, 37], volleyballers [18], basketballers [24, 25], soccer players [7, 10, 12, 32] and young athletes from different sports like Track & Field, Netball, Field Hockey, Basketball, Squash, and Cricket [31]. Remarkably, all ten studies consistently reported a significant improvement in muscular strength following CT interventions. This collective agreement highlights the robust efficacy of CT as a potent strategy for enhancing muscular strength across a wide range of assessment methods and athlete populations. The versatility and effectiveness of CT in enhancing muscular strength underscore its potential as a valuable component of athletic training regimens, with implications for improved athletic performance and overall physical fitness.

Effect of CT on power
Within the context of this comprehensive systematic review, encompassing eighteen distinct studies, the evaluation of power as a critical performance metric emerges as a central theme. Thirteen of these studies specifically focused on evaluating power. Notably, the majority of the studies reported substantial improvements in power parameters following CT interventions. These improvements were observed in the counter movement jump test, vertical jump test, medicine ball put, medicine ball toss, and standing broad jump. However, one study did not find significant enhancements in explosive power, as indicated by the Standing Broad Jump test. These findings collectively underscore the efficacy of CT in enhancing power across diverse athletic disciplines, providing valuable insights for athletes, coaches, and sports professionals seeking to optimize training regimens. In one of the studies, the HICT group showed significant differences in explosive strength compared to the MICT group [7]. HICT is more effective in improving explosive strength because it involves more repetitive and strenuous exercises.

Effect of CT on balance
Balance, specifically dynamic balance, was a focus in only two of the eighteen studies incorporated in this systematic review. Boraczyński et al. [27] and Belli et al. [10] used different measurement tools to assess balance in their CT intervention studies. Boraczyński et al. [27] utilized the Flamingo balance test, which involved maintaining balance on one leg on a 3 cm beam for one minute. In contrast, Belli et al. [10] implemented the Y-Balance Test to assess balance in both the right and left lower limbs. The study participants in these investigations were exclusively football players. Belli et al. [10] conducted an 8-week in-

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tervention extended over 28 weeks. The variation in intervention durations provided an opportunity to explore the potential cumulative effects of CT on dynamic balance. Notably, the findings from both studies underscore the positive impact of CT on balance improvement among football players. This suggests that CT interventions could enhance dynamic balance, a crucial element for athletes in sports like football, where stability and control of movement are essential for optimal performance.

Effect of CT on body composition

The impact of CT on body composition received limited attention within the studies included in this review. Only two of the studies examined this aspect, and the findings suggest that CT can indeed play a valuable role in positively influencing body composition, potentially offering benefits for athletes and individuals aiming to manage their body composition for improved performance and overall well-being. Nevertheless, it's important to note that further research may be needed to explore the specific mechanisms and long-term effects of CT on body composition within different athletic contexts and populations. Another study found that CT did not significantly alter body fat percentage, lean body mass, or fat mass [30]. The study observed that high school boys, typically having a lower percentage of body fat and fat mass, showed no impact on body composition from six weeks of CT. So six weeks of CT showed no impact on the body composition of high school male basketball players. It was found that a well-designed, planned, and executed CRT program can reduce fat percentage, especially in adolescent athletes [31].

Effect of CT on agility

Agility emerged as a prominent focus across many studies in this comprehensive review. Significantly, the majority of these studies [2, 4, 7, 10, 26, 28, 29, 31, 32, 36, 37] reported significant and noteworthy improvements in agility following CT interventions. In contrast, two studies i.e., Hermassi et al. [17] and Kumar [5] did not reveal any significant changes in agility. In some cases, such as in study [17], the results can be attributed to the relatively small sample size. Whereas, the HICT group and MICT group didn't show any significant differences in agility ability [7]. The variability in outcomes may stem from factors like specific training protocols, participant differences, or limitations in the CT interventions' duration and intensity.

Effect of CT on flexibility

In this systematic review discussion, we observed that only five of the included studies provided insights into the impact of CT on flexibility. These studies employed well-established measures of flexibility, including the sit and reach test and flexometer, which are commonly used in health-related and physical fitness assessments to evaluate hamstring and lower back flexibility [2, 4, 31, 32, 36]. Notably, the study participants were diverse, comprising volleyball players [18], football players [2, 32], basketball players [4], and moderately trained athletes involved in Track & Field, Netball, Field Hockey, Basketball, Squash, and Cricket [31]. Crucially, the findings of these studies collectively pointed towards a highly significant improvement in flexibility following an 8-week CT regimen [2, 4, 31, 32, 36]. This collective evidence not only highlights the efficacy of CT but also underscores its potential as a potent tool for fostering flexibility enhancements. These findings are crucial, not only for athletes across different sports but also for individuals aiming to improve their overall physical fitness through systematic CT.

Effect of CT on muscular endurance

In the discussion, it is noteworthy that the assessment of muscular endurance emerged as a focal point within this systematic review, with seven out of the eighteen studies incorporated in this analysis dedicating attention to this critical aspect [2, 10, 25, 29, 31, 32, 36]. Various methodologies were employed across these studies to comprehensively evaluate muscular endurance. These methodologies encompassed the utilization of the one-minute sit-up test [18], curl-ups [10], bent-arm hangs [27], hanging leg raises [25], bent-knee sit-ups [29], and modified sit-ups [31]. The diverse nature of the study subjects further contributes to the richness of this discussion. Muscular endurance assessments were conducted on a range of athletes, including young football players [2, 10, 29, 32], basketball players [25], female volleyball players [18], and moderately trained athletes participating in Track & Field, Netball, Field Hockey, Basketball, Squash, and Cricket [31]. Significantly, all of these studies uniformly reported positive outcomes about muscular endurance following the intervention. This collective trend underscores the effectiveness of the respective interventions in enhancing muscular endurance across various athletic populations, thus emphasizing the potential utility of these interventions within sports training and conditioning programs.

Effect of CT on cardiovascular endurance

One notable and encouraging finding is that all of these studies reported significant positive effects of CT on Cardiovascular Endurance following the intervention. This consistency in results across a diverse set of studies and subject populations suggests that CT can be an effective method for improving Cardiovascular Endurance in various athlete groups. However, it is important to consider potential limitations and areas for future research in this field. For instance, the duration and intensity of the CT programs, as well as the specific exercises included, could vary among these studies, and these factors may have contributed to the observed improvements in Cardiovascular Endurance. Additionally, the long-term sustainability of these improvements and their transferability to different sports and populations should be explored in more detail. In conclusion, the eight studies reviewed here provide strong evidence that CT can positively impact Cardiovascular Endurance across a range of athletic disciplines. Further research should aim to standardize training protocols and investigate the long-term effects and applicability of CT in various athletic contexts.

Limitations

The present review provides substantial evidence of fair quality and the beneficial effects of different CT programs on physical fitness among athletes. However, there are several limitations to this review. Firstly, one of the important limita-

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tions observed in this systematic review is related to the lack of training protocol in two studies were not mentioned in details [4, 7]. Secondly, some included studies did not specify their sample size calculation method. Accurate sample size determination is crucial for study quality, and incorrect calculations can affect study outcomes. Thirdly, most of the studies did not record or regulate exercises conducted by participants beyond the study environment. Moreover, these studies generally did not account for external factors such as temperature, time, and other variables that could impact the physical fitness of athletes. Finally, there were no follow-up assessments in the studies, both in the short-term and long-term. This makes it challenging to anticipate the lasting effects of CT on athletes' physical fitness.

Conclusion

Based on the findings of our systematic review, several key conclusions can be drawn regarding the factors influencing the outcome of CT. The CT is one of the most effective and time-efficient exercise modalities to improve the physical condition of the athletes. Our analysis indicates that the progressive increase in training load is a critical factor for achieving favourable outcomes in CT programs. The CT with decreased rest intervals generally affects physical component.This highlights the importance of carefully planning and adjusting the resistance levels to optimize training benefits. The number of exercises incorporated into CT has a significant impact on the training outcomes. Tailoring the selection and quantity of exercises to specific training goals is essential for achieving desired results. Intensity emerges as one of the most influential factors affecting training outcomes. Higher training intensity levels consistently correlate with greater improvements, emphasizing the need for appropriately challenging workouts in CT routines. The intensity of CT is crucial for achieving the desired adaptations. Trainers and coaches must carefully consider and manage intensity to ensure the effectiveness of the training program. Our analysis highlights the importance of considering the duration of CT sessions. Longer training sessions may yield different outcomes compared to shorter. More intense workouts should be considered when designing training programs. The types of exercises integrated into CT programme significantly influence training outcomes. Careful consideration of exercise selection and variety is necessary to target specific variables and achieve desired improvements. Factors such as age, gender, and prior training experience emerge as substantial determinants of training outcomes. Tailoring CT programs to individual characteristics can enhance effectiveness. The number of participants in training studies is a critical factor for ensuring the validity and reliability of the results. Larger sample sizes can provide more robust insights into training outcomes, and studies with smaller sample sizes should be interpreted with caution. CT appears to be a good strategy for improving the performance of players during the pre, in, and off-season periods. Different types of CT, including continuous, interval, and repetitive CT, yield varying outcomes. The choice of CT modality should align with specific training objectives. The nature of the sport or activity integrated into CT can impact the training outcome.

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