HUMAN MOVEMENT (ISSN 1899-1955)
2025; 26(1): 15–41

Biological and physical fitness adaptations in soccer players after jump training: a systematic scoping review

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DOI: https://doi.org/10.5114/hm/199886

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ABSTRACT
Purpose. To conduct a systematic scoping review assessing the effects of jump training in soccer players physical fitness.
Methods. Included studies incorporated: (i) soccer players; (ii) jump-training interventions; and (iii) outcomes related to physical fitness (e.g. endurance). Selection was not based on comparator groups and/or study designs. PubMed, Web of Science, and Scopus databases were searched for documents. One author led the process, and a second author independently verified the process. The type of outcome measure determined studies aggrupation [e.g. vertical jump (e.g. height; contact time)], with a narrative synthesis accompanied by data summaries (e.g. percentage).
Results. Included studies involved males (adults k = 25; youths k = 52) and females (adults k = 8; youths k = 3). Non-randomised interventions (single-arm and multi-arm) comprised ~40% of the studies, with durations between 3–96 weeks, and improvements in ≥ 1 outcome, including body composition, stiffness, electromyographic activity, potential injury risk factors, kicking velocity, repeated sprint ability, linear sprinting, endurance, balance, maximal strength, and jump performance. However, only 10-13 participants were involved in jump training groups. Further, false significant results and publication bias in favour of studies with significant findings are potentially common issues in the available literature.
Conclusions. Jump training may improve physical fitness in soccer players. However, methodological issues (e.g. non-randomised-controlled studies) and evidence gaps (e.g. fewer female studies) were noted. More and better-designed jump training studies on soccer participants are advised before robust recommendations regarding optimal jump training regimens can be made.
Key words: human physical conditioning, resistance training, plyometric exercises, sports, football, athletic performance

Introduction

Soccer is very popular around the world, with an estimated 270 million participants [1]. A myriad of factors [2] may influence success in the sport of soccer, such as well-developed soccer physical fitness, which applies to adult females [3] and males [4], and youth participants from both sexes [5–7]. The specificity of fitness seems particularly relevant when playing at higher levels of competition. For example, tournaments, such as the World Cup, are played at a greater pace than ever before, requiring participants to possess a very high standard of physical fitness to meet the demands of competitions [8]. Moreover, in the English

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Received: September 30, 2024
Accepted for publication: January 01, 2025

Citation: Thapa RK, Garcia-Carrillo E, Sortwell A, Byrne PJ, Afonso J, Ramirez-Campillo R. Biological and physical fitness adaptations in soccer players after jump training: a systematic scoping review. Hum Mov. 2025;26(1):15–41; https://doi.org/10.5114/hm/199886.

Premier League, data across seven seasons indicated increased high-intensity running and sprint distances, as well as an increased number of explosive sprints [9]. Indeed, physical fitness characteristics such as repeated-sprint ability (RSA), linear running speed (e.g. 10 m), strength, and muscular power of the lower limbs (e.g. vertical jump height) may discriminate between competitive levels [10, 11]. Further, linear sprints (i.e. 45%), jumps (i.e. 16%), and change-of-direction (COD) sprints (i.e. 6%) are common movement tasks preceding goal situations [12]. Additionally, match success and league positioning are related to shooting performance [13–15], the latter closely associated with lower-limb power (i.e. jumping) [16]. Indeed, lower-limb power and jumping ability may relate to team success (i.e. final league standing) [17]. Repeating short-duration maximal and near-maximal actions across a 90-minute game is also important and might be associated with endurance [18]. Additionally, reduction of injury risk factors may be a key aspect of success in soccer [17].

Physical fitness is commonly targeted with jump training (JT), an umbrella term encompassing the systematic use (e.g. ≥ 1 weekly session for ≥ 2 weeks) of ≥ 1 jump-related exercise (e.g. jump; hop; skip; leap; bounce). High rates of force development and neuromuscular activity (e.g. electromyography signal) are characteristics of JT exercises [19–21]. Jump exercises are performed with a variety of ground contact times (GCT). For example, rapid hopping (GCT < 200 ms) [22] and hurdle jumps [23] (GCT < 250 ms) usually involve brief GCTs and might be commonly known as plyometric jumps or fast stretch-shortening cycle (SSC) jumps [24, 25]. Longer GCT may be noted during depth jumping (≥ 360 ms) or countermovement jumps (CMJ; > 800 ms) [23, 26, 27], and might be termed as non-plyometric jumps or slow SSC jumps. The JT exercises frequently involve multi-joint movements of the lower limbs, demanding considerable voluntary effort from individuals against gravity during the concentric phase of a jump, as well as effectively absorbing strain on the musculoskeletal system during the eccentric (decelerating) landing phase [28–30], making it highly effective for improving the final phase of jump-related actions [31–33]. Depending on factors such as participants' training level, different types of jumps may involve varying levels of eccentric ground-impact forces, ranging from low (e.g. jump to box) to high (e.g. drop jump), which can be up to 10 times an individual's body mass [28–30]. Moreover, JT can involve unilateral and bilateral leg movements, with or without external load (e.g. loaded CMJ; unloaded CMJ) [34], and different inter-repetition patterns [35, 36], such as continuous jumps (e.g. rope jump) [37] or non-continuous jumps (e.g. jump from the swimming start-platform toward the water) [38].

The wide range of variation in JT exercises provides ample options along the force-velocity curve to target a well-developed physical fitness profile in soccer players [39–41], addressing key underlying biological and biomechanical factors of physical fitness [42–46], offering advantages over other training methods. For example, JT seems to be equally (or even more) effective compared to other training methods (e.g. traditional resistance training [RT]) for the improvement of several physical fitness outcomes (e.g. muscle strength, COD, and power) [20, 47]. Indeed, unlike RT, JT allows for the avoidance of deceleration towards the end of a given movement (e.g. terminal hip and knee extension [48, 49]). Additionally, JT may be inexpensive compared to other training methods, as it requires little or no equipment, typically involving drills with the body mass used as resistance [50]. JT may also be conducted in a relatively small physical space, which may be an important advantage during certain environments or scenarios (e.g. encountering pandemic restrictions) where participants may be restricted to training at their homes [51]. Moreover, JT may be considered more fun-oriented than other training methods (e.g. long-duration, low-intensity endurance running), particularly among younger soccer participants [52]. Further, JT might reduce injury risk factors [53–55] and can be adapted for successful rehabilitation programmes [56]. Furthermore, a meaningful transference effect between JT exercises and soccer-specific physical performance (e.g. jump, sprint, and kicking velocity) has been reported [57–59].

Attesting the relevance of JT for soccer players physical fitness, the rate of JT publications per year increased 25-fold between 2000 and 2017 compared to any other previous period [47], and a simple title/abstract search in PubMed for "training" AND "jump" AND "football" OR "soccer" (date: 2024/09/24) retrieved soccer-related studies at a rate of > 100 per year since 2000. However, a common concern in the sports science literature related to JT and soccer is the use of small sample sizes (i.e. n = 10) [20, 47, 60] and a narrow focus on highly trained participants [61]. In an attempt to solve the problem of studies with small sample sizes, systematic reviews with meta-analyses included males [53], females [62], and youth soccer players [63]. Systematic reviews with meta-analyses commonly include randomised-controlled studies, usually with reduced risk of bias compared to non-randomised and/or non-controlled studies, offering more robust confidence in the evidence. Indeed, systematic reviews are at the higher end of the evidence-based pyramid and may assist practitioners in selecting more effective and safer JT prescriptions through an evidence-based decision approach [7, 64, 65]. However, systematic reviews may leave out analysis studies performed with highly trained participants, where including a control group might not be possible. Additionally, the inherent limitations of meta-analyses [66–70] preclude a more comprehensive analysis regarding the potential effects of JT on physical fitness adaptations. For example, systematic reviews with meta-analyses usually pose a specific research question, commonly revolving on a specific outcome measure (e.g. linear sprinting), precluding a comprehensive analysis of JT's potential to improve a wider range of outcomes. In this scenario, an alternative approach to traditional systematic reviews would involve a systematic scoping review.

Systematic scoping reviews include low-biased randomised controlled studies, in addition to non-randomised and/or non-controlled trials. Fitting into the broad approach of most systematic scoping reviews, these aim not to provide pooled results or analytical comparisons, but to perform a systematic mapping of existing evidence and relevant gaps [71, 72]. Future research would benefit from clear guidance based on an evidence-gap map [73, 74], conveying an intuitive interpretation of research effort allocation (i.e. where the evidence is rich versus where it is scarce) [73–75], exposing areas requiring further research [73–75], including sports medicine-related areas [76–78]. A systematic scoping review can provide a clearer picture of what is known and what still needs to be explored about JT and the impact on soccer players' adaptations, helping to inform future policies and funding, and providing clearer evidence regarding JT optimization.

Although a previous narrative review attempted to cover JT literature in soccer [79], the authors did not address a great portion of the literature. Further, a previous systematic scoping review [80] covered JT literature in soccer; however, the study was focused on JT programming factors, leaving out the adaptations derived from such intervention.

Therefore, this systematic scoping review aimed to assess the scientific literature related to JT in soccer, with special reference to physiological and physical fitness adaptations. This systematic scoping review also aimed to identify gaps and potential limitations in the available literature, as well as potential future directions for research.

Material and methods

International guidelines for conducting and reporting systematic scoping reviews were considered [81–83], and the full protocol can be accessed elsewhere in its original version [47], updated version [20], and its most recent update to soccer-related literature [80].

Eligibility criteria

Original peer-reviewed full-text articles were considered, with no limit on language or publication year. Table 1 describes the eligibility criteria according to a PICOS approach. Considering the nature of systematic scoping reviews, no restriction was set a priori for the selection of physical fitness outcomes. Some outcomes may take relatively longer periods to show significant changes (e.g. bone density), while other outcomes (e.g. vertical jump height, horizontal jump distance, biomechanical variables related to jump performance [e.g. force], and change of direction speed) can respond rapidly (2–3 weeks) [20, 31, 84, 84] to the stimuli induced by jump-related exercises. Therefore, the minimal eligible duration for studies that applied JT interventions was set at ≥ 2 weeks. In line with principles of systematic scoping reviews [20, 85, 86], randomised, non-randomised, controlled, and non-controlled studies (i.e. studies with no comparator group) were included.

Information sources and search

The electronic databases PubMed (including MEDLINE), Web of Science (core collection), and Scopus were searched. After an initial search in the databases from their inception up to April 2017 [47], accounts were created in the respective databases for the lead author. Through these accounts, the lead author received automatically generated emails for updates regarding the search terms used. The search was refined in May 2019 [20], and again in September 2021 [80], and studies were selected up to June 2022. Considering the long-lasting nature of the systematic scoping review, results from the collection process, analyses, and discussion, an approximate 2-year period was taken for final manuscript preparation. Indeed, in line with the aims of systematic scoping reviews, we performed a sensitive literature search [87], aimed to retrieve as many relevant reports as possible. Therefore, to increase the comprehensiveness of relevant reports being identified after the literature search, the keywords related to the population (e.g. soccer, football, beach soccer, futsal) were not used. Nonetheless, the

Table 1. Eligibility criteria

Category	Inclusion criteria	Exclusion criteria
Population	Soccer players, with no restrictions on their fitness, competitive level (e.g. recreative and international level), age, or sex. Mixed sports studies were considered if the inclusion of soccer was clearly stated.	Participants unable to complete a jump at maximal effort (e.g. injured participants).
Intervention	Jump training with a minimal duration of ≥ 2 weeks, which included unilateral and/or bilateral jump-related exercises, which commonly utilize a pre-stretch or countermovement stressing the stretch-shortening cycle. When jump training was delivered in conjunction with other training interventions (e.g. high-load resistance training), the studies were includable when the jump-related exercises represented > 50% of the total training load (e.g. number of exercises)[¥].	Training interventions not involving jump-related exercises (e.g. upper-body throws and sprints), repeated-bout effect interventions, and cross-sectional studies (e.g. participants exposed to a single session).
Comparator	In line with principles of systematic scoping reviews, studies with and without comparator groups, studies with comparator groups of soccer players participating in regular training schedules, studies with comparator groups of soccer players involved in alternative training methods (e.g. high-load resistance training), and studies comparing different jump training approaches (e.g. different intensity) without additional comparator group(s).	Not applicable.
Outcome	Studies that incorporated testing relevant to soccer (e.g. physical fitness, biomechanics, and anthropometrics), with results reported after or before-after interventions.	Lack of baseline and follow-up data.
Study design**	Single and multi-arm trials, randomised, non-randomised, controlled, and non-controlled studies (i.e. studies with no comparator group).	Retrospective-prospective analyses, studies with ambiguous protocols (e.g. jump exercises not clearly described), overtraining studies, and detraining studies*.

* In the case of detraining studies, if there was a training period prior to a detraining period, the study was considered for inclusion.
** Congress documents were assessed when appearing in electronic databases as full text, although none were included.
[¥] From an ecological point of view, a combination of jump training with other training methods is a common practice. However, in this systematic scoping review, studies that delivered jump training in conjunction with other training interventions were includable when the jump-related exercises represented > 50% of the total training load (e.g. number of exercises), and when a comparator group with a similar combination of exercises (other than jumps) was included.

precision of the literature search was also considered, using keywords collected through expert opinions, a systematic literature review, and controlled vocabulary (e.g. Medical Subject Headings: MeSH). The following keywords were used in different combinations through the Boolean operators “AND” or “OR”: “ballistic”, “complex”, “explosive”, “force”, “velocity”, “plyometric”, “exercise”, “stretch”, “shortening”, “cycle”, “jump”, and “training”. An example of search terms in PubMed was as follows: (plyometric[All Fields]) AND (training[All Fields]). The full electronic search strategy for all databases can be accessed elsewhere [20, 47, 80].

Selection of sources of evidence

One author (RRC) conducted the initial search and removed duplicates. Automated removal of duplicates was performed using EndNote 20.6 (ClarivateTM Analytics, Philadelphia, PA, USA), but further manual duplicate removal was required. In selecting studies for inclusion, a review of all relevant titles was conducted before examination of the abstracts, and the latter before examination of full-text versions. One author (RRC) conducted the process. A second author verified the process and selected eligible studies (RKT).

Data charting (extraction) process, data items, and synthesis of results

One investigator (RRC) processed all data and then a second author verified (RKT). Based on previous recommendations, including the expert opinions of 7 researchers from the list of top 10 world-level researchers in the field of JT scientific literature [20, 47, 80, 88], several data items were considered for extraction. An outline of each of these items has been previously reported [20, 47]. Briefly, the main characteristics related to the participants (e.g. age, sex, and competition level), JT interventions (e.g. duration), and outcome measures (e.g. vertical jump performance) were extracted. For this systematic scoping review, the following main outcomes were included: body composition (including anthropometry and muscle architecture), histological outcomes (skeletal muscle fibres characteristics), stiffness, electromyographic activity, potential injury risk factors, kicking velocity, repeated sprint ability, linear sprinting, change of direction speed, endurance, balance, maximal strength, and jump performance.

A custom-made Excel spreadsheet assessed by the research team before its use [20, 47, 80] was utilised to save the extracted data items. Studies were grouped according to the type of outcome they measured (e.g. linear sprint performance or vertical jump performance). Additionally, considering that sex and age are commonly used to determine soccer competition level, whenever possible, results were grouped according to the participant's sex and age. A narrative synthesis was performed for data items, accompanied by data summaries (e.g. number and percentage).

Critical appraisal of individual sources of evidence

Considering the principles of systematic scoping reviews [86, 89, 90], including those in the field of RT and JT [20, 47, 91], no restrictions were imposed to select articles based on the randomisation process, incorporation (or not) of a comparator group, or sample size, although these data items were registered for a critical appraisal of individual sources of evidence.

Results and discussion

Sources of evidence selection, main characteristics, and critical appraisal

From 7,556 studies [2,370 from PubMed; 2,387 from Scopus; 2,776 from Web of Science; 23 from other sources (e.g. manual search in personal library)], 4,886 were duplicates. After the exclusion of studies based on titles and abstracts screening, 498 studies remained to be fully screened. Thereafter, 88 studies in soccer and 35 studies that recruited soccer players mixed with athletes from other sports [58, 92–213], were deemed eligible for further analysis. The study selection process is depicted in Figure 1. Whenever relevant, specific sections are provided for studies (k = 35) that

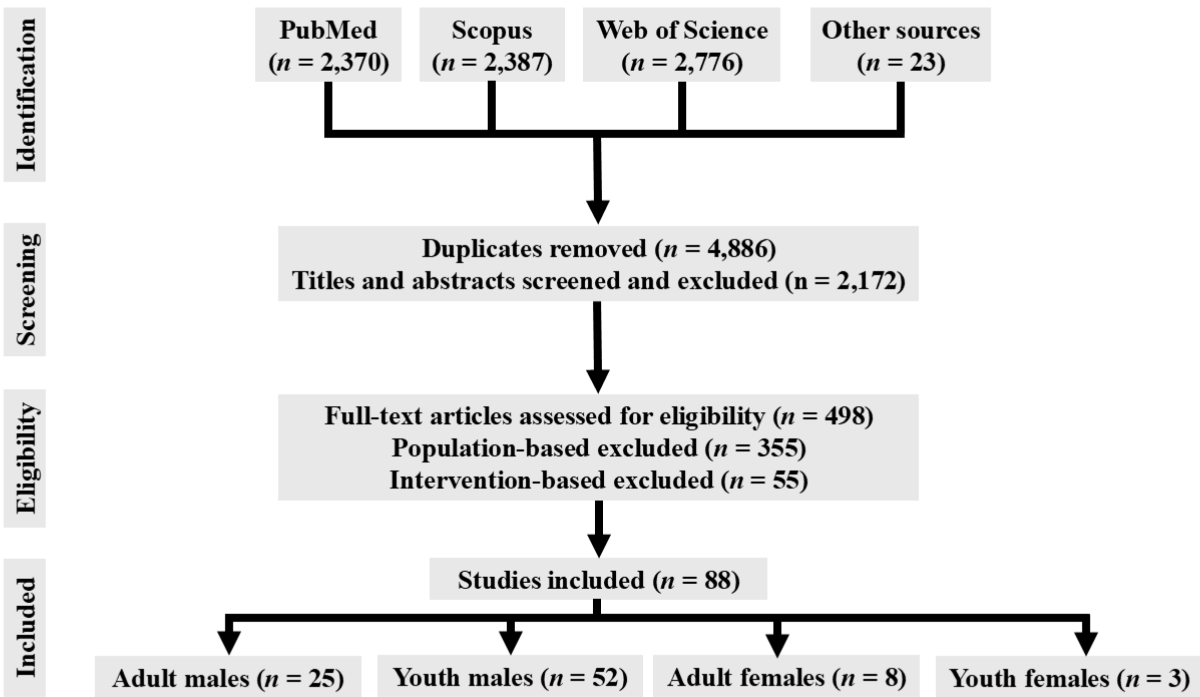

Figure 1. Studies eligibility process

recruited soccer players mixed with athletes from other sports.

The participant characteristics in the eligible studies according to biological sex and age (based on mean group age reported in studies) included males (k = 25) [58, 95–97, 100, 104, 107, 112, 114, 122, 123, 125, 128–130, 136–138, 144, 166, 171, 178, 179, 181], youth (i.e. < 18 years) males (k = 52) [57, 98, 99, 103, 105, 106, 108–111, 113, 116–121, 124, 131, 133, 135, 140–143, 145, 146, 148–158, 160, 162–165, 167, 168, 170, 172–174, 176, 177, 180, 182–185], females (k = 8) [92–99], and youth females (k = 3) [100–102]. The median number of participants in JT groups varied between n = 10 to n = 13 across soccer player's age and sex categories. The age, body mass, and height of participants spanned from: (i) males: 18 to 25 years, 60.7 to 83.1 kg, and 161 to 184 cm, respectively; (ii) youth males: 9.5 to 17.8 years, 31.0 to 74.5 kg, and 130 to 180 cm, respectively; (iii) females: 18.3 to 24.3 years, 54.9 to 61.1 kg, and 158 to 167 cm, respectively; and (iv) youth females: 13.4 to 16.5 years, 50.8 to 61.5 kg, and 162 to 167 cm, respectively. Most studies involving males (k = 17, 68%), youth males (k = 50, 96%), females (k = 6, 75%), and youth females (k = 3, 100%) included participants with no JT experience (or failed to report this information). Most studies in males (k = 22), youth males (k = 45), females (k = 7), and youth females (k = 3) included participants with a high-moderate physical fitness level, although only 18 studies included participants with a high physical fitness level (the definition for physical fitness levels can be obtained elsewhere) [20, 47].

Most studies involving males (k = 15), youth males (k = 39), females (k = 6), and youth females (k = 2) included JT during the in-season. Description of JT duration, frequency, intensity, exercises, sets, and repetitions was reported in 60% of included studies: males, k = 18; youth males, k = 29; females, k = 6; youth females, k = 0. Similarly, randomised-controlled study designs represented 63% of included studies: males, k = 14; youth males, k = 34; females, k = 6; youth females, k = 1. Further, most studies in youth males (k = 35), but not youth females (k = 0), reported biological maturity (e.g. pubertal stage or predicted age of peak height velocity [APHV]). Of note, a lower number of outcomes were analysed in females compared to males. One study mixed females and males [103], and one study with youths did not report the participants' sex [104]. Both studies were not included in the previous sentences of this paragraph.

Studies that mixed soccer with other sports

Mixed studies included soccer (and related modalities), basketball, rugby, track and field, and tennis, among other sports. The median number of participants in JT groups was n = 12. Studies included males (k = 10), females (k = 13), mixed samples of males and females (k = 9), or did not report the participant's sex (k = 3). The age, body mass, and height of participants spanned from 14.1 to 27.0 years, 50.6 to 84.5 kg, and 163 to 183 cm, respectively. The JT prescription was insufficiently described in most studies (k = 24), and only 66% of studies reported randomisation procedures. Most studies (k = 28) included participants without JT experience. Studies included participants with low physical fitness (e.g. rehabilitation or amateur) up to high (k = 3). Studies that included youth participants (k = 7) did not report biological maturity.

Morphophysiological adaptations to JT

The datasets generated during and/or analysed during the current systematic scoping review, including data from each included source of evidence and are available from the corresponding author upon reasonable request. An overview of the datasets is presented in the next sections.

Body composition, anthropometry, and muscle architecture

In males (age, 18–25 years), interventions between 4–10 weeks induced several adaptations (0.3–18%, ES 0.2–1.2), including increased muscle thickness, total leg muscle volume, thigh muscle volume, mean thigh CSA, pennation angle and fascicle length in the vastus lateralis muscle, reduced fat-free mass, body mass, and body mass index [105–109]. In youth males, 8–10 weeks of JT improved vastus lateralis thickness (8%) [110] and reduced body fat and summed skinfolds (9–11%) [111]. In youth females (age, 16.5 years) [100], fat-free mass increased (2.4%), and fat mass decreased (–11.6%), after 10 weeks. For males and females from mixed sports, 6 weeks of loaded JT (15–30% of body mass) improved (4–15%) vastus lateralis and rectus femoris muscle thickness, fascicle length, and pennation angle [112]. In contrast, in males, compared to RT, adding 8 weeks of JT did not improve vastus lateralis fasciculus length; vastus lateralis pennation angle; vastus lateralis CSA; vastus medialis, vastus intermedius, or rectus femoris thickness [113]; and body mass was unchanged [114]. In youth males (age, 10.7 to 15.5 years), no improvement was reported after 6–12 weeks in leg and thigh muscle volume, leg lean volume, thigh CSA, free fat mass, calf circumference, skeletal muscle mass, fat indices, body mass, height, or arm span [110, 111, 115–123]. In females (age, 19–24 years), body mass and body fat were unchanged after 6–12 weeks [92–95]. Most studies in mixed sports, involving males, females, and youths (age, 13 to 25 years) [112, 124–128], noted no changes in body mass, standing height, body mass index, or indices of body fat or muscle mass after 6–7 weeks. Overall, although JT may affect body composition, diet was rarely controlled [94, 95, 129], suggesting a degree of caution in data interpretation. Overall, body composition was trivially affected in females, youths, and mixed sports, except when JT was combined with RT or loaded jumps. In males, JT may improve muscle mass, although in youth males, JT seems less effective in modifying either fat-related or muscle-related indices. However, most studies among youth males included participants ≤ 12.7 years of age, involving an APHV of –1.6 years, a Tanner stage I–II, and/or testosterone levels of 14.7 ng · dl^{-1}. Therefore, future studies need to clarify if some biological markers (e.g. testosterone) modulate body composition adaptations to JT. Additionally, although JT allows normal somatic growth (i.e. body mass and height) [129, 130], and can favour bone health, studies should clarify the role of JT on the development (and its rate) of different tissues (e.g. muscle vs. tendon) in youths, and its relationship with health and performance [131–133].

Skeletal muscle fibre adaptations

Males from mixed sports exhibited changes in myosin-heavy-chain isoform composition in type I/IIa fibres after 8 weeks of JT, and increased cross-sectional area (CSA), absolute peak calcium-activated force, maximum unloaded and loaded shortening velocity, absolute and normalised peak power, the velocity at peak power, and absolute force at which peak power was reached [134]. Additionally, the percentage of type I/IIa and IIa fibres increased, while IIx fibres decreased in vastus lateralis, with increased fibre diameter, maximal calcium-activated force, and calcium sensitivity (without changes in calcium-activation threshold) [135].

Stiffness

Studies assessed stiffness with indirect measures (e.g. jump-related) and direct measures (i.e. skeletal muscle fibre). Leg stiffness (i.e. while jumping) increased (22–32%; effect size [ES] 1.3–1.4) in youth males (age, 14 years) after 8 weeks of JT [136]. Leg stiffness also increased (4–15%; ES 0.3–1.3) in youth males (age, 13 years) after 4 weeks [137]. In males from mixed sports, 8 weeks of training increased stiffness when assessed via hysteresis and complex Young's modulus, although with mixed findings at the skeletal muscle fibre level, with improvements in stiffness (14–24%) among type IIa/IIx and IIa fibres, and not in type I, IIx, or I/IIa fibres [134]. Moreover, a study noted no stiffness changes after JT [138]. Overall, stiffness was usually improved after 4–8 weeks of JT. However, some contrasting findings have been reported. Contrasting results were also reported in a previous narrative review [85], although a more recent systematic review reported stiffness improvement after JT [139]. Nonetheless, the reduced number of studies conducted on soccer players precludes a robust analysis regarding optimal JT effects on stiffness adaptations across age/sex groups.

Skeletal muscle electromyographic activity

Females from mixed sports, after 6 weeks, increased electromyography (EMG) of hip adductor muscles (50–56%) and hip adductor-abductor co-activation (102%) during a drop-jump task, suggesting decreased injury risk by enhancing dynamic joint stability in the lower extremity [140]. In youth males (age, ~16 years), EMG increased (72–110%) in the vastus medialis and rectus femoris muscles during a SJ and CMJ, after 8 weeks [123]. However, in females from mixed sports, after 9 weeks, EMG was unchanged [141], similarly to youth females from mixed sports after 4 weeks [142], females plus males from mixed sports after 6 weeks of loaded jumps [112], and to youth males (age, ~13 years) after 8 weeks of an intervention [110]. Overall, EMG-related outcome adaptations seem less consistent compared to skeletal muscle fibres and stiffness adaptations. The EMG-derived outcome measures are usually considered a key mechanism related to the physical fitness improvements derived from JT, although adaptations at the skeletal muscle fibre (e.g. force, velocity, stiffness) may also be relevant [85, 143]. Alternatively, the inherent limitations of EMG-related measurement techniques might have precluded a comprehensive analysis of potential neural adaptations derived from JT [30, 144].

Potential injury risk factors adaptations to JT

In females (age, ~19 years) [96], 10 weeks of JT (as multicomponent training) improved the isometric strength of hip extensors (26%), flexors (18–20%), and adductors (14%), additionally it improved knee (199%) and hip abduction (71%) at initial contact during a stop-jump task, as well as hip abduction (170%) at peak knee flexion. In youth males (age, ~17 years) [145], the ratio of dominant leg/non-dominant leg peak torque for the knee extensors and flexors improved (~10%) after 5 weeks of JT (as multicomponent training). In males (age, ~21 years), 8 weeks of training improved the hamstring eccentric/quadriceps concentric ratio (7%) [105]. Similarly, males (age, ~23 years) [146], after 7 weeks of JT (as multicomponent training), noted improvements (5–10%) in the hamstring/quadriceps peak concentric torque ratio in the dominant and non-dominant leg, and in the hamstring eccentric/quadriceps concentric peak torque ratio in the dominant and non-dominant legs. Most studies that assessed injury risk factors mixed soccer players with participants from other sports. In youth females from mixed sports (age, ~14 years) [147], 6 weeks of training improved lower-limb unilateral and bilateral landing biomechanics at the hip and knee level, including flexion, adduction, and abduction rotation and moment (suggesting reduced anterior cruciate ligament [ACL] injury risk). Also, in youth females (age, ~16 years), 7 weeks of JT (as multicomponent training) [127] improved dynamic force stabilisation during a single-leg landing task, plus reduced dominant and non-dominant limb asymmetries, improved non-dominant and dominant leg hamstrings/quadriceps torque ratios, and hamstring torques. Similarly, youth females (age, ~16 years) improved drop jump landing mechanics [128]. Youth females (age, 15 years) [148], after 6 weeks of JT (as multicomponent training), improved right and left knee flexion-extension range of motion (ROM) during the landing phase of a box drop into a vertical jump task (7–8%), and right knee internal valgus and varus torque at landing (28–38%). In females (age, 21–22 years), 4 weeks of unstable surface training improved step width, pelvis rotation, and trunk rotation during COD after a lateral unilateral reactive jump [149]. In males plus females with an acute ankle sprain (age, ~25 years), 6 weeks of training improved (30–110%) climbing down stairs time, raising on the heel and on toes time, single-limb stance time, and eversion and eversion ankle strength [150]. In mixed adult and youth males and females, after ACL reconstruction, 8 weeks of JT (with and without body weight support) [151] mitigated some risk factors for a second injury. Similarly, mixed adult and youth males and females, after ACL reconstruction [152], 5 weeks of JT (as multicomponent training) improved (2–20%) jump performance, perceived knee function, and quality of life.

In contrast, most outcome measures (n = 105) related to the biomechanics of hip and knee joints in jumping-landing tasks showed no improvement after 6 weeks in youth females (age, ~15 years) [153]. Similarly, the lower limb symmetry index (–1.5 to 2.2%) during SJ, CMJ, and triple jump with/without cross-over were unchanged after 8 weeks in youth males (age, ~17 years) [154]. Further, males (age, ~20.0 years) [155], after 9 weeks of intervention, noted no improvements in hamstring/quadriceps peak concentric torque ratios, nor the hamstring eccentric/quadriceps concentric peak torque ratios. Additionally, after 6 weeks of JT in males (age, ~24 years), landing impact force at first and second contact after a CMJ were unchanged [156]. Most studies that assessed injury and associated risk factors mixed soccer players with other sports. In males from mixed sports (age, ~22 years), dominant and non-dominant limb vertical stiffness, vertical stiffness asymmetry, and peak force remained unchanged during a unilateral cyclical hop test barefoot after 8 weeks of water-based JT [138]. Similarly, mixed males and females (age, ~24 years) with ankle instability underwent 6 weeks of JT or JT plus balance training [157], and most (21 of 31) lower-limb biomechanical outcome measures during unilateral landing tasks remained unchanged. Among females (age, 18–22 years) [140], 6 weeks of training did not change most outcome measures (38 out of 42) during a drop-jump task. Also, most outcome measures (41 out of 51) were unchanged in females (age, 19 years) after 6 weeks of JT (as multicomponent training) [158]. Further, 17 of 19 outcomes were unchanged after 9 weeks of JT (as multicomponent exercises) in females (age, 21.1 years) [141]. Furthermore, youth females (age, ~15 years) found no improvements in 36 of 37 neuromuscular and biomechanical outcome measures (usually associated with knee-ligament injury risk), after 4 weeks of JT (as multicomponent exercises) [142].

Previous paragraphs discussed studies that measured variables considered "predictive" of injury risk. However, only three studies measured injury-related incidence. In a prospective study [159], 4–6 weeks of JT (as multicomponent training) reduced (2.4 times) the relative incidence of injury, serious knee injury incidence, serious non-contact knee injury incidence, and non-contact ACL injuries during 1-year of follow-up. In contrast, in youth females, assessed across two consecutive competitive seasons [160], the intervention focused on the mechanics of landing from a jump (and deceleration when running). However, it did not reduce the rate of non-contact ACL injuries. Further, in males (age, ~24 years), after 39 weeks of intervention (bounding drills), no changes were noted in hamstring injury, recurrent injuries, injury severity, days absent from training, type of injury, number of hamstring injuries per 1,000 hours of exposure, time-to-first hamstring injury, or days off-play [161]. Overall, contrast findings appear in the literature. Most studies reported improvements by including JT as part of multicomponent training. Of note, some studies reported improvements only in a minor portion (e.g. 2.7%) of the total number of included outcome measures. Further, most studies mixed soccer players with participants from other sports. Moreover, most studies measured variables that are considered "predictive" of injury risk, while only three studies measured injury-related incidence. More research should be conducted to clarify the optimal prescription of JT to improve physical fitness and reduce injury, particularly when combined with multicomponent training, in long-term interventions.

Running-based physical fitness adaptations to JT

Linear sprinting

In males (age, 18–25 years), studies assessed sprint performance (first step up to 50 metres) after JT of 4–10 weeks, with improvements between (0.3% up to 28.9%; ES 0.21 up to 1.6) depending on the outcome measure (e.g. time vs joint angle) [58, 98, 105–107, 146, 155, 162–168]. In youth males (age, 10.3–17.8 years), studies assessed sprint performance (5 metres up to 40 metres) after JT of 4–16 weeks, with improvements between 0.4% to 32.2%, depending on the outcome measured [99, 103, 109, 113, 118, 121, 133, 141, 143, 146, 149, 152, 156, 158, 160, 162, 165, 167, 168, 176, 180, 185]. In females (age, 18.3–24.3 years) [94, 95, 97-99] and youth females (age, 16.5 years) [100], 15-metre up to 30-metre performance improved (3.1% to 9.5%) after 6–10 weeks. In mixed males and females [103], 25-metre performance improved (9%) after 11 weeks. In contrast, in males (age, 18–25 years), studies assessed sprint performance (5 metres up to 50 metres), with no improvements after 3–8 weeks of JT (–8.2% to 1.4%; ES –1.1 to 0.17, depending on the outcome measured). Of note, although the studies found significant sprint performance improvements, some studies cited in the previous paragraph also reported no significant changes for several linear sprint distances [58, 105, 146, 155, 162, 163]. Moreover, several studies found no effect of JT on any linear sprint outcome [108, 114, 156, 169–171]. In youth males, several studies found conflicting effects [111, 119, 172–181]. For example, sprint performance improved at 30 metres (1.9%), although not at 10 metres (0.5%) [182]. Furthermore, several studies found no favourable effect of JT on any measure of linear sprint performance [118, 122, 145, 183–189]. As soccer involves a relatively large number of sprints [12, 190], the potential to improve sprinting after JT might be limited, particularly among more trained/competitive participants [114]. Overall, some contrasting results seem to emerge from published studies. Additionally, although JT might improve linear sprint performance, the adaptation magnitude is usually small. Some programming factors may increase the magnitude of the adaptative response, including (but not limited to) progressive overload, a combination of specific jump types (e.g. horizontal, unilateral, and cyclical jumps, in line with the horizontal, unilateral, and cyclical nature of linear sprints) [58], applied under-rested conditions (i.e. after warm-up vs. end of the training session), with adequate/optimal intensity, a combination of JT with loaded/unloaded sprints (e.g. composite training) [191], a combination of JT with RT (e.g. block-complex training), weighted jumps, and JT combined with hamstring-emphasised neuromuscular training.

Change of direction speed

Studies assessed COD using the *T*-test and Illinois test (including original and modified versions), 5–0–5 test, L-run test, V-cut test, Balsom test, figure 8 test, zig-zag tests (e.g. 3 × 3 metres with 100° turns; 4 × 2.5 m with 60° turns; 5 × 2 metres with 60° turns), shuttle-run tests (e.g. 10 × 5 metres with 180° turns; 5 × 10 m with 180° turns; 9–3–6–3–9 metres with 180° turns; 9–3–6–3–9 metres with backward and forward running), and hurdle agility run test (i.e. included jumping). In males, 11 studies assessed COD [98, 105, 155, 156, 162–165, 167, 171, 192], 36 studies in youth males [98, 99, 106, 108–111, 113, 116–118, 120, 121, 124, 133, 135, 141–143, 146, 149, 150, 152–155, 157, 158, 160, 162, 163, 165, 167, 168, 176, 180], and 4 studies in females [94, 95, 98, 99]. Most JT interventions in males lasted ≤ 7 weeks, and improvements usually achieved a magnitude of ≤ 3%. In youth males, most JT studies lasted ≤ 8 weeks, and most improvements reached ≤ 5%. In females, the values were ≤ 6 weeks and ≤ 4%, respectively. Overall, JT seems effective in improving COD, irrespective of sex or age, although the lack of studies in youth females precludes the comparative response with the other groups. To maximise the potential benefits on COD performance derived from JT, interventions should consider incorporating JT drills in the initial portion of a training session as opposed to the end portion [177], combining types of jumps (e.g. vertical, horizontal, unilateral, bilateral, load jumps) [105, 175, 193], including RT [123], COD, and balance exercises [194].

Repeated sprint ability

In youth males (age, 12.7–17.0 years; APHV, –1.3 years; Tanner stage II–V), 6–11 weeks of JT improved (2–3%; ES = 0.2–1.6) best, mean, and total RSA times [117, 182, 187, 188, 195]. In females (age, ~23 years), 6 weeks of training improved (4–7%; ES = 0.4–0.9) mean RSA times [94, 95]. Although best and total RSA were unchanged, youth males (age, 15.7 years) had the biggest improvement in best and total RSA with COD (4%) [172]. Males (age, 18.4 years) also improved their mean RSA with COD (1.4%; ES = 0.85) and fatigue index (27.8%; ES = 0.91) after 8 weeks, with an unchanged best RSA with COD [113]. In youths from mixed sports (age, 16.8 years), the best, slowest, and mean RSA times and fatigue index improved after 10 weeks of JT [196]. Overall, improvements in RSA (with or without COD) were reported after JT. However, JT probably should not be viewed as an isolated training method for the improvement of RSA [182, 187]. Further, most of the evidence comes from male youth participants, requiring further research before extrapolating current findings to other age-sex groups.

Endurance

Measures of endurance were performed after JT between 3 to 36 weeks and included time-trial tests with distances ranging from 1.6 to 2.4 km, the Yo-Yo intermittent recovery test (level one and level two), the 20-metre multistage shuttle run test (i.e. Course-Navette test), the Loughborough Intermittent Shuttle Test (LIST), maximal oxygen consumption measurement, time to fatigue, and maximal speed during a maximal oxygen consumption running protocol. In males, studies noted improved level one Yo-Yo tests (10–28%; ES < 1.21) [156, 169] and Course-Navette test performances (7–10%; ES = 0.42–0.62) [98]. In youth males, studies observed improvements for level one Yo-Yo tests (11–19%; ES = 0.27–0.41) [174, 175, 193], 2.4 km time trials (2%) [184], and Course-Navette tests (10%; ES 0.5–0.8) [177, 197]. Youth females improved on the LIST tests (61%) [100], and females on the level one Yo-Yo tests (10%; ES 0.3) [99], Course-Navette tests (6–10%; ES = 0.3–0.6) [94, 95, 98], and several indexes (3–11%) during a maximal oxygen consumption running test (time to fatigue, maximal oxygen consumption, maximal velocity, reduced relative oxygen consumption at 9 km · h^{-1}, and respiratory exchange ratios) [92]. In mixed sports, 1.6 km time trials improved (8%) [196]. In contrast, studies in males found no improvement in level one (169) and level two (125) Yo-Yo tests. In youth males, studies observed no changes in the Course-Navette test [129], level one Yo-Yo test [118, 198], maximal oxygen consumption [116], or 2.4 km time trials [176]. Although some contrasting findings have been reported in the literature (e.g. improvement vs. no change in Yo-Yo test level one), favourable endurance adaptations were most noted, with improvements between 2% (i.e. time-trial) up to 61% (LIST test). Female soccer players seem particularly responsive to JT. Improved endurance was particularly noted in tests requiring sudden COD, involving the SSC (e.g. Yo-Yo test). Greater improvements might be achieved after JT involving progressive overload (e.g. volume-based overload), and a combination of bilateral-unilateral and vertical-horizontal jumps.

Soccer-specific adaptations

Dribbling ability was assessed in youth males (age, 12–17 years) after 6 weeks of JT, with improved 20-metre dribbling sprints (6–33%) [199]. However, dribbling with COD was unchanged (3%) after 8 weeks in youth males (age, 11 years) [194]. Kicking ability (after a free [e.g. running] approach) was also assessed, mainly in studies with youth males (age, 10.3 to 15.5 years), with JT lasting 6–12 weeks, with improvements in kicking velocity (7.0% to 16.0%) and kicking distance (11.0% to 37.0%) [57, 109–111, 113, 117–119, 124, 145, 153, 154, 160, 167, 180]. Similar improvements in kicking velocity (8–13%) and kicking distance (23%) after 8–12 weeks of JT were noted among youth females [102]. Females [93, 99] and males [107] had similar improvements in the dominant (7–12%) and non-dominant leg's (8–13%) kicking performance [93, 107, 115, 198]. The JT programmes that incorporated a progressive load increase (e.g. volume) [174], a combination of vertical-horizontal and unilateral-bilateral drills [175], loaded jumps [200, 201], and different types of surfaces [202] were particularly effective.

Non-running-based physical fitness adaptations to JT

Balance

Studies involved mostly youth males (age, ~11–16 years) and a few adult/female soccer samples from mixed sports [119, 127, 136-138, 150, 157, 175, 180, 193, 194, 203, 204]. Balance was measured using field-based tests (i.e. stork balance test and Y balance test) and laboratory-based tests (e.g. balance-force plates), under different conditions (e.g. stable surface, unstable surface, one-leg stance, two-leg stance, eyes open, and eyes closed), and different directions (e.g. anterior-posterior and medial-lateral). Interventions lasted 4–8 weeks, with improvements between 3% to 211% (ES 0.2 to 5.3). Compared to stable surface JT, balance improved particularly after unstable surface JT [119] and unstable plus stable JT [204]. However, the favourable effect of an unstable surface in balance performance after JT needs replication [180]. Independent of the surface, combining unilateral-bilateral and vertical-horizontal drills may induce greater balance improvements [175, 193]. Combined JT and balance drills appear to induce greater balance improvements compared to JT only [127, 157], although engagement in balance drills before jumping exercises seems particularly effective [136, 137].

Maximal strength

Studies in males (age, ~21 years), after interventions of 6–9 weeks, noted improvements (4–53%; ES 0.27–0.35) in isometric (e.g. isometric knee extension) and dynamic (e.g. 1–3 repetition maximum [RM] squat and half-squat) actions, dominant and non-dominant limbs, unilateral and bilateral actions, and in concentric and eccentric actions of the plantar flexors, knee extensors, and knee flexors muscles [105, 109, 114, 146, 155, 162, 168, 169, 171, 192]. Similarly, youth males (age, 10.7 to 17.5 years, APHV –1.52 to 1.04 years, Tanner stages I–V, and testosterone level 14.7 ng · dl^{-1}) completed 6–12 weeks of JT of 8 weeks (as added training load in four of eight studies), with improvements between ~2.0% to 78.0% (ES 0.3–0.8), involving isometric (e.g. torque and force) and dynamic (e.g. 1–5 RM back and half-squat) maximal strength tests, mainly for the knee extensors and flexors muscles [116, 136, 154, 176, 178, 205, 206]. Additionally, in females mixed with males, 11 weeks of JT plus RT improved 4-RM squats with a similar magnitude compared to RT plus weightlifting [103]. Moreover, youth females (age, ~17.0 years) increased 1RM squat, leg extension, and calf raises (~5–30 kg) after 10 weeks, although measurements were conducted only in the experimental group [100]. In contrast, 1RM squats were unchanged in males after 8 weeks of JT (plus RT) compared to RT [113]. Further, in youth males (age, 11.0–17.8 years; APHV 2.7 years) after 5–8 weeks of JT (as added training load in three of four studies), no improvements were noted in isometric (e.g. torque and force) and dynamic (e.g. 1RM half-squat) maximal strength tests, in the dominant and non-dominant legs, mainly for the knee extensors and flexors muscles and back extensors [110, 123, 145, 194]. Furthermore, in females (age, ~19 years) [92], the maximal isometric strength of dominant and non-dominant knee flexors and extensors was unchanged after 10 weeks of JT. Similarly, in females (age, ~19 years) [96], 10 weeks of JT did not improve most outcomes measures of maximal strength, including hip muscles (internal and external rotators, abductors, extensors, adductors) and knee flexors and extensors muscles. Overall, the effects of JT on maximal strength seem favourable, particularly when combined with RT (i.e. complex training), and/or after JT with greater/optimal (individualised) intensity, including overloads (e.g. jump squat) and more specific exercises to measure strength (e.g. bilateral jumps for bilateral squat). Nonetheless, although most studies included randomisation procedures, JT was commonly added to the comparison (e.g. RT group compared to RT plus JT group). Therefore, if the JT effect is due to its nature or the added training load, further clarification is needed. Indeed, a recent JT meta-analysis [207] noted maximal strength improvements in soccer players, but the certainty of the evidence was considered low to very low for the main analyses.

Jump performance

Assessments included bilateral and/or unilateral jumps: drop jumps from different heights (16 cm up to 50 cm) and different indexes (e.g. height; contact time), CMJ, CMJ with arm swing (CMJA) and SJ height and biomechanical indexes (e.g. concentric work, eccentric work, force, velocity, power, EMG, ground impact force, joint angle, and force-velocity curve), elastic index (i.e. the difference between CMJ and SJ height), repeated vertical jumps for 15 seconds, loaded jumps (at different percentages of 1RM), run-up jump, horizontal CMJA, three-repeated horizontal jump, and five-repeated horizontal jump distance. In males (age, 18.0–25.0 years), JT of 3–10 weeks improved (4.0% to 15.9%) most jump outcome measures [58, 98, 105–107, 113, 114, 163-169, 171, 192]. In youth males (age, 9.5–17.8 years) interventions lasted 4–96 weeks (median, 7 weeks), with jump performance improvements in most jump outcome measures between 2.1% to 43.2% [99, 103, 105, 106, 108, 109, 111, 113, 116–119, 121, 124, 131, 135, 140–143, 145, 146, 148, 149, 152–154, 156, 158, 160, 162, 167, 172, 173, 176, 177, 180, 208]. In females (age, 18.3–24.3 years) [93–95, 97–99] and youth females (age, 13.4–16.5 years) [100, 102] jump performance improved (1.7% to 19.1%) after 6–12 weeks of JT. Jump performance improved (7%) after 11 weeks in mixed males and females [103]. Mixed sports studies included females (k = 11), youth females (k = 2), and males (k = 8) [40, 41, 128, 187, 189–191, 196–198, 200, 206, 209–213], and interventions lasted 5–12 weeks, with jump performance improvements between 2.8% to 38.5%. However, in males, unchanged jump performance measurements were also reported [108, 155, 156, 208], as in youth males [110, 118, 120, 129, 145, 174, 177, 189, 194], and females [100]. Although some opposite findings were reported, it is not surprising that most studies reported favourable effects of JT on soccer players' jump performance (irrespective of age or sex), given the specificity of JT with the jump performance measures assessed in studies. Of note, several JT prescription variables were reported (e.g. intensity and type of surface). However, clear benefits did not emerge for most of the assessed moderators (e.g. contrast findings between studies and single study results without replication). Future studies are needed to identify JT prescription factors for the maximisation of jump performance adaptations.

Other adaptations

In females (age, ~19.5 years) from futsal, flexibility improved (~13%) [209], as well as in youth males (5–6%) [197]. Other studies observed improvements in foot speed (i.e. quickness; ~12%) [103], medicine ball throwing (5–7%) [98], motor coordination (8%) [203], respiratory exchange ratio during a maximal oxygen consumption treadmill test (~3%) [92], and force-velocity profile [40, 41]. Pre-pubertal males improved cycle ergometer power (~12%) [111]. Similarly, cycle ergometer pedalling rate, peak power, and relative peak power improved (~19–44%) in youth males (age, 15.7 years) [123]. Females from mixed sports improved (~16–17%) cycle ergometer peak power [210]. Similarly, males from mixed sports improved (up to 10%) 6-second cycle ergometer maximal power [211]. Females (age, ~21 years) improved (~2–4%) in 60-second CMJ power [94], although youth males did not [116]. Males (age, 25 years) reduced (~35–45%) mean weekly values of muscle soreness during JT. Similarly, muscle soreness perception of knee extensors decreased (20–90%) in youth males across 6 weeks of JT [212]. Reductions in muscle soreness were noted with JT in grass, sand, or water surfaces [166, 212]. Reductions in muscle soreness are expected with habituation to JT in both youths and adults [213]. However, a study with youth males (age, ~13.8 years) applied 36 weeks of JT [129]. Compared to the first week, training attendance was reduced (~49.1%) during the last 12 weeks of training, associated with soreness in the lower leg muscle groups, pain in the knees, and fatigue. Of note, in the latter study, a volume of ~8,880 jumps were completed, including loaded jumps. Moreover, although the study reported data specific to soccer, other sports were included [129], and different adaptations were noted between sports, suggesting the need to adapt training programming according to participants' sporting backgrounds. However, what remains unanswered is if a combination of excessive load and a non-motivating exercise routine (i.e. CMJ, depth 90°, and arm swing not allowed) leads toward lower JT compliance at the latter stage of the intervention.

Research gaps and future research areas

– A smaller number of studies are available on females compared to males. Such a difference is particularly noted among youth males compared to their female peers. Further, the age range for youth female studies was narrower (13.4 to 16.5 years) compared to youth males (9.5 to 17.8 years). Moreover, the number of outcomes analysed was lower in studies conducted with females compared to males. Although extrapolation of physical fitness results derived from JT conducted in males toward females is tempting [98], the underlying mechanisms leading to such results can be substantially different between males and females [214], suggesting important room for optimisation of JT prescriptions according to the participants' sex. Future studies should invest more in addressing female soccer players' responses to JT, particularly since the number of female players worldwide is increasing exponentially. Indeed, currently, there is an aim to reach 60 million female players by 2026 [215], hence, research on female players is required to enhance knowledge with regard to a scientific approach to soccer performance in that population [216].

– The age of participants from included studies spanned from ~9 up to 25 years. However, no study reported the inclusion of older soccer players. With the increasing popularity of some soccer modalities (e.g. walking soccer) [217], the number of senior soccer players is rising. Moreover, in older adults (non-soccer participants), JT can increase physical fitness [218]. Future studies are advised on senior soccer players. Similarly, although most studies in youth males (k = 35; not youth females, k = 0) reported biological maturity (e.g. pubertal stage; APHV), comparisons between maturity groups were rarely reported. Considering the potential for youth's biological age to affect the adaptative response to JT [219–222], more research addressing this issue is advised.

– Considering that soccer demands during a game can vary according to playing position on the field [3, 4, 223, 224], it might be argued that the responses and adaptations to a given JT stimulus may vary between players. Indeed, it has been reported of the inclusion of outfield-only soccer players in JT (i.e. goalkeepers excluded) [113]. Future studies may consider the position on the field (e.g. goalkeepers and defenders) and its potential moderator role on the response of soccer players to JT. Relatedly, the adaptations to JT may be modulated by the type of sport practised by the participants, particularly for the outcome (e.g. sprint) [225–227], which may be more related to team success (i.e. scoring goals) [12]. Further, very few studies were found regarding soccer variants (e.g. futsal, beach soccer, walking soccer, and Paralympic soccer), with only two studies detected in futsal [209, 228]. Considering the potential differences between soccer and futsal [229], current findings should not be extrapolated to futsal, requiring more studies in this soccer modality.

– Inter-individual responses to a "fixed" JT prescription (i.e. one fit-all model) were reported in soccer [40, 120, 230]. However, for more individualised JT programmes, future research in this area needs to identify potential prescription variables (e.g. reactive strength index [176] and force-velocity profile [39–41]).

– Movement competency is usually acknowledged as a baseline marker of implementation and progression of RT programmes in general [231], and in JT programmes in particular [50, 232, 233]. However, JT studies in soccer players frequently fail to report on participants' movement competency during JT exercises and progressive overload. Relatedly, adverse effects and the participants' JT experience are not reported in most studies with soccer players. To improve physical fitness attributes in soccer players and to reduce any potential adverse effects derived from JT programmes, further investigation is warranted, including the reporting of participants' movement competency, progressive overload, adverse effects, and the JT experience of soccer players.

– Studies commonly report on soccer players' years of soccer training, although its relationship with adaptations to JT has not been reported. A ceiling effect may be anticipated with increased years of sports practice, meaning that a diminished return from JT might be expected on the player's physical fitness. However, when soccer players' chronological age has been meta-analysed in relation to the physical fitness adaptations to JT [63, 225], similar or even greater improvements have been noted among older players. Maybe other factors, such as JT programme characteristics (e.g. intensity and duration), the physical fitness level of soccer players entering the JT programme, or the player's previous JT experience, may become more relevant to explain a soccer player's adaptations to JT. More research on this field is warranted.

– Relatively few studies have addressed mechanistic (e.g. physiologic) adaptations to JT in soccer. Indeed, most of the available evidence comes from mixed sports. Limited evidence derived from studies conducted in soccer precludes a robust analysis on this subject. Further research is needed to understand the underlying mechanisms of physical fitness (and injury/risk factors) adaptations to JT in soccer.

– Only 63% of included studies used randomised study designs, and the median number of participants included in JT groups was n = 10. This may suggest that most studies are underpowered, and therefore, their results, when considered individually, should be taken with a grain of salt. Further, several studies reported significative results, although only a minor portion of total measures achieved statistical significance. Future studies should clarify primary and secondary outcomes and statistical strategies to address multiple outcome measures. Additionally, future studies should consider recruiting larger (more representative) sample sizes, using randomised-controlled research approaches.

– Criteria used in this systematic scoping review to categorise studies with an exhaustive description of JT (duration, frequency, intensity, exercises, sets, and repetitions) were not particularly strict. For example, although the report of JT intensity (e.g. high and moderate) was considered, details of how this was measured (e.g. 90% of maximal vertical jump height) were not included. Nonetheless, the number of studies that provided exhaustive descriptions of JT interventions reached only ~60% (0% in youth female). Studies should provide complete details of JT interventions (e.g. jump exercise technique and quantification of intensity).

– Among the 88 soccer studies included 42 analysed moderator factors (e.g. prescription variables) related to the effect of JT on physical fitness (a detailed discussion of JT prescription factors is beyond the scope of the current systematic scoping review and can be found elsewhere [80]). It seems that effective and safe JT interventions aimed to improve soccer players physical fitness would entail durations between 3–96 weeks, with 1–2 sessions per week, ~80 jumps/session or 140–240 jumps/week, usually requiring significant voluntary effort (intensity), with inter-repetition rest (if needed) < 15 seconds, inter-set rest of ≥ 30 seconds, inter-session recovery of ≥ 24–48 hours, using progressive overload (e.g. 10% weekly increase in number of jumps) coupled with taper strategies (e.g. reduced volume and intensity maintained) when required, using appropriate surfaces such as grass, and applied in a well-rested state (i.e. non-fatigued), when combined with other training methods. However, from the limited available evidence and its shortcomings (e.g. only 60% of included studies provided a comprehensive description of JT prescription), elucidation of optimal JT programming parameters is not possible. Future studies are required to elucidate optimal JT programming.

– Although the current recommendation of searching multiple databases needs to be evaluated further [87, 234], in this systematic scoping review, the literature search was conducted in multiple electronic databases and was recognised as exhaustive (i.e. PubMed, Web of Science, Scopus). Nonetheless, we were unable to include the SPORTDiscus database due to logistical issues. Future updates of this systematic scoping review should consider the possible inclusion of the SPORTDiscus database.

Conclusions

A considerable body of scientific evidence is currently available regarding the effects of JT on soccer players' physical fitness, involving adult, youth, male, and female participants, from different competitive levels. Most studies reported physical fitness improvements in soccer players after JT (Table 2).

However, relatively few studies explored the underlying mechanisms (e.g. physiological) of physical fitness improvement. Moreover, most of the evidence comes from male (adult, youth) non-professional soccer players, with particularly few studies in youth females. Relatedly, studies did not report outcome measures adaptations according to playing position, inter-individual responses, movement competency, or safety issues. Further, a considerable number of outcome measures have been addressed only in one or two studies (e.g. precluding robust results confirmation). Relatedly, although 21 (from a total of 52) sex/age group outcome measures were reported in three or more studies, most studies included reduced sample sizes (e.g. n = 10) and ~40% of the studies used a non-randomised design, in addition to false significant results being a common issue.

Table 2. Biological and physical fitness adaptations in soccer players after jump training

	Male		Female	
	Adult (*k* = 25)	Adult (*k* = 52)	Adult (*k* = 8)	Adult (*k* = 3)
BC, A, MA	7	11	4	1
Skeletal mucle fibre				
Stiffness		2		
Electromyographic activity		2		
Potential injury risk factors	5	2	2	2
Linear sprinting	20	44	5	1
Change of direction speed	11	36	4	
Repeated sprint ability	1	6	2	
Endurance	5	11	5	1
Soccer-specific	1	17	2	1
Balance		9		
Maximal strength	11	12	2	1
Jump performance	20	46	7	2

black – not reported, grey – < 3 studies, white – ≥ 3 studies, BC, A, MA – body composition, anthropometry, and muscle architecture, *k* – number of total studies included (per sex/age group) in the systematic scoping review

The numbers in the columns below each sex/age group denote the number of studies that reported results for the respective outcome measure.

Overall, JT seems to be an effective and safe method to improve physical fitness in soccer players, although the limitations noted in the currently available literature preclude robust recommendations, particularly regarding optimal JT prescription according to sex/age groups. The methodological issues and evidence gaps identified in this systematic scoping review may help to conduct future studies aiming for more robust evidence.

Ethical approval
The conducted research is not related to either human or animal use.

Informed consent
Informed consent was obtained from all individuals included in this study.

Conflicts of interest
The authors state no conflicts of interest.

Disclosure statement
No author has any financial interest or received any financial benefit from this research.

Funding
This research received no external funding.

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