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ESCOLA DE EDUCAÇÃO FÍSICA, FISIOTERAPIA E DANÇA

Eduardo Fallavena Freitas

Effects of strength training protocols on sprint performance of soccer players: A systematic review

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Trabalho de conclusão de curso apresentado na Escola de Educação Física, Fisioterapia e Dança da Universidade Federal do Rio Grande do Sul como requisito para aprovação no curso de Bacharelado em Educação Física.

Orientador: Professor Dr. Eduardo Lusa Cadore

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Conceito final:

Aprovado em .... de ....de..........

BANCA EXAMINADORA

Prof. Dr. Giovani dos Santos Cunha – UFRGS

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To never forget:

“If you can dream it, you can do it.”

Walt Disney

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Autores: Eduardo Fallavena Freitas[1], Rafael Grazioli[1], Filipe Veeck[1], Eduardo Lusa Cadore[1].

[1]Escola de Educação Física, Fisioterapia e Dança, Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brasil.

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Autor correspondente:

Eduardo Fallavena Freitas

E-mail: fallavenaef@gmail.com

Escola de Educação Física, Fisioterapia e Dança – Laboratório de Pesquisa do Exercício (LAPEX) - Universidade Federal do Rio Grande do Sul (UFRGS).

Rua Felizardo, 750 – Bairro Jardim Botânico - CEP: 90690-200 - Porto Alegre – RS, Brasil.

Phone: +55 51 33085894.

RESUMO

Sprints lineares, com mudança de direção e repetidos desempenham um papel importante no futebol. Essas ações são fundamentais para os gols e as demandas em alta velocidade têm aumentado ao longo dos anos. Embora o desempenho de *sprint* seja crucial para o futebol moderno, os efeitos positivos encontradas por meio do treinamento de força são altamente sensíveis (ou seja, apenas 1-5% de aumentos no desempenho de *sprint*). Portanto, a assertividade e a tomada de decisão para um protocolo de treinamento de força eficaz visando melhorar as habilidades de *sprint* de jogadores de futebol são absolutamente importantes para treinadores de força e condicionamento físico e cientistas do esporte. Também faltam estudos de revisão que produzam uma compilação sistemática de resultados a fim de identificar a eficácia dos protocolos e suas características, aumentando as habilidades de prescrição de treinadores de força e condicionamento. O objetivo do presente estudo foi revisar e integrar sistematicamente evidências sobre os efeitos do treinamento de força no desempenho de *sprint* linear, com mudança de direção e repetidos em jogadores de futebol. Foram identificados 34 estudos. Seis modalidades de treinamento foram encontradas com desfechos de desempenho de *sprint* no futebol. Treinamento de força tradicional e concorrente (11 estudos), pliometria e treinamento de potência (10 estudos), treinamento de *sprints* resistidos (6 estudos), treinamento excêntrico (3 estudos), treinamento *Flywheel* (2 estudos), treinamento baseado em velocidade (1 estudo) e eletroestimulação de corpo inteiro (1 estudo). Essas modalidades, em sua maioria, demonstraram resultados positivos importantes para o desempenho de *sprint* no futebol. No entanto, alta carga de trabalho de treinamento cardiorrespiratório, nível de aptidão física, doses de treinamento, volume e intensidade são fatores importantes para modular aumentos, diminuições e manutenção das habilidades de *sprint*.

Palavras-chave: treinamento de força; treinamento de potência; desempenho de sprint; mudança de direção; futebol.

ABSTRACT

The linear, with change of direction, and repeated sprint abilities play an important role in soccer. These actions are crucial for goals and the high-velocity demands for soccer players have been increased over the years. Although the sprint performance is crucial for modern soccer, the positive changes found through strength training are highly sensible (i.e., only 1-5% of increases in sprint performance). Therefore, the assertiveness and decision-making for an effective training protocol to improve sprint abilities of soccer players are absolutely important for strength and conditioning coaches and sport scientists. There is also a lack of review studies producing a systematic compilation of results in order to identify the effectiveness of the protocols and its characteristics, increasing the prescription skills of strength and conditioning coaches. The purpose of the present study was to review and integrate systematically evidences regarding the effects of strength training on linear, with change of direction, and repeated sprint performance in soccer players. Thirty-four studies were identified. Six training modalities were found with sprinting outcomes in soccer. Traditional and concurrent strength training (11 studies), Plyometrics and power training (10 studies), resisted sprints training (6 studies), Eccentric training (3 studies), Flywheel training (2 studies), Velocity-based training (1 study), and Whole-body electrostimulation (1 study). These modalities mostly demonstrated important positive results for sprint performance in soccer. However, high-workload of cardiorespiratory training, fitness status, training dosages, volume, and intensity are important factor to modulate increases, decreases, and maintenance of sprint abilities.

Key-words: strength training; power training; sprint performance; change of direction; soccer.

SUMMARY

INTRODUCTION

The sprinting demands have been progressively increased in soccer during the past several years (Barnes et al., 2014). These actions are mandatory for more than half of goals scored during modern championships as well as soccer players are required to be faster over seasons (Haugen et al., 2014). During the last decade, the focus in soccer-related research has shifted from aerobic (despite its predominance) to anaerobic demands. Elite/professional players have become faster over time while aerobic capacity has plateaued or decreased slightly (Haugen et al., 2014). Thus, the capacity of athletes to perform well and cope with these strenuous (and frequent) neuromuscular actions during matches is absolutely important. The outfield soccer players cover 9 to 12 km during a match, being 8% to 12% of high-intensity running or sprints. Wide midfielders and external defenders develop more high-intensity running and sprints compared with the other playing positions. Peak velocities during the game are 31 to 32 km/h. The players perform 17 to 81 sprints per game (i.e., >25km/h) with mean sprint duration between 2 and 4 seconds, mostly shorter than 20m. It is important to emphasize that running speed between 20 to 22 km/h is equivalent to the mean velocity in male elite endurance runners, and sub-elite sprinters run faster than 35 km/h (Haugen et al., 2014). Therefore, a well-trained soccer player can be considered untrained in terms of sprint abilities when compared to other sprint-related sports (Haugen et al., 2014). Positive training interventions diverge in terms of training-time investment and time-consuming, and this is a point to the training protocols be declined (or not) by team coaches. Taking into account these considerations, it is important to identify criteria for success to improve soccer-related sprinting skills. In this sense, sport science research has proposed diverse training protocols in order to improve sprint capabilities of soccer players (Loturco et al., 2017; Pareja-Blanco et al., 2017; Grazioli et al., 2020; Haugen et al., 2014).

It is consensus among soccer practitioners that combined strength/power training programs involving different movement patterns are able to transfer positive changes for sprinting abilities on the pitch (Silva et al., 2015). Strength/power training programs in soccer incorporate a significant number of exercises targeting the efficiency of stretch-shortening-cycle activities and soccer-specific strength-based actions (Silva et al., 2015). In addition, given the conditional concurrent nature of the sport, these components are often prescribed simultaneously with endurance requirements (i.e., small sided games, high-intensity interval training, tactical activities) (Núñez et al., 2008; Suarez-Arrones et al., 2018), which could differently affect the neuromuscular adaptations due to aerobic interference effect (Loturco et al., 2015; Fyfe et al., 2014). However, although the sprint performance is crucial for modern soccer, the positive changes found through strength training are highly sensible (i.e., only 1-5% of increases in sprint performance) (Wong et al., 2010; Loturco et al., 2019; Grazioli et al., 2020). Therefore, the assertiveness and decision-making for an effective training protocol to improve sprint capabilities of soccer players are of utmost importance.

In this rationale, although there are several experimental studies regarding strength training on sprint capacities, there is also a lack of review studies producing a systematic compilation of results in order to identify the effectiveness of the protocols and its characteristics. These findings could increase the prescription skills of strength and conditioning coaches for improving soccer athletes' sprint performance.

OBJECTIVES

The purpose of the present study was to review and integrate systematically evidences regarding the effects of strength training on linear and with change of direction sprint performance in soccer players. Current study also aimed to review the training characteristics used in those studies, in order to identify the strength training interventions effectiveness for improving sprint abilities.

METHODS

Study selection procedure

This study was undertaken in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Liberati et al., 2009), and the used method was based on the minimum criteria established by the Cochrane Back Review Group (CBRG) (Furlan et al., 2009).

The search was conducted up to June 2021, using the following electronic databases: MEDLINE, accessed through PubMed, and PEDro (Physiotherapy Evidence Database). In addition, we performed a manual search in the manuscripts reference lists to detect studies potentially eligible for inclusion. The terms used were: "Resistance

Training” OR "Training, Resistance" OR "Strength Training" OR "Training, Strength" OR "Weight-Lifting Strengthening Program" OR “Strengthening Program, Weight-Lifting” OR “Strengthening Programs, Weight-Lifting” OR “Weight Lifting Strengthening Program” OR “Weight-Lifting Strengthening Programs” OR “Weight-Lifting Exercise Program” OR “Exercise Program, Weight-Lifting” OR “Exercise Programs, Weight-Lifting” OR “Weight Lifting Exercise Program” OR “Weight-Lifting Exercise Programs” OR “Weight-Bearing Strengthening Program” OR “Strengthening Program, Weight-Bearing” OR “Strengthening Programs, Weight-Bearing” OR “Weight Bearing Strengthening Program” OR “Weight-Bearing Strengthening Programs” OR “Weight-Bearing Exercise Program” OR “Exercise Program, Weight-Bearing” OR “Exercise Programs, Weight-Bearing” OR “Weight Bearing Exercise Program” OR “Weight-Bearing Exercise Programs” OR “Plyometrics” OR “Power Training” OR “Resisted Sprint Training” OR “Sled Training” AND "Professional Soccer Players" OR "Professional Football Players" OR "Professional Footballers" OR "Professional Soccer Athletes" OR "Professional Football Athletes" OR "Elite Soccer Players" OR "Elite Football Players" OR "Elite Soccer Athletes" OR "Elite Football Athletes".

Intervention, controls, and outcome measures

This review included experimental studies that assessed the strength training programs effects with or without other components on sprint capacity outcomes among soccer players. Parameters assessed were linear sprint times (i.e., 5m to 40m), change of direction sprint times, and repeated sprint ability outcomes. The inclusion criteria were: participants should be (1) male soccer players, (2) with sprint performance measures such as linear sprint times or velocities between 5m to 40m as well as change of direction sprint times, and (3) participating in a longitudinal strength training program. The exclusion criteria were as follows: (1) the inclusion of participants with neuromuscular injuries and (2) crossover design and pilot studies.

Risk of bias assessment

The Risk of bias assessment was performed by two investigators independently (F.V. and R.G.) and took into consideration the following characteristics of the included studies: random sequence generation, blinding of outcome assessors, concealed allocation concealment, description of losses and exclusions, and intention-to-treat analysis. Studies without a clear description of these features were considered unclear or not reported. The risk of bias is demonstrated in Table 1 (Annex 1).

Data Extraction

Titles and abstracts of all identified articles by the search strategy were independently evaluated by two researchers, in duplicate (F.V. and R.G.). Abstracts that did not provide sufficient information regarding the inclusion and exclusion criteria were selected for full-text evaluation. In the second phase, the same reviewers independently evaluated these full-text articles and selected them in accordance with the eligibility criteria. Disagreements among reviewers were solved by consensus, and if disagreement persisted, a third reviewer will be consulted.

The data extraction was performed by the same two reviewers independently via standardized form. Information about interventions, outcomes and participants was collected. Discordance between reviewers will be solved by consensus or by a third reviewer. The primary outcomes analyzed were linear sprint times (i.e., 5m to 40m), change of direction sprint times, and repeated sprint abilities. In addition, intervention period, strength training models and protocols, and adverse events were informed and extracted. The Figure 1 shows the study selection procedures.

RESULTS AND DISCUSSION

All studies aimed to investigate the effects of strength training alone, in combination of other neuromuscular stimuli, or in a concurrent training program in soccer players. Searches in the electronic databases were performed on September 2021. We retrieved 107 studies (Pub-Med and PEDro databases), and 53 studies were excluded after titles as well as abstracts assessment, and inclusion criteria analysis. Thirty-four studies were eligible and included by database search and manual search (Figure 1). Studies characteristics are presented in Table 2 (Annex 2). Six training modalities to improve sprint performance were found during this review and it was demonstrated as traditional and concurrent strength training, resisted sprint training, flywheel training, plyometrics and power training, velocity-based training, eccentric training, and whole-body electrostimulation training.

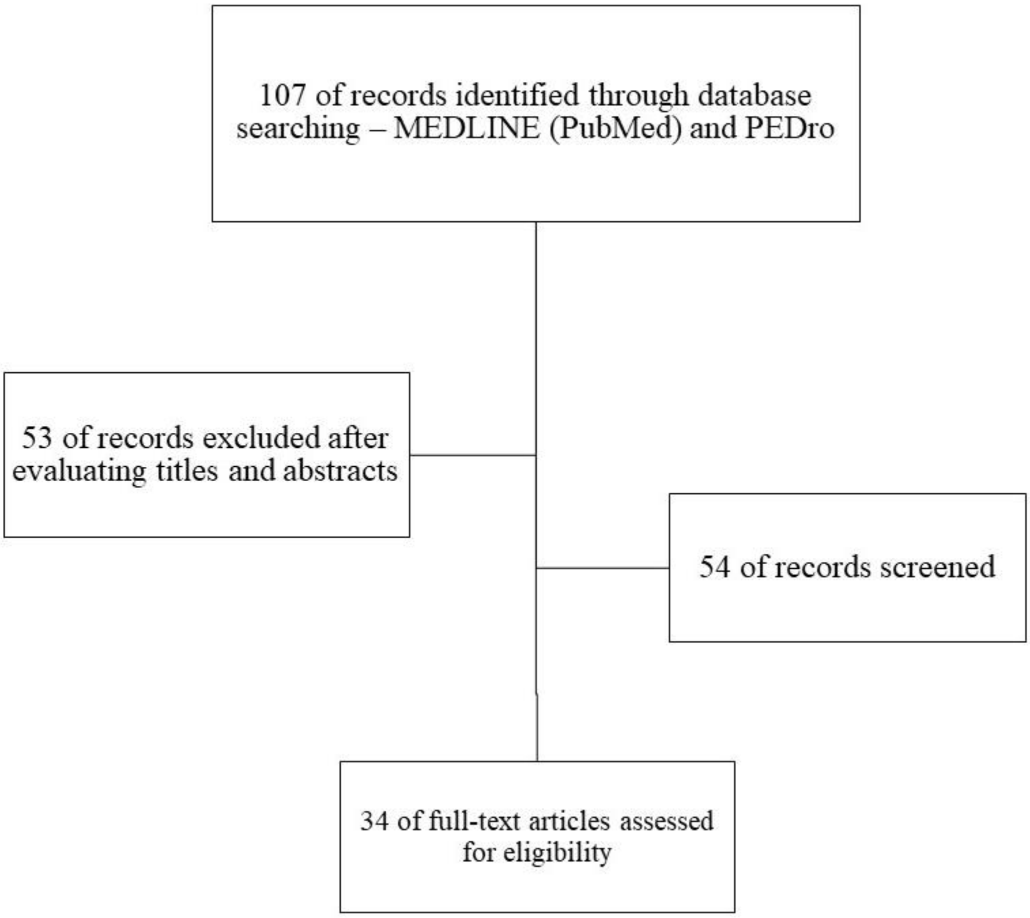

Figure 1. Studies selection flowchart.

Traditional and concurrent strength training

In relation to traditional or concurrent training, eleven studies were found. Enright et al. (2015) compared the adaptive responses to two concurrent training programs frequently used in professional soccer players who compete in the English Premier League. In addition to completing their habitual training practices, the participants were asked to alter the organization concurrent training by performing strength training either prior to or after soccer-specific endurance training for 5 weeks. The authors suggested order and recovery periods of concurrent training could modulate the changes in sprint performance, although in small magnitudes. In this context, Jullien et al. (2008) analyzed the effects of specific leg strength training on sprint and agility performances in young professional soccer players. Twenty-six players were divided into 3 groups. One group performed individual technical work only, the other one performed a circuit designed to promote agility, coordination, and balance control (together with some technical work) and the squat group performed 3 sets of 3 repetitions (at 90% of one repetition maximum – 1RM) and a sprint repetition after that. These training interventions were developed 5 times a week for 3 weeks. Before the experimental session and at the end of each week, agility, shuttle test with changes of direction, and 2 sprints over 10 and 7.32 meters were assessed. The authors concluded that linear and change of direction performance were not optimized with lower limb strengthening exercise (squat) at 90% of 1RM. Sprint performance improved in all 3 groups, however, more accentuated in the technical and coordination groups.

Other similar studies such as Keiner et al. (2014) tested a high number of players (n = 112) between 13 and 18 years of age. For almost 2 years, 1 group (control group) only participated in traditional soccer training, and the other group (strength training group) participated in an additional strength training program. The change of direction sprint performance of 34 professional soccer players of the first and second divisions in Germany were measured consistently. The authors demonstrated that long-term strength training improved the change of direction abilities. Moreover, Koundourakis et al. (2014) examined the effects of three seasonal training programs, largely different in strength volume, on 10 m and 20 m sprint performance assessed prior at the beginning of the pre-season period, at the middle (mid-point), and at the end of the competition period (end-point). The authors suggested that the volume of strength training combined with intensive soccer training caused important linear sprinting improvements. The study also assessed blood samples and identify the elevation of endogenous androgens as a result of the volume of strength training. In order to explore the influence of force orientation during strength training, Los Arcos et al. (2013) compared the effects of two strength training programs involving either purely vertically oriented or combining vertically and horizontally oriented exercises on acceleration and other soccer-relevant performance variables. Players trained two times per week during all the pre-season (5 weeks) and 3 weeks of the competitive season. Sprint performances over 5 and 15m were assessed demonstrating small improvements in 5m ($P < .05$; ES = 0.27 and 0.25 for vertical training and vertical plus horizontal training, respectively) and 15m sprint times ($P< .05$; ES = 0.19 and 0.24 for vertical plus horizontal training, respectively). One study focused on core stability and neuromuscular control, Prieske et al. (2016) investigated changes in sprint performance following core strength training performed on unstable compared with stable surfaces in youth soccer players. Thirty-nine male elite soccer players were assigned to two groups performing a progressive core strength-training program for 9 weeks (2-3 times/week) in addition to regular in-season soccer training. There were important improvements in 10-20-m sprint time (3%, $P < 0.05$, $d = 2.56$) after training for both groups. Also comparing different surfaces, Sanchez-Sanchez et al. (2020) examined the effects of 10-week (2/week) strength training on stable vs. unstable surfaces in young male soccer national-level U19 players. To our interest, repeated sprint ability and change of direction speed (Illinois COD test) were assessed. The strength training on unstable conditions in addition to regular soccer training was effective to improve repeated sprint ability. Related to repeated sprint ability, Spineti et al. (2015) compared traditional strength training and complex contrast training on the repeated-shuttle-sprint ability in twenty-two young male elite soccer players. The complex contrast training consisted of power exercises performed before high-velocity exercises and traditional strength training based on a set-repetition format through daily, undulatory periodization. The results demonstrated that complex contrast training provided a significant improvement in the repeated sprint ability (moderate effect size), while traditional strength training was able to improve maximal strength and morphological aspects.

Styles et al. (2016) examined if a simple in-season strength training program would result in 5, 10, and 20m improvements after a 6-week (2/week) in-season strength training (85-90% 1RM) intervention. There were small yet significant improvements in sprint performance over 5 m ($p \leq 0.001$, $d = 0.55$), 10 m ($p \leq 0.001$, $d = 0.45$), and 20 m ($p \leq 0.001$, $d = 0.31$). This study highlighted the importance of developing maximal strength to improve short sprint performance. Using a concurrent approach, Wong et al. (2010) examined the effect of high-intensity running interval training and strength training. Thirty-nine players participated in the study, where both the experimental group and control group participated in 8 weeks of regular soccer training, with the experimental group receiving additional strength training and high-intensity interval training twice per week. The strength training consisted of 4 sets of 6RM (repetition maximum) of high-pull, jump squat, bench press, back half squat, and chin-up exercises. The high-intensity interval training consisted of 16 intervals each of 15-second sprints at 120% of individual maximal aerobic speed interspersed with 15 seconds of rest. The improvements were significantly higher (p < or = 0.01) in the experimental group compared to control for 10m and 30m sprint times, demonstrating that high-intensity strength training additionally to cardiorespiratory training was able to improve acceleration. Zouita et al. (2016) observed the effect of strength training in fifty-two elite young soccer players (13-14 years) which were divided into experimental group and control group. For the experimental group, 2 to 3 sessions of strength training were introduced weekly in their training program for 12 weeks (4 × 3 weeks separated by 1-week recovery). Sprint tests (10-20-30 m) before and after training were tested and, compared to control group, the experimental group performed significantly better in sprint running after training ($p < 0.01$). In conclusion, the majority of studies involving traditional strength training showed important enhancements in linear and change of direction sprint performances of soccer players during pre-season or even in season.

Resisted sprints training

Currently, one of the most used specific strength training method to improve sprint abilities in soccer has been resisted sprints through sled towing or pushing. It was found six studies applying resisted sprints training in soccer. Firstly, Grazioli et al. (2020) investigated the effects of a 11-week moderate-to-heavy sled training intervention on 10m and 20m sprint times. Seventeen players were randomly allocated into 2 groups, based on different velocity losses: 10% of velocity decrease and 20% of velocity decrease. The velocity-based sled training consisted of 20-m resisted sprints with a progressive loading increase from 45 to 65% of body-mass throughout the intervention. Two-way repeated measures analysis of variance revealed a significant time-effect for decreases in 10m and 20m sprint times ($p = 0.018$ and $p = 0.033$, respectively), but without a time-group interaction, although greater magnitude-based inference was found for 10% of velocity decrease group. This study demonstrated that resisted sprint training with moderate-to-heavy loads improved linear sprints in professional soccer players, specially using lower volume of sprints from lower velocity loss magnitudes (i.e., 10%). In other survey, Brahim et al. (2020) evaluated the effects of 6-week combined strength and resisted sprint training using both sled and weight vest compared with regular soccer training in thirty-four male soccer players randomly assigned into a resisted sprint training group, using both weight vest and sled, and a control group. Sprinting ability (5 m and 20 m) were assessed and significant changes were observed ($p<0.01$; ES= 0.97 for 20m sprint times). The authors concluded that strength training combined with resisted sprint training were more effective to improve sprint abilities in comparison to control group. Also comparing methods, De Hoyo et al. (2016) demonstrated the effects of 3 different low/moderate load strength training methods (full-back squat, resisted sprint with sled towing, and plyometric and specific drills training, 2/week during 8 weelks) on linear and with change of direction abilities in thirty-two soccer players. The full-back squat protocol consisted of 2-3 sets × 4-8 repetitions at 40-60% 1 repetition maximum while the resisted sprint training was composed by 6-10 sets × 20-m loaded sprints (12.6% of body mass). The plyometric and specific drills training was based on 1-3 sets × 2-3 repetitions of 8 plyometric and speed/agility exercises. It was tested 20m sprint (10m split time) and a 50m sprint (30mm split time) as well as change of direction test (i.e., Zig-Zag test). Improvements in 30-50m sprints (ES= 0.45-0.84) were found in all groups in comparison to pretest results. Moreover, players in Plyometric and specific drills and Full back squat groups also showed substantial enhancements (likely to very likely) in 0-50 m (ES= 0.46-0.60). In addition, 10-20 m was also improved (very likely) in the Full back Squat group (ES= 0.61). Between-group outcomes showed that improvements in 10-20m (ES= 0.57) and 30-50 m (ES= 0.40) were likely greater in the full back squat group than in the Resisted sprint with sled towing group. Also, 10-20 m (ES= 0.49) was substantially better in the full back squat group than in the Plyometric and specific drills group. Plyometrics and traditional strength training were more effective than low-intensity resisted sprint to improve acceleration in soccer players.

Gil et al. (2018) compared a resisted sprint training with overload control versus an unresisted sprint training program in eighteen elite soccer players during 6 weeks. Both groups improved linear and change of direction sprinting abilities at all distances evaluated (Linear: 5m, 10m, 15m, 20m, 25m) and change of direction. Their findings support the effectiveness of a short-term training program involving resisted and unresisted sprint exercises to improve acceleration of soccer players. Recently and using heavier loads, Lahti et al. (2020) investigated 9 weeks of resisted sprints training in two soccer teams (control and experimental) while the experimental team was matched into two heavy resisted sled training subgroups based on their sprint performance. Subgroup one trained with a resistance that induced a 60% velocity decrement from maximal velocity and subgroup two used a 50% velocity decrement. Both heavy resistance subgroups improved significantly all 10-30-m split times ($p < 0.05$, $d = -1.25; -0.62$) and post-hoc analysis showed that 50% of velocity decreases improved significantly more compared to control group in 0-10m split-time ($d = 1.03$). Also using moderate-to-heavy loads, McMorrow et al. (2019) investigated the effect of resisted sprint training during the competitive season on sprint and change of direction performance in professional soccer players during 6 weeks (in-season). The resisted sprint group at a sled load of 30% body mass performed a total sprinting distance of 800m, whereas an unresisted sprint training group performed the same distance of unresisted sprinting. A 20m maximal sprint with split times measured at 5, 10, and 20 m and the sprint 9-3-6-3-9 m with 180° turns change of direction test were performed before and after the intervention. Sprint performance was improved in both groups over 5m (likely moderate magnitudes), 10m (very likely moderate and very likely large magnitudes for unresisted and resisted groups, respectively), and 20m (likely moderate and very likely moderate for unresisted and resisted groups, respectively). Change of direction was improved in both groups (URS, most likely large and most likely moderate for unresisted and resisted groups, respectively), without differences between groups. Both interventions were similarly effective at improving sprint and change of direction performances. Although consistently applied, the resisted sprint training compared to unresisted sprints are not completely defined as an optimized method. Their effects seem to depend of training dosages, volume, and intensity.

Flywheel training

The present review found two studies regarding flywheel training to improve sprint performance. Raya-González et al. (2021) investigated the effects of a weekly flywheel strength training session over a 10-week period in twenty young soccer players assigned to an experimental or control group. Linear sprint times at 10m, 20m, and 30m and change of direction sprint test in 5 + 5m and 10 + 10m were performed before and after flywheel training period. Significant within-group differences were found in control group for change of direction sprint test 10 + 10m ($p = 0.01$; ES = large while differences in experimental group were observed in all change of direction sprint variables ($p = 0.001$-0.04; ES = large). Also, between-groups analysis revealed differences favorable to the experimental groups in change of direction sprint variables ($p = 0.001$-0.05). Moreover, De Hoyo et al. (2014) analyzed the effect of an eccentric-overload training program (i.e., half-squat and leg-curl exercises using flywheel ergometers) in thirty-six young players assigned to an experimental or control group. The training program consisted of 1 or 2 sessions/wk (3-6 sets with 6 repetitions) during 10 weeks. The sprint performance was assessed through 10m and 20m linear sprint times. A substantial better improvement (likely to very likely) was found in 20m sprint time (ES= 0.37), 10m flying-sprint time (ES= 0.77) compared to control group, and substantial improvements were obtained in 20m sprint time (ES= 0.32), 10m flying-sprint time (ES= 0.95) in experimental group. In these two studies, the findings suggest a weekly flywheel training session is suitable to improve change of direction as well as linear sprint abilities abilities in young soccer players.

Plyometrics and power training

Plyometric and power training are strategies widely used in team-sports to enhance sprint-related capabilities. For this topic, it was founded ten studies. First, Otero-Esquina et al. (2017) showed the effects of a combined power and strength training in thirty-six elite young soccer players randomly allocated in experimental groups or a control group and also examined the effects when this training was performed one or two days per week. Performance was assessed through a 20m linear sprint test with split-times at 10m, and a change of direction test 1 week before starting the training and also 1 week after performing the intervention. The experimental group that performed two sessions of training per week achieved better improvements in 20m (ES= 0.48-0.64) than the group that performed one session per week and control group. Also, two sessions per week showed greater enhancements in 10m (ES= 0.50) and change of direction tests (ES= 0.52) than one session per week. Thus, depending on the possibilities and congested schedule of soccer, two sessions of power and strength training per week showed greater benefits on sprint performances. In order to compare the effects of explosive strength vs. repeated shuttle sprint training on repeated sprint ability, Buchheit et al. (2010) assessed fifteen young elite soccer players who trained once a week for a total of 10 weeks. Repeated shuttle training consisted of 2-3 sets of 5-6 × 15- to 20m repeated shuttle sprints interspersed with 14 seconds of passive or 23 seconds of active recovery. Explosive strength training consisted of 4-6 series of 4-6 exercises (e.g., maximal unilateral countermovement jumps, calf and squat plyometric jumps, and short sprints). Before and after training, sprint performance was assessed by 10 and 30m sprint times as well as repeated sprint ability test. After training, except for 10m ($p = 0.22$), all performances were significantly improved in both groups. Relative changes in 30 m (-2.1 ± 2.0%) were similar for both groups ($p = 0.45$). Improvements in the repeated sprint ability test were only observed after repeated shuttle training. Both groups were efficient at enhancing maximal sprinting. Testing different surfaces on which plyometrics were applied, Granacher et al. (2015) investigated the effects of plyometric training on stable vs. highly unstable surfaces in twenty-four male sub-elite soccer players that were allocated to 2 groups performing plyometric training for 8 weeks (2 sessions/week). The plyometric training on stable group conducted plyometrics on stable and the highly unstable surfaces group on unstable surfaces. There were significant main effects in 10m sprint time

($p<0.05$, f=0.58) and change of direction ($p<0.01$, f=1.15), without different between groups. Thus, after 8 weeks, similar sprint performances adaptations were observed in the highly unstable surfaces and plyometric training on stable groups. Testing exercises order effect, Hammami et al. (2016) examined the effect of sequencing balance and plyometric training in twenty-four young elite soccer players who trained twice per week for 8 weeks either with an initial 4 weeks of balance training followed by 4 weeks of plyometric training or 4 weeks of plyometric training preceded by 4 weeks of balance training. Pre- and post-training sprint testes were 10m, 20m, and 30m linear sprints as well as change of direction. Both groups improved similarly the sprint capabilities, without significant effect of plyometric exercises order. Since plyometrics are able to be applied using or not overloads, Kobal et al. (2017) investigated the effects of loaded and unloaded plyometric training strategies during 6 weeks in twenty-three elite young soccer players. The athletes were pair-matched in two training groups: loaded vertical and horizontal jumps using an haltere type handheld with a load of 8% of the athletes' body mass and unloaded vertical and horizontal plyometrics. Sprint performances (velocity) at 5m, 10m, and 20m, were evaluated. Using magnitude-based inferences, an almost certainly decrease in the sprinting velocities along the 20m course were found in the loaded vertical and horizontal jumps group. In the unloaded vertical and horizontal jumps likely to very likely decreases were observed for all sprinting velocities tested. In this study, both plyometric strategies failed to produce worthwhile improvements in maximal speed, which is possible related to the interference of concurrent training effects (i.e., soccer players are often exposed to high-workload aerobic and anaerobic stimulus through traditional soccer training). In other very interesting approach, Loturco et al. (2017) compared the effects of two different mixed training programs (optimum power load + resisted sprints and optimum power load + vertical/horizontal plyometrics) in eighteen elite soccer players during a short-term training preseason. Sprint performances at 5m, 10m, 20m, and 30m as well as change of direction speed before and after 5 weeks of training. Both groups showed improvements in the change of direction speed for both training groups. Moreover, meaningful decreases were observed in all sprint times. Therefore, both mixed strategies (i.e., optimum load training added to resisted sprints or plyometrics) were able to improve speed capabilities. Given the modern importance of prescribing optimum power load in plyometrics and power training, Loturco et al. (2016) also investigated changes in sprint performances in response classic strength-power periodization or optimum power load in twenty-three professional soccer players during 6 weeks (in-season, 3 times per week). Strength-power periodization involved half squats or jump squats, depending on the respective training block, while optimum power load involved only jump squats at the optimum power load. Both groups demonstrated similar significant gains in change of direction speed and linear sprinting speed. Furthermore, delta change scores demonstrated a superior effect of optimum power load to improve 10m and 20m speed. It seems, therefore, that optimum power load using plyometrics exercises such as jump squat are more effective to improve linear sprint abilities. Since jump squat and half-squat are the most used exercises in soccer practices to improve power-related tasks on the pitch, Loturco et al. (2015) tested these two types of exercises (i.e., jump squat or half squat) throughout a preseason (4 weeks) twenty-three soccer players which were randomly allocated into two groups with one of these exercises. Both groups improved linear acceleration from 5 to 10 m (ES = 0.52). However, jump squat was more effective at reducing the acceleration decrements over 0-5m (ES = -0.38 vs. -0.58, for jump squat and half squat, respectively). Here, similar to Kobal et al. (2017), the high-workload of cardiorespiratory training during pre-season was mandatory to sprint changes. Thus, it is of utmost importance that training strategies during this period are minutely prescribed to find the optimal dosage in order to improve sprint abilities or even reduce impairments. Using approaches based on velocity or intensity, Loturco et al. (2013) investigated the effects of two power training loading schemes in thirty-two elite soccer players during 6 weeks. Sprint performance were evaluated before and after two weeks. The two randomly training groups were velocity- or intensity-based. After the individual determination of the optimal power load, both groups completed a 3-week traditional strength training period. After, the velocity group performed 3 weeks of power-oriented training with increasing velocity and decreasing intensity (from 60 to 30% 1RM) throughout the training period, whereas the intensity-based group increased the training intensity (from 30 to 60% 1RM) and thus decreased movement velocity throughout the power-oriented training period. The 10m sprint (velocity group: -4.3%; intensity group: -1.6%) improved in both groups, but the 30m sprint time showed no improvements for both groups. The authors concluded that similar sprint performance changes occurred when training intensity manipulation is performed around only a small range within the optimal power training load. Comparing power training with sprinting exercises, Mujika et al. (2009) examined the effects of 2 sprint-based or power training with soccer drills as transferring exercises on 15m sprint speed, and change of direction speed in twenty elite junior soccer players during 7 weeks that were randomly allocated to either a contrast (power and soccer drills) or sprint group. The contrast protocol consisted of alternating heavy-light loads (15-50% body mass) with soccer-specific drills (small-sided games or technical skills). Sprint training protocol was linear 30m sprints (2-4 sets of 4 x 30 m with 180 and 90 seconds of recovery, respectively). A time x training group interaction was found for 15m sprint performance (velocity) with the contrast group showing significantly greater improvements than the sprint group. Therefore, this study pointed out that, when linear sprint is preferred to be enhanced, perhaps contrast protocols (power training added to soccer drills) are more indicated. Finally, Ronnestad et al. (2011) examined a combination of strength and plyometric training with strength training alone (7 weeks) in twenty-one professional soccer players. The players were randomly positioned into 2 groups. Group strength performed heavy strength training twice a week and the group strength plus power performed a plyometric training program in addition to the same maximal strength training as the strength group. There was also a control group. Sprint acceleration, peak sprint velocity, and total time on 40m sprint were assessed in this study. There were no significant differences between the “strength plus power group” and “strength group”. There were significant improvements in sprint acceleration, peak sprinting velocity, and total time on 40m sprint. In fact, the results of this investigation emphasized that no additional gain is obtained when plyometrics is added to maximal strength training on sprinting capabilities. Therefore, summarizing this topic, the plyometrics and power training methods are consistent to improve sprint abilities in soccer players. Some important factors are important to consider such as the high-workload of cardiorespiratory training added to these neuromuscular stimuli, since this seems to be a factor for improvements, decrements or even maintenance of sprint abilities specially during pre-seasons.

Velocity-based training

The velocity-based approaches (i.e., in which velocity loss during repetitions are monitored and sets are finished when a given threshold is achieved) have been consistently studied and applied in practical scenarios. In relation to sprint changes in soccer players, one study was found. Pareja-Blanco et al. (2016) analyzed the effects of 2 strength training programs that used the same relative loading but different repetition volume, using the velocity loss during the set as the independent variable: 15% vs 30% of velocity loss. Sixteen professional soccer players were randomly assigned to 2 groups (15% or 30%), following a 6-week velocity-based program in squat exercise, controlling the repetition velocity in the whole intervention. The sprint times of 30m was reported. Although greater benefits were found for 15% group in vertical jump, for example, the sprint performance adaptations were unclear/unlikely for both groups. Since this is an isolated study, further investigation is needed to develop more consistent evidence about velocity-based training adaptations in soccer players regarding sprinting capabilities.

Eccentric training

Eccentric training was found to be one method to improve sprint abilities in soccer. The Nordic Hamstring Exercise was the most frequent approach and three studies were identified in this topic. Firstly, Krommes et al. (2017) tested nineteen male soccer players to perform Nordic Hamstring Exercise during 27 sessions at pre-season, or to control group. Sprint performance (30m with 5m and 10m split times) was measured before the mid-seasonal break and again after 10 weeks of performing the Nordic Hamstring Exercise protocol. Sprint performance on the short distances improved for most players in the Nordic Hamstring Protocol (5m: - 0.068 s; 10m: - 0.078 s), while control group showed no changes. In the same line, Suarez-Arrones et al. (2019) examined the consequence of implementing a Nordic Hamstring exercise protocol during the first 15 to 17 weeks of the season on sprint capacity in fifty professional football players divided in two intervention groups (with and without experience in Nordic Hamstring Exercise) and one control. Linear sprint at 5m, 10m, and 20m were assessed before and after training. Sprint times were substantially improved in all groups (ES from -2.24±0.75 to -0.60±0.37). The improvements in 20m were substantially greater in the group with high experience in Nordic Hamstring Exercise vs. the group without experience, and there were no differences in sprint performance changes between the group without experience and control group. Finally, Suarez-Arrones et al. (2018) examined the changes in sprint performance (40m linear sprint) in response to an entire competitive season of football training with two inertial eccentric-overload training sessions a week. The eccentric-overload training consisted of 1-2 sets of 10 exercises of upper-body and core (Day 1) and lower-body (Day 2), during the entire competitive season (27 weeks). There was a substantial increase in 40m sprint performance (from 1.1% to 1.8%, ES from -0.33 to -0.44) after the intervention. These evidences suggested that Nordic Hamstring Exercise could be an interesting tool to improve sprint abilities in soccer players, independently of the increases in hamstring eccentric strength.

Whole-body electrostimulation

The whole-body electrostimulation is a controversy training modality. It was found one study using this approach to observe changes in sprint performance of soccer players. Thus, Filipovic et al. (2016) investigated the effect of a 14-week dynamic Whole-Body Electrostimulation training program on sprint abilities in twenty-two players which were assigned to 2 groups: Whole-Body-Electrostimulation group or jump-training only group. The training programs were conducted twice a week concurrent to 6-7 soccer training sessions during the second half of the season. The findings were that a 14-week in-season Whole-Body Electrostimulation program significantly improved linear sprinting (5m: 1.01 vs. 1.04s, p=0.039) as well as sprinting with change of direction (3.07 vs. 3.25s, p = 0.024). The results bring insights that two sessions of a dynamic whole-body electrostimulation training in addition to 6-7 soccer sessions per week could be effective for improving linear sprinting and agility of soccer players. However, since this is an isolated study, further investigations are needed for consensus.

CONCLUSION

The present study aimed to review and integrate systematically evidences regarding the effects of strength training on linear, with change of direction, and repeated sprint ability in male soccer players. Current study also aimed to exposed the training characteristics used in those studies, in order to identify the strength training interventions effectiveness for improving sprint abilities. Six training modalities were found with sprinting outcomes in soccer. Traditional and concurrent strength training (11 studies) was the most investigated and, therefore, the majority of studies involving traditional strength training showed important enhancements in linear and change of direction sprint performances of soccer players during pre-season or even in season. Plyometrics and power training (10 studies) was also highly investigated and this method is consistent to improve sprint abilities in soccer players. Some important factors are important to consider such as the high-workload of cardiorespiratory training in addition to these neuromuscular stimuli, since this seems to play a role for improvements, decrements or even maintenance of sprint abilities specially during pre-seasons. Moreover, resisted sprints training (6 studies) was a frequent modality of training demonstrated to improve sprinting performance, however, compared to unresisted sprints, resisted sprints training is not completely defined as an optimized method for soccer players. Their effects seem to depend of fitness status, training dosages, volume, and intensity. Further experimental studies are important to be developed in soccer. The Eccentric training (3 studies) was mostly applied in form of the Nordic Hamstring Exercise and this exercise could be an interesting strategy to improve sprint abilities in soccer players, independently of the increases in hamstring eccentric strength. The Flywheel training (2 studies) was showed to be suitable for improving change of direction as well as linear sprint abilities in young soccer players. The Velocity-based training (1 study) and Whole-body electrostimulation (1 study) showed only one evidence and further investigation is needed to develop more consistent data about sprint adaptations in soccer players from these modalities.

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ANNEX 1

Table 1. Risk of bias assessment.

Study	Random sequence generation	Concealed allocation	Blinding of outcome assessor	Description of losses and exclusions	Intention-to-treat analysis
Raya-González et al. (2021)	N	-	-	-	-
Lahti J et al. (2020)	N	-	-	-	-
Ben Brahim et al. (2020)	Y	Y	-	-	-
Grazioli et al. (2020)	Y	Y	-	Y	-
Sanchez-Sanchez et al. (2020)	Y	Y	-	-	-
Suarez-Arrones et al. (2019)	N	-	-	-	-
McMorrow et al. (2019)	N	-	-	-	-
Suarez-Arrones et al. (2018)	N	-	-	-	-
Gil et al. (2018)	Y	Y	-	-	-
Loturco et al. (2017)	Y	Y	-	-	-
Krommes et al. (2017)	Y	Y	-	-	-
Kobal et al. (2017)	N	Y	-	-	-

Otero-Esquina et al. (2017)	Y	Y	-	-	-
Filipovic et al. (2016)	Y	Y	-	-	-
Loturco et al. (2016a)	N	N	N	Y	-
Loturco et al. (2016b)	Y	Y	-	Y	-
Pareja-Blanco et al. (2017)	Ý	Y	-	-	-
Hammami et al. (2016)	Y	Y	-	-	-
Zouita et al. (2016)	Y	Y	-	-	-
de Hoyo et al. (2016)	N	Y	-	-	-
Spineti et al. (2016)	Y	Y	-	Y	-
Styles, Matthews and Comfort (2016)	N	N	-	-	-
Enright et al. (2015)	N	Y	-	-	-
Loturco et al. (2015)	Y	Y	-	-	-
Granacher et al. (2015)	Y	Y	-	-	-
Prieske et al. (2016)	Y	Y	-	-	-
de Hoyo et al. (2015)	Y	Y	-	Y	-
Koundourakis et al. (2014)	N	Y	-	-	-

Keiner et al. (2014)	N	Y	-	-	-
Los Arcos et al. (2014)	Y	Y	-	-	-
Loturco et al. (2013)	Y	Y	-	-	-
Rønnestad, Nymark and Raastad (2011)	Y	Y	-	-	-
Buchheit et al. (2010)	Y	Y	-	-	-
Mujika, Santisteban and Castagna (2009)	Y	Y	-	-	-
Wong et al. (2010)	Y	Y	-	-	-
Jullien et al. (2008)	Y	Y	-	-	-
Ronnestad et al. (2008)	Y	Y	-	-	-

Table 2. Studies characteristics: sample size, level of sample, intervention type, intervention time, group, and main outcomes.

Study	N	Level	Intervention	Time	Group	Main outcomes
Raya-González et al. (2021)	20	U-16 elite	Weekly flywheel resistance training	10-week	10 control vs. 10 intervention	-
Lahti J et al. (2020)	32	Professional	Resisted sprint training based on decrement from maximal velocity	11-week	Control vs. resistance that induced a 60% velocity decrement from maximal velocity vs. subgroup two used a 50% velocity decrement resistance based on individual load-velocity profiles.	Both heavy resistance subgroups improved significantly all 10-30-m split times ($p < 0.05$, $d = - 1.25$; -0.62). Post-hoc analysis showed that HS50% improved significantly more compared to CON in 0-10-m split-time ($d = 1.03$)
Ben Brahim et al. (2020)	34	U-19 elite	Resisted sprint training group	6-week	Randomly assigned into a resisted sprint training group using	Within-group interactions showed significant combined muscular strength and

					both weight vest and sled, and a control group.	resisted sprint training effects were observed for all the tests' measurements (effect sizes = 0.97 for 20-m sprint). However, significant increases of performances were observed for 5-m and 20-m sprinting time (= 0.25, $p < 0.01$ and = 0.22, $p < 0.01$, respectively) in RSTG with large effect size.
Grazioli et al. (2020)	17	Professional	The velocity-based resisted sprint training	11-week	Two groups, based on different magnitudes of velocity loss: 10% of velocity decrease and 20% of velocity decrease.	Two-way repeated measures analysis of variance revealed a significant time-effect for decreases in 10- and 20-m sprint times ($p = 0.018$ and $p = 0.033$, respectively), but without a time-group interaction. The G10 showed greater

						beneficial effects than G20 for both 10-m (-5.5 ± 3.3%, magnitude-based inference [MBI]: possibly vs. -1.7 ± 5.9%, MBI: possibly trivial) and 20-m (-2.5 ± 2.1%, MBI: possibly vs. -1.4 ± 3.7%, MBI: likely trivial) sprint times.
Sanchez-Sanchez et al. (2020)	65	U-19 national-level	Resistance training on stable vs. unstable surfaces	10-week	Resistance training group (uRT) or a stable resistance training group (sRT).	A significant main effect of time was observed for Hop non-D, RSAbest, and RSAmean (p = 0.003-0.06, effect size [ES] = 0.06-0.15). Furthermore, significant group × time interactions were shown for RSAbest (p = 0.007, ES = 0.13) and RSAmean (p = 0.002, ES = 0.2). Post hoc analysis revealed

						significant pre- to post-training improvements for RSAbest ($p = 0.002$, ES = 0.35) and RSAmean ($p = 0.0002$, ES = 0.36) in the uRT. In the sRT, however, no significant pre-post performance changes were observed in RSAbest and RSAmean.
Suarez-Arrones et al. (2019)	50	Professional	Nordic	17-week	Nordic-Group1 (NG-1) and Nordic-Group2 (NG-2, extensive experience in NHE)] and 1 team as a control-group (CG).	Sprint times were substantially improved in all groups (ES from -2.24±0.75 to 0.60±0.37). The improvements in T20-m were substantially greater in NG-2 vs. NG-1, and there were no differences in sprint performance changes between NG-1 and CG. Changes in sprinting performance and

						NHEs were unrelated. Results indicate that the improvements in sprint are not dependent on the NHEs changes, with no relationships between NHEs and sprint performance, and between sprint changes and changes in NHEs.
McMorrow et al. (2019)	13	Professional	Resisted sled sprinting (RSS)	6-week	RSS training group performed RSS at a sled load of 30% body mass for a total program running distance of 800 m, whereas an unresisted sprint (URS) training group performed the same distance of unresisted sprinting.	Sprint performance (mean, 95% confidence limits, qualitative inference) was improved in both groups over 5 m (URS, 5.1%, -2.4 to 12.7, likely moderate; RSS, 5.4%, 0.5-10.4, likely moderate), 10 m (URS, 3.9%, -0.3 to 8.1, very likely moderate; RSS, 5.0%, 1.8-8.0, very likely large), and 20 m (URS, 2.0%, -0.6 to

						4.5, likely moderate; RSS, 3.0%, 1.7-4.4, very likely moderate). COD was improved in both groups (URS, 3.7%, 2.2-5.2, most likely large; RSS, 3.3%, 1.6-5.0, most likely moderate). Between-groups differences were unclear.
Suarez-Arrones et al. (2018)	40	Young elite	Inertial eccentric-overload training	27-week	-	There was a substantial increase in sprint performance (from 1.1% to 1.8%, ES from -0.33 to -0.44).
Gil et al. (2018)	18	Elite	Resisted sprint training	6-week	Resisted sprint training with overload control versus an unresisted sprint training Program.	Both groups improved sprinting ability at all distances evaluated (5m: UR = 8%, RST = 7%; 10m: UR = 5%, RST = 5%; 15m:

						UR = 4%, RST = 4%; 20m: UR = 3%, RST = 3%; 25m: UR = 2%, RST = 3%;), COD (UR = 6%; RST = 6%), SJ (UR = 15%; RST = 13%) and CMJ (UR = 15%; RST = 15%).
Loturco et al. (2017)	18	Professional	Optimum power load [OPL] + resisted sprints [RS] and OPL + vertical/horizontal plyometrics [PL])	5-week	The athletes were pair-matched in two training groups: OPL + RS and OPL + PL.	Meaningful improvements were observed in the COD speed test for both training groups comparing pre- and post-measures. In both unloaded and resisted sprints, meaningful decreases were observed in the sprinting times for all distances tested. This study shows that a mixed training approach which comprises exercises and workloads able to produce positive adaptations in different

						phases of sprinting can be a very effective strategy in professional soccer players.
Krommes et al. (2017)	19	Elite	Nordic Hamstring Protocol (NHP)	10-week	NHP during pre-season or control group (CG).	Sprint performance on the short split distances improved for most players in the NHP (6 out of 9 improved, median changes for 5 m split: - 0.068 s; 10 m split: - 0.078 s), but not CG (2 out of 5 improved, median changes for 5 m split: + 0.1 s; 10 m split: CG: + 0.11 s), but both groups had small declines at 30 m sprint (NHP: 7 out of 9 declined, median changes: + 0.116 s; CG: 4 out of 5 declined, median changes: + 0.159 s).
Kobal et al. (2017)	23	U-17 elite	Loaded and unloaded	6-week	The athletes were pair-matched in two training	An almost certainly decrease in the sprinting velocities along

			plyometric training strategies		groups: loaded vertical and horizontal jumps using an haltere type handheld with a load of 8% of the athletes' body mass (LJ) and unloaded vertical and horizontal plyometrics (UJ).	the 20-m course were found in the LJ group (00/00/100 for all split distances tested). Meanwhile, in the UJ likely to very likely decreases were observed for all sprinting velocities tested (03/18/79, 01/13/86, and 00/04/96, for velocities in 5-, 10-, and 20-m, respectively).
Otero-Esquina et al. (2017)	36	U-17 and U-19 elite	Strength-training programme	6-week	Experimental groups (EXP1: 1 s w-1; EXP2: 2 s w-1) or a control group (CON).	Within-group analysis showed substantial improvements in COD (ES: 0.70 and 0.76) in EXP1 and EXP2, while EXP2 also showed substantial enhancements in all linear sprinting tests (ES: 0.43-0.52). Between-group analysis showed that EXP2

						achieved a substantial better performance in 20-m (ES: 0.48-0.64) than EXP1 and CON. Finally, EXP2 also showed greater enhancements in 10-m (ES: 0.50) and V-cut test (ES: 0.52) than EXP1.
Filipovic et al. (2016)	22	Elite	Dynamic Whole-Body Electrostimulation (WB-EMS)	14-week	WB-EMS group (EG), jump-training group (TG).	Improved linear sprinting (5m: 1.01 vs. 1.04s, p=0.039) and sprinting with direction changes (3.07 vs. 3.25s, p = 0.024) performance. .
Loturco et al. (2016a)	22	Elite	-	8-week	-	We could verify decrements in the 20-m and COD sprint performances, which were rated as very likely and almost certainly, respectively.

Loturco et al. (2016b)	23	Professional	Classic strength power periodization (TSP) or optimum power load (OPL)	6-week	Classic strength-power periodization (TSP) or optimum power load (OPL)	Results revealed that both groups presented similar significant ($P<0.05$) improvements in change of direction speed. In addition, although both groups reported significant increases in sprinting speed ($P<0.05$); delta change scores demonstrated a superior effect of OPL to improve 10- and 20-m speed.
Pareja-Blanco et al. (2017)	16	Professional	Resistance-training (RT)	6-week	VL15 or VL30 velocity-based squat-training program.	The effects on T30 performance were unclear/unlikely for both groups.
Hammami et al. (2016)	24	Young elite	Balance and plyometric training	8-week	Initial 4 weeks of balance training followed	Similar changes for both groups.

					by 4 weeks of plyometric training (BPT) or 4 weeks of plyometric training proceeded by 4 weeks of balance training (PBT).	
Zouita et al. (2016)	52	Young elite	Strength training	12-week	Experimental group (EG) and control group (CG).	Compared to CG, EG performed significantly better in sprint running ($p < 0.01$).
de Hoyo et al. (2016)	32	U-19 elite	Strength training	8-week	3 different low/moderate load strength training methods (full-back squat [SQ], resisted sprint with sled towing [RS], and plyometric and specific drills training [PLYO]).	Substantial improvements (likely to almost certainly) in 30-50 m (ES: 0.45-0.84) were found in every group in comparison to pretest results. Moreover, players in PLYO and SQ groups also showed substantial enhancements (likely to very likely) in 0-50 m (ES: 0.46-0.60). In

						addition, 10-20 m was also improved (very likely) in the SQ group (ES: 0.61). Between-group analyses showed that improvements in 10-20 m (ES: 0.57) and 30-50 m (ES: 0.40) were likely greater in the SQ group than in the RS group. Also, 10-20 m (ES: 0.49) was substantially better in the SQ group than in the PLYO group.
Spineti et al. (2016)	22	U-20 elite	Traditional strength training (TST) and complex contrast training (CCT)	-	CCT or TST.	After statistical analysis ($P<0.05$), the results demonstrated that the specific CCT regimen provided a significant improvement in the RSSA percent decrement (moderate effect size).

Styles, Matthews and Comfort (2016)	17	Professional	Strength training	6-week	Strength training (85-90% 1RM)	Strength training resulted in small yet significant improvements in sprint performance over 5 m (before = 1.11 ± 0.04 seconds, after = 1.05 ± 0.05 seconds, $p \leq 0.001$, Cohen's d = 0.55), 10 m (before = 1.83 ± 0.05 seconds, after = 1.78 ± 0.05 seconds, $p \leq 0.001$, Cohen's d = 0.45), and 20 m (before = 3.09 ± 0.07 seconds, after = 3.05 ± 0.05 seconds, $p \leq 0.001$, Cohen's d = 0.31).
Enright et al. (2015)	50	Youth elite	Concurrent training	5-week	Concurrent training by performing strength (S) training either prior to (S + E) or after (E + S) soccer specific endurance training (E).	No effects for 30 m sprint performance ($P < 0.05$).

Loturco et al. (2015)	23	Elite	Strength training	4-week	Jump squat (JS) or half-squat (HS).	Both groups improved acceleration (ACC) from 5 to 10 m (ES = 0.52). JS was more effective at reducing the ACC decrements over 0-5 m (ES = -0.38 vs. -0.58, for JS and HS, respectively).
Granacher et al. (2015)	24	Sub-elite	Plyometric training	8-week	Plyometric training on stable (SPT) vs. highly unstable surfaces (IPT).	Statistical analysis revealed significant main effects of time for 0-10-m sprint time ($p<0.05$, $f=0.58$). Following 8 weeks of training, similar improvements in speed in the two groups.
Prieske et al. (2016)	32	Elite	Core strength training	9-week	Core strength training performed on unstable (CSTU) compared with stable surfaces (CSTS).	Statistical analysis revealed significant main effects of test (pre vs post) for 10-20-m sprint time (3%, $P < 0.05$, $d = 2.56$).

de Hoyo et al. (2015)	36	U-17 to U-19 elite	Eccentric-overload training	10-week	Experimental (EXP) or control group (CON).	Regarding muscle performance, a substantial better improvement (likely to very likely) was found in 20-m sprint time (ES: 0.37), 10-m flying-sprint time (ES: 0.77) for EXP than for CON. Within-group analysis showed an unclear effect in each variable in CON. Conversely, substantial improvements were obtained in 20-m sprint time (ES: 0.32), 10-m flying-sprint time (ES: 0.95), and injury severity (ES: 0.59) in EXP.
Koundourakis et al. (2014)	67	Professional	Strength training	-	Strength intensity of the training programs were assessed as high (for Team-A), moderate (for Team-B), and low (for Team-C).	All performance parameters increased significantly until mid-point in all teams ($p<0.001$). However,

						performance was further increased only in Team-A only for sprinting ability between end-point vs mid-point (p<0.001). An effect of the training program of Team-A on TT levels was evident exhibiting significant differences between at all point-measurements (baseline/mid-point:p=0.024, baseline/end-point:p<0.001, mid/end-point:p=0.008), while a marginally significant effect (p=0.051) was detected within Team-B and a non-significant effect in Team-C.
Keiner et al. (2014)	-	Professional	Strength training.	2-years	2 groups with 4 subgroups (A = under 19 years of age, B = under 17 years of age,	Our data show that additional strength training over a period of 2 years significantly affects

					and C = under 15 years of age). For approximately 2 years, 1 group (control group [CG]) only participated in routine soccer training, and the other group (strength training group [STG]) participated in an additional strength training program with the routine soccer training.	the performance in the COD. The STG in all subcohorts reached significantly ($p < 0.05$) faster times in the COD than did the CG. The STG amounted up to 5% to nearly 10% better improvements in the 10-m sprint times compared with that of the CG. Furthermore, our data show significant ($p < 0.05$) moderate to high correlations ($r = -0.388$ to -0.697) between the SREL and COD. Our data show that a long-term strength training improves the performance of the COD.
Los Arcos et al. (2014)	22	Professional	Strength and conditioning programs	8-week	Vertical strength (VS) and vertical and horizontal strength (VHS).	Both groups obtained significant small practical improvements in 5-m- ($P < .05$;

						ES = 0.27 and 0.25 for VS and VHS, respectively) and 15-m-sprint time (P < .05; ES = 0.19 and 0.24 for VS and VHS, respectively).
Loturco et al. (2013)	32	Elite	Power training	9-week	Velocity-based (VEL) or intensity-based (INT).	The 2 groups also presented significant improvements (within-group comparisons) in all of the variables. However, no between-group differences were detected. The 10-m sprint (VEL: -4.3%; INT: -1.6%) was also improved in both groups at T2. Curiously, the 30-m sprint time (VEL: -0.8%; INT: -0.1%) did not significantly improve for both groups.

Rønnestad, Nymark and Raastad (2011)	14	Professional	Strength training	12-week	1 strength maintenance training session per week (group 2 + 1), whereas the other group performed 1 session every second week (group 2 + 0.5).	The preseason strength training resulted in an increased sprint ($p < 0.05$). During the first 12 weeks of the in-season, the initial gain in strength and 40-m sprint performance was maintained in group 2 + 1, whereas both strength and sprint performance were reduced in group 2 + 0.5 ($p < 0.05$).
Buchheit et al. (2010)	15	Young elite	Explosive strength (ExpS) and repeated shuttle sprint (RS)	10-week	Explosive strength (ExpS) vs. repeated shuttle sprint (RS)	After training, except for 10 m ($p = 0.22$), all performances were significantly improved in both groups (all p's < 0.05). Relative changes in 30 m (-2.1 ± 2.0%) were similar for both groups ($p = 0.45$). RS training induced greater improvement in RSAbest (-

						2.90 ± 2.1 vs. -0.08 ± 3.3%, p = 0.04) and tended to enhance RSAmean more (-2.61 ± 2.8 vs. -0.75 ± 2.5%, p = 0.10, effect size [ES] = 0.70) than ExpS.
Mujika, Santisteban and Castagna (2009)	20	Elite junior	Sprint and power training	7-week	Contrast vs. sprint.	At baseline no difference between physical test performance was evident between the 2 groups (p > 0.05). A time x training group effect was found for Sprint-15m performance with the CONTRAST group showing significantly better scores than the SPRINT group (7.23 +/- 0.18 vs. 7.09 +/- 0.20 m.s, p < 0.01). In light of these findings CONTRAST training should be preferred to line sprint

						training in the short term in young elite soccer players when the aim is to improve soccer-specific sprint performance (15 m) during the competitive season.
Wong et al. (2010)	39	Professional	Concurrent muscular strength and high-intensity running interval training	8-week	Experimental group (EG) and control group (CG)	Within-subject improvement was significantly higher (p < or = 0.01) in the EG compared with the CG for 10-m and 30-m sprint times.
Jullien et al. (2008)	26	U-17 to U-19	Strength training	3-week	The reference group (Re) performed individual technical work only, the coordination group (Co) performed a circuit designed to promote agility, coordination, and balance control (together with some technical work) and the	Our results indicate that in the short sprints or shuttle sprint with changes in direction, lower limb strengthening did not improve performance.

					Squat group (Sq) underwent 3 series of 3 squat repetitions (at 90% of the individual maximum value) and a sprint.	
Ronnestad et al. (2008)	21	Professional	Strength (ST) and plyometric (P) training	8-week	Group ST vs. group ST+P vs. control group.	No significant differences between the ST+P group and ST group. Thus, the groups were pooled into 1 intervention group. The intervention group significantly improved in sprint acceleration, peak sprint velocity, and reduced total time on 40-m sprint. However, a significant difference between groups was not observed in sprint acceleration, peak sprinting velocity, and total time on 40-m sprint.