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A Review of the Effect of Resistance Exercise on Development of Anaerobic and Balance Performance in Adolescent Footballers

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ABSTRACT

Background: The resistance exercises underpin the strength and power development of muscle activation in adolescent footballers. **Objective:** The study purposed to review the effectiveness of different resistance exercise models on improving anaerobic and balance characteristics among young football players. **Methods:** A systematic search of Scopus, SPORT Discus, and the Web of Science was undertaken to identify the study content using a combination of searches related to resistance exercise, balance, and anaerobic performance. Titles and abstracts were used to search for keywords, and data were extracted using the subject characteristics, training intervention, measurement, and outcomes. **Results:** Fourteen studies were identified that investigated the effects of resistance programs on the anaerobic and balance characteristics. A combination of plyometric and regular football training significantly improved the anaerobic characteristics, and balance performance in young footballers. Based on high-quality evidence, anaerobic and balance performance enhancement appears after conducting resistance exercises for approximately eight weeks, with two to three sessions on alternate days a week. The volume consists of 2-3 sets per exercise, 6-12 repetitions per set, and intensity was classified as moderate to high, with one repetition maximum. **Conclusion**, Integrating resistance exercise into the regular training sessions improves the anaerobic performance of young footballers, such as jumping, sprinting, and changing direction, while improving balance ability, indicated by reducing the center of pressure area side-asymmetry and sway speed during unipedal and bipedal leg stance.

Key words: Resistance Exercise, Anaerobic, and Balance Performance, Young Football Players

INTRODUCTION

Resistance exercise has been a priority of attention for improving physical performance and preventing injury in young athletes. Resistance training is defined as a training method that focuses on gradually increasing levels of resistance and using different training types to improve overall health, fitness, and athletic performance (Faigenbaum et al., 2009; Harries et al., 2012; Lloyd et al., 2014; Zwolski et al., 2017). Moreover, resistance exercise intervention is related to changing teenagers' body composition, physical fitness, and lifestyle behavior (Duarte Junior et al., 2024). The effectiveness of various resistance exercises, levels of resistance, numbers of sets and repetition, and the interval between sets of work (González-Badillo et al., 2015; Naclerio et al., 2013) have proved to enhance and maintain the physical and physiological adaptation of adolescent athletes (Harries et al., 2012).

Implementing resistance exercise into regular training can considerably affect the physical demands of football players (Fernández-Galván et al., 2022; Nuñez et al., 2022). For instance, a combination of resistance exercises enhanced muscle strength in various jumps and sprints (linear or changing direction) for young footballers (Otero-Esquina et al., 2017; Zghal et al., 2019). Furthermore, several training methodologies have been employed to improve body composition (Suarez-Arrones et al., 2019), vertical jump, and sprinting abilities by using a combination of plyometric (Falces-Prieto et al., 2021), jumping, sprinting, and peak power in power training (Loturco et al., 2020), and electrostimulation to improve jumping and kicking skills (Billot et al., 2010).

As mentioned above, consistent scientific studies have revealed that resistance exercise positively impacts adolescent athletes' muscular power and motor skill performance. Developing muscular strength to enhance anaerobic performance (Nikolaidis et al., 2018) and postural balance (Steinberg et al., 2016) is crucial throughout the puberty

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phase. Nobari et al. (2021) raised attention to the evidence that anaerobic profiles might substantially impact the performance of elite young football players. Football matches require the performance of anaerobic characteristics like sprints, jumps, and cutting maneuvers (Evangelos et al., 2016). Anaerobic capacity and power play a crucial role, where high-intensity action occurs 150 to 250 times throughout a match (AlTaweel et al., 2022; Bangsbo et al., 2007).

Along with anaerobic characteristics, balance is important for successful actions and technique in a football match (Butler et al., 2012). Balance performance is needed for duels with opponents, maintaining balance on a slippery field, adjusting to the ball's trajectory, and changing direction (Evangelos et al., 2012). Studies by Bishop et al. (2018), Brown et al. (2018), Paillard (2017), and Zemková and Zapletalová (2022) have shown that football players who can maintain their balance on the field are better in their match performance, minimizing injuries and falling during games. The strong correlation between anaerobic parameters and balance performance (Cinarli et al., 2022; Falces-Prieto et al., 2022; Lockie et al., 2018; Wilczyński et al., 2021) emphasizes the crucial role of lower limb strength and power. Furthermore, repetitive anaerobic activities can lead to general and localized fatigue, which can subsequently cause disruptions in balance performance (Pau et al., 2014; Steinberg et al., 2016).

The current review (Martinez-Perez & Vaquero-Cristobal, 2021) revealed that resistance training enhances preadolescent and adolescent football players' physical performance. Plyometric training, followed by strength and isoinertial training, has emerged as the predominant type of exercise for football players due to its effectiveness in enhancing their physical development and motor skills. Based on our current understanding, there has yet to be a review of the optimization of anaerobic and balance performance through exercise intervention. Thus, this review aimed to review the resistance exercise model's effectiveness in improving young football players' anaerobic and balance characteristics.

METHODS

Research Design and Ethics

The systematic review was registered on PROSPERO-CRD42024572885 (https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=572885) and completed following the PRISMA criteria.

Literature Search

The systematic review search of the Scopus, Sport Discus, and WOS databases covered papers published in the last five years. Papers meeting the criteria were considered for inclusion until December 31st, 2023. The search method used by the operators AND OR, along with the following keywords: ("resistance training" OR "strength training" OR "traditional exercise" OR "weight training" OR "ballistic exercise" OR "plyometric training" OR "eccentric training" OR "weight lifting" OR "Olympic exercise" AND ("Static balance" OR "Dynamic Balance" OR "Balance "star excursion" OR "Y-balance test" OR "Romberg test" OR "single-leg stance" OR "limits of stability" OR "postural stability" OR "timed up and go") AND ("anaerobic power" OR "anaerobic capacity" OR" peak power" OR "sprint test" OR "vertical jump" OR "counter movement jump" OR "squat jump" OR "Wingate test") AND ("football" OR "soccer" OR "young" OR "Adolescent" OR "Children" OR "Youth" OR "Teenager" OR "boys"). The studies were restricted to the full-text original articles written in English.

The references to systematic reviews found in the database were searched manually and carefully. We looked for articles and published randomized, multi-arm-controlled trials in all resistance exercise types and their impact on anaerobic and balance characteristics in young football players. The retrieved literature was imported into Mendeley reference manager 1.19.8 to eliminate duplicates. The two writers (ARS and IP) independently conducted the database search. The authors conducted parallel screenings of authors, year of publication, samples, intervention characteristics, assessment, and outcomes from each paper. If there were any potential differences between the two authors during the search and review process, they were resolved through consensus by presenting an external validator.

Eligibility Criteria

Based on Methley et al. (Methley et al., 2014), the study employed the PICOS tool to establish clear criteria for including and excluding participants. The study focused on young males aged 10 to 19 for the population (P). Studies with neurological or musculoskeletal illnesses such as Parkinson's disease, multiple sclerosis, osteoarthritis, or persistent pain were excluded based on specific criteria. Intervention (I) criteria included an experimental group engaged in resistance exercise, while studies without RE interventions were excluded. Comparator (C) was an active control group, where one experimental group and the other performed regular training. The outcome (O) was testing balance and anaerobic characteristics. Lack of baseline and follow-up data before and after intervention was excluded. The study design (S) was multi-arms trials and randomized control trials. The systematic review, cohort study, cross-section, and case-control study were all eliminated.

The current systematic review evaluated only complete original articles that contained full text. References from books, chapters, and abstracts at the conference were excluded. Furthermore, cross-sectional studies and RE programs that deal with athlete physical performance, psychological intervention, a general sample, and injury prevention and rehabilitation, were excluded.

Quality Assessment

This review used the Physiotherapy Evidence Database (PEDro) scale to analyze each article. A '+' score signifies the fulfillment of the PEDro scale criteria, whereas a '-' score indicates non-fulfillment. The PEDro scales of 0-3, 4-5, 6-8, and 9-10 indicate poor, moderate, good, and excellent, respectively (Morton de, 2009; Maher et al., 2003; Yamato et al., 2017). Details of PEDro scoring items are shown in Table 1.

Data Analysis and Synthesis

The studies included in the review were sourced from restricted subjects (only adolescents of football players), applying different resistance exercise interventions, and employing a range of various dosages of training that might affect the outcome. The strength of the evidence was assessed using the best evidence synthesis method (Burns et al., 2011; Yu et al., 2023). Quantity of studies, method quality, and consistency of findings throughout all evidence were assessed. 1) substantial evidence from more than two high-quality studies with consistent significant results; 2) intermediate evidence using one high-quality research and several low-quality trials with consistent results; 3) limited evidence if only one study was available or two contained contradictory outcomes; 4) conflicting evidence when more than two studies had incompatible results; and 5) no evidence when there were no case-control analyses.

RESULTS

Study Selection

The search approach identified a total of 668 studies across three databases. The PRISMA flow employed the study selection approach (Page et al., 2021)(see Figure 1). Following the reduction of duplicate research (*n* = 82), a total of 586 were re-examined. After evaluating the abstract and title, 299 papers were excluded. After thoroughly reading 287 publications, 211 studies were rejected for selected reasons, including the absence of RE intervention. In the end, 14 publications were selected as eligible for inclusion in this systematic review.

Population Characteristics, Puberty Stage, and Maturity Status

The cumulative sample size of the research considered in this analysis was 568 young male adolescent football players. The sample sizes ranged from 6 to 104 participants. The study included participants with an average age of 15.27±0.4 years. The participants' maturity status and puberty stage were not reported in the largest number of studies (*n* =8 studies). Subjects' biological maturity in pre-peak height velocity (PHV) *n* =1 study (-0.25±0.3 years from PHV), approaching -peak height velocity *n* = 3 studies (-1.95±0.3 years from PHV), and *n* =2 studies were late post-peak height velocity (2.5±0.6 years from PHV). Furthermore, a study conducted by Zghal et al. (2019) reported the puberty stage of players (puberty stages 3-4) according to the Tanner method (Beunen et al., 1992), before and after intervention resistance exercise by the same investigator (a medical doctor). The maturity offset was estimated by operating the formula developed by Moore et al. (2015), anthropometry assessment (Mirwald et al., 2002), and the puberty stage was determined by the Tanner method in observing pubic hair growth and genital development (Beunen et al., 1992).

Study Quality Assessment

Table 1 explains how the PEDro scale evaluates the quality of research. Out of the total number of studies, *n*=1 received 5 points on the PEDro scale, indicating moderate quality, while *n*=13 received a score of 6-8 points, a score considered excellent quality. Across the board, the studies met the threshold for minimal risk of bias (mean quality score = 6.85 ± 0.83). The rating score reveals a varied quality of research, with a significant proportion of studies being of high quality. Most of the analyzed trials failed to fulfill the blinding of the subjects, therapists, and assessors. Given this situation, future studies must be performed at a higher quality and evidentiary level.

Table 1. Physiotherapy evidence database (PEDro) scores of reviewed studies

Study	1	2	3	4	5	6	7	8	9	10	11	Total score
(Aloui et al., 2022)	+	+	-	+	-	-	-	+	+	+	+	7
(Muehlbauer et al., 2019)	+	+	-	+	-	-	-	+	-	+	+	6
(Hammami M. et al., 2020)	+	+	+	+	-	-	-	+	-	+	+	7
(Chaalali et al., 2022)	+	+	-	+	-	-	-	+	+	+	+	7
(Zghal et al., 2019)	+	+	+	+	+	-	-	-	-	+	+	7
(Barbalho et al., 2018)	+	+	-	+	-	-	+	+	+	+	+	8
(Jlid et al., 2019)	+	+	-	+	-	-	-	+	+	+	+	7
(Hammami R. et al., 2023)	+	+	-	+	-	-	-	+	+	+	+	6
(Seong et al., 2022)	+	-	-	+	-	-	-	+	+	-	+	5
(Arslan et al., 2021)	+	+	+	+	-	-	-	+	+	-	+	7
(Aloui et al., 2021)	+	+	-	+	-	-	+	+	+	+	+	8
(Makhlouf et al., 2018)	+	+	-	+	-	-	-	+	+	+	+	7
(Dafkou et al., 2021)	+	+	-	+	-	-	+	+	+	+	+	8
(Gasim et al., 2022)	+	+	-	+	-	-	-	+	+	-	+	6

1. Eligible to participate, 2. Radom allocation, 3. Concealed allocation, 4. Group similar at baseline, 5. Blind subject, 6. Blind Therapist, 7. Blind assessor, 8. Dropout<15%, 9. Intention to threat method, 10. Comparison between groups, 11. Point measure and variability

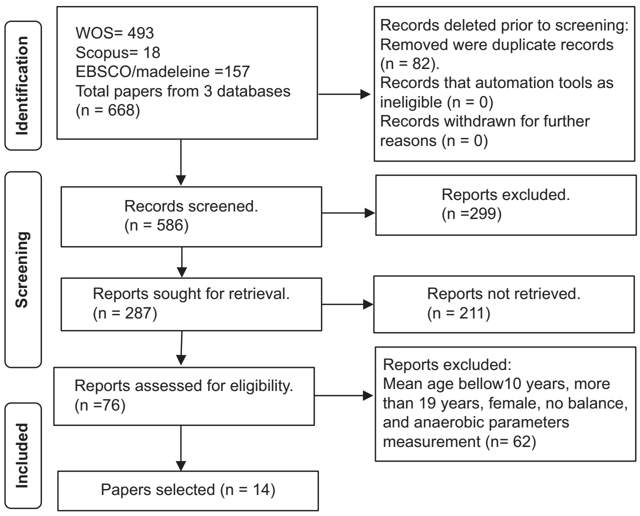

Figure 1. The flowchart is based on the process of searching and selecting studies

The Intervention of Resistance Exercise Characteristics

The study included different resistance exercise models for multiple activities. The variety of jumps in varied heights (20-80 cm) (Jlid et al., 2019), running with resistance (Chaalali et al., 2022), diverse balance exercises (Muehlbauer et al., 2019), weight lifting (Zghal et al., 2019), small-sided games (Arslan et al., 2021), core strength training (Gasim et al., 2022), and change of direction drills (Aloui et al., 2021). All studies indicate that integration into exercise models enhances anaerobic and balance performance among adolescent footballers. Regarding the characteristics of interventions (Table 2), the studies performed the programs from 2 to 15 weeks, with an average (7.71±2.68) weeks. One study had a shorter duration of 2 weeks (Seong et al., 2022), while another had a longer duration of 15 weeks (Barbalho et al., 2018). Resistance exercise programs were conducted 2 or 3 times weekly (2.64±0.97) on alternate days. The volume training consists of 2-3 sets of 6-12 repetitions of each activity, with moderate to high intensity. The type of plyometric training was applied 54-144 ground contacts per session.

Assessment of Anaerobic Performance

The preceding field tests employed to assess anaerobic power in athletes were the vertical jump tests, sprints, and hopping (Çakir-Atabek, 2014; Gross & Lüthy, 2020; Haugen et al., 2013; Nikolaidis, 2011). Furthermore, Bongers et al. (2015) determined that the repeated sprint anaerobic test (RAST) is a valid and non-sophisticated field test for evaluating anaerobic performance in healthy children and adolescents. The studies employ various jump tests (squat jump test, standing long jump test, drop jump test, countermovement jump test, five jump test, single leg hop test, triple leg hop test, and different types of sprint (linear sprint test, change of direction test, sprints backward and forward, repeated shuttle sprint ability) to evaluate anaerobic power and capacity in young football players.

Assessment of Balance Performance

Static and dynamic tests should be provided to evaluate balance, as postural control performance in both is unrelated (Pau et al., 2015). Both types of balance tests independently assess the participants' motor experience-related balance performance situations (Paillard & Noé, 2020). The current study operated the star excursion balance test (SEBT, n = 1), the Y-balance test (YBT, n = 7) in maximum reach distance from the center of pressure to anterior, posteromedial, and posterolateral to evaluate dynamic balance, and the stork balance test (SBT, n = 3) to test static balance ability. Two studies applied a stabilization device (Dafkou et al., 2021; Seong et al., 2022), which provided more valuable information about anterior-posterior, right/left lateral, right/left anterolateral, and right/left posterolateral to evaluate postural balance.

DISCUSSIONS

The primary purpose of this study was to review the literature on the effects of resistance exercise on improving anaerobic and balance performance among adolescent football players. Moreover, this study provided an interpretation of the principles for selecting the most effective exercise based on the quality of evidence. The study review analyzed different resistance exercise models, type of exercise, frequency, resistance levels, number of sets and repetitions per set, and duration of relief between the sets.

The literature reveals that incorporating core strength and plyometric exercises during the off-season, alongside aerobic programs, improved core dynamic balance and reduced asymmetry between legs (Seong et al., 2022). The experimental study combines core strength and small-side game (Arslan et al., 2021), hamstring eccentric and core stability training (Dafkou et al., 2021) that showed growth in lower body strength and balance standing on the non-dominant and dominant leg. Moreover, combining different resistance exercise models and plyometric training (Aloui et al., 2021, 2022; Gasim et al., 2022; Hammami M. et al., 2020; Jlid et al., 2019; Makhlouf et al., 2018; Muehlbauer et al., 2019) can improve static and dynamic balance characteristics while minimizing the center of pressure, anterior-posterior, and medial-lateral sway speed. Improvement of static balance was followed by a decreasing score of the sway speed center of pressure (COP) in the non-dominant and dominant leg, advancements in lower extremity muscle co-contraction, and change in proprioception and neuromuscular control. Indeed, balance improvement through the training session could be linked to a more precise contraction of the muscles in the lower extremities (Kim & Chou, 2022) or changes in proprioception and neuromuscular control (Kim & Chou, 2022).

The present study highlights the importance of integrating resistance exercise with regular football training, considering factors such as age group, competitive level, and duration of the training program. The findings showed that implementing resistance exercises for approximately eight weeks significantly improved static and dynamic balance performance. In line with a previous review (Šarabon &

Table 2. Resistance exercise of the studies included

No	Study	Subject	Type RE	Training Intervention	Measurement	Result
1	(Aloui et al., 2022)	IG, n = 17, age: 14.6 ± 0.5 years CG, n = 17, age: 14.6 ± 0.4 years	PT + SPT	8 weeks, 4 sessions x biweekly, ground contacts per session rose steadily from 72 to 144, and the number of sets for each workshop increased from 3 to 6 sets. The training session included various jumps and strides, followed by a short sprint.	SJ, CMJ, 5JT, and LST = 10-30 m, CoD (sprint 90◦ turns (S90◦), SBF = 9–3–6–3–9, RSSA, and YBT	Anaerobic, jumping, dynamic balance, and the ability to change directions and sprint significantly improved from before to after intervention.
2	(Muehlbauer et al., 2019)	IG, N = 10, age: 13.0 ± 0.9 CG, N = 10, age: 13.1 ± 0.1	BT + PT	6 weeks, 4 x per week, 15 to 26 min and including submaximal running, BT (beam walking forward and backward, unipedal stance on perturbation devices, et al), PT (skipping, hip in/out, submaximal multidirectional jumps)	YBT, SJ, CMJ, DJ, LST = 15m (with split time), and T-test	Significant pre to post-improvement in dynamic postural stability, power of lower limb, speed, and agility
3	(Hammami M. et al., 2020)	IG, N = 12, age: 16.2 ± 0.2 years, IG, N = 14, age: 16.3 ± 0.4 years CG, N = 12, age: 16.4 ± 0.2 years	UPT * LPT	10 weeks, 2 x per week, 2-6 repetitions, (sprint, 36-98 unilateral jumps, and 12-36 bilateral jumps. LPT positioned above the ankle joint had a mass of 2.5 percent of the total body weight.	LST = 40 m, CoD = sprint 180◦ turns (S180◦), SBF = 9–3–6–3–9, RSSA = 4 × 5 m sprints, CMJ, SJ, 5JT, YBT and SBT	Significant improvements in sprint, change direction, jump, repeat of changes direction, static and dynamic balance before to after the intervention.
4	(Chaalali et al., 2022)	N = 12, age: 16.6 ± 0.2 years IG, N = 6 CG, N = 6	RST + NRST	6 weeks, 2x per week, 2 sessions, 3 minutes interval set, 3-4 repetitions, sprint 10-30 m, distance cover per set 90-360 m., intensity 100%. (RST) The first stage consists of sprinting half the distance in four seconds before their partner releases the player to complete the second stage.	CMJ, SJ, 5JT, LST = 30 m (5, 10, 20m split times), and analysis of kinematics	Improvement in sprinting, strides frequency, lower-limb explosive force, and jump performance from before to after intervention.
5	(Zghal et al., 2019)	N = 30, age: 14.5 ± 0.52 years IG, N = 13	RT + PT * PT	7 weeks, 2x per week. Leg extension and press (60-80%	CMJ, SJ, DJ, knee extensor (KE) MVIC, LST = 5, 10, 20 m and CoD	Significant pre to post-improvement in peak torque, rate of torque development (RTD), RTD

(Contd...)

Table 2. *(Continued)*

No	Study	Subject	Type RE	Training Intervention	Measurement	Result
		IG, N = 9 CG, N = 8		1 RM, 2-3 sets x 6-8 rep.), Half squat, vertical hurdle, jump/sprint, stride hurdle (2-4 sets x 6-8 rep)		normalized to torque (RTDr, speed, and jump ability
6	(Barbalho et al., 2018)	IG, N = 11, age: 19.1 ± 0.9 years CG, N = 12, age: 18.8 ± 0.8 years	RT	15 weeks. 3 x per week, weeks 1, 5, 9, and 13 (12–15 RM with 30–60 s intervals), weeks 2, 6, and 10 and 14, (4–6 RM, 3–4 mins intervals), weeks 3, 7, 11 and 15 (10-12 RM, 1-2 mins interval), weeks 4, 8, and 12 (6–8 RM at 2–3 min intervals). Leg presses at 45 degrees, free squats with a bar, seat leg curls, and calf stands on the machine are some of the lower limb exercises, while the upper limb exercises consist of seat low row, bench press, shoulder press, triceps pulley, and biceps curl, and lateral pull down.	1 RM, LST = 40-yard, T-test, CMJ, SLJ	Significant pre-to post increase in 1 RM, Power lower max (CMJ and SLJ), speed, and agility
7	(Jlid et al., 2019)	IG, N = 14, age: 11.8 ± 0.4 years CG, N = 14, age: 11.6 ± 0.5 years	MPT	8 weeks, 2 x per week, 20–25 min, 54-124 ground contacts, alternating jumps and jumps with feet together, progressing in volume and intensity over the weeks	SJ, CMJ, T test, CoD, SEBT	Significant improvement in SJ, CMJ, CoD, and dynamic balance from pre to post-test
8	(Hammami R. et al., 2023)	IG, N = 12, age: 15.7 ± 0.6 years CG, N = 12; age: 15.4 ± 0.8 years	NT	8 weeks, 2 x per week, 2-3 sets, 5-10 reps. INT of 5 workouts in rest between sets (60-120s), and exercise (balance, half squat, side lunge with a medical ball 2 kg, plyometrics, CoD. The difficulty and intensity of INT	YBT, 1RM, 5 JT, SLH, CMJ, LST 10 and 30m, CoD with Ball	Dynamic balance, muscle strength, speed and jump performance pre-to post improvement.

(Contd...)

Table 2. *(Continued)*

No	Study	Subject	Type RE	Training Intervention	Measurement	Result
				were regularly adjusted every two weeks, while the training volume remained consistent.		
9	(Seong et al., 2022)	IG, N = 75, age: 14.28 ± 0.98 years CG, N = 104, age: 17.33 ± 0.84 years	RT + Aerobic	2 weeks off-season, 5 x per week with 150 mins, core muscle on interval/ circuit training (20 repetitions, 3–4 sets, 30 sec), Aerobic (80% 1RM HRmax, 30 seconds, 3-4 sets, 1-minute recovery). Inferior of body functional exercise (step, ladder coordination, jumps, turns, acceleration, and deceleration with rope at 60-70% of 1RM, 20 reps, 3-4 sets, 30 seconds recovery)	CDBT, SLJ, PTT, SLJ, and CoD	Improvement from pre to post in jump, speed, dynamic balance, back extensor, and flexor muscle strength, and reduction of differences between left and right leg
10	(Arslan et al., 2021)	N = 38, age: 16.50 ± 0.51 years IG, N = 20 CG, N = 18	CST + SSG	6-weeks, 3x per week, 3 x 25-50 sec, work relief 1:1, CST (push-up, push-up rotation, bird dog crunch, scissor kick, mountain climbing, full squat), SSGs (2-4 min, number of bouts 4, rest 3 mins.	LST = 5–20m, CMJ, SJ, TLH, ZA with or without ball, TCRT, YBT	Speed, agility, lower limb muscles power and strength, and balance improvement from pre-to post.
11	(Aloui et al., 2021)	IG, N = 18, age: 16.6 ± 0.5 years CG, N = 16, age: 16.6 ± 0.5 years	PT + SCoD	8 weeks, 2x per week, PT + SCoD of 4 workshop x 3 rep each workshop/ week. Ground contacts per session rose steadily from 72 to 144, and the number of sets for each workout increased from 3 to 6 sets.	SJ, CMJ, SLJ, LST = 5m, 20, CoD, RSA, SBT	Improvement from pre to post in jump performance, speed, agility, anaerobic performance, and static balance
12	(Makhlouf et al., 2018)	IG, N = 21, age: 11.29 ± 0.85 years IG, N = 20, age: 11.06 ± 0.75 years CG, N = 16, age: 10.98 ± 0.80 years	PT + BT * Agility + PT	8 weeks. 2x per week. BT (stand on Swiss ball by knee, unilateral and bilateral standing on an inflated disk progressing to squat, etc., 1-2 set/30-45 s or 8-15/ leg,PT (lateral hops, vertical, horizontal,	CMJ, TLH, RSI, MVIC, RSSA, Illinois, CoD, YBT, SBT, LST = 10–30 m	Improvement from pre to post in jump, back extensors, knee extensors muscle strength, agility, speed, static and dynamic balance

(Contd...)

Table 2. *(Continued)*

No	Study	Subject	Type RE	Training Intervention	Measurement	Result
				drop, jumps, etc., 1-2 set x 8-15 rep)		
13	(Dafkou et al., 2021)	IG, N = 11 age: 17.7 ± 1.15 years CG, N = 10 age: 18.1 ± 0.57 years	EBCM	8 weeks, 2 x per week, 16 sessions, 2-4 set x 6-10 rep. A hamstring eccentric exercise, 4 core-muscle, 5 single-leg balance variations (4-6 set x 30-45 sec)	Strength tests (3 subs and three maximum concentric and eccentric at 30◦/s, 180◦/s, and 240◦/s), balance test, and bridge test (trunk movement stability)	Significant increase of isokinetic, concentric hamstring strength, reduction in center of pressure sways in a stance on the non-dominant leg.
14	(Gasim et al., 2022)	IG, N = 6, age: 17.2 ± 0.4 years IG, N = 6, age: 17.3 ± 0.5 years CG, N = 6, age, 17.7 ± 0.5 years	PT + CST	8 weeks, 2x per week, PT = 1-2 sets x 6-10 rep (1-4 weeks), 1-2 sets x 8-12 rep. (5 -week), CST = 1-4 sets x 15 reps. or sec (1-4 weeks), 2-4 sets x 15 reps. or sec(5-8 weeks) CST (plank + side, crunch on Pilates ball, back extension on Pilates, hip raise, dog kick (right & left)	YBT	Significant improvement pre to post in anterior and posteromedial directions in the dominant leg, anterior, posteromedial, and posterolateral in the non-dominant leg.

Abbreviation and symbols: IG = Intervention Groups, CG = Control Groups, PT = Plyometric Training, RT = Resistance Training, SPT = Short Sprint Training, BT = Balance Training, UPT = Unloaded Plyometric Training, LPT = Loaded Plyometric Training, RST = Resisted Sprint Training, NRST = No resisted Sprint Training, MPT = Multidirectional Plyometric Training, INT = Integrative Neuromuscular Training, CST = Core Strength Training, SSG = Small-Sided Games, SCoD = Sprint With Change-Of-Direction, EBCM = Eccentric Balance and Core Muscles Exercises, SJ = Squat Jump test, SLJ = Standing Long Jump test, DJ = Drop Jump test, CMJ = Countermovement Jump test, 5JT = 5 jump test, SLH = single leg hop test, TLH = Triple Leg Hop test, LST = Linear Sprint Test, CoD = Change of Direction test, SBF = Sprints Backward And Forward, RSSA = repeated shuttle sprint ability, RSA = Repeat Sprint ability, YBT = Y balance test , SBT = Stork Balance test, SEBT = Star Excursion Balance Test, CDBT = Core dynamic balance test, RSI = Reactive Strength Index, MVIC = Maximal Voluntary Isometric Contraction, 1 RM = one repetition maximum, PTT = Peak Torque Test, ZA = Zigzag Agility Test, TCRT = Three Corner Run Test. Symbol = (+) Combination, (*) Versus

Kozinc, 2020), training interventions to enhance balance ability should be of sufficient duration (at least four weeks) and follow general resistance exercise principles.

Resistance exercise significantly improves strength and power in the lower body of young footballers by integrating with football-specific training. The evaluation of anaerobic performance has been extensively used to assess short-term power action (Cossio-Bolaños et al., 2021; Gross & Lüthy, 2020; Haugen et al., 2013; Ostojić et al., 2010). Anaerobic characteristics in football include explosive actions in various jumps, sprints, changes of movement directions, acceleration, and other short intense actions. The simultaneous use of resistance and plyometric exercises improved strength, sprinting, and jumping performance compared to plyometric alone (Zghal et al., 2019). Unilateral lower limb plyometric training significantly enhanced the strength and power of football players compared to bilateral or football training alone (Drouzas et al., 2020). Combinations of multiple resistance models (Aloui et al., 2022; Arslan et al., 2021), agility and plyometric training (Makhlouf et al., 2018), aerobic and resistance training (Seong et al., 2022), and resistance and plyometric training (Hammami et al., 2020; Zghal et al., 2019), demonstrated improvements in anaerobic performance, including short explosive force, sprinting, jumping, change of direction, and repeated sprint ability.

A crossbreed of morphological and neural factors supports muscular strength development (Suchomel et al., 2018). Moreover, the baseline of strength (Buckner et al., 2017), the quality of resistance exercise, and genetics (Yang et al., 2003) influence the improvement of anaerobic performance. The relationship between maturity and training-related neuromuscular adaptations remains ambiguous (Silva et al., 2022; Kumar et al., 2021). Growth and maturation significantly affect muscle-tendon and neuromuscular adaptations (Radnor et al., 2018) (Hiort, 2002). However, contrary evidence (Perroni et al., 2024) stated that physical performance might be negatively associated with chronological age, relative age, and pubertal status.

In this review, the combination of resistance exercise models may have the most significant potential to increase muscular strength and power. Resistance exercise models propose the flexibility to manage loads and intensities within a single training session. The various exercises can provide a new stimulus when training is tedious and needs a new variation and challenge. Through various resistance exercise models, instructors and coaches could present high-load exercises to maintain or increase strength and low-load training to build power and speed. Future research should look into these links, especially the possibility of using integrated resistance exercises to improve anaerobic performance, and static and dynamic balance considering football players' chronological ages and puberty stages.

The review article provides valuable insights into the impact of resistance exercise on anaerobic and balance performance in adolescent football players. However, we need to address some methodological limitations. The selection of studies may be biased due to the exclusion of abstracts, titles, or studies published in non-peer-reviewed journals. The anaerobic and balance of young male players aged 10 to 19 consistently improve with resistance exercise interventions, and these results must be carefully chosen before application to the specific population group.

Strength and Practical Implication

According to the findings of the articles reviewed in the present study, various resistance exercise models positively improve the characteristics of anaerobic and balance in adolescent football players. In addition, the plural type of exercise is plyometric, which has multiple movements such as jumping and sprinting that align well with the demands of football games. Integrating resistance exercise into regular training is more beneficial than stand-alone. Young football players should undergo training intervention for about eight weeks, 2-3 times weekly on developing anaerobic and balance performance. In addition, strength and conditioning coaches should prescribe these, considering specific resistance exercise loads in young football players.

CONCLUSION

Interventions of different resistance exercise models improve young footballers' anaerobic and balance performance, encompassing muscular strength and power development. Incorporating the resistance exercise into routine football training sessions was highly recommended due to safety and efficiency for young football players. Moreover, resistance exercise presents diverse movements and technical advantages that improve other physical demands in football games. Resistance programs took place two or three times each week throughout eight weeks. The volume training consists of 2-3 sets of 6-12 repetitions, with moderate to high intensity. The study provided practical insights for trainers and coaches to enhance anaerobic and balance performance and overall physical fitness in young football players. However, current findings should be considered cautiously due to methodological limitations, high variability in assessing anaerobic and balance parameters, and training dosages among studies.

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DATA AVAILABILITY

The data presented in this study are available on request from the corresponding author.

ETHICAL APPROVAL

Ethical approval was not required because the study is unrelated to humans or animals.

AUTHOR CONTRIBUTIONS

Conceptualization, ARS, and IP. Methodology, ARS, and IP. Software, ARS, Investigation, ARS, and IP. Manuscript writing, ARS, and IP. Visualization, ARS. Supervision, IP. All authors have read and approved the final versions of the manuscripts.

REFERENCES

Aloui, G., Hermassi, S., Bartels, T., Hayes, L. D., Bouhafs, E. G., Chelly, M. S., & Schwesig, R. (2022). Combined Plyometric and Short Sprint Training in U-15 Male Soccer Players: Effects on Measures of Jump, Speed, Change of Direction, Repeated Sprint, and Balance. *Frontiers in Physiology*, 13, 757663. https://doi.org/10.3389/fphys.2022.757663

Aloui, G., Hermassi, S., Hayes, L. D., Hayes, N. E. M. S., Bouhafs, E. G., Chelly, M. S., & Schwesig, R. (2021). Effects of plyometric and short sprint with change-of-direction training in male u17 soccer players. *Applied Sciences (Switzerland),* 11(11). https://doi.org/10.3390/app11114767

AlTaweel, A., Nuhmani, S., Ahsan, M., Al Muslem, W. H., Abualait, T., & Muaidi, Q. I. (2022). Analysis of the Anaerobic Power Output, Dynamic Stability, Lower Limb Strength, and Power of Elite Soccer Players Based on Their Field Position. *Healthcare (Basel, Switzerland),* 10(11), 2256. https://doi.org/10.3390/healthcare10112256

Arslan, E., Soylu, Y., Clemente, F. M., Hazir, T., Isler, A. K., & Kilit, B. (2021). Short-term effects of on-field combined core strength and small-sided games training on physical performance in young soccer players. *Biology of Sport*, 38(4), 609–616. https://doi.org/10.5114/biolsport.2021.102865

Bangsbo, J., Iaia, F. M., & Krustrup, P. (2007). Metabolic response and fatigue in soccer. *International Journal of Sports Physiology and Performance*, 2(2), 111–127. https://doi.org/10.1123/IJSPP.2.2.111

Barbalho, M., Gentil, P., Raiol, R., Del Vecchio, F. B., Ramirez-Campillo, R., & Coswig, V. S. (2018). Non-linear resistance training program induced power and strength but not linear sprint velocity and agility gains in young soccer players. *Sports*, 6(2), 43. https://doi.org/10.3390/sports6020043

Beunen, G. P., Malina, R. M., Renson, R., Simons, J., Ostyn, M., & Lefevre, J. (1992). Physical activity and growth, maturation, and performance: a longitudinal study. *Medicine and Science in Sports and Exercise*, *24*(5), 576–585. https://europepmc.org/article/med/1569854

Billot, M., Martin, A., Paizis, C., Cometti, C., & Babault, N. (2010). Effects of an electrostimulation training program on strength, jumping, and kicking capacities in soccer players. *Journal of Strength and Conditioning Research*, 24(5), 1407–1413. https://doi.org/10.1519/JSC.0B013E3181D4370

Bishop, C., Turner, A., & Read, P. (2018). Effects of inter-limb asymmetries on physical and sports performance: a systematic review. *Journal of Sports Sciences*, 36(10), 1135–1144. https://doi.org/10.1080/02640414.2017.1361894

Bongers, B. C., Werkman, M. S., Blokland, D., Eijsermans, M. J. C., Van Der Torre, P., Bartels, B., Verschuren, O., & Takken, T. (2015). Validity of the Pediatric Running-Based Anaerobic Sprint Test to Determine Anaerobic Performance in Healthy Children. *Pediatric Exercise Science*, *27*(2), 268–276. https://doi.org/10.1123

Brown, S. R., Brughelli, M., & Lenetsky, S. (2018). Profiling Single-Leg Balance by Leg Preference and Position in Rugby Union Athletes. *Motor Control*, 22(2), 183–198. https://doi.org/10.1123/MC.2016-0062

Buckner, S. L., Mouser, J. G., Jessee, M. B., Dankel, S. J., Mattocks, K. T., & Loenneke, J. P. (2017). What does individual strength say about resistance training status? *Muscle & Nerve*, 55(4), 455–457. https://doi.org/10.1002/mus.25461

Burns, P. B., Rohrich, R. J., & Chung, K. C. (2011). The Levels of Evidence and their role in Evidence-Based Medicine. *Plastic and Reconstructive Surgery*, *128*(1), 305. https://doi.org/10.1097/PRS.0B013E318219C171

Butler, R. J., Southers, C., Gorman, P. P., Kiesel, K. B., & Plisky, P. J. (2012). Differences in Soccer Players' Dynamic Balance Across Levels of Competition. J*ournal of Athletic Training*, 47(6), 616. https://doi.org/10.4085/1062-6050-47.5.14

Çakir-Atabek, H. (2014). Relationship between anaerobic power, vertical jump and aerobic performance in adolescent track and field athletes. *Journal of Physical Education and Sport*, *14*(4), 643–648. https://doi.org/10.7752/jpes.2014.04100

Chaalali, A., Bouriel, K., Rouissi, M., Chtara, M., Mkaouer, B., Cronin, J., Chaouachi, A., & Chamari, K. (2022). Resisted sprint training with partner towing improves explosive force and sprint performance in young soccer players – A pilot study. *Biology of Sport*, 39(2), 379–387. https://doi.org/10.5114/biolsport.2022.103574

Cinarli, F. S., Adanur, O., Esen, O., Barasinska, M., Cepicka, L., Gabrys, T., & Karayigit, R. (2022). Relationship between Unilateral Leg Extension Strength and Dynamic Balance in Healthy Young Men. *Applied Sciences*, 12(18). https://doi.org/10.3390/APP12188985

Cossio-Bolaños, M., Vidal-Espinoza, R., Albornoz, C. U., Portella, D. L., Vega-Novoa, S., Mendez-Cornejo, J., Lopez, J. F., & Gomez-Campos, R. (2021). A systematic review of intervention programs that produced changes in speed and explosive strength in youth footballers. *European Journal of Translational Myology*, *31*(3). https://doi.org/10.4081/EJTM.2021.9692

Dafkou, K., Sahinis, C., Ellinoudis, A., & Kellis, E. (2021). Is the integration of additional eccentric, balance, and core muscles exercises into a typical soccer program effective in improving strength and postural stability? *Sports*, 9(11). https://doi.org/10.3390/sports9110147

Drouzas, V., Katsikas, C., Zafeiridis, A., Jamurtas, A. Z., & Bogdanis, G. C. (2020). Unilateral Plyometric Training is Superior to Volume-Matched Bilateral Training for Improving Strength, Speed, and Power of Lower Limbs in Preadolescent Soccer Athletes. *Journal of Human Kinetics*, 74(1), 161–176. https://doi.org/10.2478/hukin-2020-0022

Duarte Junior, M. A., Gaya, A. R., Mello, J. B., Faigenbaum, A. D., García-Hermoso, A., & López-Gil, J. F. (2024). Meeting muscle-strengthening recommendation is associated with lower adiposity, higher physical fitness, and healthier lifestyle in adolescents: The EHDLA study. *Acta Paediatrica, International Journal of Paediatrics*, 113(5), 1059–1067. https://doi.org/10.1111/apa.17126

Evangelos, B., Georgios, K., Konstantinos, A., Gissis, I., Papadopoulos, C., & Aristomenis, S. (2012). Proprioception and balance training can improve amateur soccer players' technical skills. *Journal of Physical Education and Sport*, 12(1), 81–89.

Evangelos, B., Lefteris, M., Aristotelis, G. Ioannis, G., & Kombodieta N. (2016). Original Article Aerobic and anaerobic capacity of professional soccer players in annual macrocycle. *Journal of Physical Education and Sport*, 16(2), 527–533. https://doi.org/10.7752/jpes.2016.02083

Faigenbaum, A. D., Kraemer, W. J., Blimkie, C. J. R., Jeffreys, I., Micheli, L. J., Nitka, M., & Rowland, T. W. (2009). Youth resistance training: updated position statement paper from the National Strength and Conditioning Association. *Journal of Strength and Conditioning Research*, 23(5 Suppl). https://doi.org/10.1519/jsc.0b013e31819df407

Falces-Prieto, M., González-Fernández, F. T., García-Delgado, G., Silva, R., Nobari, H., & Clemente, F. M. (2022). Relationship between sprint, jump, dynamic balance with the change of direction on young soccer players' performance. *Scientific Reports*, 12(1), 1–9. https://doi.org/10.1038/s41598-022-16558-9

Falces-Prieto, M., Raya-González, J., de Villarreal, E. S., Rodicio-Palma, J., Iglesias-García, F. J., & Fernández, F. T. G. (2021). Effects of combined plyometric and sled training on vertical jump and linear speed performance in young soccer players. *Retos*, 42, 228–235. https://doi.org/10.47197/retos.v42i0.86423

Fernández-Galván, L. M., Casado, A., García-Ramos, A., & Haff, G. G. (2022). Effects of Vest and Sled Resisted Sprint Training on Sprint Performance in Young Soccer Players: A Systematic Review and Meta-analysis. Jo*urnal of Strength and Conditioning Research*, 36(7), 2023–2034. https://doi.org/10.1519/JSC.0000000000004255

Gasim, Z. K., Cengizel, E., & Günay, M. (2022). Core Vs Plyometric Training Effects on Dynamic Balance in Young Male Soccer Players. *Revista Brasileira de Medicina Do Esporte*, 28(4), 326–330. https://doi.org/10.1590/1517-8692202228042021_0048

González-Badillo, J. J., Pareja-Blanco, F., Rodríguez-Rosell, D., Abad-Herencia, J. L., Del Ojo-López, J. J., & Sánchez-Medina, L. (2015). Effects of velocity-based resistance training on young soccer players of different ages. *Journal of Strength and Conditioning Research*, 29(5), 1329–1338. https://doi.org/10.1519/JSC.0000000000000764

Gross, M., & Lüthy, F. (2020). Anaerobic power assessment in athletes: Are cycling and vertical Jump tests interchangeable? *Sports*, *8*(5). https://doi.org/10.3390/sports8050060

Hammami, M., Gaamouri, N., Suzuki, K., Aouadi, R., Shephard, R. J., & Chelly, M. S. (2020). Effects of unloaded vs. Ankle-loaded plyometric training on the physical fitness of U-17 male soccer players. *International Journal of Environmental Research and Public Health*, 17(21), 1–18. https://doi.org/10.3390/ijerph17217877

Hammami, R., Negra, Y., Nebigh, A., Ramirez-Campillo, R., Moran, J., & Chaabene, H. (2023). Preseason Integrative Neuromuscular Training Improves Selected Measures of Physical Fitness in Highly Trained, Youth, Male Soccer Players. *Journal of Strength and Conditioning Research*, 37(6). https://doi.org/10.1519/JSC.0000000000004394

Harries, S. K., Lubans, D. R., & Callister, R. (2012). Resistance training to improve power and sports performance in adolescent athletes: a systematic review and meta-analysis. *Journal of Science and Medicine in Sport*, 15(6), 532–540. https://doi.org/10.1016/j.jsams.2012.02.005

Haugen, T. A., Tønnessen, E., & Seiler, S. (2013). Anaerobic performance testing of professional soccer players 1995-2010. *International Journal of Sports Physiology and Performance*, *8*(2), 148–156. https://doi.org/10.1123/IJSPP.8.2.148

Hiort, O. (2002). Androgens and puberty. *Best Practice and Research: Clinical Endocrinology and Metabolism*, *16*(1), 31–41. https://doi.org/10.1053/beem.2002.0178

Jlid, M. C., Racil, G., Coquart, J., Paillard, T., Bisciotti, G. N., & Chamari, K. (2019). Multidirectional Plyometric Training: Very Efficient Way to Improve Vertical Jump Performance, Change of Direction Performance and Dynamic Postural Control in Young Soccer Players. *Frontiers in Physiology*, 10. https://doi.org/10.3389/fphys.2019.01462

Kim, H. K., & Chou, L. S. (2022). Lower limb muscle activation in response to balance-perturbed tasks during walking in older adults: A systematic review. *Gait & Posture*, 93, 166–176. https://doi.org/10.1016/j.gaitpost.2022.02.014

Lloyd, R. S., Faigenbaum, A. D., Stone, M. H., Stone, J. L., Jeffreys, I., Moody, J. A., Brewer, C., Pierce, K. C., McCambridge, T. M., Howard, R., Herrington, L., Hainline, B., Micheli, L. J., Jaques, R., Kraemer, W. J., McBride, M. G., Best, T. M., Chu, D. A., Alvar, B. A., & Myer, G. D. (2014). Position statement on youth resistance training: the 2014 International Consensus. *British Journal of Sports Medicine,* 48(7), 498–505. https://pubmed.ncbi.nlm.nih.gov/24055781

Lockie, R. G., Jalilvand, F., Jordan, C. A., Callaghan, S. J., Jeffriess, M. D., Luczo, T. M., & Schultz, A. B. (2018). The Relationship between Unilateral Dynamic Stability and Multidirectional Jump Performance in Team Sport Athletes. *Sport Science Review,* 24(5–6), 321–344. https://doi.org/10.1515/ssr-2015-0022

Loturco, I., Pereira, L. A., Reis, V. P., Bishop, C., Zanetti, V., Alcaraz, P. E., Freitas, T. T., & Mcguigan, M. R. (2020). Power training in elite young soccer players: Effects of using loads above or below the optimum power zone. *Journal of Sports Sciences*, 38(11–12), 1416–1422. https://doi.org/10.1080/02640414.2019.1651614

Maher, C. G., Sherrington, C., Herbert, R. D., Moseley, A. M., & Elkins, M. (2003). Reliability of the PEDro Scale for Rating Quality of Randomized Controlled Trials. *Physical Therapy*, *83*(8), 713–721. https://doi.org/10.1093/PTJ/83.8.713

Makhlouf, I., Chaouachi, A., Chaouachi, M., Othman, A. Ben, Granacher, U., & Behm, D. G. (2018). Combination of agility and plyometric training provides similar training benefits as combined balance and plyometric training in young soccer players. *Frontiers in Physiology*, 9(NOV). https://doi.org/10.3389/fphys.2018.01611

Martinez-Perez, P., & Vaquero-Cristobal, R. (2021). Systematic review of strength training in preadolescent and adolescent football players. *Retos-Nuevas Tendencias En Educacion Fisica Deporte Y Recreacion*, 2021(41), 272–284.

Methley, A. M., Campbell, S., Chew-Graham, C., McNally, R., & Cheraghi-Sohi, S. (2014). PICO, PICOS, and SPIDER: A comparison study of specificity and sensitivity in three search tools for qualitative systematic reviews*. BMC Health Services Research*, 14(1), 1–10. https://doi.org/10.1186/S12913-014-0579-0/TABLES/7

Mirwald, R. L., G. Baxter-Jones, A. D., Bailey, D. A., & Beunen, G. P. (2002). An assessment of maturity from anthropometric measurements. *Medicine and Science in Sports and Exercise*, *34*(4), 689–694. https://doi.org/10.1097/00005768-200204000-00020

Moore, S. A., McKay, H. A., Macdonald, H., Nettlefold, L., Baxter-Jones, A. D. G., Cameron, N., & Brasher, P. M. A. (2015). Enhancing a Somatic Maturity Prediction Model. *Medicine and Science in Sports and Exercise*, *47*(8), 1755–1764. https://doi.org/10.1249/MSS.0000000000000588

Morton de, N. A. (2009). The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. *The Australian Journal of Physiotherapy*, *55*(2), 129–133. https://doi.org/10.1016/S0004-9514(09)70043-1

Muehlbauer, T., Wagner, V., Brueckner, D., Schedler, S., Schwiertz, G., Kiss, R., & Hagen, M. (2019). Effects of a blocked versus an alternated sequence of balance and plyometric training on physical performance in youth soccer players. *BMC Sports Science*, Medicine, and Rehabilitation, 11(1). https://doi.org/10.1186/s13102-019-0131-y

Naclerio, F., Faigenbaum, A. D., Larumbe-Zabala, E., Perez-Bibao, T., Kang, J., Ratamess, N. A., & Triplett, N. T. (2013). Effects of different resistance training volumes on strength and power in team sport athletes. *Journal of Strength and Conditioning Research*, 27(7), 1832–1840. https://doi.org/10.1519/JSC.0b013e3182736d10

Nikolaidis, P. T., Matos, B., Clemente, F. M., Bezerra, P., Camões, M., Rosemann, T., & Knechtle, B. (2018). Normative Data of the Wingate Anaerobic Test in 1 Year Age Groups of Male Soccer Players. *Frontiers in Physiology,* 9(NOV), 1619. https://doi.org/10.3389/fphys.2018.01619

Nikolaidis, P. (2011). Anaerobic power across adolescence in soccer players. *Human Movement, 12*(4), 342–347. doi: 10.2478/v10038-011-0039-1

Nobari, H., Alves, A. R., Clemente, F. M., Pérez-Gómez, J., Clark, C. C. T., Granacher, U., & Zouhal, H. (2021). Associations Between Variations in Accumulated Workload and Physiological Variables in Young Male Soccer Players Over the Course of a Season. *Frontiers in Physiology,* 12, 233. https://doi.org/10.3389/FPHYS.2021.638180

Nuñez, J., Suarez-Arrones, L., De Hoyo, M., & Loturco, I. (2022). Strength Training in Professional Soccer: Effects on Short-sprint and Jump Performance. *International Journal of Sports Medicine*, 43(6), 485–495. https://doi.org/10.1055/A-1653-7350

Ostojić, S. M., Stojanović, M., & Ahmetović, Z. (2010). Vertical jump as a tool in assessment of muscular power and anaerobic performance]. *Medicinski Pregled*, *63*(5–6), 371–375. https://doi.org/10.2298/MPNS1006371O

Otero-Esquina, C., de Hoyo Lora, M., Gonzalo-Skok, Ó., Domínguez-Cobo, S., & Sánchez, H. (2017). Is strength-training frequency a key factor to develop performance adaptations in young elite soccer players? *European Journal of Sport Science*, 17(10), 1241–1251. https://doi.org/10.1080/17461391.2017.1378372

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S.,… Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ (Clinical Research Ed.)*, 372. https://doi.org/10.1136/BMJ.N71

Paillard, T. (2017). Plasticity of the postural function to sport and/or motor experience. *Neuroscience and Biobehavioral Reviews*, 72, 129–152. https://doi.org/10.1016/j.neubiorev.2016.11.015

Paillard, T., & Noé, F. (2020). Does monopedal postural balance differ between the dominant leg and the non-dominant leg? A review. *Human Movement Science*, *74*, 102686. https://doi.org/10.1016/J.HUMOV.2020.102686

Pau, M., Ibba, G., & Attene, G. (2014). Fatigue-induced balance impairment in young soccer players. *Journal of Athletic Training*, 49(4), 454–461. https://doi.org/10.4085/1062-6050-49.2.12

Pau, M., Arippa, F., Leban, B., Corona, F., Ibba, G., Todde, F., et al. (2015). Relationship between static and dynamic balance abilities in Italian professional and youth league soccer players. *Phys. Ther. Sport,* 16, 236–241. https://doi.org/10.1016/j.ptsp.2014.12.003

Perroni, F., Amatori, S., Corsi, L., Bensi, R., Guidetti, L., Baldari, C., Rocchi, M. B. L., Castagna, C., Gobbi, E., Sisti, D., & Buzzachera, C. F. (2024). Assessment of Performance in Youth Soccer Players: Should We Consider the Maturation Status? *Journal of Human Kinetics*, *93*, 119–131. https://doi.org/10.5114/jhk/184276

Radnor, J. M., Oliver, J. L., Waugh, C. M., Myer, G. D., Moore, I. S., & Lloyd, R. S. (2018). The Influence of Growth and Maturation on Stretch-Shortening Cycle Function in Youth. *Sports Medicine (Auckland, N.Z.)*, *48*(1), 57–71. https://doi.org/10.1007/S40279-017-0785-0

Šarabon, N., & Kozinc, Ž. (2020). Effects of Resistance Exercise on Balance Ability: Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Life (Basel, Switzerland)*, 10(11), 1–16. https://doi.org/10.3390/life10110284

Seong, D., Seo, B. U., & Kim, S. H. (2022). The effects of combined aerobic and resistance training program in Korean male youth soccer players. Journal of Men's Health, 18(5). https://doi.org/10.31083/j.jomh1805115

Silva, A. F., Ramirez-Campillo, R., Ceylan, H. İ., Sarmento, H., & Clemente, F. M. (2022). Effects of Maturation Stage on Sprinting Speed Adaptations to Plyometric Jump Training in Youth Male Team Sports Players: A Systematic Review and Meta-Analysis. *Open Access Journal of Sports Medicine*, *13*, 41–54. https://doi.org/10.2147/OAJSM.S283662

Steinberg, N., Nemet, D., Pantanowitz, M., Zeev, A., Hallumi, M., Sindiani, M., Meckel, Y., & Eliakim, A. (2016). Longitudinal Study Evaluating Postural Balance of Young Athletes. *Perceptual and Motor Skills,* 122(1), 256–279. https://doi.org/10.1177/0031512516628989

Suarez-Arrones, L., Lara-Lopez, P., Torreno, N., de Villarreal, E. S., Di Salvo, V., & Mendez-Villanueva, A. (2019). Effects of Strength Training on Body Composition in Young Male Professional Soccer Players. *Sports*, 7(5). https://doi.org/10.3390/sports7050104

Suchomel, T. J., Nimphius, S., Bellon, C. R., & Stone, M. H. (2018). The Importance of Muscular Strength: Training Considerations. *Sports Medicine (Auckland, N.Z.)*, 48(4), 765–785. https://doi.org/10.1007/S40279-018-0862-Z

Tumkur Anil Kumar, N., Oliver, J. L., Lloyd, R. S., Pedley, J. S., & Radnor, J. M. (2021). The Influence of Growth, Maturation and Resistance Training on Muscle-Tendon and Neuromuscular Adaptations: A Narrative Review. *Sports (Basel, Switzerland)*, *9*(5). https://doi.org/10.3390/sports9050059

Wilczyński, B., Hinca, J., Ślęzak, D., & Zorena, K. (2021). The relationship between dynamic balance and jumping tests among adolescent amateur rugby players. A preliminary study. *International Journal of Environmental Research and Public Health*, 18(1), 1–10. https://doi.org/10.3390/ijerph18010312

Yamato, T. P., Maher, C., Koes, B., & Moseley, A. (2017). The PEDro scale had acceptably high convergent validity, construct validity, and interrater reliability in evaluating methodological quality of pharmaceutical trials. *Journal of Clinical Epidemiology*, *86*, 176–181. https://doi.org/10.1016/J.JCLINEPI.2017.03.002

Yang, N., MacArthur, D. G., Gulbin, J. P., Hahn, A. G., Beggs, A. H., Easteal, S., & North, K. (2003). ACTN3 genotype is associated with human elite athletic performance. *American Journal of Human Genetics*, 73(3), 627–631. https://doi.org/10.1086/377590

Yu, X., Kamalden, T. F. T., Dev, R. D. O., Gasibat, Q., Rani, B., Dai, Y., Bao, L., & Li, J. (2023). Effects of Combining Physical and Cognitive Training on Older Adults' Physical Performance and Functional Abilities: A Systematic Review. *International Journal of Kinesiology and Sports Science*, *11*(2), 35–50. https://doi.org/10.7575/aiac.ijkss.v.11n.2p.35

Zemková, E., & Zapletalová, L. (2022). The Role of Neuromuscular Control of Postural and Core Stability in Functional Movement and Athlete Performance. *Frontiers in Physiology*, 13. https://pubmed.ncbi.nlm.nih.gov/35283763

Zghal, F., Colson, S. S., Blain, G., Behm, D. G., Granacher, U., & Chaouachi, A. (2019). Combined resistance and plyometric training is more effective than plyometric training alone for improving physical fitness of pubertal soccer players. *Frontiers in Physiology*, 10. https://doi.org/10.3389/fphys.2019.01026

Zwolski, C., Quatman-Yates, C., & Paterno, M. V. (2017). Resistance Training in Youth: Laying the Foundation for Injury Prevention and Physical Literacy. *Sports Health*, 9(5), 436–443. https://doi.org/10.1177/1941738117704153