Central European Journal of Sport Sciences and Medicine | Vol. 46, No. 2/2024: 89–101
ISSN (print): 2300-9705 | ISSN (online): 2353-2807 | DOI: 10.18276/cej.2024.2-08

THE EFFECTS OF TRAINING WITH ADDITIONAL WEIGHT SHORTS ON PHYSICAL PERFORMANCE OF ADOLESCENT SOCCER PLAYERS

Efthimios Bogiatzidis[A, B, D]

Department of Physical Education and Sport Sciences, Democritus University of Thrace, Komotini, Greece
ORCID: 0000-0001-6017-9792 | e-mail: ebogiatz@phyed.duth.gr

Ioannis Ispyrlidis[A, B]

Department of Physical Education and Sport Sciences, Democritus University of Thrace, Komotini, Greece
ORCID: 0000-0002-2932-6632

Vassilios Gourgoulis[A, C]

Department of Physical Education and Sport Sciences, Democritus University of Thrace, Komotini, Greece
ORCID: 0000-0001-6857-2564

Aikaterini Bogiatzidou[D]

Department of Psychology, Aristotle University of Thessaloniki, Greece
ORCID: 0000-0003-1105-711X

Ilias Smilios[A, D]

Department of Physical Education and Sport Sciences, Democritus University of Thrace, Komotini, Greece
ORCID: 0000-0002-7330-3198

[A] Study Design; [B] Data Collection; [C] Statistical Analysis; [D] Manuscript Preparation

Abstract This study examined the effects of an on field combined strength/speed/soccer training program on the physical performance of 20 male adolescent (age: 14.0 ±0.7 years) soccer players, who were divided into an experimental and a control group (EG, CG). The EG players wore "weight shorts", with 300 gr of additional weight on each thigh and participated 2 times/week in a 12-week training intervention program. The CG followed the same training program without wearing the "weight shorts". The physical abilities were evaluated the week before (pre) and two days after the 12-week intervention training period (post) and the follow-up evaluation was performed 4 weeks after the post measurement. The measured parameters were: a) sprint/repeated sprint ability (straight and with 180° turns, RSA-best/mean/total), b) RSA fatigue-index, c) vertical jump ability and d) lower body maximal strength. The EG improved significantly more ($p < 0.05$) compared to the CG on 10-m-straight, 30-, 35-, 40-m with 180° turns RSAbest-sprints, RSA fatigue-index, squat jump, leg curl (single right/left leg) and in split squat (single right/left leg) 5RM load. Using special shorts with additional weights on the thighs during soccer training improved speed/RSAbest-times and fatigue-index, jump ability and lower limbs maximal strength in youth soccer players.

Key words: youth, lower limbs, speed, strength, power

Introduction

Soccer is a sport of intermittent efforts, in which sudden variations in both the intensity of the game and the type of actions or motor tasks occur continuously (Cossio-Bolaños et al., 2021). During the game on average, every 2 to 4 seconds, soccer players perform a total of 1200–1400 of intensive actions (Škomrlj et al., 2022). Typical soccer movements such as tackling, jumping, sprinting, shooting, and rapid change-of-directions (COD) require high levels of physical fitness and they are crucial for optimal performance not only in adult but also in youth soccer (Zghal et al., 2019). In various youth age groups, including 13–18 years (Murtagh et al., 2018), it has been shown that strength, jump and sprint performances clearly differentiate between elite and sub-elite youth level soccer players (Stewart et al., 2014). Developing a high level of muscular strength is a decisive goal in preparing for competition as stronger soccer players perform better (Fischerova et al., 2021) and are more resilient to fatigue, possess greater capacity to preserve power output at a given intensity and greater repeated sprint ability (RSA) tasks (Yu et al., 2020). Especially the lower-limb muscles play a crucial role, and are mostly used during jumps, sprints, changes of direction and kicks (Beato et al., 2021). Thus, soccer players must both manage technical and tactical tasks and use appropriate strength training programs which could enhance several explosive actions that are crucial to the result of the game (Rodriguez-Rosel et al., 2017).

Previous studies were conducted to enhance athletic performance in youth soccer players with several types of strength training (e.g., machine based, free weight or combined, plyometric/complex/functional training), training periods, intensities, volumes and exercise choices. Some of them demonstrated positive findings of general and soccer-specific performance and others not (Granacher et al., 2016). Among them, some studies applied resistance training additionally to soccer training (Christou et al., 2006), plyometric exercises into the regular soccer training (Negra et al., 2018), complex training (combining resistance and plyometric training) additionally to regular soccer training (Hammami et al., 2017) and only one study applied strength training by performing specific soccer movements with additional weight during regular soccer training (Bogiatzidis et al., 2022). In the above studies, some significant differences were observed between the experimental and control groups, specifically in maximal strength of the upper and/or the lower body (Christou et al., 2006; Bogiatzidis et al., 2022), in sprint times during 5- to 40- meters and in RSA (Hammami et al., 2017; Negra et al., 2018), in vertical jump height (CMJ, SJ or DJ) (Christou et al., 2006; Negra et al., 2018; Bogiatzidis et al., 2022) and in agility (Christou et al., 2006; Hammami et al., 2017).

Strength training must be integrated into sport skills training (Hammami et al., 2017) to enhance motor performance and to reduce the risk of sports related injuries. Thus, youth athletes may benefit from implementing muscular fitness enhancing exercises in their regular training (Granacher et al., 2016). In this context, training equipment which could be used by any team and is portable and relatively inexpensive can provide positive training effects. As far as we know, only one study has examined the effects of an on-field strength training for the lower limbs on adolescents using portable wearable training equipment such as additional weights on the thighs into regular soccer training (Bogiatzidis et al., 2022). The current study is the evolution based on this previous pilot study and the purpose was to examine the effects of an on-field lower limbs' combined strength and speed/soccer training program into regular soccer training using portable wearable equipment on physical performance of youth soccer players. It was hypothesized that taking part for 12 weeks in targeted speed/soccer training sessions, while wearing special-construction Additional Weight Shorts (AWS) with 300 gr on each thigh as strength load, would improve speed, RSA performance, maximal strength and jump ability of youth soccer players.

Methods

Participants

Twenty male regional soccer players, aged 14.0 ±0.7 years, voluntarily participated in the current study. The players and their parents were informed about the nature and the aim of the study, its benefits and risks. Afterwards, the parents signed an informed consent form which was approved by the University's institutional review board and ethics committee. All the procedures were in accordance with the Declaration of Helsinki. The participants were randomly separated into an experimental group (EG; N = 10) and a control group (CG; N = 10) (Table 1).

Table 1. Mean and standard deviation of the participants' characteristics before the intervention

	Experimental Group (N = 10)	Control Group (N = 10)
Age (years)	14.1 ± 0.7	13.8 ± 0.8
Training Age (years)	7.0 ± 2.7	5.8 ± 3.5
Height (m)	1.72 ± 0.08	1.73 ± 0.06
Weight (kg)	64.1 ± 12.8	64.3 ± 8.14
BMI (kg/m^2)	21.45 ± 2.92	21.38 ± 2.21
Waist Circumference (cm)	70.50 ± 6.25	71.50 ± 5.48
Dominant Leg Right/Left	8/2	8/2

No group differences were significant ($p > 0.05$). BMI = body mass index

Training program

The soccer players from both groups (EG, CG) were trained together as one team, 4 times per week (Monday, Tuesday, Wednesday and Thursday). They participated in exactly the same training sessions during the 12-week intervention program on a soccer field with natural grass. The only difference between the two training groups was that the EG players wore in each training-intervention session (Tuesday and Thursday) special shorts designed by the researchers and constructed exclusively for the purposes of the current study, the Additional Weight Shorts (AWS). In these shorts, the additional weight for each leg was 300 gr which was used as strength load (Figure 1a). The additional weight was added in a special socket at the height of the thighs (Figures 1b and 1c). The soccer players wearing the AWS (Figure 1d) were able to run, jump, pass, shoot and take part in overall soccer training without any discomfort. To fit each participant well, there were different sizes (XL youth-size, S-L adult-sizes) of shorts.

(a) (b) (c) (d)

Figure 1. (a) Additional weight case of 300 gr. (b, c) Socket for the additional weight. (d) Additional Weight Shorts (AWS). (Photographs: Efthimios Bogiatzidis)

Each training session lasted 90 min and the aim was to improve the soccer players' technical, tactical and physical performance. Each standard training-intervention session consisted of – warm-up: 25 min (running, stretching, rondo games i.e., 5vs2), – main part: 20–30 min intervention program, 25–35 min soccer training e.g. practice games with goals (large or small) for retaining possession and passing the ball as a group, small side games, multiple actions or games with tactic elements/guided games, and final games (e.g. free play, freedom of expression, spontaneity, creativity), – cool down: 10 min (5 min recovery-leisurely running and 5 min stretching). No other strength or speed exercises were performed in the standard training sessions on Monday and Wednesday (technical/tactical training the same for all participants), except for those in the intervention program, which were integrated into standard training twice per week on Tuesday and Thursday and consisted of four exercises. Table 2 presents the training contents applied throughout the 12-week intervention program which is quantified in table 3. The exercises used in the intervention program were chosen for improving the soccer players' performance through competitive training mainly with the ball, because they simulate the soccer match. They were specific soccer-related exercises (speed/strength/power, individual/subgroup tactics), which contained accelerations-decelerations, 15–30 m sprints, changes of direction, vertical jumps, 1vs1 and 2vs2 actions. The training load of the intervention program was progressively increased from 1st week-12th week as shown in Table 3. In addition, during the 12 weeks of training all participants took part in 6 official regional soccer-matches on Saturday, lasting 80 minutes (2 × 40 minutes/half). To ensure an equal participation time of all soccer players in these matches, they were divided into 2 subgroups (group A and B), in each of which 5 soccer players who wore the AWS participated. All participants started the matches and played with a mean duration of 60 ±5 min in the matches. On the remaining 6 Saturdays without a match, training took place in 3 of them with same contents for all soccer players (technical/tactical training) and in the other 3 they had a free day.

Table 2. Training contents applied throughout the 12-week intervention program

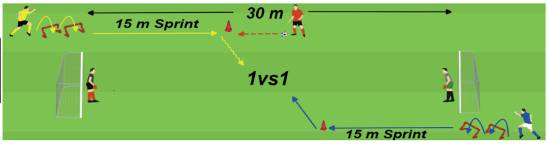
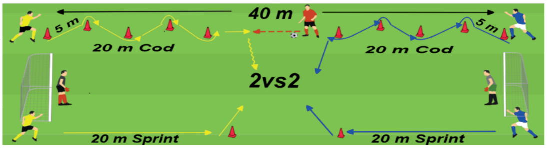
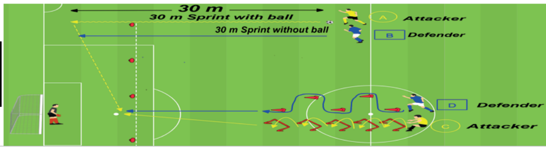
Exercise	Illustration	Description
Exercise a and a*		Exercise a: Knee lifts with 300 gr on each thigh Exercise a*: Knee lifts with 600 gr on each thigh
Exercise b		Players from both sides perform 2x 45 cm hurdle jumps, then 15-m straight sprint with ball receiving from one side (attacker) and try 1vs1 to score against the defender
Exercise c		Players from both sides perform straight sprints and cods each 20-m, then receiving the ball from one side (attackers) and try 2vs2 to score against the defenders
Exercise d		Attacker A with ball, defender B without (3 sec later) are starting a 30-m straight sprint. Attacker C jumps 5x 45 cm hurdles and receiving attacker 's A pass trying to score, defender D performs 5x cods and prevent C to score. Then all players sprint 15-m back to marked line

Table 3. Training program during the 12-week intervention traing period

	Week 1		Week 2		Week 3	Week 4		
Exer	Ses 1	Ses 2	Ses 3	Ses 4	Ses 5	Ses 6	Ses 7	Ses 8
a)	10 × 2	10 × 2	10 × 3	10 × 3	–	10 × 3	–	10 × 3
a*)	–	–	–	–	10 × 3	-	10 × 3	–
b)	× 4 (2 + 2)	–	× 6 (3 + 3)	–	× 6 (3 + 3)	-	× 8 (4 + 4)	–
c)	× 4 (2 + 2)	–	× 4 (2 + 2)	–	× 6 (3 + 3)	-	× 6 (3 + 3)	–
d)	–	× 2	–	× 3	–	× 3	–	× 3
	Week 5		Week 6		Week 7	Week 8		
Exer	Ses 9	Ses 10	Ses 11	Ses 12	Ses 13	Ses 14	Ses 15	Ses 16
a)	–	10 × 3	–	10 × 3	–	10 × 3	-	10 × 3
a*)	10 × 3	–	10 × 3	–	10 × 3	–	10 × 3	–
b)	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–
c)	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–
d)	–	× 3	–	× 3	–	× 3	–	× 3
	Week 9		Week 10		Week 11	Week 12		
Exer	Ses 17	Ses 18	Ses 19	Ses 20	Ses 21	Ses 22	Ses 23	Ses 24
a)	–	10 × 3	–	10 × 3	–	10 × 3	–	10 × 3
a*)	10 × 3	–	10 × 3	–	10 × 3	–	10 × 3	–
b)	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–
c)	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–
d)	–	× 3	–	× 3	–	× 3	–	× 3

All repetitions were separated by work to rest ratio 1/5. Work 10 sec/rest 50 sec (exercises a, a*, b) and work 20 sec/rest 100 sec (exercises c, d). Between exercises 100 sec rest. After 8 weeks in exercise d 20-m sprint back

Testing procedures

The physical abilities were evaluated the week before (pre) and two days after the 12-week intervention training period (post) and the follow-up evaluation was performed 4 weeks after the post measurement.

The tests were executed at an outdoor soccer field with natural grass, where the participants wore soccer shoes, and at a gym with fitness equipment, where they wore indoor shoes. The week before testing there was a familiarization with the execution of the physical ability tests and proper form and technique of each test was practiced according to the instructions of the research assistants. Before testing, the soccer players abstained from physical exercise for 1 day. Verbal encouragement was used throughout all tests to achieve maximum effort. The same researcher measured all the participants.

Sprint and Repeated Sprint Ability (RSA) testing: 40-meters (20 + 20-m) of six shuttle sprints time was measured with 3 paired photocells using the Witty Microgate (Bolzano, Italy), which began with a standardized warm-up of 20 minutes. A photocell was placed at the start, at 5- and 10-m at a height of 90 cm from the ground. The player started from a standing position 50 cm from the first photocell to avoid an early activation of the timing mechanism, sprinted for 20-m, touched a line with a foot, turned 180º and came back to the starting photocell as fast as possible. After 20 sec of passive rest, the soccer player started again. Five seconds before the start of each sprint, the player assumed the ready position and was given a 5-sec countdown to an acoustic start signal (Rampinini et al., 2007). Immediately after the warm-up, players completed a practice single shuttle sprint and rested for 5 minutes before starting the definitive test. The best time in a single trial (RSAbest) in straight sprint at 5- and 10-m, with 180º turns in sprint at 30- (20 + 10-m), 35- (20 + 15-m) and 40-m (20 + 20-m), the mean and total times all of them (RSAmean, RSAtotal) were recorded and the 6 × 40m (20 + 20-m) fatigue-index (RSAfatigue-index) was calculated according to the formula: Fatigue = ([Slowest two sprint times ÷ 2] – [fastest two sprint times ÷ 2]) ÷ ([fastest two sprint times ÷ 2]) × 100 (Glaister et al., 2008) and used for further analysis.

Vertical jump performance: Vertical jump ability was assessed using the squat jump (SJ), the countermovement jump (CMJ) and the drop jump (DJ). Vertical jump height (SJ, CMJ, DJ) time contact and power (DJ) were assessed using an optical measurement system consisting of a transmitting and receiving bar (Optojump Microgate. Bolzano, Italy). For the execution of the SJ, the participant placed his feet in the area between the bars with the arms akimbo, adopted the semi-squat position (knees angle at 90°) and without any pre-stretch performed a maximal vertical jump. The researcher was taking care that the participant was descending at each jump until a knee angle of 90° was formed, landing with the toes and approximately in the same area between the bars. For the CMJ, each participant placed his feet in the area between the bars and his body was in an upright position with the arms akimbo. The participant moved from an upright position down to a semi-squat and performed a maximal vertical jump (stretching-shortening cycle), taking care to land on approximately in the same area between the bars with the legs kept outstretched during the jump. For the DJ, 40 cm drop height was used. The participant stood on top of the box with his arms akimbo, took one step forward with the leading leg straight to ensure a drop height of 40 cm and dropped in the area between the bars with both legs on the ground with a short and powerful contact extending the ankles and performed a vertical jump, without bending the knees and landed likewise in an extended position in the same area between the bars. The average value of the 3 trials of each test was used for further analysis, with one minute of rest between the 3 trials of each test.

Maximum strength: Maximum strength of the lower limbs was measured with single right and left leg in the exercises leg curl and split squat. As an index of maximum strength, the maximum load that could be lifted for

5 repetitions (5RM load) in each exercise was considered. As a warm-up, one set of 8 repetitions was performed with a 50% load of the estimated 5RM load, and one set of 5 repetitions with a 75% load of which the estimated 5RM load were executed. After those 5 repetitions with the load estimated to be the 5RM load, attempts were performed. If the trial was successful, the load was increased by 10% until the participant was unable to successfully perform 5 repetitions, which occurred within two to four trials. The rest interval between sets was 3 minutes.

Leg curl testing was performed on a leg curl machine (Super Sport, Athens, Greece) with the participant lying face down, the hands grasping handles and performing a single right/left full knee flexion.

The split squat testing was executed using a smith machine (Sfitness, Shanghai, China). The test started with the participant standing upright on one leg. The top of the leg which did not participate in the movement was placed on a standard gym bench, positioned behind the participant, to ensure that the working leg was isolated to perform the attempt. The participant had to execute a single right/left-leg squat until a 90° angle was formed between the thigh and the shank.

Statistical analysis

The normal distribution criterion was satisfied after contacting the Shapiro-Wilk test. Two-Way Repeated measures ANOVAs were used for the statistical treatment of the data, with “Group” as between and “Time” as within factor, along with the post hoc test Bonferroni, except Drop Jump time contact, in which Two-Way Ancova Repeated measures were used. The statistically significant level was set as $p < 0.05$. All results are reported as mean ±SD.

Results

Twenty participants successfully completed the study without reporting any injury during the intervention or the overall soccer training program. Before the intervention program, the two groups (EG, CG) did not differ significantly (all, $p > 0.05$) regarding chronological age, training age (i.e., training background) and their anthropometric characteristics. After the 12-week intervention program, significant interactions were revealed between the two factors (“Group” and “Time”). The EG showed statistically significant improvements compared to the CG in 10-m-straight [$F_{(2,36)} = 3.612$; $p = 0.037$], with 180º turns in 30-m (20 + 10-m) [$F_{(2,36)} = 3.296$; $p = 0.048$], 35-m (20 + 15-m) [$F_{(2,36)} = 4.158$; $p = 0.024$] and 40-m (20 + 20-m) [$F_{(2,36)} = 4.396$; $p = 0.020$] RSAbest-sprints, in RSAfatigue-index [$F_{(2,36)} = 3.573$; $p = 0.038$], in Squat Jump height [$F_{(2,36)} = 3.393$; $p = 0.045$], in Drop Jump time contact [$F_{(1,17)} = 6.054$; $p = 0.025$], in Leg Curl single right and left leg [$F_{(2,36)} = 5.004$; $p = 0.012$], [$F_{(2,36)} = 5.842$; $p = 0.006$], in Split Squat single right and left leg [$F_{(2,36)} = 11.928$; $p = 0.000$], [$F_{(2,36)} = 15.569$; $p = 0.000$] with no significant differences in all above variables between the two groups, except in RSAfatigue-index in the post intervention measurement [$F_{(1,18)} = 14.715$; $p = 0.001$], in Drop Jump time contact in the follow up measurement [$F_{(1,17)} = 9.798$; $p = 0.006$], in Split Squat single right leg in the follow up measurement [$F_{(1,18)} = 12.949$; $p = 0.002$] and in Split Squat single left leg in the post measurement [$F_{(1,18)} = 4.934$; $p = 0.039$] and follow up measurement [$F_{(1,18)} = 16.514$; $p = 0.001$].

A significant simple main effect of the within factor “Time” was observed only in the EG in 10-m-straight [$F_{(2,17)} = 11.795$; $p = 0.001$], with 180º turns in 30-m (20 + 10-m) [$F_{(2,17)} = 12.717$; $p = 0.000$], 35-m (20 + 15-m) [$F_{(2,17)} = 16.936$; $p = 0.000$] and 40-m (20 + 20-m) [$F_{(2,17)} = 16.325$; $p = 0.000$] RSAbest-sprints, in Squat Jump height [$F_{(2,17)} = 15.400$; $p = 0.000$] and in Drop Jump time contact [$F_{(1,17)} = 9.953$; $p = 0.006$]. The post hoc Bonferroni test revealed significant differences between the post intervention and the follow up measurement in 10-m best straight-sprint, between the pre intervention and the follow up measurement and between the post intervention and the follow up measurement with 180º turns in 30-m (20 + 10-m), 35-m (20 + 15-m) and 40-m (20 + 20-m) RSAbest-sprints, between all measurements. No significant differences between the post intervention and the follow up measurement on Squat jump height and between the pre intervention and the follow up measurement in Drop Jump time contact were observed (Table 4).

A significant simple main effect of the within factor "Time" was observed in both groups in Leg Curl single right leg EG: [$F_{(2,17)}$ = 24.550; p = 0.000], CG: [$F_{(2,17)}$ = 6.589; p = 0.008], in Leg Curl single left leg EG: [$F_{(2,17)}$ = 26.666; p = 0.000], CG: [$F_{(2,17)}$ = 6.677; p = 0.007], in Split Squat single right leg EG: [$F_{(2,17)}$ = 43.336; p = 0.000], CG: [$F_{(2,17)}$ = 7.388; p = 0.005] and in Split Squat single left leg EG: [$F_{(2,17)}$ = 59.000; p = 0.000], CG: [$F_{(2,17)}$ = 9.678; p = 0.002]. However, in all the above variables in the EG, the post hoc Bonferroni test revealed significant differences between all measurements, while in the CG, significant differences were found between all measurements, except between the post intervention and the follow up measurements (Table 4).

A statistically significant main effect of the within factor "Time" was observed in 5-m best straight-sprint [$F_{(2,36)}$ = 4.333; p = 0.021], with 180º turns in 30-, 35- and 40-m RSAmean scores [$F_{(2,36)}$ = 6.507; p = 0.004], [$F_{(2,36)}$ = 8.297; p = 0.001], [$F_{(2,36)}$ = 8.828; p = 0.001], with 180º turns on 30-, 35- and 40-m RSAtotal scores [$F_{(2,36)}$= 6.524; p= 0.004], [$F_{(2,36)}$= 8.297; p= 0.001], [$F_{(2,36)}$= 8.828; p= 0.001], in CMJ [$F_{(2,36)}$ = 9.259; p = 0.001], in Drop Jump height [$F_{(2,36)}$ = 4.352; p = 0.020] and in Drop Jump power [$F_{(2,36)}$ = 7.847; p = 0.01] regardless of "Group". The post hoc Bonferroni test revealed significant differences between the post intervention and the follow up measurement in 5-m best straight-sprint between all measurements, except between the pre and the post intervention measurements with 180º turns in 30-, 35- and 40-m RSAmean and RSAtotal scores, and in CMJ, between the pre and the post intervention measurement in Drop Jump height and between all measurements, except between the post intervention and the follow up measurement in Drop Jump power. No significant differences were found in 5- and 10-m RSAmean and RSAtotal scores, neither between the two groups, nor between the pre, post intervention and follow up measurements.

Table 4. Mean and SD values of the pre-intervention, after 12 weeks of the training intervention, and after a 4 week follow up period in the experimental and control groups

	Experimental Group (N=10)			Control Group (N=10)		
	Pre	Post	Follow up	Pre	Post	Follow up
10-m best straight sprint (s)	1.91 ± 0.05	1.94 ± 0.07	1.86 ± 0.06 #	1.91 ± 0.10	1.96 ± 0.11	1.94 ± 0.10
30-m (20+10m) best sprint (s)	6.14 ± 0.18	6.12 ± 0.21	5.95 ± 0.21 ^#	6.24 ± 0.40	6.21 ± 0.34	6.20 ± 0.34
35-m (20+15m) best sprint (s)	6.93 ± 0.20	6.90 ± 0.25	6.70 ± 0.24 ^#	7.05 ± 0.44	7.00 ± 0.42	6.98 ± 0.40
40-m (20+20m) best sprint (s)	7.70 ± 0.22	7.66 ± 0.29	7.44 ± 0.28 ^#	7.86 ± 0.54	7.82 ± 0.48	7.80 ± 0.48
RSAfatigue-index (%)	6.96 ± 2.77	5.39 ± 1.93 *	6.27 ± 1.95	7.79 ± 3.21	9.66 ± 2.94	8.07 ± 3.48
Squat Jump Height (cm)	22.55 ± 3.10	25.55 ± 4.52 ^	26.82 ± 3.87 ^	22.55 ± 4.81	23.66 ± 5.58	24.50 ± 5.55
Drop Jump T. Contact	0.207 ± 0.01 s	-2.70 ± 8.38 %	-10.54 ± 6.84 % ^*	0.228 ± 0.01 s	-6.21 ± 6.60 %	-4.83 ± 7.39 %
5RM Leg Curl Right-leg (kg)	17.40 ± 7.36	24.00 ± 9.47 ^	26.90 ± 11.52 ^#	17.30 ± 2.35	20.50 ± 3.53 ^	22.20 ± 3.76 ^
5RM Leg Curl Left-leg (kg)	16.80 ± 5.57	23.50 ± 7.92 ^	26.10 ± 9.55 ^#	16.00 ± 1.76	18.90 ± 2.92 ^	20.80 ± 2.86 ^
5RM Split Squat Right-leg (kg)	41.20 ± 11.16	60.20 ± 14.70 ^	77.10 ± 14.85 ^#*	41.60 ± 9.22	49.50 ± 7.94 ^	56.30 ± 10.65 ^
5RM Split Squat Left-leg (kg)	41.10 ± 10.00	59.10 ± 12.19 ^*	75.60 ± 11.47 ^#*	41.40 ± 8.72	48.90 ± 7.88 ^	54.90 ± 11.30 ^

* Significantly different from the control group
^ Significantly different in comparison with the pre-intervention measurement
# Significantly different in comparison with the post-intervention measurement

Discussion

This is the main study based on the previous pilot study (Bogiatzidis et al., 2022) and the aim was to examine the effects of using a specific strength training tool, weighted shorts with 300 gr on each thigh worn while participating in an on-field lower limbs combined strength/speed/soccer training program, on the development of physical performance of U-16 youth male soccer players. The main findings of the current study were that sprinting speed, RSA fatigue-index, strength of the lower limbs, the vertical jump ability (Squat Jump) and the Drop Jump time contact of the young soccer players were improved, while RSAmean and RSAtotal scores, the height of Countermovement Jump and the height and power of the Drop Jump were not affected.

Several contrasting findings were observed in the studies regarding the effectiveness of strength training on sprint performance. Studies that found no effect or even a negative effect were reported (Gorostiaga et al., 2004; Lopez-Segovia, et al., 2010; Bogiatzidis et al., 2022). The current findings are in agreement with studies that observed an improvement in sprint performance in youths of similar ages with our sample, following a standard strength or a combined strength training period. Hammami et al. (2017) observed an improvement in sprint times of 5-, 10-, 20-, 30- and 40-m in male soccer players, aged 16.0 ±0.5 years after an 8-week in-season intervention program, which used the back half squat as a training exercise before standard training sessions. Christou et al. (2006) showed a significant improvement in 30-m, but not in 10-m sprint time in male soccer players aged 13.8 ±0.4 years, after a 16-week strength training program twice a week, which included 10 machine based and free weight exercises (e.g., leg press, bench press, leg extension, pec-dec). In the current study the performance on straight 10-m best-sprint in the EG improved significantly compared to the CG but not in 5-m. It seems, that to improve the 5-m speed performance, a more targeted and specific program may be required, once in the current study the distances covered by the soccer players during the intervention were between 15-30 meters and longer. Regarding the other sprint/RSA distances, the EG improved significantly compared to the CG in RSAbest-sprints with 180º turns in 30- (20 + 10-m), 35- (20 + 15-m) and 40-m (20 + 20-m) and in RSAfatigue-index, while in RSAmean and RSAtotal scores revealed no differences between the two groups. As far as we know, no other study measured RSA scores in 5- and 10-m straight sprints, with 180º turns at 30- (20 + 10-m) and 35-m (20 + 15-m) in addition to 40-m (20 + 20-m). Therefore, there is an agreement only regarding RSAbest 40-m (20 + 20-m), but regarding the RSAtotal 40-m (20 + 20-m) and RSAfatigue-index parameters it is in disagreement with the findings in a previous study in prepuberal soccer players aged 12.7 ±0.2 years (Negra et al., 2018). Another study conducted in adolescent soccer players aged 16.0 ±0.5, revealed no significant differences in all RSA parameters (RSAbest/mean/total/fatigue-index) after 8-weeks of standard and contrast strength training (Hammami et al., 2017). Both of the above studies used the same RSA-test like our study. The lack of improvement in our study in RSAmean and RSAtotal scores can be logically explained. As it is shown and quantified in the intervention training program (Table 3), applying suitable and age-related training in our age-sample, the main goal was the improvement of speed-force parameters and not the improvement of sprint-speed endurance, that is anaerobic lactate capacity. This is also shown from the relation work-rest time, where the rest times were long. Therefore, no positive effects were revealed in the above RSA scores, although there seems to be a tendency to improvement.

However, our RSA test consisted of 6 shuttle sprints of 40-meters (20-m straight, turn 180º and again 20-m straight). That is, it also contained elements of changes of direction (COD). Improvements in COD after a strength training in similarly age groups with our study were reported (Hammami et al., 2017; Negra et al., 2018). Falces-Prieto et al. (2022) reported that linear sprinting speed may influence COD, while angle and entry velocity can also constraint the COD performance. Additionally, body mass, lower limb power, and strength can also play important roles in COD performance. They confirmed in males aged 14.8 ±0.4 years, that jump performance and linear speed in 10-m were determinants of COD performance. Brughelli et al. (2008) stated that the training protocols reporting improvements in COD have utilized exercises that more closely mimic the demands of COD, which include sport-specific and general COD training. In our training program we included both straight-line speed and COD exercises.

In relation to power in the current study, the vertical jump ability measured by Squat Jump test improved significantly in the EG compared to the CG, but not in Countermovement Jump test. The explanation for this may be, that wearing the AWS in which the weights were placed on the thighs, this muscle unit was more affected, which mainly and actively participates in the execution of the Squat Jump and therefore contributed to the improvement of its performance in the EG. The execution of the Countermovement Jump requires the participation of all lower limb muscles and perhaps for this reason it was not improved. Similarly, with our findings reported Chelly et al. (2009) after an 8-week resistance training program, using the back half squat with 1-RM previously measured as a training exercise twice a week, immediately before the regular soccer training session. On the contrary, Bogiatzidis et al. (2022) reported in male soccer players aged 15 ±0.5 years significant improvement in the EG compared to the CG in the Countermovement Jump, but not in Squat Jump test after 12 weeks in-season training period. The soccer players of the EG used to wear like our intervention the AWS with additional weight of 300 gr on each thigh and the players of CG not. However, the EG and CG players participated normally in the soccer training sessions, without any specific target for improving any separately soccer ability/skill, and it seems that it has affected more the muscle units used in the Countermovement Jump. Regarding the Drop Jump test in our study, the EG improved significantly compared to the CG only in the ground contact time, but not in height and power. Keiner et al. (2018) using 32 cm Drop Jump height evaluated the effects of long-term (2 years) strength training on reactive strength in male adolescent soccer players aged U13-U16 years, using parallel squats (back/front), deadlift, upper extremity exercises (bench press, neck press, standing row and trunk muscle exercises) 2 times/week immediately before the regular soccer training session. The strength training group improved significantly compared to the control group in jump height but not in contact time over time. They reported that jump height is more affected by strength training than contact time and maybe a combination of both strength and reactive strength training is more effective in improving contact time than just strength training alone. In our study, we combined strength and plyometric jump exercises and it seems that they were effective in improving the ground contact time.

Regarding the strength performance in the current study, using the Leg Curl and the Split Squat (single right and single left leg) as training exercises with 5-RM load, the EG achieved a significantly higher performance compared to the CG in both exercises with the single right and single left leg. Bogiatzidis et al. (2022) reported no difference in improvement between the two groups in Leg Curl, but using the typical form of the Leg Curl (both legs) and in Split Squat single right/left leg, they reported a significant improvement in the EG performance compared to the CG only with the single left leg, but not with the single right leg.

In our study, we observed several improvements in the follow-up measurements after the end of the training period, although the EG-players did not wear the AWS during training for 4 weeks. Perhaps due to the physical adaptations that took place from the 12-week training period. Probably, to reveal the positive effects of this particular training method, a decreasing period of stress and training without additional load on the thighs was essential. Conversely, the improvement e.g., in Leg Curl and Split Squat single right/left leg of the CG may be due to the participants growth, because they were in adolescence but also from the soccer training participation alone that leads to improvements in the lower body performance. According to this, Christou et al. (2006) showed in male soccer players aged 13.8 ±0.4 years, significant increases in lower-body strength (leg press) not only after 8 and 16 weeks of strength/soccer and soccer training but in the control group as well.

As far as we know, the current study is the first which examined the effects of a combined strength and speed/soccer training program using weighted shorts during regular soccer training on the improvement of physical performance of adolescent soccer players. The Additional Weight Shorts is: a) an easily added and removed portable wearable training tool, b) by wearing it, all soccer-specific movements can be executed, the soccer players can participate normally in all soccer training sessions, and the coaches have nothing to change in their planning, and c) no training-related injuries were reported, so it appears to be a safe alternative strength training tool.

However, there are limitations in our study. First of all, the small number of participants. A bigger sample could have provided better results about the effects of training with AWS on the physical performance of young soccer players. Also, our study consisted of only adolescent male soccer players limited to the specific U-16 age-group. Therefore, the results cannot be generalized to other developmental ages and gender. Furthermore, the results were based on the chronological rather than the biological age of the participants. We did not assess the maturity status before the study, and there may have been differences between participants, which could have affected the results of our study. Moreover, the improvements achieved in the present study are test-specific, meaning that the selection of different tests of physical abilities (other sprint tests or distances, lower-limbs measures etc.), training periods and intensities may have produced different results and correlations.

Therefore, further research should aim to include larger sample sizes, different age-groups, assessment of maturity status, and females as well as adults. Additionally, more field and laboratory tests and of course different training protocols should be included (using greater than 300 gr as strength load at each thigh or adding the strength load on other muscle parts like hamstrings etc.), to provide a more complete picture of the effects of these different strategies on physical performance of young soccer players.

In any case, this study is practically important, because it was applied on the field with a new and alternative strength training tool without disturbing the regular training sessions.

Conclusions

The current study revealed, as it was expected, that U-16 age male soccer players from both groups (EG, CG) who participated in the same 12-week strength/speed/soccer program showed improvement in some parameters of physical performance. However, the soccer players from the EG who wore the AWS during the training program improved their performance more compared to the CG in RSAbest-sprints (straight and with 180° turning), RSA fatigue-index, strength/power of the lower limbs and jump performance. Although, the results should be interpreted with caution. Firstly, due to the small sample size. Also, on the one hand, our findings showed that the greater improvements from the EG may have been caused by the progressively increased training load using the AWS, but on the other hand, at this age-stage some changes could also have happened due to the maturity. Furthermore, our results were based on the chronological and not on the biological age of the participants. However, our findings are encouraging and important to soccer coaches/scientists, because without additional time and changes in training using a practical, cheap and portable tool, this modality can be directly applied in practice for development and training of young soccer players.

References

Beato, M., Young, D., Stiff, A., & Coratella, G. (2021). Lower-limb muscle strength, anterior-posterior and inter-limb asymmetry in professional, elite academy and amateur soccer players. *Journal of Human Kinetics*, *77*, 135–146. https://doi.org/10.2478/hukin-2020-0058

Bogiatzidis, E., Ispyrlidis, I., Gourgoulis, V., Bogiatzidou, A., Chatzinikolaou, A., Mantzouranis, N., & Smilios, I. (2022). The effects of an alternative training method on physical and technical abilities of adolescent soccer players: A pilot study. *Central European Journal of Sport Sciences and Medicine*, *1*(37), 45–56. https://doi.10.18276/cej.2022.1-04

Brughelli, M., Cronin, J., Levin, G., & Chaouachi, A. (2008). Understanding change of direction ability in sport: a review of resistance training studies. *Sports Medicine*, *38*(12), 1045–1063. https://doi.10.2165/00007256-200838120-00007

Chelly, M. S., Fathloun, M., Cherif, N., Ben Amar, M., Tabka, Z., & Van Praagh, E. (2009). Effects of a back squat training program on leg power, jump, and sprint performances in junior soccer players. *Journal of Strength and Conditioning Research*, *23*(8), 2241–2249. https://doi.10.1519/JSC.0b013e3181b86c40

Christou, M., Smilios, I., Sotiropoulos, K., Volaklis, K., Pilianidis, T., & Tokmakidis, S. (2006). Effects of resistance training on the physical capacities of adolescent soccer players. *Journal of Strength and Conditioning Research*, *20*(4), 783–791. https://doi.10.1519/R-17254.1

Cossio-Bolaños, M., Vidal-Espinoza, R., Ura Albornoz, C., Leite Portella, D., Vega-Novoa, S., Mendez-Cornejo, J., Fuentes Lopez, J., & 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), 1–10. https://doi.10.4081/ejtm.2021.9692

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. *Scientifc Reports*, *12*(12272), 1–9. https://doi.org/10.1038/s41598-022-16558-9

Fischerova, P., Nitychoruk, M., Smolka, W., Zak, M., Golas, A., & Maszczyk, A. (2021). The impact of strength training on the improvement of jumping ability and selected power parameters of the lower limbs in soccer players. *Baltic Journal of Health and Physical Activity*, *13*(1), 83–90. https://doi.10.29359/BJHPA.13.1.09

Glaister, M., Howatson, G., Pattison, J. R., & McInnes, G. (2008). The reliability and validity of fatigue measures during multiple-sprint work: An issue revisited. *Journal of Strength and Conditioning Research*, *22*(5), 1597–1601. https://doi.org/10.1519/JSC.0b013e318181ab80

Gorostiaga, E. M., Izquierdo, M., Ruesta, M., Iribarren, J., Gonzalez-Badillo, J. J., & Ibanez, J. (2004). Strength training effects on physical performance and serum hormones in young soccer players. *European Journal of Applied Physiology*, *91*(5–6), 698–707. https://doi.10.1007/s00421-003-1032-y

Granacher, U., Lesinski, M., Büsch, D., Muehlbauer, T., Prieske, O., Puta, C., Gollhofer, A., & Behm, D. G. (2016). Effects of resistance training in youth athletes on muscular fitness and athletic performance: A conceptual model for long-term athlete development. *Frontiers in Physiology*, *7*(164), 1–14. https://doi.org/10.3389/fphys.2016.00164

Hammami, M., Negra, Y., Shephard, R. J., & Chelly, M.S. (2017). The effect of standard strength vs. contrast strength training on the development of sprint, agility, repeated change of direction, and jump in junior male soccer players. *Journal of Strength and Conditioning Research*, *31*(4), 901–912. https://doi.org/10.1519/JSC.0000000000001815

Keiner, M., Sander, A., Hartmann, H., Mickel, C., & Wirth, K. (2018). Do long-term strength training and age affect the performance of drop jumps in adolescents? Separating the effects of training and age. *Journal of Australian Strength and Conditioning*, *26*(4), 24–38.

Lopez-Segovia, M., Andres, J. M. P., & Gonzalez-Badillo, J. J. (2010). Effect of 4 months of training on aerobic power, strength, and acceleration in two under-19 soccer teams. *Journal of Strength and Conditioning Research*, *24*(10), 2705–2714. https://doi.10.1519/JSC.0b013e3181cc237d

Murtagh, C. F., Brownlee, T. E., O' Boyle, A., Morgans, R., Drust, B., & Erskine, R. M. (2018). Importance of speed and power in elite youth soccer depends on maturation status. *Journal of Strength and Conditioning Research*, *32*(2), 297–303. https://doi.10.1519/JSC.0000000000002367

Negra, Y., Chaabene, H., Fernandez-Fernandez, J., Sammoud, S., Bouguezzi, R., Prieske, O., & Granacher, U. (2018). Short-term plyometric jump training improves repeated-sprint ability in prepuberal male soccer players. *Journal of Strength and Conditioning Research*, *34*(11), 1–9. https://doi.org/10.1519/JSC.0000000000002703

Rampinini, E., Bishop, D., Marcora, S. M., Ferrari Bravo, D., Sassi, R., & Impellizzeri, F. M. (2007). Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. *International Journal of Sports Medicine*, *28*(3), 228–235. https://doi.org/10.1055/s-2006-924340

Rodriguez-Rosell, D., Franco-Márquez, F., Mora-Custodio, R., & González-Badillo, J. J. (2017). Effect of high-speed strength training on physical performance in young soccer players of different ages. *Journal of Strength and Conditioning Research*, *31*(9), 2498–2508. https://doi.org/10.1519/JSC.0000000000001706

Stewart, A, Bloom, L, Clarkson, B., & Comfort, P. (2014). A comparison of field test performances between elite and sub-elite academy soccer players. *Journal of Athletic Enhancement*, *3*(4). https://doi.org/10.4172/2324-9080.1000158

Škomrlj, J., Veršić, S., & Foretić, N. (2022). Analysis of association of the anthropometric, motor and functional parameters on competitive efficiency in youth football players. *Sport Mont*, *20*(2), 35–40. https://doi.org/10.26773/smj.220606

Yu, L., Altieri, C., Bird, S. P., Corcoran, G., & Jiuxiang, G. (2020). The importance of in-season strength and power training in football athletes: A brief review and recommendations. *International Journal of Strength and Conditioning*, *1*(1), 1–8. https://doi.org/10.47206/ijsc.vi0.23

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*(1026), 1–11. https://doi.org/10.3389/fphys.2019.01026

Cite this article as: Bogiatzidis, E., Ispyrlidis, I., Gourgoulis, V., Bogiatzidou, A., Smilios, I. (2024). The Effects of Training with Additional Weight Shorts on Physical Performance of Adolescent Soccer Players. *Central European Journal of Sport Sciences and Medicine*, *2*(46), 89–101. https://doi.org/10.18276/cej.2024.2-08