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Effects of Resistance Training on the Physical Capacities of Adolescent Soccer Players

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ABSTRACT. Christou, M., I. Smilios, K. Sotiropoulos, K. Volaklis, T. Pilianidis, and S.P. Tokmakidis. Effects of resistance training on the physical capacities of adolescent soccer players. *J. Strength Cond. Res. 20(4):783–791. 2006.*—This study examined the effects of a progressive resistance training program in addition to soccer training on the physical capacities of male adolescents. Eighteen soccer players (age: 12–15 years) were separated in a soccer (SOC; $n = 9$) and a strength-soccer (STR; $n = 9$) training group and 8 subjects of similar age constituted a control group. All players followed a soccer training program 5 times a week for the development of technical and tactical skills. In addition, the STR group followed a strength training program twice a week for 16 weeks. The program included 10 exercises, and at each exercise, 2–3 sets of 8–15 repetitions with a load 55–80% of 1 repetition maximum (1RM). Maximum strength ([1RM] leg press, bench-press), jumping ability (squat jump [SJ], countermovement jump [CMJ], repeated jumps for 30 seconds) running speed (30 m, 10 × 5-m shuttle run), flexibility (seat and reach), and soccer technique were measured at the beginning, after 8 weeks, and at the end of the training period. After 16 weeks of training, 1RM leg press, 10 × 5-m shuttle run speed, and performance in soccer technique were higher ($p < 0.05$) for the STR and the SOC groups than for the control group. One repetition maximum bench press and leg press, SJ and CMJ height, and 30-m speed were higher ($p < 0.05$) for the STR group compared with SOC and control groups. The above data show that soccer training alone improves more than normal growth maximum strength of the lower limps and agility. The addition of resistance training, however, improves more maximal strength of the upper and the lower body, vertical jump height, and 30-m speed. Thus, the combination of soccer and resistance training could be used for an overall development of the physical capacities of young boys.

KEY WORDS. agility, flexibility, growth, running speed, strength, vertical jump

INTRODUCTION

Resistance training is proven to be safe and effective for adolescents when it is properly designed and supervised. Established scientific organizations recommend resistance training for young people to enhance muscular strength, prevent sport injuries, improve performance in sports and recreational activities, and affect health and lifestyle in a positive way (1, 3, 26).

Several studies have shown that resistance training increases muscular strength more than natural growth in adolescents (14, 20, 21, 25). However, as far as the effect of resistance training on motor performance is concerned, some studies have shown a positive effect on some physical capacities, whereas other studies have not indicated a similar effect. For example, after a resistance training program, vertical jump performance was found to either increase (21) or not show changes at all (20). When the effect of resistance training on running speed was examined, resistance training failed to influence running performance (20). Similarly, resistance training failed to affect anaerobic capacity (15, 21). To our knowledge, no study has examined the effects of resistance training on flexibility and agility in young boys. Therefore, research findings concerning the effects of resistance training on motor performance are either limited or inconclusive, and further studies of the potential role of resistance training on physical capacities of adolescents are required to provide useful information to coaches.

After participating in resistance training programs, sport performance of youths is expected to improve. Anecdotal comments on strength training suggested that this is enhanced (18). Definitely, sports performance is the outcome of multiple factors, and it would be difficult to control and assess the net impact of resistance training. Nevertheless, Gorostiaga et al. (20) found that handball throwing velocity in adolescent players increased after resistance training. Thus, it would be interesting to examine if strength training would have a positive impact on specific tasks of soccer involving fast running and effective handling of the ball at the same time.

On the other hand, it is unknown whether a resistance training program incorporated with regular soccer training would enhance the physical capacity of adolescent players compared with soccer training alone. Soccer is a sport that requires acceleration, rapid change of direction, and many powerful movements. Therefore, training of the sport itself may enhance muscular performance especially during the developmental period. It would have been interesting for physical educators and coaches to recognize if soccer training would have an effect on motor performance and if resistance training combined with soccer training would have an extra effect on motor performance. The purpose of this study was to investigate the effects of soccer training combined with resistance training as well as the effects of regular soccer training alone on physical capacities such as muscular strength, vertical jump performance, running speed, agility, and flexibility, and on soccer technique of male adolescent soccer players.

METHODS

Experimental Approach to the Problem

The objectives of this study were to examine (a) the effects of soccer training on anthropometric characteristics, muscular strength, jumping ability, running speed, agility, flexibility, and specific technical skills of male adolescent players, and (b) the effects of a combined soccer and resistance training program for 16 weeks on the above physical capacities. For these reasons, a team of male regional soccer players was divided into a strength-soccer training group (STR) and a soccer training group (SOC). Soccer training (5 times per week) for the development of technical and tactical skills was the same in both groups. The STR group not only trained in soccer, but in a strength training program as well, using free weights and machines twice a week (Table 1). No boy had regularly participated in any form of resistance training before this study. To assess the effect of natural growth on physical capacities, a control group (CON) was used with boys of a similar age and physical characteristics. The subjects of this group did not participate in any structured training program. Anthropometric characteristics, maximum strength, vertical jump performance, running speed, agility, flexibility, and soccer-specific technical skills were measured at the beginning of the training program and after 8 and 16 weeks of training.

TABLE 1. Strength training program throughout the 16-week training period.*

Week	Session	Set × repetitions	Intensity (%1RM)
1	1	2 × 15	55–60
	2	2 × 15	55–60
2	3	3 × 15	55–60
	4	2 × 15	55–60
3	5	3 × 15	55–60
	6	3 × 15	55–60
4	7	2 × 15	55–60
	8	2 × 15	55–60
5	9	2 × 12	65–70
	10	2 × 12	65–70
6	11	3 × 12	65–70
	12	2 × 12	65–70
7	13	3 × 12	65–70
	14	3 × 12	65–70
8	15	2 × 12	65–70
	16	2 × 12	65–70
9	17	2 × 10	70–75
	18	2 × 10	70–75
10	19	3 × 10	70–75
	20	2 × 10	70–75
11	21	3 × 10	70–75
	22	3 × 10	70–75
12	23	2 × 10	70–75
	24	2 × 10	70–75
13	25	2 × 8	75–80
	26	2 × 8	75–80
14	27	3 × 8	75–80
	28	2 × 8	75–80
15	29	3 × 8	75–80
	30	3 × 8	75–80
16	31	2 × 8	75–80
	32	2 × 8	75–80

* 1 RM = 1 repetition maximum.

Subjects

Eighteen soccer players with training experience of 4.3 ± 1.9 years and ranging from 12 to 15 years of age volunteered to participate in this study. The boys were equally divided into 2 groups: STR (13.8 ± 0.4 years; $n = 9$) and SOC (13.5 ± 0.9 years; $n = 9$). In addition, 8 boys were recruited as a CON group (13.3 ± 0.7; $n = 8$). The maturation status of the boys was determined according to the development of pubic hair, based on the Tanner 5-point scale (23), at the beginning, after 8 weeks, and after 16 weeks of strength training by the same investigator. There were no significant differences between groups for age or Tanner ratings. The physical characteristics of the subjects are presented in Table 2.

All boys underwent medical evaluation before the beginning of the study, and the following exclusion criteria were used: (a) boys with a chronic pediatric disease; (b) boys with an orthopedic limitation; and (c) boys who were not classified as Tanner stage 3–5 at the beginning of the study. Both the boys and their parents were informed about the scope and the objectives of the study as well as the risks associated with strength training. A written consent was obtained from the parents. The experimental protocol was approved by the Institutional Review Board Committee.

Training Program

Weight-Training Program. The study was performed at the beginning of the competitive season. The STR group followed an introductory weight training program of 4 weeks (2 times per week), focusing on proper lifting techniques with low volume and intensity (2 sets of 15 repititions at ≈30–50% of 1 repetition maximum [1RM]). After this period, players began the strength training program, 2 times per week for 16 weeks with a total of 32 training sessions. Weight-training sessions were separated by at least 48 hours of rest. Each player performed the exercises in order: leg press, bench press, leg extension, peck-deck, leg flexion, overhead press, lat pull-downs, calf raise, sit-ups, and upper-lower back extension. The specific configuration of the acute program variables during the course of the 16-week training period is presented in detail in Table 1. In summary, the intensity was 55% of the 1RM at the beginning of the program and progressively increased up to 80% of the 1RM. For each exercise, 2–3 sets of 8–15 repetitions with 2–3 minutes of rest between sets and 3–5 minutes between exercises were performed. When a boy was able to complete the predetermined number of repetitions with proper form and without help, the load was increased by 5%. Subjects performed up to 2–3 sets of 20–30 repetitions of the body weight exercises.

Strength training was performed before soccer training, and the duration of each session lasted approximately 45 minutes. A warm-up period of 10 minutes, including low to moderate intensity aerobic exercises and stretching, was carried out before strength training. In addition, boys performed stretching exercises for about 1 minute after each set of exercises and for 5 minutes after the end of each session. A qualified instructor, who monitored proper exercise techniques and made adjustments in training load and repetitions, supervised strength training sessions. No injuries occurred during the training and testing sessions.

Soccer Training Program. Both training groups followed a soccer training program 5 times a week, with each session lasting ≈90 minutes. In addition, both groups participated in a 70-minute official game once a week (two 35-minute halves). Soccer training focused on the development of technical and tactical skills first and

Table 2. Anthropometric characteristics for the 3 groups for the 16-week training program (mean ± *SE*).*

Group	Pretraining	8 weeks	Adjusted means	16 weeks	Adjusted means
Body mass (kg)					
Strength-soccer ($n = 9$)	52.0 ± 3.3	54.3 ± 3.4†	56.3 ± 0.4	55.6 ± 3.5†	57.5 ± 0.7
Soccer ($n = 9$)	54.1 ± 2	54.3 ± 2.0	54.2 ± 0.4	55.3 ± 2.0†‡	55.1 ± 0.7
Control ($n = 8$)	55.8 ± 4.5	57.4 ± 4.4	55.6 ± 0.4	57.5 ± 4.1	55.8 ± 0.7
Pretraining (covariate)	54.0				
Height (cm)					
Strength-soccer ($n = 9$)	162.0 ± 3.8	164 ± 3.9†	164.7 ± 0.3	165.2 ± 3.9†‡	165.9 ± 0.4
Soccer ($n = 9$)	163.0 ± 2.5	164 ± 2.5†	163.7 ± 0.3	165.3 ± 2.5†‡	165.0 ± 0.4
Control ($n = 8$)	163.2 ± 4.5	164.9 ± 4.2†	164.5 ± 0.4	165.6 ± 4.0†	165.2 ± 0.5
Pretraining (covariate)	162.8				
Maturational status (Tanner 5-pt scale)					
Strength-soccer ($n = 9$)	4.0 ± 0.2	4.2 ± 0.2	4.1 ± 0.1	4.3 ± 0.2	4.3 ± 0.1
Soccer ($n = 9$)	3.9 ± 0.3	4.0 ± 0.2	4.0 ± 0.1	4.2 ± 0.1	4.2 ± 0.1
Control ($n = 8$)	3.8 ± 0.3	4.0 ± 0.3	4.1 ± 0.1	4.1 ± 0.2	4.2 ± 0.2
Pretraining (covariate)	3.9				
Sum of 4 skinfolds (mm)					
Strength-soccer ($n = 9$)	30.0 ± 1.9	28.3 ± 1.6	38.9 ± 1.4	28.1 ± 1.6	37.6 ± 1.8
Soccer ($n = 9$)	40.0 ± 3.5	38.4 ± 3.5	40.4 ± 1.2	37.5 ± 3.3†	39.2 ± 1.6
Control ($n = 8$)	58.7 ± 6.6	55.4 ± 5.7	41.2 ± 1.6	47.2 ± 5.5†‡	34.4 ± 2.1
Pretraining (covariate)	42.3				
Body fat (%)					
Strength-soccer ($n = 9$)	12.2 ± 0.9	11.9 ± 0.7	16.9 ± 0.7	12.0 ± 0.7	16.8 ± 0.8
Soccer ($n = 9$)	16.6 ± 1.5	15.8 ± 1.6	16.9 ± 0.6	15.8 ± 1.5	16.9 ± 0.6
Control ($n = 8$)	24.8 ± 2.9	23.5 ± 2.6	17.4 ± 0.8	20.3 ± 2.5†‡	14.6 ± 0.8
Pretraining (covariate)	17.8				
Girth, midthigh (cm)					
Strength-soccer ($n = 9$)	45.4 ± 1.1	46.4 ± 1.4†	48.0 ± 0.3	48.1 ± 1.4†‡	49.4 ± 0.6
Soccer ($n = 9$)	47.7 ± 0.9	48.3 ± 0.8	47.6 ± 0.3	48.9 ± 0.8†	48.3 ± 0.6
Control ($n = 8$)	47.9 ± 1.9	49.3 ± 1.8	48.5 ± 0.4	48.3 ± 1.5	47.5 ± 0.6§
Pretraining (covariate)	47.0				
Girth, calf (cm)					
Strength-soccer ($n = 9$)	32.9 ± 0.8	33.1 ± 0.9	34.0 ± 0.2	33.6 ± 0.9†	34.4 ± 0.2
Soccer ($n = 9$)	33.9 ± 0.4	34.1 ± 0.6	34.0 ± 0.2	34.4 ± 0.6†	34.2 ± 0.2
Control ($n = 8$)	34.5 ± 1.2	34.7 ± 1.2	34.0 ± 0.2	34.2 ± 1.1	33.5 ± 0.2§
Pretraining (covariate)	33.8				
Girth, upper arm (cm)					
Strength-soccer ($n = 9$)	23.8 ± 1.0	23.7 ± 0.9	24.1 ± 0.2	24.0 ± 0.9	24.4 ± 0.2
Soccer ($n = 9$)	23.4 ± 0.4	23.0 ± 0.4†	23.7 ± 0.2	23.4 ± 0.4‡	24.1 ± 0.2
Control ($n = 8$)	25.2 ± 1.1	25.4 ± 1.3	24.3 ± 0.2	24.8 ± 1.0	23.8 ± 0.2
Pretraining (covariate)	24.1				
Girth, midbiceps (flexed) (cm)					
Strength-soccer ($n = 9$)	25.7 ± 1	26 ± 1	26.7 ± 0.3	26.4 ± 1	26.9 ± 0.3
Soccer ($n = 9$)	26.0 ± 0.5	25.4 ± 0.5	25.7 ± 0.3	25.6 ± 0.5	25.9 ± 0.3
Control ($n = 8$)	27.0 ± 1.2	26.9 ± 1.3	26.1 ± 0.3	26.2 ± 1	25.5 ± 0.3
Pretraining (covariate)	26.2				

* $p < 0.05$.
† From pretraining.
‡ From 8 weeks.
§ Between strength soccer and control.

then on the improvement of physical capacities. Technical skills, such as dribbling, passing, receiving, shooting, and heading were performed for 40–50 minutes in at least 3 training sessions a week. In addition, soccer drills and games were performed in small areas from squads with a reduced number of players (1 vs. 1, 3 vs. 3, 4 vs. 4) to work on offensive and defensive strategies and individual tactics. High-intensity training for the development of running speed and agility (with and without a ball) was carried out twice a week, and 1 training session per week included soccer games or interval training for the development of aerobic capacity. A half-field game lasting 20–30 minutes was played at the end of each training session. Stretching exercises for the main muscle groups were executed in the warm-up and cool-down periods.

Testing Procedures

A standardized 15- to 20-minute warm-up consisting of submaximal aerobic exercises and stretching exercises preceded each test.

Anthropometric Measurements. All boys were measured for height, weight, body fat, and selected girths.

Body fat was measured using triceps and calf skinfolds as described by Slaughter et al. (33). Girth measures of the upper arm, midbiceps (flexed), midthigh, and calf (maximum girth of calf muscle) were obtained with an anthropometric tape measure as described by Callaway et al. (11). All anthropometric and body composition measures were taken from the right side by the same investigator.

Maximum Strength. All boys were evaluated for 1RM in the bench press and leg press. The 1RM was typically determined within 6 trials using the protocol of Ramsey et al. (29). All testing procedures were closely supervised (an instructor-to-subject ratio was 1:1), and verbal encouragement was given to all boys. All measurements were performed with a constant position of the body, using the same resistance equipment by the same test administrator. The intraclass correlation coefficient (ICC) and the coefficient of variation (CV) of the *SEM* for the measurement of maximum strength were $r = 0.975$ and 2.81%, respectively.

Vertical Jump Performance. Vertical jump performance was measured with 3 types of jumps: a squat jump (SJ; initiated from a knee flexion of 90°), a countermovement jump (CMJ), and repeated jumps (RJ) for 30 seconds (9, 10). During the performance of the jumps, the hands of the boys were placed on the waist. The jumps were executed on a platform connected to a digital timer (Ergojump, Psion CM; MAGICA, Rome, Italy) that measured flight time and calculated jump height. For the SJ and the CMJ, after 2–3 practice trials, 3 trials were carried out for each type of jump (1–2 minutes of rest were allowed between jumps), and the best trial was used for further analysis. For the RJ test, the boys were instructed to jump continuously using maximal effort. For every jump, the position of takeoff and landing were the same. To standardize knee angular displacement during the contact phase, the boys were instructed to bend the knee to about 90°. Pilot testing revealed an ICC and a CV of the *SEM* of $r = 0.971$ and 2.47% for the SJ, $r = 0.957$ and 3.42% for the CMJ, and $r = 0.932$ and 3.44% for the RJ, respectively.

10- and 30-m Sprint Time. Sprint time was measured using 3 electronic photo cells connected to a Lafayette 63501 timer (Lafayette Instrument Co. Systems, Lafayette, IN). A photocell was placed at the start, at 10 m, and at 30 m. The first photocell was positioned at a height of 50 cm from the ground and the photocells of 10 and 30 m were placed at the height of the head of the boys, in an attempt to standardize the part of the body breaking the photocell (5). The boys started on a visual signal from a standing position and ran the 30-m distance as fast as possible on an indoor running track. After 1 practice trial, 2 sprints were performed, separated by a 5-minute recovery period, and the fastest was used for subsequent analysis. All performance times were recorded with an accuracy of 0.001 seconds, and the time from 0 to 10 m and total sprint time from 0 to 30 m was recorded. These sprint distances were selected because they are the most common during soccer games (6). The ICC and the CV of the *SEM* for the 10-m sprint were $r = 0.958$ and 1.46%, and for the 30-m sprint, $r = 0.979$ and 0.83%, respectively.

Agility (10 × 5 m). Agility was evaluated using a 10 × 5-m maximal shuttle run on an indoor running track following the protocol of Eurofit (16). After 1 practice trial and at least 5 minutes of rest, a maximum test was performed. Performance time was recorded with an accuracy of 0.01 seconds. The ICC and the CV of the *SEM* for the 10 × 5-m shuttle run test were $r = 0.935$ and 1.01%, respectively.

Flexibility. Flexibility of the lower back and hamstrings was measured using the sit and reach test as suggested by the American Alliance of Health, Physical Education, Recreation, and Dance (2). Two trials were performed, and the best one was used for further analysis. The ICC and the CV of the *SEM* for the sit and reach test were $r = 0.979$ and 2.71%, respectively.

Soccer Technique Test. Technical skills in soccer were evaluated using a slalom dribble test (35). The boys performed zigzag dribbling with the preferred leg around a series of 9 cones with a distance of 1.5 m between them (total distance, 14 m). After 2 practice trials, 2 maximum efforts of zigzag dribbling were performed separated by a 2-minute rest. The fastest and most successful trial (without losing possession of the ball) was recorded for further analysis. All performance times were recorded with an accuracy of 0.001 seconds, using an electronic timer (Lafayette Instrument Co. Systems). Pilot testing revealed an ICC and a CV of the *SEM* of $r = 0.982$ and 1.88%, respectively.

Statistical Analyses

The effects of training on each group were tested using a repeated-measures analysis of variance and the effect size ([posttest mean − pretest mean]/*SD*) for the magnitude of treatment effects was determined (12, 30). A two-way analysis of covariance (ANCOVA), using initial values as covariate and η^2 for effect size, was used to determine the differences between groups at the 8th and 16th week of training. Statistical power (*P*) for the ANCOVA was determined as suggested by Keppel (22). Significant differences between means were located with the Tukey honestly significant difference procedure. The statistical significance level was set at $p < 0.05$.

Results

Anthropometric Measurements

Significant main effects ($p < 0.05$) were observed for height and weight, but no differences ($p > 0.05$) were found between groups. No significant changes were observed between groups for percentage of body fat and the sum of 4 skinfolds. Analysis of covariance revealed that midthigh and calf circumferences were larger ($p < 0.05$) for the STR group compared with the CON after 16 weeks of training (Table 2).

Maximal Strength

Leg Press (1RM). Training resulted in significant increases ($p < 0.01$) in lower body strength for the STR (58.8%) and SOC groups (33.8%). A significant increase (17.3%; $p < 0.05$), indicative of growth, was also observed for the control group (Table 3). For all groups, the greatest increase was observed after the first 8 weeks of training (37.7, 20.7, and 9% respectively). Further analysis (ANCOVA) revealed significant differences between groups in maximum strength ($p < 0.01$, $\eta^2 = 0.551$, $P = 1$). Leg press 1RM for the STR group was greater than that achieved by the SOC and CON groups after 8 and 16 weeks of training. Maximum strength of the SOC group

TABLE 3. Physical performance and soccer technique scores for the three groups for the 16-week training program.*

Group	Pretraining	8 weeks			16 weeks		
	Means ± *SE*	Means ± *SE*	Effect size	Adjusted means	Means ± *SE*	Effect size	Adjusted means
Flexibility (cm)							
Strength-Soccer (n = 9)	26.7 ± 1.8	23.7 ± 2.2†	−0.5	20.1 ± 1.2	24.6 ± 1.9	−0.37	21.2 ± 1.1
Soccer (n = 9)	22.1 ± 3.8	23.2 ± 3.3	0.11	23.5 ± 1.2	24.7 ± 2.8	0.26	24.9 ± 1.1
Control (n = 8)	18.3 ± 2.9	18.7 ± 1.2	0.05	22.1 ± 1.2	18.4 ± 2.8	0.01	21.5 ± 1.2
Pretraining (covariate)	22.5						
Sprint time 10 m (s)							
Strength-soccer (n = 9)	2.16 ± 0.06	2.18 ± 0.07	0.14	2.14 ± 0.04	2.09 ± 0.04	−0.41	2.06 ± 0.03
Soccer (n = 9)	2.00 ± 0.04	2.04 ± 0.04	0.4	2.13 ± 0.04	1.98 ± 0.04	−0.15	2.05 ± 0.03
Control (n = 8)	2.18 ± 0.05	2.20 ± 0.06	0.12	2.15 ± 0.04	2.11 ± 0.04	−0.48	2.07 ± 0.03
Pretraining (covariate)	2.11						
Sprint time 30 m (s)							
Strength-Soccer (n = 9)	5.07 ± 0.16	5.16 ± 0.16	0.19	5.13 ± 0.05	4.94 ± 0.12†‡	−0.3	4.91 ± 0.04
Soccer (n = 9)	4.85 ± 0.09	4.88 ± 0.10	0.1	5.04 ± 0.05	4.85 ± 0.10	0	5.00 ± 0.04
Control (n = 8)	5.20 ± 0.11	5.26 ± 0.06	0.22	5.12 ± 0.05	5.22 ± 0.10	0.06	5.09 ± 0.04‡
Pretraining (covariate)	5.04						
Agility 10 × 5 m (s)							
Strength-soccer (n = 9)	19.92 ± 0.24	19.25 ± 0.29†	−0.83	19.43 ± 0.16	18.84 ± 0.16†	−1.74	18.97 ± 0.19
Soccer (n = 9)	19.78 ± 0.21	19.07 ± 0.22†	−1.08	19.34 ± 0.16	18.99 ± 0.24†	−1.13	19.19 ± 0.20
Control (n = 8)	20.86 ± 0.63	20.89 ± 0.41	0.02	20.43 ± 0.18‡§	21.12 ± 0.40	0.17	20.78 ± 0.22‡§
Pretraining (covariate)	20.18						
Mean height of repeated jumps for 30 s (cm)							
Strength-soccer (n = 9)	21.6 ± 1.4	22.4 ± 1.3	0.2	21.4 ± 0.5	24.8 ± 1.4†‡	0.76	23.7 ± 0.7
Soccer (n = 9)	22.2 ± 1.3	23.0 ± 1.2	0.21	21.4 ± 0.5	23.7 ± 1.2†	0.41	22.0 ± 0.8
Control (n = 8)	16.9 ± 1.4	16.9 ± 1.1	0	19.5 ± 0.6	18.3 ± 1.4	0.36	21.0 ± 0.9
Pretraining (covariate)	20.21						
Soccer technique test (s)							
Strength-soccer (n = 9)	7.91 ± 0.20	7.51 ± 0.18	−0.69	7.95 ± 0.18	7.32 ± 0.10	−1.22	7.72 ± 0.19
Soccer (n = 9)	7.40 ± 0.24	7.21 ± 0.24	−0.25	8.08 ± 0.20	7.10 ± 0.26	−0.39	7.90 ± 0.22
Control (n = 8)	10.27 ± 0.55	10.32 ± 0.52	0.03	8.85 ± 0.26§	10.30 ± 0.51	0.02	8.95 ± 0.28‡§
Pre-training (covariate)	8.52						
Squat jump (cm)							
Strength-soccer (n = 9)	24.9 ± 1.4	28.1 ± 1.4†	0.76	27.9 ± 1	32.4 ± 1.6†	1.65	32.1 ± 1
Soccer (n = 9)	23.8 ± 1.2	25.2 ± 1.2	0.4	25.7 ± 1	25.9 ± 1.1	0.62	26.6 ± 1¶
Control (n = 8)	25 ± 2	26.5 ± 1.8	0.28	26.2 ± 1.1	27 ± 2.1	0.35	26.6 ± 1¶
Pretraining (covariate)	24.5						
Countermovement jump (cm)							
Strength-soccer (n = 9)	29 ± 1.6	32.9 ± 1.4†	0.86	33.1 ± 0.6	35.7 ± 1.4†	1.49	35.9 ± 0.8
Soccer (n = 9)	29.7 ± 1.7	30.3 ± 1.5	0.12	30 ± 0.6¶	31.1 ± 1.3	0.3	30.8 ± 0.8
Control (n = 8)	29 ± 2	30.6 ± 1.4	0.33	30.7 ± 0.7¶	31.2 ± 1.5	0.44	31.3 ± 0.9
Pretraining (covariate)	29.2						
Leg press 1RM (kg)							
Strength-soccer (n = 9)	102.8 ± 2.5	142.8 ± 8.5†	1.73	148.7 ± 4.7	163.9 ± 7.4†	2.77	170.1 ± 4.4
Soccer (n = 9)	106.1 ± 7	126.7 ± 6.7†	1	118.9 ± 4.8¶	139.4 ± 6†	1.7	132.5 ± 4.6¶
Control (n = 8)	93.8 ± 5.2	102.5 ± 6.7†	0.52	108.3 ± 5§	110 ± 6.8†	0.95	115.2 ± 4.8§‖
Pretraining (covariate)	100.9						
Bench press 1RM (kg)							
Strength-soccer (n = 9)	36 ± 1.6	45.9 ± 2.5†	1.57	50.6 ± 1.1	55 ± 3.1†	2.54	60.6 ± 1.5
Soccer (n = 9)	48.3 ± 3.2	47.8 ± 2.6	−0.01	41.4 ± 1.2¶	45.8 ± 3.4	−0.25	38.2 ± 1.5¶
Control (n = 8)	39.4 ± 2.7	41 ± 2.4	0.22	42.7 ± 1.1§	40.5 ± 2.5	0.15	42.5 ± 1.5§
Pretraining (covariate)	41.2						

* $p < 0.05$.
† From pretraining.
‡ From 8 weeks.
§ Between strength-soccer and control.
‖ Between soccer and control.
¶ Between strength-soccer and soccer.

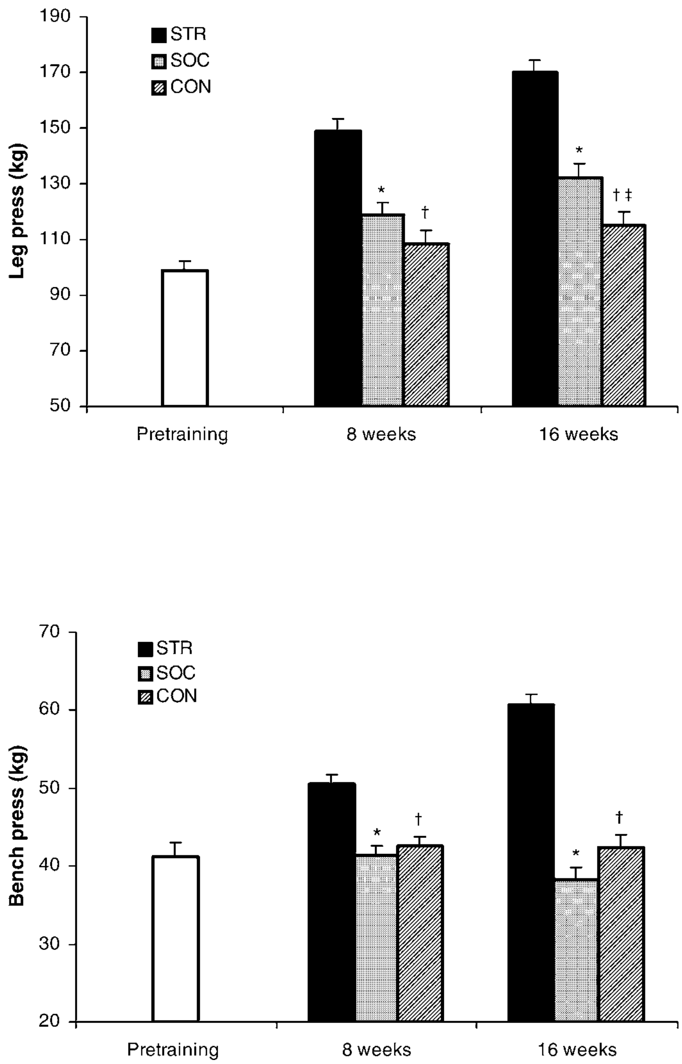

FIGURE 1. Differences between the strength-soccer (STR), soccer (SOC), and control (CON) groups in 1RM leg press and bench press. $*p < 0.01$ between STR and SOC, $\dagger p < 0.01$ between STR and CON, $\ddagger p < 0.05$ between SOC and CON.

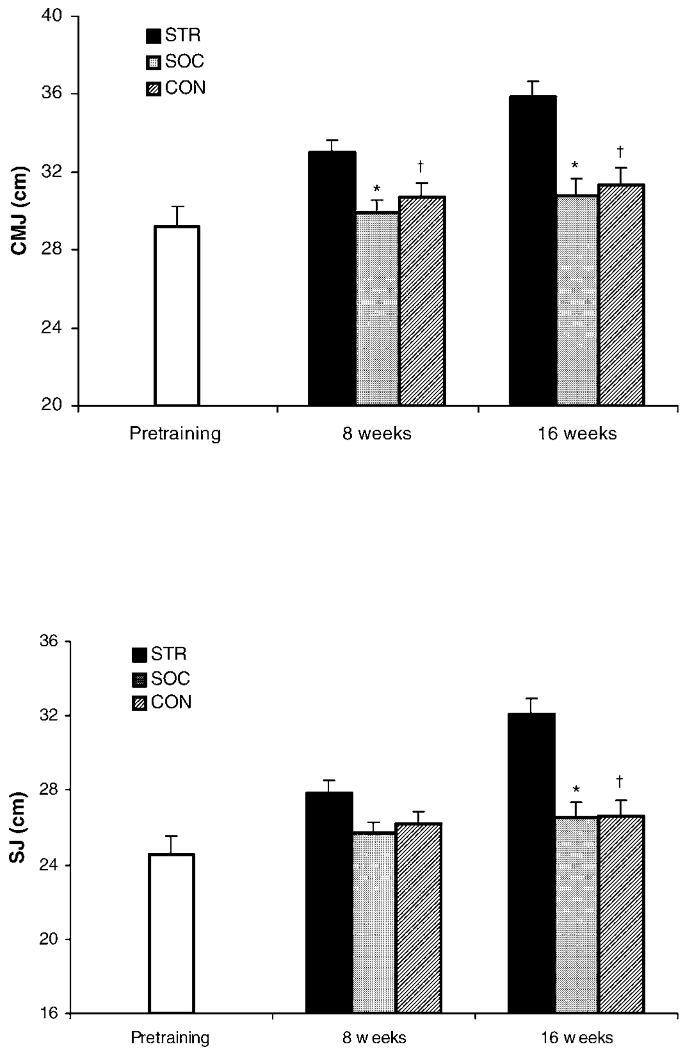

FIGURE 2. Differences between the strength-soccer (STR), soccer (SOC), and control (CON) groups in countermovement jump (CMJ) and squat jump (SJ). $*p < 0.05$ between STR and SOC, $\dagger p < 0.05$ between STR and CON.

was greater compared with the CON group only at the end of the 16-week training period (Figure 1).

Bench Press (1RM). After 8 and 16 weeks of training, bench press 1RM was significantly higher ($p < 0.01$) for the STR group than the SOC and CON groups ($p < 0.01$, $\eta^2 = 0.79$, $P = 1$; Figure 1). In particular, upper body strength increased only in the STR group (52.3%; $p < 0.01$), whereas no significant differences ($p > 0.05$) were observed for the SOC and CON groups (-5.4 and 3.3% respectively; Table 3).

Vertical Jump Performance

Squat Jump. After 16 weeks of training, SJ height was higher ($p < 0.05$, $\eta^2 = 0.33$, $P = 0.83$) for the STR group compared with the SOC and CON groups (Figure 2). SJ height was significantly improved by 13.5 and 31% for the STR after 8 and 16 weeks of training, respectively ($p < 0.05$). The increases observed for the SOC (9.8%) and CON (9.6%) groups were not significant ($p > 0.05$; Table 3).

Countermovement Jump. After 8 and 16 weeks of training, CMJ height was greater ($p < 0.01$, $\eta^2 = 0.49$, $P = 1$) for the STR group compared to the SOC and CON groups (Figure 2). CMJ height improved by 14.4 and 24.6% for the STR after 8 and 16 weeks of training, respectively ($p < 0.05$). No significant changes were observed for the SOC (6.3%) and CON (9.5%) groups (Table 3).

Repeated Jumps for 30 Seconds. After 16 weeks of training, the STR and the SOC groups improved significantly in average height during repeated jumps for 30 seconds (15.8 and 7.2%, respectively; $p < 0.05$), whereas the CON group showed a nonsignificant improvement (9.8%; $p > 0.05$). No significant differences were observed between groups after the end of the training period ($p = 0.07$, $\eta^2 = 0.21$, $P = 0.57$; Table 3).

Sprint and Agility Times

Running Speed. There were no significant improvements for 10-m acceleration speed in any group during the study, although the STR group showed a higher speed (3.1%) than the SOC (0.7%) and CON (2.7%) groups. No differences were observed between groups ($p = 0.99$, $\eta^2 = 0.01$, $P = 0.07$). Significant improvements in 30-m sprint time ($p < 0.05$) occurred only with the STR group

(2.5%) after 16 weeks of strength training, whereas no significant differences were found for the SOC (0.04%) and CON (−0.5%) groups. Sprint velocity was higher for the STR group compared with the SOC and CON groups at the end of the training period ($p = 0.049$, $\eta^2 = 0.24$, $P = 0.65$; Table 3).

Agility Time. Improvements were observed in the 10 × 5-m shuttle run for the STR and SOC groups after 8 (3.4 and 3.5%, respectively; $p < 0.05$), and 16 weeks (5.4 and 4%, respectively) of training, whereas no changes were observed in the CON (−1.6%) group. The ANCOVA revealed significant differences between groups in agility time ($p < 0.01$, $\eta^2 = 0.65$, $P = 1$) with the STR and the SOC groups being faster than the CON group (Table 3).

Flexibility

Sit and reach scores decreased significantly by 8.2% in the STR group ($p < 0.05$), whereas they increased, but not in a significant way, in the SOC and CON groups. The 3 groups did not differ in flexibility scores throughout the course of the study ($p = 0.07$, $\eta^2 = 0.22$, $P = 0.62$; Table 3).

Soccer Technique Test

The STR and SOC groups improved their performance (6.8 and 4.0%, respectively) in the soccer technique test after training, but this improvement was not significant ($p > 0.05$). No changes were observed in the CON group (−0.4%; $p > 0.05$). The scores in the soccer technique test, at the end of the training period, were better for both the STR and SOC groups compared with the CON group, whereas no differences were observed between them ($p < 0.05$, $\eta^2 = 0.34$, $P = 0.83$; Table 3).

Discussion

The soccer training applied in this study improves agility, flexibility, and strength of the lower extremities. Strength training twice a week in addition to soccer training (5 times per week) caused greater increases in upper- and lower-body strength and improved more vertical jump performance compared with soccer training alone. Furthermore, strength-soccer training improved agility time and 30-m running speed compared with subjects who did not get any structured training. Flexibility decreased (8%), and 10-m acceleration time was not affected by strength training.

All 3 groups increased their lower-body strength (leg press). However, upper-body strength (bench press) improved only in the STR group, whereas the SOC and CON groups showed minor increases. These results, based on the principle of specificity, confirm the findings of other studies in children (29) and adolescents (20, 21). Lower-body muscles are used more in daily physical activities and are strengthened faster than the upper-body muscles that may be used less frequently (29). Therefore, strength training for the upper-body muscles of adolescents seems to be necessary for an optimal growth of the whole body and especially for participants in sports such as soccer, where strength stimuli for the upper body are rare.

The high acceleration of sprint, the stopping movements after a sprint, and the changes in direction are actions that occur frequently in soccer. These activities require the development and application of high forces from the legs, causing a greater leg strength increase in our soccer training group than natural growth. The specific effect that soccer has on leg strength is supported by the fact that these adaptations are limited to the leg musculature, because maximum strength of the arms, which are not used in soccer, did not increase.

Specific neural adaptations, such as increased motor unit recruitment and coordination, and improved coordination of the involved muscle groups have been reported after resistance training programs in children and adolescents (28, 29). The STR group improved significantly in 1RM bench press without any increases in their flexed midbiceps circumferences, indicating that strength increases were mainly caused by neural adaptations. However, the possibility of muscular hypertrophy in adolescents caused by strength training should not be overlooked (8, 21, 25). The strength improvements of the lower body muscles (1RM leg press) for the STR group were accompanied by an increase in midthigh and calf circumferences, with minor changes in midthigh and calf skinfold sites. Although circumference increases may follow natural growth and development (24), our data suggest the possibility of muscular hypertrophy caused by strength training. The use of advanced techniques, such as magnetic resonance imaging, would provide better results on muscular hypertrophy in adolescents after strength training.

Vertical jump performance (SJ and CMJ) increased significantly only in the STR group. Our results confirm previous studies with prepubescent active men (31, 36) and pubescent athletes (21). It seems that the increase in the maximal muscle force, as a result of strength training, also improves muscular power, despite the absence of specific exercises for the improvement of jump performance. To our knowledge this is the first study that shows significant improvement in jumping ability as a result of strength training in adolescent soccer players.

Strength training combined with soccer training or soccer training alone had no effects on anaerobic capacity, evaluated with the average height of repeated jumps for 30 seconds. Similarly, other studies using the Wingate test in preadolescents and adolescent subjects did not find changes in anaerobic capacity, after strength training (15, 21). In the STR group, SJ and CMJ performance increased to a greater rate than in the SOC and CON groups. Although no significant differences were observed between groups for repeated jump performance, the STR group showed higher performance than the SOC and CON groups. The results may be caused by the different neuromuscular and metabolic components of anaerobic performance. Short-term power output (SJ and CMJ) depends more on the degree of neuromuscular activation than on energy provision from anaerobic metabolism (27). Besides the need of high neuromuscular activation, the 30-second all-out test (intermediate anaerobic performance) activates anaerobic glycolysis and causes lactate production because of the length of the protocol. Thus, when increasing their maximum strength, children and adolescents can benefit to a greater degree on maximum anaerobic power.

Running speed has been found to correlate with maximum strength and VJ performance (4, 21). However, an improvement in maximum strength does not assure an improvement in sprinting velocity as well (13, 37). In a study concerning a similar age group with ours, Hetzler et al. (21) did not find an improvement in a 40-yd sprint in boys who followed strength training. In this study, however, where the STR group followed strength and sprint training, a significant improvement in 30-m sprint time was observed, along with an improvement in maximum strength and vertical jump performance. Soccer training did not lead to an improvement in sprint despite the fact that specific sprint training took place 2 days a week. It seems that a combination of strength and speed training may be more beneficial for speed development. It should be noted, however, that based on the data of our study, the transfer of strength gain to speed was rather small (58.8% increase in leg strength vs. 2.5% in 30-m speed), and a low correlation was observed between the percent increase in leg strength and 30-m speed (r = 0.24).

Agility was affected in a similar way in both the STR and SOC groups, indicating the specificity of soccer training. Soccer training drills and games involved continuous changes of direction. Thus, agility performance improved with this type of training, without any further contribution from strength training. Furthermore, it is interesting to note that the soccer training group improved only during the agility test, which involved fast running with changes in direction, and not in 30-m speed that involved forward fast running. This probably reflects the specificity of soccer training and the need for targeted speed training for an overall improvement of soccer performance. To our knowledge, the only study that examined the effects of 12 weeks of strength training in agility involving preadolescent boys was that of Falk and Mor (19) and it is in agreement with our result. Despite these limited data, it seems that strength training has a minor effect on agility performance of young people. There is a minor transfer of the strength gain to agility, which probably involves a motor control pattern that is not strongly influenced by the neural adaptations, which occur with resistance training.

Flexibility increased in the soccer training group. Although it was not significantly different from the control group, it seems that the participation in soccer training does not impair flexibility development when proper care is taken to include stretching exercises in the training program. Studies performed in adults reported that if stretching exercises are part of the strength training program, flexibility would not be impaired and it may even increase (34). In this study, stretching exercises were performed before, during, and after the strength training sessions. However, flexibility of the hamstrings and the lower back muscles decreased (8%) in the STR group. Previous studies involving children and prepubescents reported either increases or no changes in flexibility after strength training when using programs with low to moderate volume and intensity (17–19, 32, 36). The high volume and intensity of resistance training or the combination of soccer and resistance training in our study probably interfered with flexibility. More emphasis was probably required on specific stretching exercises. Furthermore, our subjects were adolescents and the phase of their physical development might also interact with flexibility levels. It should be noted that, even in the control group, a slight decrease in flexibility was observed. Studies reported that inadequate flexibility might limit joint mobility and predispose the muscles or the connective tissue to injury and reduced performance (7, 34). However, no injury was observed during the course of this study in the STR group and other physical performance components improved in this group. In any case, it seems that additional stretching exercises or sessions for the maintenance or improvement of flexibility are necessary to prevent muscles from becoming tight during strength training. Further research is needed to determine which factors might impede flexibility or not when adolescent soccer players lift weights.

Resistance training had no effects on the soccer technique test used in this study. The nature of the test (dribbling with a ball between cones) is such that resistance training would have a minor effect in comparison with a training program focusing more on motor performance development. This does not mean that resistance training has no effect on any soccer-related action. If we had used another soccer-specific test (e.g., speed of the ball after a shot), we might have seen some sort of effect through the increased leg force after strength training. For example, Gorostiaga et al. (20) found that handball throwing velocity in adolescent handball players increased after resistance training. Furthermore, resistance training may improve performance during a soccer game through a greater speed and jumping ability, which help the player to get control of the ball. In any case, it should be noted that in this study we applied a low-frequency resistance training program of moderate to submaximal intensity, using basic core exercises and not sport specific strength exercises, during the competition period. The aim was not to maximize soccer performance but to develop the neuromuscular system of the athletes and help them to tolerate the mechanical stress of the various soccer actions more and protect them from possible injuries. This might be even more important than an improved performance in the sport.

Practical Applications

Soccer is a popular sport worldwide, and many youths participate in soccer training programs. Soccer training in adolescents provides a pleasant pastime and seems to increase the parameters of physical capacity and soccer-related skills. Soccer training alone improves maximal strength of the lower-body muscles and agility, and when stretching is included in the training program flexibility also increases. The application of soccer training combined with low frequency of moderate to submaximal intensity resistance training offers an overall development of physical capacities by improving in a greater degree soccer-related abilities such as maximal strength of the upper- and lower-body muscles, VJ performance, and 30-m speed compared with regular soccer training. More emphasis should be given, however, to stretching exercises when the soccer training program is combined with resistance training. This may prevent any possible inconvenience caused after resistance training on flexibility during the developmental period.

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