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Changes in Muscle Strength, Jump, and Sprint Performance in Young Elite Basketball Players: The Impact of Combined High-Speed Resistance Training and Plyometrics

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Abstract

Yáñez-García, JM, Rodríguez-Rosell, D, Mora-Custodio, R, and González-Badillo, JJ. Changes in muscle strength, jump, and sprint performance in young elite basketball players: the impact of combined high-speed resistance training and plyometrics. *J Strength Cond Res* XX(X): 000–000, 2019—This study aimed to compare the effect of a combined resistance training (RT) and plyometrics on strength, sprint, and jump performance in basketball players of different ages. Thirty three elite basketball players from the same academy were categorized into 3 groups by chronological age: under-13 (U13, $n = 11$); under-15 (U15, $n = 11$); and under-17 (U17, $n = 11$). Players participated in a 6-week strength training program that included 2 sessions each week and consisted of full squats with low loads (45–60% 1 repetition maximum) and low volume (2–3 sets and 4–8 repetitions), jumps, and sprint exercises. All repetitions were performed at maximal intended velocity. In addition to strength training sessions, subjects performed 4 on court basketball training sessions plus 2 official matches per week. After training program, all 3 experimental groups resulted in significant improvements ($p < 0.05$–0.001) in maximal strength (Δ: 9.2–27.3%; effect size [ES]: 0.38–0.82), countermovement jump height (Δ: 6.6–11.6%; ES: 0.37–0.95), and sprint time in 10 and 20 m (Δ: −3.9 to −0.3%; ES: 0.09–0.69) for all experimental groups. Comparison between groups showed that training program was more effective in inducing improvements in most variables assessed for U13 compared with U15 (ES: 0.11–0.42) and U17 (ES: 0.20–0.43), whereas differences between U15 and U17 were relevant in jump and strength parameters (ES: 0.20–0.35). Therefore, these findings suggest that high-speed RT combined with plyometrics produces increments in several important variables, including strength, jump, and sprint, to yield high performance during a match in young basketball players. However, training program used seems to be generally less effective as the age of the basketball players increased.

Key Words: strength training, strength gains, chronological age, maturity status, full squat

Introduction

Basketball is an intermittent team sport characterized by high-intensity running displacements, accelerations, decelerations, sprints, continuous changes of direction, jumping, and specific technical skills (4,5). Thus, improvements in these actions could provide important benefits in offensive and defensive tasks such as dribbling, blocking, shooting, and rebounding, which are motor skills of paramount importance to success during a basketball game (47,52). For this reason, performance in basketball players is highly related to strength and muscular power of the lower limbs, being the capacity to apply high rates of force production a crucial factor for success during the competition. In fact, several studies have shown a positive relationship between lower-limb strength and jump ability, acceleration, and change of direction capacity in basketball players (8,48). In addition, it was found that strength decrement in knee flexors and extensors was significantly related to jump and sprint fatigue during the basketball game (43), whereas other studies (12) have shown the ability to sustain high-intensity intermittent efforts and strength/power characteristics (vertical jump height) can differentiate between basketball players of different competitive levels and playing position. Thus, it seems that the implementation of strength training programs that allow to improve several high-speed actions could be adequate in obtaining high levels of performance in basketball players (42,44,47).

Several strength training methods, including resistance training (RT), plyometric training (PT), and combined RT and PT, have been shown to be effective in eliciting beneficial effects on neuromuscular performance in young athletes and nonathletes (9–11,21,38). Specifically, in young basketball players, most studies have used PT (18,23,27,45), generally showing increments in vertical jump (10–15%), sprint (3–5%), and change of direction (6–10%) performance after 6- to 8-week training period. However, although previous studies have suggested that short-term combined RT and PT programs induce improvements on sport-related motor skills and strength performance than PT or RT alone (10,11), little is known about the effect of this type of training program in young basketball players (7,42).

Traditionally, studies using RT (either alone or in combination with PT) in young subjects involved high loads and repetitions ending at or close to muscle failure (9,10,42). However, recent studies (14,16,33,34,36,49,50) have indicated that RT programs with low loads, low volume, and maximal intended lifting

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velocities, either alone or in combination with plyometric exercises, are equally or more effective than RT programs with heavy loads in inducing strength, jump, and sprint improvements, as well as performance increments in the ability to reproduce maximal sprint efforts separated by short rest periods, in soccer and futsal players of different ages. However, whether a strength training program with these characteristics is effective in inducing physical performance improvements in young basketball players remains unknown. In addition, to the best of our knowledge, no studies have analyzed the influence of maturity levels on changes in strength and sport-related performance in basketball players after engaging in strength training programs with these characteristics.

During the maturation process occur several changes in body size, composition, and functional capacities (6,26). These morphological and neural changes could play an important role in the ability of the neuromuscular system to adapt to a specific training stimulus (6,26). Therefore, because of the differences in physical performance and physiological development between boys of contrasting maturity status, it is likely that individuals of different sexual and skeletal maturity may adapt differently to a given training stimulus (26). In this regard, some studies (15,24,25,28,33,40,51) have analyzed the effect of applying the same strength training program on changes in physical performance in different age groups. Generally, these studies were (15,24,28,31,40,51) conducted using RT programs with loads ranging from 70 to 90% of 1 repetition maximum (1RM) (combined or no with plyometrics training) and showed conflicting results depending on the measured variable. For strength gains, previous studies have showed no significant differences between different age training groups (24,31) or greater effect for older compared with young individuals (28,51). However, for sport-related tasks, most studies have shown superior gains in younger compared with older individuals (15,24,40), although others studies using heavy-load RT or combined training resulted in greater beneficial effects on sprint time for older than younger subject, whereas the effect on jump performance was the opposite (25). Despite these findings, to the authors' knowledge, the changes in sprint, jump, and strength performance in basketball players of different maturity status after a given strength training program have not yet been studied.

Therefore, in light of the aforementioned considerations, the aim of this study was to analyze and compare the effect of adding to the typically technical-tactical basketball training an RT program with low loads and low numbers of repetitions per set combined with plyometrics on strength, jumping, and sprint performance among under-13 (U13), under-15 (U15), and under-17 (U17) elite basketball players over 6 weeks of the in-season phase.

Methods

Experimental Approach to the Problem

This study was designed to analyze the effect of a 6-week RT program with low loads and low volume combined with jump and speed exercises on physical performance in basketball players of 3 different categories (U13, U15, and U17). At the time of the study, all players were competing at national level (i.e., Spanish National Basketball League). All the players, regardless of group, participated in 4 on court basketball training sessions plus 2 official matches per week. All subjects were evaluated before (Pre) and after (Post) 6 weeks of training period using a battery of tests performed in the following order: (a) 20-m all-out running sprints; (b) countermovement vertical jumps (CMJ); and (c) a progressive isoinertial loading test in full squat exercise. The intervention was performed during the season period (January–February). During the preceding 2 weeks of this study, 4 preliminary familiarization sessions were undertaken with the purpose of to ensure a proper execution technique of full squat and CMJ exercises.

Subjects

Thirty three trained young basketball players between 12 and 17 years of age volunteered for this study. Players belonged to a first Spanish basketball division (ACB-Liga Endesa) club academy squad and were competing in the under-13 (U13, $n = 11$), under-15 (U15, $n = 11$), or under-17 (U17, $n = 11$) divisional age groups. Only those players who participated in at least 90% of all training sessions were included into statistical analyses. Player's characteristics are displayed in Table 1. All subjects were basketball trained for more than 2 (U13), 4 (U15), and 6 (U17) years and were injury free for at least 6 months before participating in this study. Subjects had no experience in strength training, and they did not perform strength training as part of their normal training routine. Coach and parents were informed about the different test procedures performed during the study. Parental/guardian consents for all players involved in this investigation were obtained. The study was conducted according to the Declaration of Helsinki and was approved by the Research Ethics Committee of Pablo de Olavide University.

Procedures

Anthropometric measurements were taken before the physical testing. The standing height (cm) and body mass (kg) were measured. The maturity status of the subjects was determined using years from/to peak-height velocity (PHV) (i.e., maturity offset $= -7.999{,}994 + [0.0036124 \times \text{age} \times \text{height}]$ $[R^2 = 0.896]$) (29) as well as the percentage of predicted adult stature (46). Neuromuscular performance was assessed before and after training using a battery of tests performed in a single session in a fixed sequence as described below. The tests were performed after 48 hours of rest. Testing sessions were performed at the same venue (covered research center) and time of day (±1 hour) for each subject under the same environmental conditions (~21° C and ~60% humidity). Before the physical performance assessment, all subjects performed a general standardized warm-up consisting of 5 minutes of running at a self-selected intensity, 5 minutes of joint mobilization exercises, followed by 3 sets of progressively faster 30-m running accelerations. Exactly the same testing protocol was performed during both Pre and Post testing sessions. Strong verbal encouragement was provided during all tests to motivate subjects to give a maximal effort.

Table 1
Subject's physical characteristics (mean ± *SD*).*

Groups	Age (y)	Mass (kg)	Height (m)	MO (y)	PAS (%)
U13	13.1 ± 0.5	64.2 ± 13.7	1.76 ± 0.07	0.32 ± 0.49	92.9 ± 2.1
U15	14.8 ± 0.4	77.1 ± 12.5	1.87 ± 0.05	2.03 ± 0.49	98.4 ± 1.1
U17	16.5 ± 0.5	84.0 ± 10.6	1.93 ± 0.07	3.50 ± 0.66	100.0 ± 0.9

*MO = maturity offset; PAS = predicted adult stature.

Running Sprints. Two 20-m sprints, separated by a 3-minute rest, were performed in an indoor synthetic running track, and the best of both attempts (taking as a criterion the shortest time in 20 m) was kept for analysis. Photocell timing gates (Polifemo Radio Light, Microgate, Bolzano, Italy) were placed at 0, 10, and 20 m, so that the times to cover 0–10 m (T10), 0–20 m (T20), and 10–20 m (T10-20) could be determined. A standing start with the lead-off foot placed 1 m behind the first timing gate was used. Subjects were required to give an all-out maximal effort in each sprint, and the best of both trials was kept for subsequent analysis. The same warm-up protocol, which incorporated several sets of progressively faster 30-m running accelerations, was followed in the pre-tests and post-tests. The coefficients of variation (CV) for test-retest reliability and the intraclass correlation coefficients (ICC) for T10, T20, and T10-20 in each training group are displayed in Table 2.

Vertical Jump. The height of the jump was measured with an infrared timing system (Optojump, Microgate, Bolzano, Italy). Each player performed 5 maximal jumps with their hands on their hips separated by 45-second rests. The highest and lowest values were discarded, and the resulting mean value was kept for analysis. The warm-up consisted of 2 sets of 10 repetitions of squat without extra load and 1 set of 5 CMJs. The CMJ test was chosen because it has been shown to have high reliability and high relationship with strength and sprint performance in basketball players of different ages (35). The absolute reliability and relative reliability for CMJ test are presented in Table 2.

Progressive Loading Test in SQ Exercise. A Smith machine (Multipower Fitness Line; Peroga, Murcia, Spain) was used for the isoinertial test. A detailed description of the testing procedures used in this study has recently been reported elsewhere (16,39). The players performed the full squat from an upright position, descending at a controlled velocity and ascending at maximal velocity. The initial load was set at 10 kg (for U13) or 20 kg (for U15 and U17) and was progressively increased in 5 kg (for U13) or 10 kg (for U15 and U17) increments until the attained mean propulsive velocity (MPV) was ~1.00 $m \cdot s^{-1}$ (range: 0.96–1.04 $m \cdot s^{-1}$) (16,33). The subjects performed 3 repetitions with each load. The interset recovery time was 3 minutes. The total number of increasing loads performed during the progressive loading test was 7.1 ± 2.4, 7.3 ± 2.1, and 8.6 ± 2.9 for U13, U15, and U17, respectively. Warm-up consisted of 5 minutes of joint mobilization exercises, followed by 2 sets of 6 repetitions (3 minutes rest) with 10 kg (for U13) or 20 kg (for U15 and U17). A linear velocity transducer (T-Force System; Ergotech, Murcia, Spain) was used to register bar velocity. The estimated 1RM (1RMest) was calculated for each individual from the MPV attained against the heaviest load (kg) lifted in the progressive loading test, as follows: $(100 \times \text{LOAD})/(-5.961 \times \text{MPV}^2) - (50.71 \times \text{MPV}) + 117.0$ ($R^2 = 0.954$; $SEE = 4.02\%$) (39).

Strength Training Program

Experimental groups trained twice a week on nonconsecutive days (Monday and Thursday), for a period of 6 weeks using free-weight full squat combined with jumps, sprints, and changes of direction. These training sessions lasted ~40 minutes. Table 3 shows in detail the characteristics of the training program. Training exercises were performed in the same order in which they appear in such table (e.g., in session 2, training exercises were performed in the following order: full squat, CMJ, and sprint), and all training sets of an exercise (e.g., full squat) had to be completed before performing the following training exercise. The loads used by each player in full squat exercise were assigned according to 1RMest in the initial isoinertial squat loading test. Thus, relative intensity of the squat exercise progressively increased from ~45% 1RM to ~60% 1RM. The RT program was combined with vertical jumps to box, linear sprint of 20 m, and displacements with changes of direction without extra loads. This exercise was performed on 3 attached squares of 8-m side length. Within this area, the subjects had to perform displacements at maximum speed, changing direction (forward, backward, left, and right) according to researcher indications for 10 seconds. Approximately 3-minute rest periods were allowed between each set and each exercise. The subjects were instructed to perform all exercises as fast as possible to obtain the highest possible gains (30). At least 2 trained researchers supervised each workout session and recorded the compliance and individual workout data during each training session. In all sessions, warm-up consisted of 5 minutes of jogging and 3 minutes of joint mobilization exercises. Then, 2 sets of 8 and 6 repetitions (separated by 3-minute rests) of full squat with lower loads at maximal scheduled load in each session were performed.

Statistical Analyses

The values are expressed as mean ± *SD*. Homogeneity of variance for all categories and across experimental groups (U13 vs. U15 vs. U17) was verified using the Levene's test, whereas the normality of distribution of the data was examined with the Kolmogorov-Smirnov test. A 1-way random-effects model (model 2,1) ICC with absolute agreement was used to determine relative reliability. Absolute reliability was reported using the CV (1). Data were first analyzed using a 3 × 2 factorial analysis of variance (ANOVA) with repeated measures with Bonferroni post hoc comparisons using 1 interfactor (U13 vs. U15 vs. U17) and 1 intrafactor (pre-training vs. post-training). Percentage of change for each variable was calculated ([post − pre/pre] × 100), and a 1-way ANOVA was conducted to examine between-group differences with Gabriel's post hoc comparisons (U13 vs. U15 vs. U17)

Table 2
Reliability (ICC and CV) of variables analyzed during running sprint and vertical jump tests for each age category.*

	Under-13		Under-15		Under-17	
Variables	ICC (95% CI)	CV (%)	ICC (95% CI)	CV (%)	ICC (95% CI)	CV (%)
T10	0.989 (0.960–0.997)	2.4	0.917 (0.706–0.977)	1.9	0.983 (0.941–0.995)	0.9
T20	0.988 (0.959–0.997)	0.7	0.980 (0.929–0.994)	0.9	0.982 (0.936–0.995)	0.9
T10-20	0.978 (0.923–0.994)	0.7	0.980 (0.929–0.994)	1.8	0.890 (0.936–0.966)	1.4
CMJ	0.992 (0.979–0.998)	1.2	0.996 (0.990–0.999)	1.7	0.991 (0.975–0.997)	1.4

*ICC = intraclass correlation coefficients; CV = coefficients of variation; CI = confidence interval; T10 = 10-m sprint time; T20 = 20-m sprint time; T30 = 30-m sprint time; T10-20 = 10- to 20-m split sprint time; CMJ = countermovement jump.

Table 3

Characteristics of strength training program.*

Exercises	Sessions 1	2	3	4	5	6	7	8	9	10	11	12
FS (S × R) (% 1RMest)	2 × 8 (45%)	3 × 8 (45%)	3 × 8 (45%)	3 × 6 (50%)	3 × 6 (50%)	3 × 8 (50%)	2 × 6 (55%)	3 × 6 (55%)	3 × 6 (55%)	2 × 4 (60%)	3 × 4 (60%)	3 × 4 (60%)
CMJ (S × R)		3 × 5		3 × 5		3 × 5		3 × 5		3 × 5		3 × 5
COD (R × T)	3 × 10 s		3 × 10 s		4 × 10 s		4 × 10 s		5 × 10 s		3 × 10 s	
Sprint (R × D)		3 × 20 m		3 × 20 m		3 × 20 m		3 × 20 m		3 × 20 m		3 × 20 m

*FS = full squat; CMJ = countermovement jump; COD = changes of directions; 1RMest = estimated 1 repetition maximum S × R = sets × repetitions; R × T = repetitions × duration. R × D = repetitions × distance; U13 = under-13; U15 = under-15; U17 = under-17.

to clarify the interaction. Pearson correlation coefficients were calculated to analyze the respective relationships between the relative changes of all measured variables. In addition to this null hypothesis testing, the data were assessed for clinical significance using an approach based on the magnitudes of change (20). The effect sizes (ES) were calculated using Hedge's g (17) to estimate the magnitude of the training effect on the selected neuromuscular variables within each group, as follows: g = (mean post − mean pre)/combined *SD*. The standardized difference for changes between groups (U13 vs. U15 vs. U17) in each dependent variable was calculated on log-transformed values using the pooled pre-training *SD* (20). Probabilities were also calculated to establish whether the true (unknown) differences were lower, similar or higher than the smallest worthwhile difference or change (0.2 multiplied by the between-subject *SD* (20)). Quantitative chances of higher or lower differences were evaluated qualitatively as follows: < 1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, likely; 95–99%, very likely; and >99%, almost certain. If the chances of having higher or lower values than the smallest worthwhile difference were both >5%, the true difference was assessed as unclear. Inferential statistics based on interpretation of magnitude of effects were calculated using a purpose-built spreadsheet for the analysis of controlled trials (19). The statistical analyses were performed using SPSS software version 18.0 (SPSS, Inc., Chicago, IL). Statistical significance was established at the $p < 0.05$ level.

Results

Data for all variables analyzed were homogeneous and normally distributed ($p > 0.05$). No significant differences between groups were observed at baseline in any variable. Compliance with the training program was 100% of all sessions scheduled for all training groups. Mean values, percent changes from pre-training to post-training, and intragroup ES for all variables analyzed are reported in the Table 4. Comparisons of the changes in all age groups (U13 vs. U15 vs. U17) are presented in Figure 1.

Training period resulted in significant ($p < 0.05$–0.001) improvements in 1RMest, CMJ, T10, and T20 for all groups. In addition, U13 and U15 showed significant ($p < 0.05$) enhancements in T10-20, whereas the change in this variable for U17 was not significant. There were significant "group × time" interaction in T10 and T20 (Table 4). Between-group comparisons only showed significantly greater percentage of change for U13 compared with U17 in T10, T20, and 1RMest. However, qualitative outcomes showed a likely and possibly greater effect for U13 compared with U15 in all variables, whereas U15 presented a possibly beneficial effect compared with U17 in T20, T10-20, and CMJ (Figure 1). In addition, a likely greater effect was obtained for U15 respect to U17 in 1RMest, whereas for CMJ performance, the result was unclear.

When data of 3 experimental groups were pooled, a significant ($p < 0.001$) relationship was observed between the relative changes in 1RMest and the relative changes in CMJ ($r = 0.669$; Table 5), whereas the relative changes in muscle strength showed no relationship with the relative changes in sprint performance. In addition, there were significant ($p < 0.01$) correlations between the relative changes in CMJ and the relative changes in T20 ($r = -0.504$) and T10-20 ($r = -0.492$).

Discussion

The main finding of this study was that a combined high-speed RT and low-volume plyometrics resulted in significant improvements in

Table 4

Changes in selected neuromuscular performance variables to pre-test and post-test for each experimental group.*†

	U13 Pre	U13 Post	U13 Δ (%)	U13 ES	U15 Pre	U15 Post	U15 Δ (%)	U15 ES	U17 Pre	U17 Post	U17 Δ (%)	U17 ES
T10 (s)¶	1.96 ± 0.12	1.88 ± 0.09‡	−3.9	0.69	1.83 ± 0.06	1.82 ± 0.06‡	−0.9	0.28	1.78 ± 0.07	1.78 ± 0.05‡	−0.3	0.09
T20 (s)#	3.46 ± 0.19	3.34 ± 0.18‖	−3.5	0.66	3.18 ± 0.11	3.14 ± 0.10§	−1.4	0.40	3.11 ± 0.12	3.09 ± 0.11§	−0.7	0.18
T10-20 (s)	1.50 ± 0.08	1.46 ± 0.09‖	−3.1	0.55	1.35 ± 0.07	1.32 ± 0.07*	−1.9	0.37	1.32 ± 0.07	1.31 ± 0.06	−1.2	0.23
CMJ (cm)	27.0 ± 6.2	30.2 ± 6.2‖	11.6	0.51	32.5 ± 3.7	35.9 ± 3.4‖	10.3	0.95	33.9 ± 6.1	36.2 ± 6.1§	6.6	0.37
1RMest (kg)	52.9 ± 13.8	66.78 ± 14.2‖	27.3	0.82	72.9 ± 18.8	85.6 ± 21.8‖	17.5	0.66	95.8 ± 20.9	104.2 ± 19.8§	9.2	0.38

*U13 = under-13 group ($n = 15$); U15 = under-15 group ($n = 15$); U17 = under-17 group ($n = 14$); Pre = initial evaluation; Post = final evaluation; Δ = Pre-Post change; ES = intragroup effect size; T10 = 10-m sprint time; T20 = 20-m sprint time; T10-20 = 10- to 20-m sprint time; CMJ = countermovement jump height; 1RMest = estimated 1 repetition maximum.

†The positive ESs indicate a positive effect, whereas the negative ESs indicate a negative effect.

‡Significant differences intragroup: $p < 0.05$.

§Significant differences intragroup: $p < 0.01$.

‖Significant differences intragroup: $p < 0.001$.

¶Significant "group × time" interaction: $p < 0.05$.

#Significant "group × time" interaction: $p < 0.01$.

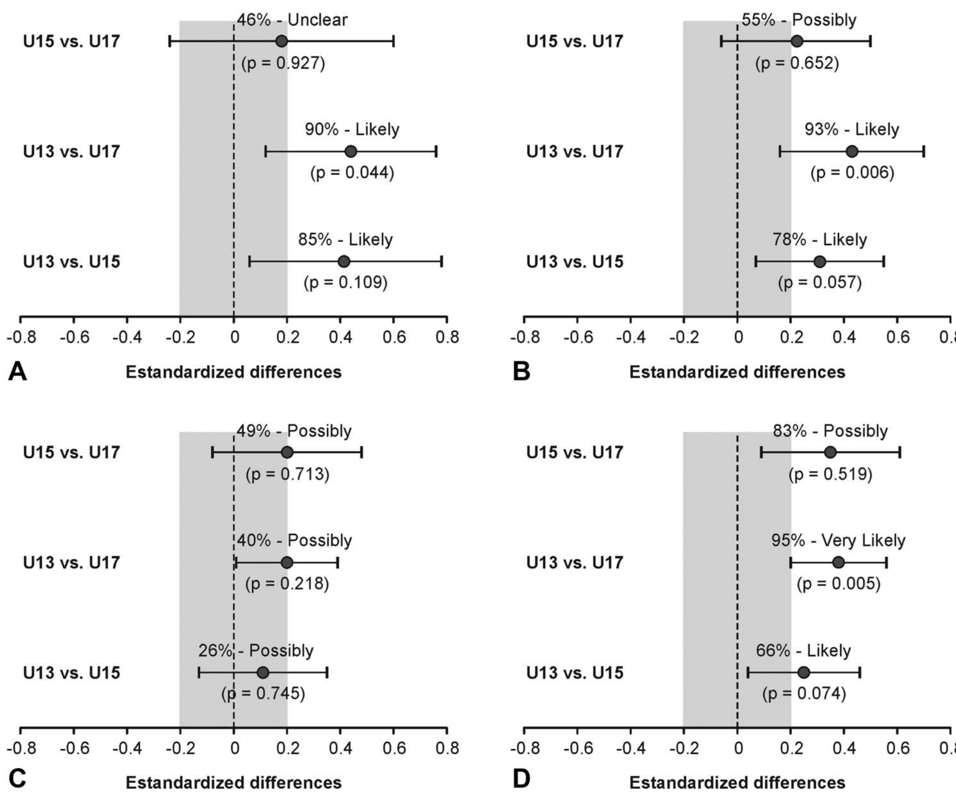

Figure 1. Standardized differences in the change (90% confidence intervals) from pre-test to post-test between under-13 (U13), under-15 (U15), and under-17 (U17) groups in 10-m (A) and 20-m (B) sprint time; countermovement jump test (C); and estimate 1 repetition maximum (D). Gray areas represent trivial differences. For clarity, all differences are presented as improvements in the first group compared with the second group (i.e., U13 vs. U15), so that negative and positive differences are in the same direction. The *p* value between-groups, the probability of the effect being practically relevant in favor of first compared with second group and the qualitative outcomes are provided in each case.

jump, sprint, and strength performance in all experimental groups, except for T10-20 in U17. In addition, a practically worthwhile differences analysis revealed a possibly or likely more beneficial effect for U13 compared with both U15 and U17 groups in all analyzed variables. These results indicate that an RT program with low load and low volume, performing each repetition as fast as possible, combined with low-volume PT, is an effective training method to improve physical performance in basketball players of different ages. However, our results also suggest that, against the same training program, the magnitude of change in physical performance decreases as the age of the players increases.

After 6 weeks of combined RT and PT, all 3 groups showed significant gains in 1RMest. Surprisingly, despite the importance of muscular strength in the lower limbs in crucial tasks for basketball such as jumping and change of direction (8,48), we know of no studies analyzing the changes in maximal leg strength in basketball players of early ages. However, in agreement with our results, previous studies conducted with soccer players of different ages have shown significant increments in maximal strength after training interventions using similar training programs (duration, load, volume, and frequency) (14,16,34). Thus, although previous meta-analysis and position stands (3,22,32) suggested that loads below 60–80% of 1RM are less likely to induce strength gains, results of this study reinforce the notion that it is not necessary to use RT with high loads (either in combination with PT or not) to obtain substantial improvements in strength performance in young basketball players without previous experience in strength training, regardless of the age of the subjects. These results represent an advance in the methodology of strength training since performing a PT combined with RT with lower loads and obtaining the same, or even greater, strength gains compared with high-load RT means: (a) an increase in training efficiency and (b) a decreased risk of injury in young players.

Comparisons between groups resulted in significantly greater percentage changes for U13 compared with U17. In addition, U13 showed a possibly and very likely more beneficial effect compared with U15 and U17, respectively, while U15 showed a likely better effect compared with U17 (Figure 1). Although a previous meta-analysis (3) conducted with untrained subjects reported that

Table 5
Relationship between the individual relative changes of the different performance variables.*

	T10	T20	T10-20	CMJ	1RMest
T10	1	0.790§	0.089	−0.321	−0.315
T20		1	0.570‡	−0.504‡	−0.277
T10-20			1	−0.492‡	−0.220
CMJ				1	0.669§
1RMest					1

*T10 = 10-m sprint time; T10-20 = 10- to 20-m sprint time; T20 = 20-m sprint time; CMJ = countermovement jump height; 1RMest = estimated 1 repetition maximum.
‡Significant relationship: $p < 0.01$.
§Significant relationship: $p < 0.001$.

mid-PHV and post-PHV individuals were more likely to obtain strength gains after an RT program (ES = 1.91) compared with pre-PHV individuals (ES = 0.81), other studies (33,40) specifically analyzing the effect of a given training program in soccer players of similar age groups that those used in this study (U13, U15, and U17) showed greater strength improvements as the chronological age decreased. Other studies in this matter have shown conflicting results, with no differences between groups (24,31) or greater effects for post-PHV groups compared with mid-PHV and pre-PHV groups (28,51). However, these studies (24,28,31,51) were conducted with nonathletes without previous training experience, which could explain, at least in part, the discrepancies with our results. Thus, in line with previous studies (13,33,40), our results seem to indicate that, for a given strength training program, strength gains are mainly related to initial strength level and the chronological age of the subjects.

For basketball players, the ability to perform sprints, decelerations, changes of directions, and jumps is considered an essential prerequisite to yield high performance during a match (4,5). Thus, analyzing the effects of combined RT and PT on sport performance, rather than solely on muscle strength, should be of interest to coaches and strength and conditioning professionals. In this study, all experimental groups showed significant improvements in CMJ and sprint time, except for U17 in T10-20 (Table 4). Studies conducted with young basketball players (U15) using RT only (42) or combined RT and PT (41) revealed similar increments in CMJ performance (Δ: 10.2–10.5; ES: 0.50–0.77). In both studies (41,42), RT involved high loads (~70–75% 1RM) and repetitions to muscle failure (10–12RM), whereas PT consisted of several jump exercises with 90–100 repetitions per session (41). Therefore, our results were obtained with a training program performed with lower relative intensity and volume during RT and lower number of exercises than previous studies (41,42), which suggest, as indicated above, that the strength training applied in this study is a more efficient training method.

Similarly to muscle strength, although the strength training program applied in this study resulted in relevant improvements for all experimental groups, it appears that the training effects for CMJ and sprint time were progressively reduced as chronological age increased. Changes in T10 ($p < 0.05$) and T20 ($p < 0.01$) were significantly greater for U13 compared with U17 (Figure 1). In addition, although the changes were not statistically significant, U13 resulted in higher percentages of change and greater intragroup and intergroup ES than U15 and U17 for all variables analyzed, whereas differences between U15 and U17 were especially relevant in T20 and CMJ performance. These changes in jump and sprint performance could be partially related with the changes observed in lower-limb strength, as showed in the correlations between the relative changes in 1RM, CMJ, and T20 (Table 5). These results agree with previous studies showing that the relative changes in CMJ and T20 are significantly related to relative changes in 1RM strength in the full squat exercise (8,14,33,34). In addition, supporting the results of this study, a meta-analysis evaluating the effectiveness of different strength training for improving jump and sprint performance in children and adolescents showed that strength training produced greater improvements in these sport-related variables as the age of subjects decreases (2). In line with this conclusion, a recent study conducted with soccer players of different ages and applying a very similar strength training program to that used in this study resulted in progressively lower improvements in CMJ and sprint time for U13, U15, and U17, respectively. However, other previous studies (15,24,25,28,40) have found conflicting results depending on several factors including the training method used, the age of subjects, and the variable assessed. Thus, according with the results of these studies, it is possible that each age group needs a different training stimulus to maximize physical development. Accordingly, several studies (13,25,33) have suggested that training stimuli should be related to individual maturity status because it has been indicated that the higher the performance in a certain motor skill, the more difficult it is to achieve performance improvements after short-term interventions (13,33). Therefore, our results seem to indicate that a low training stimulus is enough to obtain large improvements in physical performance for younger basketball players. However, it also seems that the training load should be progressively increased or the training stimulus modified with increasing chronological age or maturity status to permit further improvement for older players (13,33).

In conclusions, the results of our study showed that (a) an RT program with low loads, low volume, and low frequency, emphasizing lifting the load at maximal voluntary velocity, combined with a low volume of plyometric exercises, is effective in obtaining improvements in linear sprint, vertical jump height, and lower-limb strength in basketball players of different ages, and (b) changes in physical performance after a given strength training with these characteristics differed depending on the chronological age of the basketball players.

Obviously, the current study presents some limitations that need to be mentioned. The main limitation of this study is the low number of subjects in each group. Our results show that some effects are associated with large confidence limits for the intragroup and between-group change differences. Thus, we cannot be sure whether differences within-groups and between-groups would have been clearer with a greater number of subjects in each experimental group. However, from a practical point of view, it certainly difficult to have access to many young elite basketball players and submit them to investigation conditions. Precisely for this reason, we could not include a control group for each age category to compare the effect of adding an ST program with respect to perform a routine technical-tactical basketball training alone. Therefore, further studies involving a larger number of subjects are needed to verify the effectiveness of the ST program applied in this study and to know what type of training, RT or PT, shows the greater influence on gains in strength, sprint, and jump performance.

Practical Applications

The findings of this study suggest that the implementation of strength training programs with these or similar characteristics along with the specific technical-tactical training might be necessary for a better and greater integral development of young basketball players. Indeed, results of this study could be of great interest to coaches and strength and conditional professionals since this type of strength training is compatible with specific basketball training because it induces a low degree of fatigue (30,37), consumes a very low percentage of the total basketball training time, and induces significant improvements in relevant tasks for basketball players. Therefore, our results represent an advance in the training methodology for young basketball players because strength training with these characteristics could suppose an increase in training efficiency and a decreased risk of injury in young players. However, it is important to note that the changes in physical performance variables assessed differed with the chronological age of the subjects. Therefore, another important practical application of this study is that coaches should apply different strength training programs (manipulating the load magnitude, volume, and specific exercises) depending on the maturity status and initial strength level of the basketball players.

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