Effects of Complex Training on Explosive Strength in Adolescent Male Basketball Players

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Abstract

The purpose of this study was to evaluate the effects of a complex training program, a combined practice of weight training and plyometrics, on explosive strength development of young basketball players. Twenty-five young male athletes, aged 14–15 years old, were assessed using squat jump (SJ), countermovement jump (CMJ), Abalakov test (ABA), depth jump (DJ), mechanical power (MP), and medicine ball throw (MBT), before and after a 10-week in-season training program. Both the control group (CG; $n = 10$) and the experimental group (EG; $n = 15$) kept up their regular sports practice; additionally, the EG performed 2 sessions per week of a complex training program. The EG significantly improved in the SJ, CMJ, ABA, and MBT values ($p < 0.05$). The CG significantly decreased the values ($p < 0.05$) of CMJ, ABA, and MP, while significantly increasing the MBT values ($p < 0.05$). Our results support the use of complex training to improve the upper and lower body explosivity levels in young basketball players. In conclusion, this study showed that more strength conditioning is needed during the sport practice season. Furthermore, we also conclude that complex training is a useful working tool for coaches, innovative in this strength-training domain, equally contributing to a better time-efficient training.

KEY WORDS vertical jump, resistance training, plyometric training

Introduction

In basketball, the ability to generate maximal strength levels in the shortest period of time (muscular power) has been considered as essential to obtain high sport performance levels (6,23,27). Moreover, strength training is part of basketball preseason programs (18,33) with a background of related benefits that improve sport performance, reduce injury rate, and provide higher motivation levels for the athletes (32).

Two methods, resistance and plyometric training, are usually referred to in the literature as improving the most powerful strength characteristics (explosive strength) in basketball players. Several investigations have demonstrated the positive effects that result from the application of these methods, reporting higher increases in the explosive strength indicators (7,18,20,22,30,35,38). Conversely, significant decreases occurred in the vertical jump ability of young basketball players following 15 weeks weight training program (24).

On the other hand, complex training, a method that combines resistance training and plyometrics, has been reported in literature (8,9,11,13) and has been proposed to increase muscular power (8,11). Several authors postulated complex training as alternating biomechanically comparable high-load weight training exercises with plyometrics, set for set, in the same workout session (8,13,39). Others stated that complex training is a method in which various sets of heavy resistance exercise are followed by sets of a lighter resistance exercise (12).

In this study, we adopted the latter definition, that is, the athletes performed plyometric exercise sets on the court, following the resistance training sets in the weight room. The organizational characteristic of this methodology enables the coach to easily supervise weight and plyometric training in a single workout on the same day (13).

No studies were found on the effects resulting from the application of complex training in basketball.Thus, given the lack of literature on the effects of complex training in basketball, the aims of this study were to understand how young basketball players respond to a complex training routine and determine the changes induced by this kind of training on explosive strength indicators.

Methods

Experimental Approach to the Problem

The study was designed to assess the effects of a complex training program on the explosive strength development of young male basketball players, aged 14–15 years old. Two groups (experimental group (EG) and control group (CG)) were selected for this purpose. The EG performed resistance training followed by plyometrics, twice weekly, along with

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TABLE 1. Resistance and plyometric training protocols.

	Session 1		Session 2	
Resistance training	Weeks 1–2	Weeks 3–10	Weeks 1–2	Weeks 3–10
Leg extension	2 × 10/12 RM	3 × 10/12 RM		
Pullover	2 × 10/12 RM	3 × 10/12 RM		
Leg curl	2 × 10/12 RM	3 × 10/12 RM		
Decline press			2 × 10/12 RM	3 × 10/12 RM
Leg press			2 × 10/12 RM	3 × 10/12 RM
Lat pull down			2 × 10/12 RM	3 × 10/12 RM
Rest between sets: 2–3 min; rest between exercises: 45–60 s				
	Session 1		Session 2	
Plyometric training	Week 1	Week 2	Week 1	Week 2
Rim jump	2 × 10 reps	3 × 10 reps		
MB squat toss	2 × 10 reps	3 × 10 reps		
Zigzag drill	2 × 10 m	3 × 10 m		
2-foot ankle hop			2 × 15 reps	3 × 15 reps
MB chest pass			2 × 10 reps	3 × 10 reps
Squat jump			2 × 10 reps	3 × 10 reps
Rest between sets: 60 s; rest between exercises: 15 s				
	Weeks 3–4			
Tuck jump	3 × 10 reps			
MB overhead throw	3 × 12 reps			
Alternate leg push-off	3 × 10 reps			
Single-arm alternate-leg bound			3 × 10 m	
MB backward throw			3 × 10 reps	
Lateral jump over cone			3 × 10 reps	
Rest between sets: 60–90 s; rest between exercises: 15–30 s				
	Week 5	Weeks 6–7	Week 5	Weeks 6–7
Side jump/sprint	3 × 6 reps +5-m sprint	4 × 6 reps +5-m sprint		
MB seated chest pass	3 × 10 reps	4 × 10 reps		
Lateral box jump	3 × 10 reps	4 × 10 reps		
Depth jump			3 × 6 reps	4 × 6 reps
MB seated backward throw			3 × 10 reps	4 × 10 reps
Hurdle hops			3 × 5 reps	4 × 5 reps
Rest between sets: 2–3 min; rest between exercises: 60 s				
	Weeks 8–10			
Depth jump 180° turn	4 × 6 reps			
MB pullover pass	4 × 10 reps			
Hurdle hops	4 × 8 reps alternate lateral/frontal			
Cone hops with change of direction sprint			4 × 6 reps +5-m sprint right/left	
MB power drop			4 × 10 reps	
Multiple box-to-box jumps			4 × 6 reps	
Rest between sets: 3–4 min; rest between exercises: 60–90 s				

RM = repetition maximum; reps = repetitions; MB = medicine ball; sets × reps.

Table 2. Comparison of explosive strength test results mean (±*SD*) between the 2 groups in pre- and posttest conditions.

Test		Pre	Post	Gains		Value	
				Absolute	%	*p**	*p*†
SJ (cm)	EG	24.79 ± 4.2	28.01 ± 4.6	3.22	13	0.000	0.000
	CG	22.70 ± 4.3	20.74 ± 3.9	−1.96	−8.6	0.091	
CMJ (cm)	EG	29.88 ± 5.9	33.02 ± 6.2	3.14	10.5	0.000	0.048
	CG	30.76 ± 5.1	28.40 ± 4.0	−2.36	−7.7	0.004	
ABA (cm)	EG	34.77 ± 6.3	38.43 ± 7.1	3.66	10.5	0.000	0.122
	CG	36.12 ± 4.8	34.32 ± 4.8	−1.8	−5.2	0.030	
DJ (cm)	EG	34.71 ± 7.4	36.64 ± 8.1	1.93	5.6	0.053	0.045
	CG	31.11 ± 4.8	30.75 ± 4.1	−0.36	−1.2	0.785	
MP ($W \cdot kg^{-1}$)	EG	23.69 ± 4.0	24.48 ± 3.9	0.79	3.4	0.200	0.490
	CG	25.98 ± 6.0	23.14 ± 5.7	−2.84	−10.9	0.045	
MBT (m)	EG	3.47 ± 0.6	4.15 ± 0.5	0.68	19.6	0.000	0.000
	CG	3.10 ± 0.4	3.27 ± 0.4	0.17	5.5	0.005	

SJ = squat jump; CMJ = countermovement jump; ABA = Abalakov test; DJ = depth jump; MP = mechanical power; MBT = medicine ball throw; EG = experimental group; CG = control group.
*Significant difference from pre to post ($p < 0.05$).
†Significant difference between groups post-training ($p < 0.05$).

the regular basketball practice; the CG did not perform either resistance or plyometric training and kept with regular basketball practice. All the subjects were tested on the squat jump (SJ), countermovement jump (CMJ), Abalakov test (ABA), depth jump from a 40-cm platform (DJ), mechanical power (MP), and medicine ball throw (MBT) before and after the 10-week training program. Intraclass correlation coefficient for all the assessed variables ranged ($r = 0.79$ to $r = 0.995$), and outcome variables were compared over time and between groups.

Subjects

Twenty-five young male basketball players volunteered to take part in this study. The subjects were randomly assigned to the CG ($n = 10$: age, 14.2 ± 0.4 years old; weight, 61.1 ± 11.4 kg; height, 173.2 ± 7.6 cm; and basketball training experience, 4.3 ± 1.2 years) or the EG ($n = 15$: age, 14.7 ± 0.5 years old; weight, 72.7 ± 16.9 kg; height, 175.9 ± 9.3 cm; and basketball training experience, 5.6 ± 2.6 years). All athletes were in Tanner stage 3 or 4 for pubic hair growth and genital development (37). None of the subjects had training experience using resistance or plyometric training programs before this study. Athletes, parents, and coaches were informed about the purpose of the study, and informed consent was obtained from all subjects and parents before the study started. The Institutional Review Board of the Faculty of Sports/University of Porto approved all study procedures.

Testing Procedures

Subjects were assessed before and after a 10-week training program for upper and lower body explosive strength, according, respectively, to Cronin and Owen (10), and Bosco (4) protocols.

This procedure allowed for the assessment of the following variables: (a) SJ (cm), (b) CMJ (cm), (c) ABA (cm), (d) DJ from a 40-cm platform (cm), (e) MP ($W \cdot kg^{-1}$), and seated MBT (meters). There was previous familiarization with accurate testing procedures. Tests followed a general warm-up that consisted of running, calisthenics, and stretching. Except for mechanical power, which was assessed after two trials with a 60-second rest between trials, all the other tests were performed with 3 trials and all the correspondent mean values were considered for statistical analysis. There was a 20-second and a 10-second rest between trials for respectively the lower-body and the sitting chest throw. All jumping tests were performed using a contact platform Globus Ergo Tester (Codogne, Italy), except for the DJ, which was carried out on an electromechanical Ergojump platform (Digitest OY, Muurame, Finland).

Training Protocol

The 10-week in-season training program consisted of a set of resistance exercises followed by a series of plyometric exercises. Ten repetition maximum (10RM) was determined for each athlete in all the selected resistance exercises 1 week before the beginning of the complex training program. This procedure is similar to those described in literature (1,28,29). Additionally, the EG was instructed on the correct lifting techniques.

The complex training program is described in Table 1. Workouts occurred twice weekly on nonconsecutive days. A standardized warm-up routine consisting of running,

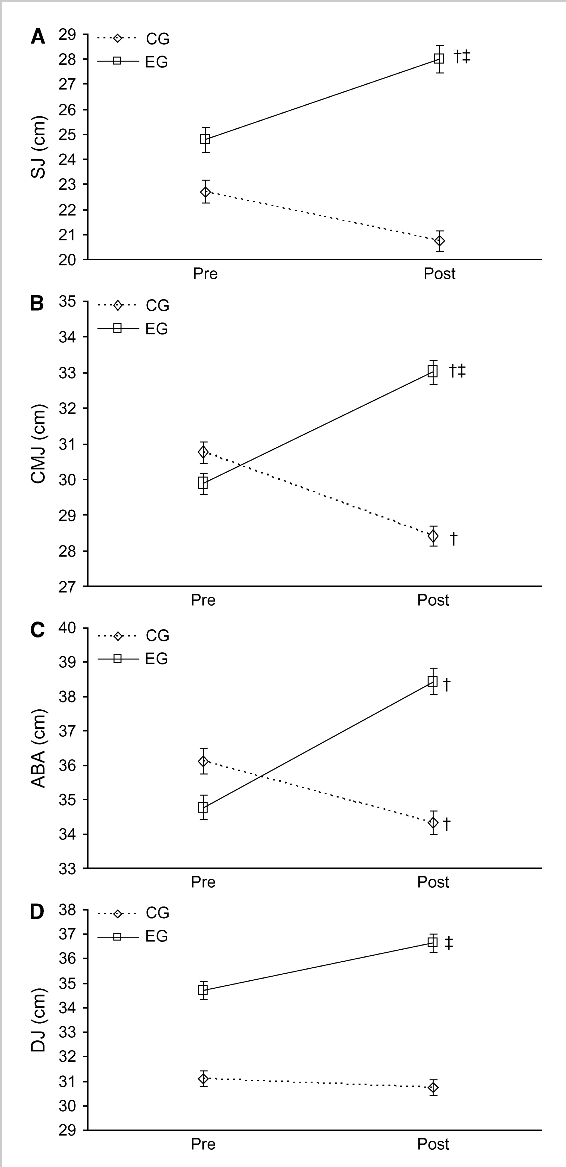

Figure 1. Squat jump (SJ) (A), countermovement jump (CMJ) (B), Abalakov test (ABA) (C), and depth jump (DJ) (D) mean heights from pre- to post-test. †Significant difference from pre to post ($p < 0.05$). ‡Significant difference between groups post-training ($p < 0.05$). CG, control group; EG, experimental group.

calisthenics, and stretching was used. During resistance training, there was a 5% increase in training load whenever athletes easily surpassed 12 repetitions on the last set.

Nautilus machines were used in the weight room, except for lat pull-down and leg press, which were performed on Technogym machines. Plyometric equipment included 3-kg medicine balls, 40-cm high boxes, 28-cm high cones, 30-cm high benches, and 50-cm- high hurdles, with 1 meter between them. The rest period between resistance training and plyometrics averaged 4 minutes.

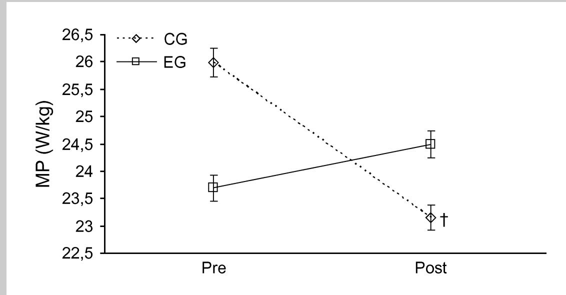

Figure 2. Mechanical power (MP) scores from pre- to post-test. Significant difference from pre to post ($p < 0.05$). CG, control group; EG, experimental group.

During the study, the CG was not involved in either the resistance or plyometric training program.

Statistical Analyses

Statistical analysis followed the most important descriptive statistics, such as mean and *SD*. A repeated-measures *t*-test was used to determine the presence or absence of gains in each group. An independent-measures *t*-test was used to determine differences between groups pre- and post-test. An α significance level of $\geq$0.05 was used.

Results

The results between the pre- and post-test for explosive strength scores in both groups and the results between groups at baseline and after the training program are presented in Table 2.

Except for the DJ and MP, the EG showed significant increases in all the variable scores. Conversely, the CG had significantly decreased CMJ, ABA, and MP scores. However, the results of MBT test showed a significant increase for the CG.

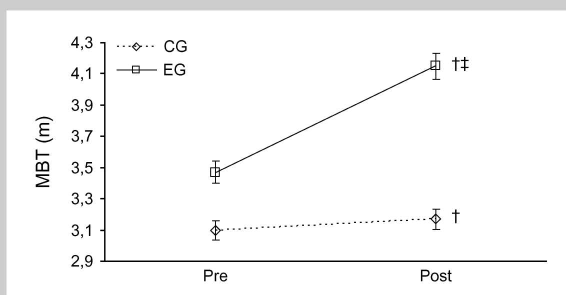

Figure 3. Medicine ball throw (MBT) mean distances from pre- to post-test. Significant difference from pre to post ($p < 0.05$). ‡Significant difference between groups post-training ($p < 0.05$). CG, control group; EG, experimental group.

The groups were similar on pre-test, but significant differences were observed post-training in all the variables, except for the ABA and MP.

Figures 1–3 illustrate the behavior of the studied indicators for each group during the 10-week training program.

Discussion

The main findings from this study were the significant increases in the height of the different jumps (SJ, CMJ, and ABA) and in the distance of the MBT, which proved the complex training efficacy. The increases in the height of the DJ and MP (5.6% and 3.4%, respectively) were statistically nonsignificant. On the other hand, the CG decreased in all the assessed variables, from pre- to post-testing, except for the distance in the MBT. These findings show the quality of the training program design.

Several factors may have contributed to the changes in vertical jump (VJ) and MBT, including a better synchronization of body segments, increased coordination levels, and a greater muscular strength/force. These factors may be related to a more effective skill domain in VJ and MBT, contributing to the improvement in the basketball shooting technique.

There is a lack of literature regarding studies on the changes in the height of VJ and in the distance of MBT in adolescent basketball players submitted to complex training programs. However, changes in VJ in adolescent male basketball players have been studied following the application of plyometric training programs. In fact, such changes have been reported in male basketball players aged 13–14 years (35). Other investigations have reported positive changes in the height of different types of VJ in young male basketball players aged 15–16 years (7,30). These results are in line with our scores and therefore both strength-training programs (complex and plyometric training) have shown similar results for the values of VJ.

In this study, the training program was designed to improve muscular power levels, focusing on VJ and MBT changes. We used a complex training methodology, combining resistance and plyometric training, which enabled coaches to supervise weight training and plyometrics in a single workout on the same day (13). Furthermore, an articulation of both these methodologies is an efficient way to produce gains in VJ ability (32), which is supported by the results of the present study.

One possible explanation for the enhanced values of VJ and MBT lies in the fact that complex training stimulates the neuromuscular system (9), that is, it activates both the muscular fibers and the nervous system, so that slow-twitch fibers behave like fast-twitch fibers (8). Furthermore, resistance training increases motor neuron excitability and reflex potentiation, which may lead to better training conditions for subsequent plyometric exercises (13); this fact may have contributed to the increments observed in the present study.

On the other hand, with the beginning of puberty and throughout the maturation process, there is an increase in boys' muscular proportion from 27% to 40% of body mass (25), with increases in muscular strength values (28). Hormonal factors, namely, an increase in circulating androgens with special reference to testosterone levels (28) may contribute to this process. From this point of view and given the studied population, the assessed gains might be due to hormonal factors. Nevertheless, the CG did not increase in muscular strength levels and there was even a decrease in most of the assessed variables. Thus, we can say that the increases verified in our study may be related to the design of the applied training program rather than to the hormonal effects resulting from the maturational process.

Concerning the adaptations to strength and power training, 2 main factors are referred to in the literature: neural and hypertrophic (31). Although the weights selected in the present study (10RM) fit the suggestions to hypertrophic development (17), it is well-known that neural adaptations dominate in the early stages of strength training programs application. (17,31,34). Furthermore, the increase in strength levels in young athletes is related to load intensity and volume and seems to result from neuromuscular increased coordination and activation rather than from muscular hypertrophy (21). We assume that these mechanisms were responsible for the strength gains achieved in the present study. Nevertheless, with the extension of the training process, muscular adaptations will become more evident and have repercussions in higher hypertrophic levels (31). In the present study and given the program duration, some muscular hypertrophy may have occurred. However, it is impossible to confirm this hypothesis since we did not submit our subjects to this kind of evaluation.

Another explanation for the success of this program may be due to the use of a high training load during plyometrics, contributing to enhanced motor unit recruitment, thus increasing training effects (13). In the complex training resistance component, a submaximal load (10RM) was used, with positive results on the final muscular power levels (VJ and MBT). The choice of a submaximal load may have limited greater results due to the smaller number of recruited motor units when a submaximal load is used. However, the selected load was determined by the criterion that postulates that adolescents must avoid the repetitive use of maximal loads when performing resistance exercises before they reach level 5 of Tanner stages (2). Besides, different authors suggest the use of this type of load (10RM) when young athletes perform strength training programs (1,28,29). On the other hand, the adopted resistance exercises were suggested by different investigators and seen as fundamental for the main muscle strength improvement in basketball players (16,28,32).

We still consider that the way in which the plyometric component intensity was selected, using Chu's progression scale (9), may have contributed to the successful training program. This scale has been referred to as essential in terms of quality when working with adolescents, namely, due to the gradual progression of the load (15). The fact that some plyometric exercises, such as DJs, depend on high-intensity movement was another concern when designing this training program. In this context, the drop height appears as a key factor when prescribing this type of exercise. According to the literature, a 40-cm drop height was selected as the most adequate when training young practitioners (5), showing solid results in the VJ enhancement (3,19). However, in the present study, no significant gains were found in DJ at the end of the 10-week training period, although there was a 5.6% increase. These data may be explained by the inclusion of the DJ in a single weekly workout, which may have conditioned the specific degree of this exercise, compromising higher results.

It is our belief that the positive results found in the present study may be related, though in a subjective and empirical way, to the athletes' adherence to the training program. Its unusual design and diversified structure may have contributed to improved performance and to the maintenance of high levels of motivation. Furthermore, we believe that such a program greatly contributes to motor learning with positive repercussions on future motor behaviors.

Finally, it is worth reporting the absence of injury during this program. This is also an advantage of the proposed program, confirming that strength training in youths helps to prevent and reduce injury risk when correctly designed and competently supervised (2,14,40).

In conclusion, we strongly believe that complex training increases VJ and MBT levels. This is an important part of sports conditioning that may contribute to improved performance in young basketball players.

Practical Applications

Upper and lower body explosivity levels of young basketball players can be improved with a combined program of plyometrics and resistance training. These strength level improvements are usually seen as essential in basketball performance (6,18,23,32,33,36). On the other hand, given the specific nature of the selected exercises (resistance and plyometric training), their incorporation in the strength training routines is fundamental for young basketball players.

Correctly designed and competently supervised, this training program carries no extra overload on adolescents' skeletal muscle development as proved by the absence of injury during the program.

As suggested by the literature (13,26), the use of both resistance and plyometric training in the same workout is an adequate strategy of training process organization, having highly positive effects on practice and training time management.

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