THE EFFECTS OF RESISTANCE TRAINING ON EXPLOSIVE STRENGTH INDICATORS IN ADOLESCENT BASKETBALL PLAYERS

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ABSTRACT
Santos, EJAM and Janeira, MAAS. The effects of resistance training on explosive strength indicators in adolescent basketball players. J Strength Cond Res 26(10): 2641–2647, 2012—The purpose of this study was to assess the effects of a lower- and upper-body 10-week in-season resistance training program on explosive strength development in young basketball players. Twenty-five adolescent male athletes, aged 14–15 years old, were randomly assigned to an experimental group (EG; n = 15) and a control group (CG; n = 10). The subjects were assessed at baseline and after training for squat jump (SJ), countermovement jump (CMJ), Abalakov test, drop jump, and seated medicine ball throw (MBT). The EG showed significant increases (p < 0.05) in all the variable scores. Conversely, the CG significantly decreased (p < 0.05) in SJ, CMJ, and Abalakov test scores and significantly increased in the results of MBT test (p < 0.05). The groups were similar on pretest, but significant differences (p < 0.05) occurred on posttest in all the variables. The results of this study show that a 10-week in-season resistance training program with moderate volume and intensity loads increased vertical jump and MBT performance in adolescent male basketball players. Coaches should know that such a short resistance training program specifically designed for young basketball players induce increased explosivity levels, which are essential to a better basketball performance, with no extra overload on adolescents’ skeletal muscle development.

KEY WORDS young athletes, vertical jump, medicine ball throw, program design

INTRODUCTION
The relevance of resistance training on the increments of strength levels in children and youngsters is well expressed in the results obtained on a meta-analysis study, which makes it possible to conclude that children and youngsters’ muscular strength has increased because of resistance training programs (37). Besides, resistance training is a basic component on fitness and conditioning programs (1,16) and a safe, effective, and profitable method for youngsters (14). Furthermore, it has been used by high-school strength and conditioning coaches who participated in a survey on strength and conditioning practices (12).

Nevertheless, in the past years, a few studies have investigated the effects of resistance training programs on the improvement of adolescent athletes’ explosivity levels (10,15,18,23,30). Despite the existence of several studies on the significant effects of plyometric training (27,36,39,40) or combined training (38,44) in young basketball players, the available literature shows a scarcity of studies on resistance training program effects with young basketball players (19,24,25). Despite the importance of resistance training on strength development in basketball players (31), a review of observational and experimental studies on vertical jump in female and male basketball players only refers to the 3 resistance training investigations just mentioned (45).

The key factor to successful resistance training at any level of fitness or age is appropriate program design (32). In a study with adolescent soccer players, the authors observed a significant improvement in jumping ability as a result of strength training characterized by the absence of specific exercises for the improvement of jump performance (10). In this way, we wanted to verify whether resistance training with moderate intensities and loads associated with basketball practice has positive effects on the athletes’ explosive strength. In other words, we wanted to know if a program design whose training variables do not specifically report to the improvement of explosive strength would benefit from the explosivity characteristic of this sport (which typically involves lots of jumping and sprinting), inducing increased levels on vertical jump and medicine ball throw (MBT) performance. In fact, resistance training should be matched...
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with the practice of specific sport to take full advantage of training-induced neuromuscular adaptations, because it is also more pragmatic when there is a combination of resistance training and sport practice (4). In this way, it seems appropriate to intensify the knowledge on basketball resistance training so that coaches may have access to working tools capable of improving the quality of their intervention on explosive strength development.

In this context, it seems reasonable to hypothesize that (a) resistance training programs in addition to basketball practice induce increases in adolescent basketball players’ explosive strength and (b) basketball practice alone cannot improve per se explosive strength levels. Thus, the aim of this study was to determine the effects of a lower- and upper-body resistance training program on explosive strength in adolescent male basketball players.

**METHODS**

**Experimental Approach to the Problem**

The study was designed to assess the effects of a 10-week in-season resistance training program on the explosive strength development of young male basketball players, aged 14–15 years. To address the hypotheses previously presented, 2 groups (experimental group [EG] and control group [CG]) were selected. The EG performed resistance training, twice weekly, along with the regular basketball practice; the CG continued regular basketball practice alone. All the subjects were tested on the squat jump (SJ), countermovement jump (CMJ), Abalakov test (ABA; a CMJ with arm swing), depth jump from a 40-cm platform (DJ), and MBT before (T0) and after the 10-week training program (T1).

**Subjects**

The sample consisted of 2 groups of adolescent male basketball players who volunteered to take part in this study. They underwent a basketball training regimen consisting of three 90-minute sessions and 1 game weekly. According to school activities, the subjects were matched before the program application. The 2 groups’ main characteristics are presented in Table 1.

Pubertal stages were determined by the same male assessor. In both groups, there were subjects in Tanner stage 3 or 4 for pubic hair growth and genital development (41). None of the subjects had previously participated in resistance, plyometric, or combined training programs. The athletes, parents, and coaches knew the purpose of the study, and informed consent was obtained from all the subjects and parents before the study began. The Institutional Review Board of the Faculty of Sport/University of Porto approved all the study procedures.

**Testing Procedures**

The subjects were assessed before and after a 10-week in-season resistance training program for upper and lower body, according to Cronin and Owen (11) and Bosco (6) protocols, respectively.

This procedure allowed the assessment of SJ (centimeters), CMJ (centimeters), Abalakov test (centimeters), and seated throw with a 3-kg medicine ball (meters). These dependent variables are commonly used when assessing explosive strength as far as the contractile muscular component and the elastic-reactive and elastic muscular component are concerned.

### Table 1. Characteristics of study participants.*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Experimental group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 15)</td>
<td>(n = 10)</td>
</tr>
<tr>
<td>Age (y)</td>
<td>14.5 ± 0.6</td>
<td>14.2 ± 0.4</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>61.6 ± 8.0</td>
<td>61.1 ± 11.4</td>
</tr>
<tr>
<td>Body height (cm)</td>
<td>172.7 ± 8.1</td>
<td>173.2 ± 7.6</td>
</tr>
<tr>
<td>Basketball training experience (y)</td>
<td>5.0 ± 2.4</td>
<td>4.3 ± 1.2</td>
</tr>
</tbody>
</table>

*Values are mean ± SD.

### Table 2. Resistance training program.*†

<table>
<thead>
<tr>
<th>Exercises</th>
<th>Workouts 1 and 2</th>
<th>Workouts 3–10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wks 1–2</td>
<td>Wks 3–10</td>
</tr>
<tr>
<td>Decline press</td>
<td>2 × 10/12 10RM</td>
<td>3 × 10/12 10RM</td>
</tr>
<tr>
<td>Leg press</td>
<td>2 × 10/12 10RM</td>
<td>3 × 10/12 10RM</td>
</tr>
<tr>
<td>Lat pull down</td>
<td>2 × 10/12 10RM</td>
<td>3 × 10/12 10RM</td>
</tr>
<tr>
<td>Leg extension</td>
<td>2 × 10/12 10RM</td>
<td>3 × 10/12 10RM</td>
</tr>
<tr>
<td>Pullover</td>
<td>2 × 10/12 10RM</td>
<td>3 × 10/12 10RM</td>
</tr>
<tr>
<td>Leg curl</td>
<td>2 × 10/12 10RM</td>
<td>3 × 10/12 10RM</td>
</tr>
</tbody>
</table>

*RM = repetition maximum; sets × repetitions.
†Rest between sets: 2–3 minutes; rest between exercises: 45–60 seconds.
There was a previous familiarization with accurate test procedures, during 2 weeks. Tests followed a general warm-up consisting of running, calisthenics, and stretching. All the tests were performed with 3 trials, and all the correspondent mean values were considered for statistical analysis. There was a 20- and a 10-second rest between trials for the lower-body and the sitting chest throw, respectively. All the jumping tests were performed using a contact platform Globus Ergo Tester® (Codogne, Italia), except for the drop jump, which was performed on an electromechanical Ergojump platform (Digitest OY, Muurame, Finland).

**Training Protocol**

The 10-week in-season resistance training program is described in Table 2.

Workouts occurred twice a week, on nonconsecutive days, in a weight room, and 10-repetition maximum (10RM) load was determined for each athlete (EG) in all the selected exercises, 1 week before the beginning of the resistance training program. This procedure and the training program variables adopted in this study are based on the available literature (16,29,31,33). Additionally, the EG received instructions on the correct lifting techniques, and all the workouts were supervised by us. The standardized warm-up routine consisted of running, calisthenics, and stretching. There was a 5% increment of training load, whenever athletes easily overpassed 12 reps on the last set.

The program design took into account several factors such as the athletes’ available time to participate in the resistance training program and the time spent in regular basketball practice and leisure activities and school timetables.

All the exercises involved Nautilus machines, except for the lat pull down and leg press, performed on Technogym machines. The rationale for this option was that beginners enjoy resistance training on weight machines because the exercise movement is relatively easy to learn and perform (13).

All through the study, the CG was not involved in any resistance, plyometric, or combined training program, just keeping on regular basketball practice alone.

**Table 3.** Intraclass correlation coefficients showing the reliability of various measures of jumping tests and medicine ball throw.*

<table>
<thead>
<tr>
<th></th>
<th>Experimental group</th>
<th>Control group</th>
<th>Experimental group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medicine ball throw</td>
<td>0.987</td>
<td>0.995</td>
<td>0.944–0.997</td>
<td>0.952–0.999</td>
</tr>
<tr>
<td>Jumping tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squat jump</td>
<td>0.981</td>
<td>0.857</td>
<td>0.915–0.996</td>
<td>0.753–0.985</td>
</tr>
<tr>
<td>Countermovement jump</td>
<td>0.946</td>
<td>0.933</td>
<td>0.760–0.988</td>
<td>0.736–0.993</td>
</tr>
<tr>
<td>Abalakov test</td>
<td>0.964</td>
<td>0.946</td>
<td>0.841–0.992</td>
<td>0.784–0.984</td>
</tr>
<tr>
<td>Depth jump</td>
<td>0.988</td>
<td>0.846</td>
<td>0.947–0.997</td>
<td>0.683–0.984</td>
</tr>
</tbody>
</table>

*ICC = intraclass correlation coefficient; CI = confidence interval.

**Table 4.** Comparison of explosive strength test results mean (± SD) between the 2 groups in the T0 and T1 conditions.*

<table>
<thead>
<tr>
<th>Test</th>
<th>Groups</th>
<th>T0</th>
<th>T1</th>
<th>Absolute</th>
<th>% Change</th>
<th>p†</th>
<th>p‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>SJ (cm)</td>
<td>EG</td>
<td>24.81 ± 3.3</td>
<td>27.92 ± 4.0</td>
<td>3.11</td>
<td>12.5</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>CG</td>
<td>22.70 ± 4.3</td>
<td>20.74 ± 3.9</td>
<td>−1.96</td>
<td>−8.6</td>
<td>0.020</td>
<td></td>
</tr>
<tr>
<td>CMJ</td>
<td>EG</td>
<td>33.30 ± 4.3</td>
<td>36.68 ± 4.2</td>
<td>3.38</td>
<td>10.2</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>CG</td>
<td>30.76 ± 5.1</td>
<td>28.40 ± 4.0</td>
<td>−2.36</td>
<td>−7.7</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ABA</td>
<td>EG</td>
<td>38.73 ± 4.9</td>
<td>42.62 ± 4.4</td>
<td>3.89</td>
<td>10.0</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>CG</td>
<td>36.12 ± 4.8</td>
<td>34.32 ± 4.8</td>
<td>−1.8</td>
<td>−5.2</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>DJ</td>
<td>EG</td>
<td>34.80 ± 4.1</td>
<td>38.10 ± 4.3</td>
<td>3.3</td>
<td>9.5</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>CG</td>
<td>31.11 ± 4.8</td>
<td>30.75 ± 4.1</td>
<td>−0.36</td>
<td>−1.2</td>
<td>0.692</td>
<td></td>
</tr>
<tr>
<td>MBT</td>
<td>EG</td>
<td>3.42 ± 0.38</td>
<td>3.68 ± 0.42</td>
<td>0.26</td>
<td>7.6</td>
<td>&lt;0.001</td>
<td>0.019</td>
</tr>
<tr>
<td></td>
<td>CG</td>
<td>3.10 ± 0.4</td>
<td>3.27 ± 0.4</td>
<td>0.17</td>
<td>5.5</td>
<td>&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>

*†Significant difference from T0 to T1 (p < 0.05).
‡Significant difference between groups, in T1 (p < 0.05).

SJ = squat jump; CMJ = countermovement jump; ABA = Abalakov test; DJ = depth jump; MBT = medicine ball throw;
EG = experimental group; CG = control group; T0 = pretest; T1 =posttest.

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Statistical Analyses
Means and SDs were used to describe the data. A repeated-measure analysis of variance with a fixed factor (group) was employed to analyze changes in time, especially a significant interaction term (group by time). When significant main effects and interactions occurred, post hoc comparisons were performed using the Bonferroni test. The reliability of jump tests and MBT was assessed using intraclass correlation coefficients (Table 3). The level of significance was set at \( p < 0.05 \). All statistical analyses were conducted using SPSS 18.0 for Windows (SPSS Inc., Chicago, IL, USA).

RESULTS
Table 4 presents the results between the pretest and posttest for explosive strength scores in both groups and the results between groups at baseline and after the training program.

DISCUSSION
Our findings validate the first hypothesis that the 10-week in-season resistance training in addition to basketball practice support statistically significant increases in vertical jump and MBT values. On the other hand, the results obtained by the CG confirm the second hypothesis that basketball practice alone cannot improve per se explosive strength levels, because the subjects decreased nonsignificantly on the depth jump and with statistical significance on the SJ, CMJ, and Abalakov test values, despite the significant increase in MBT. At the end of the study, the EG significantly differed from the CG in all the assessed variables.

Our results support the findings of previous research, which reported significant increases in nonbasketball players' vertical jump height (10,34,35,43) and medicine ball distance (15,26,34). However, conversely to our findings, other studies did not identify significant improvements in the vertical jump of basketball players (19,24,25) and nonbasketball players all submitted to resistance training programs (18,30).

Despite the well-known influence of growth and maturation in strength development in teenage athletes, surprisingly the subjects of CG decreased lower-body explosive strength, showing that at this age basketball cannot by itself increase young basketball players' explosive strength levels. In the same way, basketball starters submitted to an in-season maintenance program, decreased lower-body strength values (8). Probably, in this study, the CG-reduced basketball training experience explains that a technical-tactical performance would not be enough to maintain initial explosivity levels. This fact highlights the need to apply an in-season resistance training program. On the other hand, the subjects from the CG could be more fatigued and show a worse level of fitness throughout the 10-week period (2,22). We also believe that the CG nonparticipation in the training program may have caused a lack of motivation in these subjects, resulting in a decreased effort in the posttraining testing.
Concerning the medicine ball test final values, we think that the observed increase is because of the exceptionally low initial values rather than to the basketball regular practice (games and skill workouts).

On the other hand, the results achieved by EG clearly show the efficacy of this training methodology with adolescent basketball players. In fact, the comparison between the results of both the EG and the CG highlights the advantage of adding a resistance training program to regular basketball practice. Similarly, combining resistance training and specific sport practice is superior to specific sport practice alone for an overall development of young soccer players’ physical abilities (10) and handball players’ performance on CMJ (35).

Conversely, in a study carried out with adolescent handball players, Gorostiaga et al. (18) concluded that a heavy-resistance training program had harmful effects on the handball playing ability. In fact, these authors did not find significant increases in vertical jump height, despite significant increments in maximal strength values. According to the authors, heavy training loads with slow twitch imply a reduced improvement and even negative changes in muscular power. This understanding is not supported by our results because the moderate intensity resistance training program used in this study significantly increased vertical jump height. Similarly, our results do not sustain the idea that an upper-body resistance training program aiming muscular power should be performed with maximal speed (26). In fact, in this study, moderate training loads did not compromise gains on MBT.

Resistance training is a crucial methodology when the aim is to develop higher levels of muscular strength and power implied on basketball jumping (28). Our results support this idea because they reveal statistically significant increases in both the SJ and CMJ height. Similarly, Toumi et al. (43) reported significant increases in these variables when sedentary youngsters were submitted to a resistance training program. Like these authors, we believe that eccentric-concentric muscular actions involved in the exercises probably induced the achieved gains. Furthermore, we agree with the authors when they consider that an eccentric-concentric training will influence the jumping amortization phase, reducing ground contact time thus improving CMJ performance. We also believe that SJ increases are because of the muscular chain contractile component potentiation implied in this jump (43). In other words, the contractile component optimized in the prestretch phase will induce an increase in take-off velocity with positive effects on the SJ height.

Although not studied in this study, we believe that intrinsic muscular adaptations, motor coordination, and neuromuscular activation are possible mechanisms for the enhanced strength in adolescent athletes submitted to resistance training (5,21). On the other hand, we know that 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 (10). We are conscious that the load magnitude adopted in our study (10RM), recommended by several authors on strength training programs with young athletes (5,17,31,33) fit the suggestions to hypertrophic development (16,31). However, neural adaptations predominate in the early stages of our resistance training program (3,9). In this way, the applied program improved the ability of the central nervous system to activate and stimulate the muscles so that they learn to cooperate, synchronizing their actions and contracting the chain of muscles involved in resistance training (5). In fact, increased motor unit activation improved intermuscular coordination in terms of synergistic muscle activations and decreased coactivation of antagonistic muscles contributed to the observed increases in our study (42). We can state that at these ages, our training program contributed to the subjects’ motor learning and this may be related to physiological adaptations within the primary motor cortex (7). This fact leads to a more efficient execution of the learned movements, expressed on the superior outcomes obtained (7). We also believe that a better synchronization of body segments and the related increased levels of motor coordination have contributed to a more effective skill domain in vertical jump and MBT.

Assuming that with the extension of the training process muscular adaptations will become more evident and have repercussions in higher hypertrophic levels (31), given the program duration in this study, some muscular hypertrophy may have occurred. However, no procedure confirming this hypothesis has been adopted.

Finally, the present findings highlight the importance of in-season resistance training for basketball sportive preparation (20). This statement is in agreement with the opinion postulated by Hoffman et al. (24) who support the inclusion of twice-a-week resistance training during in-season period. Besides, increments in vertical jump height (nonsignificant) were because of resistance training combined with the more intense overall training of the preseason and in-season periods (19).

**Practical Applications**
This study showed that a 10-week in-season resistance training program for the upper and lower body increased vertical jump and MBT performance in adolescent male basketball players. Coaches should know that such a short resistance training program specifically designed for young basketball players, with no experience in resistance, plyometric, or combined training, induce increased explosivity levels. These increments are essential to a better basketball performance, and the adopted program did not involve an extra overload on adolescents’ skeletal muscle development. Furthermore, coaches should be conscious that resistance training at these ages familiarizes young basketball players with a methodology that will be part of their training routines.
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all through their sport life. This kind of physical training program clearly contributes to the motor learning process with positive repercussion on future motor performance.

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