THE EFFECTS OF STRETCH-SHORTENING CYCLE EXERCISE PROGRAM ON COORDINATION PATTERN IN YOUNG ATHLETES

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ABSTRACT
Despite the previously held belief that strength training was unsafe and ineffective for children, health organizations support children’s participation in appropriately designed and competentely supervised strength training program. There still remains fear that strength training may have detrimental effect on coordination pattern in young athletes. In this study training program consisted of stretch shortening cycle (SSC) exercises for developing explosive power was performed. Strength SSC training acts on both the musculoskeletal and neurological levels to increase an athlete’s power output. The aim of the study was to examine the effects of this type of training on coordination in young athletes. The coordination pattern was presented and analyzed with biomechanical parameters of basketball technique. The results showed that stretch shortening cycle program had no negative influences upon coordination pattern in young athletes. The true definition of eccentric action follows. The term stretch-shortening cycle describes what actually happens. The muscle is stretched quickly, the muscle is stretched slightly before the concentric action results after a stretch-shortening cycle. Thus, the term stretch-shortening cycle is the term plyometric. However, the other common explanation for the more forcible action is that a neural reflex results in a quicker shortening cycle program had no negative influences upon coordination pattern in young athletes. In this lightning phase the muscle is stretched slightly and than shortens. This slight stretching stores elastic energy. The addition of the elastic energy to the force of a normal concentric action is one of the reasons commonly given to explain why a more forcible concentric action results after a stretch-shortening cycle. The other common explanation for the more forcible concentric action is that a neutral reflex results in a quicker recruitment of muscle fibers or a recruitment of more muscle fibers. Because of this reasons we insisted on the immediate transition (short delay) between stretch (eccentric) and shortening (concentric) phases. Synonymous with the term stretch-shortening cycle is the term plyometric. However, preactivation of the muscles before eccentric phase, than a short and fast eccentric phase, and immediate transition (short delay) between stretch (eccentric) and shortening (concentric) phases. Synonymous with the term stretch-shortening cycle is the term plyometric. However, body weight jump and medicine ball throws are more accurately described by the term stretch-shortening cycle exercise than the term plyometrics.

INTRODUCTION
Despite the previously held contention that strength training was unsafe or ineffective for children, research conducted over past ten to fifteen years clearly demonstrates that children and adolescents may benefit from strength training activities. The qualified acceptance of youth strength training by medical and fitness organizations is becoming universal (1−4). In addition to increasing muscular strength and muscular power, regular participation in a youth strength training program has the potential to positively influence cardio respiratory fitness (5−8), body composition (5), blood lipids (9), bone mineral density (5,10) and motor performance skills (11).

Running, walking and hopping are typical examples in human locomotion of how external forces (e.g. gravity) lengthen the muscle. In this lightning phase the muscle is acting eccentrically, and then a concentric (shortening) action follows. The true definition of eccentric action indicates that the muscle must be active during stretch. This combination of eccentric and concentric actions forms a natural type of muscle function called the stretch-shortening cycle or SSC (12,13). Effective SSC requires three fundamental conditions: a well-timed preactivation of the muscles before eccentric phase, than a short and fast eccentric phase, and immediate transition (short delay) between stretch (eccentric) and shortening (concentric) phases. Synonymous with the term stretch-shortening cycle is the term plyometric. However, body weight jump and medicine ball throws are more accurately described by the term stretch-shortening cycle exercise than the term plyometrics.

When the sequence of concentric action is performed quickly, the muscle is stretched slightly before the concentric action. Thus, the term stretch-shortening cycle describes what actually happens. The muscle is stretched slightly and than shortens. This slight stretching stores elastic energy. The addition of the elastic energy to the force of a normal concentric action is one of the reasons commonly given to explain why a more forcible concentric action results after a stretch-shortening cycle. The other common explanation for the more forcible concentric action is that a neutral reflex results in a quicker recruitment of muscle fibers or a recruitment of more muscle fibers. Because of this reasons we insisted on the immediate transition (short delay) between stretch (eccentric) and shortening (concentric) phases in our strength training program.

SAŽETAK
Uprkos nekadašnjem mišljenju da je trening za razvoj mišićne snage kod dece neefikasan i sa potencijalnim negativnim efektima, danas sportske organizacije i udruženja podržavaju učešću vežbanja dece u adekvatnim i pravilno omraženim programima za razvoj snage. Ispak, ostaje oteženo dovođenje bih trening snage mogao da ima negativan uticaj na koordinaciju kod mladih sportista. Za potrebe ovog istraživanja sastavljen je program za razvoj snage od vežbi koje su u svojoj osnovi sadržale ciklus skraćivanja i izduživanja. Trening koji se sastoji od po- menutih vežbi deluje na mišićnotetivne i neurološke činioce koji utiču na ukupnu izpolnjenje snaga sportista. Cilj istraživanja je utvrđivanje navedenog tipa treninga na koordinaciju kod mladih sportista. Koordinacija je prepoznata i analizirana kroz biomhaničke parametre košarkaške tehnikе. Dobijeni rezultati pokazuju da trening za razvoj snage nije negativno uticao na koordinaciju, odrlosno na izabranu sportsku tehniku. Trening za razvoj snage nije narušio koordinaciju prescaranih mišićnih pokreta, ali je doveo do poboljšanja maksimalne izometrijske sile (Fmax) zabeležene tokom maksimalne voljne mišićne kontrakcije. Testom za mišića ekstenzore nogu (LEG test) zabeleženo je poboljšanje snage od 12% (177,95kg ± 60,55 pre vs. 201,9kg±62,27 post), dok je testom mišića potokolenca (CALF test) zabeleženo poboljšanje snage od 7% (112,48kg±26,24 pre vs. 120,81kg±22,48 post).

Ključne reči: sport, vežbanje skraćivanja mišića, omladina, koordinacija, biomehanika
Improvement of the maximal muscle strength of the leg extensors, as a consequence of the applied a wide variety of training studies, shows that stretch-shortening cycle exercise can improve performance in vertical jumping, long jumping, sprinting and sprint cycling. It also appears that a relatively small amount of stretch-shortening cycle exercise training is required to improve performance in these tasks (14–19). It has been demonstrated that muscle jump performance can be increased in response to plyometric training lasting from 4–12 weeks. The use of the plyometric method has emphasized the need to study the possibilities of its use in the training of young athletes in the development of vertical jumping and maximal voluntary isometric force (18, 19).

Furthermore, since muscular strength and power are required for success in many sports, it is attractive to assume that stronger and more powerful young athletes will perform better. Even though, there are no data to support theory that strength training is detrimental to players shooting, the results of some studies (20) indicate that strength training for basketball players is beneficial to their overall development as athletes. A recent study (21) showed that strength training was effective for improving precision in basketball. However, it is still common opinion among coaches that strength and power training in young athletes has a negative effect on technical performance.

The most important and most commonly used technique in basketball is jump shot. This technique consists of SSC type movements. The mastery of the mechanics of jump shot is one of the primary keys to successful performance, and it is not surprise that there is still some doubt among basketball coaches that strength training program for young athletes may have bed influence on basketball shooting technique in young athletes. This is the main reason why they have usually avoided strength training for young athletes in the past.

There were many definitions of coordination. Biomechanists focused on intersegmental coordination of the pattern of movement (22). The timing of the pattern may have been put on a continuum described by Hudson (22). The angular positions of the specific body segment involved in basketball technique were used to examine coordination pattern.

The aim of the present study was to carry out a comparative biomechanical analyses for investigating the effect of strength training on the coordination elements in young athletes.

SUBJECTS AND METHODS

The subjects of this study (n = 21) were young basketball players at the chronological age of 15.4 years ± 0.6. The age was computed from the date of birth and date of examination. All subjects were members of basketball club Junior, Cadet Champion of the Regional League of Nis Region, Serbia in 2005/06. All the players volunteered to participate in the study. Before the beginning of the study, the informed consent of both the players and the coach were obtained. A total of 21 subjects in this group underwent a protocol of investigation.

The investigation consisted of two testing protocols: initial and final. During the examination, subjects were using sport equipment. The investigation protocol included anthropometric measurements, maximal isometric muscle strength, and biomechanical parameters of basketball technique. Anthropometric apparatus was calibrated according to the manufacturer’s instruction. Stature was measured by a stadiometer (GPM, Swiss) to the nearest 0.1 cm. Body weight was determined using electronic balance scale (Tefal, M6010, France) to nearest 0.1 kg. Fat mass and the fat free mass (FFM) were determined by bioelectrical impedance analysis- BIA (23) using an Omron (Japan) device according to standardized procedure for the type of device used (24, 25).

Measurement of maximal isometric force of lower body muscle was carried out by the isometric dynamometer interfaced with the appropriate software for automatic data registration. Maximal isometric force (F max) is maximal force registered in maximal voluntary muscle contraction. Muscle tests were carried out under standardized isometric conditions on the following muscle groups: the leg extensors, by means of the „Standing leg extension” test – LEG, and the calf muscles extension from a sitting position by means of „Sitting Calf muscles extension” the - CALF (26, 27). Maximal vertical height of jump and biomechanical parameters of basketball technique were measured with digital camera interfaced with motion analysis software system (KAVideo), San Francisco, USA. The coordination pattern was presented and analyzed with biomechanical parameters of basketball technique. The specific biomechanical parameters under the investigation on the moment of ball release were: wrist angle (WA), elbow angle (EA), shoulder angle (SA), hip angle (HA), knee angle (KA), ankle angle (AA), height of the ball at release (HBR), height of the center of mass at release (HCM), ball velocity (BV) and angle of ball release (AR).

An eight week training protocol was designed specifically for all players. Training program lasted eight weeks, and it was composed of SSC exercises. Each training consisted of 10 minutes of warm up and 30 minutes of strength training. In the first 3 weeks of strength training program, two sessions per week were performed. In weeks 3–6 of training program three sessions per week were performed. In the final two weeks two training sessions were performed. This made a total of 19 training sessions in 8 weeks of strength training program. The program consisted of exercises for lower and upper body, abdominal and lower back muscles (28, 29). In each training session, 3 series of 6 different exercises were performed. Every series were consisted of six repetitions in first week, and the number of repetitions was raised for two repetitions in a series after the 3rd and the 6th week. The training sessions were predominantly directed to the lower body muscles with 3 different exercises in one session, and only one session was directed to other muscle groups. All exercises consisted of eccentric followed by...
concentric muscle contraction, which represented SSC (12, 13). Because of the role of stretch reflexes in force enhancement during SSC exercises (30, 31) we insisted on the immediate transition between stretch and shortening phases in every exercise. The strength training protocol was conducted under the author supervision. Statistical analyses were carried out with SPSS statistical package ver. 12 (Chicago, IL, USA). All values were expressed as mean ± standard deviation (SD). Statistical evaluation was performed by Student’s t test for paired observations, one-factorial and two-factorial analyse of variance. The differences were considered to be significant when p value was less than 0.05.

RESULTS
Anthropometric features of the subjects included in the investigation and isometric strength measurements are shown in table 1 (means±SD). Results of the maximal isometric force (F max) for the leg extensors (LEG test) and the calf muscles extension (CALF tests) are shown in figure 2. The results of specific biomechanical parameters are shown in table 3.

Table 1. Anthropometrical characteristics and results of isometric muscle force.

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>INITIAL MEASUREMENT</th>
<th>FINAL MEASUREMENT</th>
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<tbody>
<tr>
<td>Age</td>
<td>15.4 ± 0.6</td>
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<tr>
<td>Height (cm)</td>
<td>180.7 ± 7.9</td>
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<tr>
<td>Body Weight (kg)</td>
<td>68.6 ± 11.6</td>
<td>70.1 ± 10.9</td>
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<tr>
<td>Fat mass (%)</td>
<td>15.96 ± 4.98</td>
<td>15.03 ± 5.22</td>
</tr>
<tr>
<td>Fat free mass (kg)</td>
<td>11.03 ± 5.33</td>
<td>10.89 ± 5.56</td>
</tr>
<tr>
<td>LEG (kg)</td>
<td>177.95 ± 60.55</td>
<td>201.90 ± 62.27</td>
</tr>
<tr>
<td>CALF (kg)</td>
<td>112.48 ± 26.24</td>
<td>120.81 ± 22.48</td>
</tr>
<tr>
<td>Jump height (cm)</td>
<td>281.5 ± 15.3</td>
<td>283.4 ± 16.4</td>
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</tbody>
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Figure 1. Results of the maximal isometric force (F max) for LEG and CALF tests on initial and final testing.
Abbreviations: Standing leg extension test – LEG, Sitting Calf muscles extension – CALF.

Table 2. The results of the selected biomechanical parameters.

<table>
<thead>
<tr>
<th>Biomechanical Variables</th>
<th>WA</th>
<th>EA</th>
<th>SA</th>
<th>HA</th>
<th>KA</th>
<th>AA</th>
<th>HBR</th>
<th>HCM</th>
<th>BV</th>
<th>AR</th>
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<tr>
<td>INITIAL MEASUREMENT</td>
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<tr>
<td>min-max</td>
<td>137.88–171.37</td>
<td>129.19–174.97</td>
<td>121.12–47.37</td>
<td>157.35–96.77</td>
<td>144.28–78.35</td>
<td>107.68–142.23</td>
<td>2.22–2.53</td>
<td>1.10–1.27</td>
<td>5.94–6.84</td>
<td>38.46–50.77</td>
</tr>
<tr>
<td>Mean±SD</td>
<td>155.97±10.08</td>
<td>156.99±13.60</td>
<td>131.21±7.22</td>
<td>176.77±9.92</td>
<td>168.71±9.21</td>
<td>124.47±12.04</td>
<td>2.37±0.13</td>
<td>1.17±0.08</td>
<td>6.36±0.33</td>
<td>44.61±4.02</td>
</tr>
<tr>
<td>FINAL MEASUREMENT</td>
<td></td>
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<tr>
<td>min-max</td>
<td>139.01–169.42</td>
<td>129.37–175.94</td>
<td>119.76–47.99</td>
<td>157.89–95.41</td>
<td>159.57–78.23</td>
<td>108.17–139.88</td>
<td>2.22–2.53</td>
<td>1.10–1.25</td>
<td>5.85–6.93</td>
<td>38.36–49.70</td>
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<tr>
<td>Mean±SD</td>
<td>155.37±8.46</td>
<td>155.67±13.80</td>
<td>130.80±7.59</td>
<td>176.37±9.07</td>
<td>171.83±6.07</td>
<td>123.16±10.96</td>
<td>2.39±0.10</td>
<td>1.19±0.05</td>
<td>6.34±0.33</td>
<td>44.56±3.76</td>
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<tr>
<td>F(df[1,2]) 1.26</td>
<td>0.03</td>
<td>0.00</td>
<td>0.02</td>
<td>0.01</td>
<td>0.98</td>
<td>0.09</td>
<td>0.13</td>
<td>1.40</td>
<td>0.03</td>
<td>0.00</td>
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<tr>
<td>p-level</td>
<td>0.87</td>
<td>0.98</td>
<td>0.89</td>
<td>0.91</td>
<td>0.33</td>
<td>0.77</td>
<td>0.72</td>
<td>0.25</td>
<td>0.96</td>
<td>0.97</td>
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DISCUSSION
A motor structure of the jump-shot technique in basketball in young basketball players (age: 14–16 years), engaged in organized training for several years, is substantially automatized. Despite the individual differences, the results of biomechanical parameters are in the line with the results of the similar studies (32, 33) performed on different samples.

The results of the biomechanical analysis showed that this protocol has not influenced the coordination of the skill of jump shot in these athletes. The results of statistical analysis show that difference wasn’t statistically significant (Manova: Wilkins lambda=0.68, F approximation=0.80, df 1=10 and df 2=17, p=0.63). From these results we can conclude that strength training program did not negatively influenced the coordination of the skill of jump shot in these athletes.

The only observable difference was in variable height of center of mass at release (HCM). The increase in HCM at release from 1.17 cm to 1.19 cm and ball height (BH) at release from 2.37 to 2.39 shows that increase in lower body muscle strength and in height of vertical jump had positive transfer on the height of the center of the body mass at release and height of the ball at release in analyzed basketball technique. Although the difference is not statistically significant, it shows that applied strength training program had the strongest influence on the targeted variable.

The applied training for strength development had lead to increase in maximal isometric force (Fmax) registered during maximal muscle voluntary contraction. The test of leg extensor muscles (LEG test) has indicated increase in Fmax for 12% (177.95 kg pre vs. 201.9 kg post), while the test of calf muscles (CALF test) indicated
the increase by 7% (112.48 kg pre vs. 120.81 kg post). The gains that are achieved with the strength training program showed that stretch shortening cycle training program was well designed and that it had the positive effects on maximal isometric muscle force. The maximal isometric force (Fmax) of a muscle is directly related to its cross-sectional area (34). Strength training produces an increase in muscular force while muscular hypertrophy becomes appreciable at a later time (34). Considering the duration of applied training program we can conclude that the increase of HCM and BH is a result of neuromuscular adaptation.

The coordination pattern of the analyzed technique remains unchanged so we can recommend the stretch-shortening cycle exercises for development of the muscle strength with no fear that it would have detrimental effects on coordination pattern of the sports technique in adolescents. Since the applied training program for the development of muscle strength does not include defined external loading exercises (weight lifting), it has no negative influence on the longitudinal growth.

REFERENCES