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VERTICAL JUMPING PERFORMANCE IN YOUNG RHYTHMIC GYMNASTS

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Abstract. Vertical jumping performance characteristics were compared in female rhythmic gymnasts (n=11) and age-matched untrained controls (n=15) aged 12-13 yrs. Maximal squat (SJ), counter-movement (CMJ) and drop jumps from 40 cm height (DJ40), and a modified (30 s) Bosco anaerobic jumping power test were performed on force platform. The results of the sytudy indicated that the jump heights in SJ, CMJ and DJ40 were greater ($p<0.01$-0.001) in rhythmic gymnasts than controls. The jump height in DJ40 was greater ($p<0.001$) compared with SJ and CMJ only in rhythmic gymnasts. The jump height ratio CMJ:SJ did not differ in rhythmic gymnasts and controls. The rhythmic gymnasts had greater ($p<0.05$) jump height ratio DJ:SJ than controls. Mean mechanical power output calculated for every 15 s period of the repeated jumping, and average power output for 30 s repetitive jumping exercise were greater ($p<0.01$-0.001) in rhythmic gymnasts than controls. The rhythmic gymnasts had higher ($p<0.05$) fatigue index during repetitive jumping exercise than controls. It was concluded that young elite female rhythmic gymnasts demonstrated a markedly greater ability to use the potentiating effect of stretch-shortening cycle to vertical jumping performance than control subjects during DJ, but not during CMJ. The rhythmic gymnasts produced greater mechanical power during repetitive maximal jumping exercise, but fatigued faster than controls. ***(Biol.Sport 22:237-246, 2005)***

Key words: Vertical jumping – Rhythmic gymnastics – Anaerobic power - Children

Introduction

Children have become increasingly involved in athletic training at younger ages, especially those competing in female rhythmic gymnastics. To learn and perform the complex gymnastics skills and to reach the top level of performance in

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rhythmic gymnastics, it is obvious that girls have to begin intensive training at very young age.

In rhythmic gymnastics, the movements of lower limbs performed at high speed against resistance provided by the body weight are often used, and, therefore explosive strength of the leg extensor muscles plays a major role in the performance. Vertical jumps can be used as a model to assess explosive force-generating capacity and anaerobic power of the leg extensor muscles. The squat jump (SJ) is used as the functional expression of explosive muscle strength of the leg extensor muscles that requires only concentric contraction [3,4]. Vertical jumps are preceded by an eccentric contraction - counter-movement jump (CMJ) and drop jump (DJ), i.e. jumping down from a height and performing a maximal vertical jump upon landing, are exercises characterized by stretch-shortening cycle (SSC) [3,4,6]. It has been shown that vertical jumps preceded by an eccentric contraction result in greater vertical jump heights [1,3]. The jump height ratios CMJ:SJ and DJ:SJ have been used to evaluate the ability to use SSC during vertical jumping [6]. Several studies have validated the use of repetitive jump tests to assess anaerobic power of the leg extensor muscles during the explosive SSC type exercise in athletes [5,11]. However, the ability to use SSC in vertical jumping and anaerobic power during repetitive jumping exercise in young female rhythmic gymnasts is poorly understood. Few studies have investigated the vertical jumping performance in young female gymnasts [2].

The purpose of this study was to compare the vertical jumping performance characteristics in young elite female rhythmic gymnasts and age-matched untrained controls. We were interested in examining jump height in SJ, CMJ and DJ, i.e. in jumps without and with SSC, and mechanical power through 30 s repetitive jumping.

Materials and Methods

A total of 26 children aged 12 to 13 years participated in this study: 11 female rhythmic gymnasts and 15 age- and gender-matched untrained control subjects. Rhythmic gymnasts' group consisted of the young high-performance (elite) gymnasts at national level. Gymnasts completed a questionnaire regarding hours of training per week and onset of regular training in rhythmic gymnastics in years. The vertical jumping performance in female rhythmic gymnasts was recorded before the international level competition. The control subjects took part in regular physical education 2 hours per week at school. None of these subjects had any background in regular sports training of any kind. The anthropometric characteristics of the subject groups and the training characteristics of the rhythmic gymnasts are presented in Table I. Pubertal stages were determined according to the criteria of Tanner [19] by a female pediatrician. Tanner stage was estimated by breast development and pubic hair. All rhythmic gymnasts were in Tanner stage I-II, and untrained girls in Tanner stage II-III. The written informed parental consent was obtained prior to the children's participation in the experiment. The study carried the approval of the University Ethics Committee.

Table 1
Anthropometric data of the subjects and training characteristics of the rhythmic gymnasts (mean±SD)

Variables	Groups	
	Rhythmic gymnasts (n=11)	Untrained (n=15)
Age (years)	12.7±1.7	12.7±0.7
Height (cm)	153.9±8.7	158.4±8.3
Body mass (kg)	36.1±6.4	44.8±7.5*
Body mass index ($kg \cdot m^{-2}$)	15.4±1.6	18.1±2.4*
Training intensity (hours per week)	24.6±4.8	-
Onset of training (years)	7.1±1.7	-

*$p<0.05$ compared with rhytmic gymnasts

Prior to testing, each subject underwent a 10-min warm-up with stretching exercises. The vertical jumping performance tests were performed on force platform (PD-3A, VISTI, Russia) with the dimensions of 0.75 x 0.75 m and natural frequency of 150 Hz.

To assess the explosive force of the leg extensor muscles all subjects performed three different types of vertical jumps: SJ, CMJ and drop jump from 40 cm height (DJ40). The SJ started from a static semi-squatting position followed by subsequent action, during which the leg and hip extensor muscles contracted concentrically. The CMJ started from upright standing position and then subjects countermoved until the knee was flexed to ~ 90º. These angles were controlled by an electrogoniometer attached to the lateral side of the subject's right knee. Maximal explosive extension in opposite direction (concentric contraction) immediately followed a fast preparatory counter-movement that stretched the leg extensor muscles (eccentric contraction). The starting position during DJ was similar to that of the CMJ, but the subject stood on box at a height of 40 cm. The subject dropped from the box and rebounded after a short contact with the ground to maximal height. The leg muscle work during the ground contact constituted the SSC. The subjects were instructed to jump with their hands on the hips to eliminate the influence of the arms swing impulse. Prior to the testing, the subjects performed several preliminary trials. The testing jumps had to be performed reactively with maximal effort. By measuring the flight time (t_f) from the force-time record, the vertical velocity of take-off (V_v) was calculated by formula

$$V_v = ½ \cdot t_f \cdot g,$$

where g is the acceleration of gravity (9.81 $m \cdot s^{-2}$). Jump height (H) was then calculated as

$$H = V_v^2 \cdot (2g)^{-1}.$$

Each jump was repeated for three times with 1 min rest periods and the best result was used for further analysis. To evaluate the ability of utilization of SSC on vertical jumping the jump height ratios CMJ:SJ and DJ40:SJ (%) were calculated [6].

A modified (30 s) Bosco anaerobic jumping power test was performed on force platform (PD-3, VISTI, Russia). The CMJs were repeated consecutively with maximal leg extension during 30 s without any recovery between jumps. To standardise the knee angular displacement during the contact phase, the subjects were asked to bend the knees to about 90° and jump. The subjects were instructed to jump with their hands on the hips. The mean mechanical power per kilogram of body mass was computed by using the total number of jumps, total flight time, and total contact time over the first (0-15 s) and last (15-30 s) 15 s period, and the total 30 s period on repetitive jumping [5]. The difference between mean power during first and last 15 s periods of jumping was calculated relative to first 15 s period and used as fatigue index (%).

Standard statistical methods were used for calculations of means and standard deviations (±SD). One-way analysis of variance (ANOVA) followed by Tukey post hoc comparisons were used to test for differences between groups of subjects and for different types of vertical jumps. A level of $p<0.05$ was selected to indicate statistical significance.

Results

The rhythmic gymnasts showed less ($p<0.05$) body mass and body mass index than controls (Table 1). The body height did not differ significantly between groups. The jump heights in SJ, CMJ and DJ40 were greater ($p<0.01$-0.001) in rhythmic gymnasts than controls (Fig. 1). The jump height in DJ40 was greater ($p<0.001$) compared with SJ and CMJ only in rhythmic gymnasts. No significant differences between CMJ and SJ heights were found in two groups of children. The jump height ratio CMJ:SJ did not differ in rhythmic gymnasts and controls (Fig. 1B). The rhythmic gymnasts had greater ($p<0.05$) jump height ratio DJ:SJ than controls.

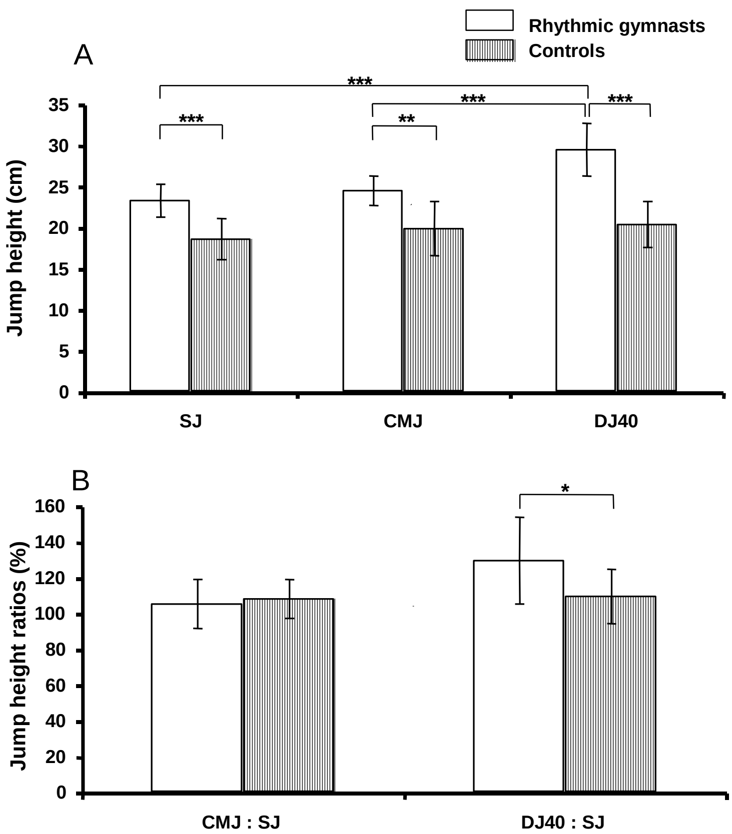

Fig. 1
Jump height in squat jump (SJ), counter-movement jump (CMJ) and drop jump from 0.40 m height (DJ40) (A) and jump height ratios CMJ:SJ and DJ:SJ (B) in rhythmic gymnasts (n=11) and controls (n=15); values are means±SD;
*$p<0.05$; **$p<0.01$; ***$p<0.001$

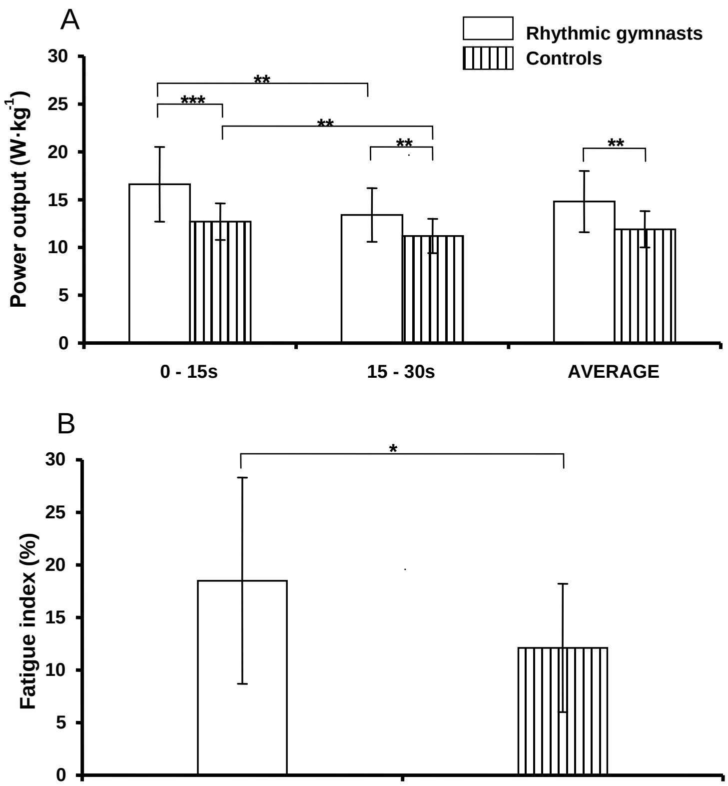

Fig. 2
Jump height in squat jump (SJ), counter-movement jump (CMJ) and drop jump from 0.40 m height (DJ40) (A) and jump height ratios CMJ:SJ and DJ:SJ (B) in rhythmic gymnasts (n=11) and controls (n=15); values are means±SD;
$^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Mean mechanical power output calculated for every 15 s period of the repeated jumping, and average power output for 30 s repetitive jumping exercise were greater ($p<0.01$-0.001) in rhythmic gymnasts than controls (Fig. 2A). The rhythmic gymnasts had higher ($p<0.05$) fatigue index during repetitive jumping exercise than controls (Fig. 2B).

Discussion

The 12-13-year-old female rhythmic gymnasts, participating in this study, started their regular specialized rhythmic gymnastic training at the mean age of 7 years. The anthropometric measurements indicated that rhythmic gymnasts were significantly lighter (19.4%) and had smaller body mass index (14.9%) than age- and gender-matched controls. All rhythmic gymnasts were classified in Tanner stage I-II, while control girls were classified in Tanner stage II-III. The delay in both breast and pubic hair development in rhythmic gymnasts in our study is in agreement with previous reports [9,10]. In female rhythmic gymnasts, intensive physical training, chronic psychological stress and modifications in nutrition, resulting inadequate energy intake relative to energy output are factors that can contribute to the observed delay in pubertal development, growth and biological maturation as compared to age-matched untrained girls and individuals in other sports [7,8,15,20].

In the present study, explosive force-generating capacity of the lower extremities was assessed by vertical jumps, performed without (SJ) and with preliminary counter-movement (CMJ and DJ). CMJ and DJ are exercises characterized by so-called SSC, in which the action of the muscles during the eccentric phase influences the subsequent concentric phase [1,3]. The most common measure of vertical jumping performance is jump height. In this study, rhythmic gymnasts had greater jump heights in SJ, CMJ and DJ40 than controls. However, the SJ and CMJ heights for female gymnasts were lower than average values for age- and gender-matched gymnasts published previously by Bencke *et al.* [2].

The vertical jump height depends on the physiological processes that take place in the muscular and nervous systems. It is well known that dynamic force of the knee extensor muscles is one important factor limiting performance in jumping exercises. Vertical jumping is a multijoint movement and requires the intra- and intermuscular coordination, i. e. the ability of agonists, antagonists and synergists to co-operate in performing the task. The present study may indicate an effect of rhythmic gymnastic training, which includes rapid ballistic movements with short explosive force (power) production. It has been suggested that a training program with ballistic movements induces only minor hypertrophic changes in skeletal muscles [14,17], and, therefore, neural adaptation mechanisms predominates.

When performing different types of vertical jumps, the intrinsic mechanism of muscle activation by central nervous system is remarkably different. The SJ can be used as the functional expression of explosive strength of the leg extensor muscles, as it requires only concentric muscle activation. The CMJ requires moderate eccentric muscle activation followed by high concentric muscle activation. The DJ requires high eccentric muscle activation followed by high concentric muscle activation, which requires a very precise coordination and extensive activation of the motor units. The ability to use SSC in vertical jumping can be evaluated by jump height ratios CMJ:SJ and DJ:SJ [3]. In this study, no significant differences between CMJ and SJ heights were found in the measured groups of 12-13-year-old girls. This is in agreement with previous findings for 11-year-old boys [16]. Also, the jump height ratio CMJ:SJ did not differ significantly in rhythmic gymnasts and controls. Thus, no potentiating effect of SSC on jumping performance when performing CMJ has been observed in the present study in 12-13-year-old girls. The jump height in DJ40 was greater compared with SJ and CMJ only in rhythmic gymnasts. The rhythmic gymnasts had also significantly greater jump height ratio DJ:SJ than controls, indicating an effective utilization of SSC when performing drop jumps. Several mechanisms have been proposed to explain the potentiating effect of SSC on vertical jumping performance. During the preceding muscle action occurs the storage and re-utilization of elastic energy [1,4] and myoelectric potentiation by spinal reflexes as well as longer-latency reflexes [13] which are used during the subsequent concentric action. It has been shown that high stiffness of series elastic component of muscles in combination with high stretching velocities migh facilitate the storage and re-utilization of elastic energy during movements [18]. The specific power (jumping) training can increase the muscle stiffness and myoelectric potentiation, and also intramuscular coordination [4,10]. The performance in DJ as a more complex motor task may be more dependent on training specificity in rhythmic gymnastics. The performance in the less complex motor tasks like SJ and CMJ may not be influenced by training to the same extent.

In the present study, evaluation of the anaerobic power was based on the method described by Bosco *et al.* [5]. This method offers a possibility of determining the mechanical power of the leg extensor muscles during the explosive SSC type exercise. The study indicated that rhythmic gymnasts had greater mechanical power calculated for the first and last 15 s, and for the total 30 s repetitive jumping exercise as compared to controls. It is well known that in adults can increase training the maximal glycolytic power. However, only few studies have measured the effect of training on anaerobic energy production in children. One of these studies [12] did not find any differences between trained and untrained boys. In this study, fatigue index during repetitive jumping exercise was higher in rhythmic gymnasts than controls. Thus, the control subjects were better able to sustain a high power development through the 30 s repetitive jumping exercise than rhythmic gymnasts. In rhythmic gymnastics, the bursts of highly intense activity are mostly so short that it is not likely to tax the anaerobic system to any high extent, and it is therefore not likely that children going in for gymnastics will perform repetitive jumping test better than untrained children. On the other hand, the high level power produced by the gymnasts may also make it impossible to sustain after depletion the phosphagen stores, and this may explain the greater drop in power in rhythmic gymnasts.

In summary, the results of the present study demonstrated that young elite female rhythmic gymnasts have greater jump height in SJ, CMJ and DJ than age-matched controls. They demonstrated a markedly greater ability to use the potentiating effect of SSC to vertical jumping performance than control subjects during DJ, but not during CMJ. The rhythmic gymnasts produced greater mechanical power during repetitive jumping maximal exercise, but fatigued faster than controls.

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