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DYNAMICS OF EXPLOSIVE POWER DEVELOPMENT IN YOUNG ATHLETES

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ABSTRACT

To better understand the selection processes and a controversial orientation in track and field, we set ourselves the goal of Establishing the periods of the highest age-related increase in speed and power abilities in adolescent athletes. The following tasks of the study were derived from that goal: (1) To determine the dynamics of increase in the explosive power, and (2) To determine the main periods of its development. The study population consisted of 245 children between 7 and 12 years of age. The measured indicators were reported by Optojump Next and the obtained results were subject to statistical analysis. Jump height ranged between 20.5 cm and 29.1 cm for boys and between 22.6 cm and 31.0 cm for girls. The RSI was in the range of 0.50-1.26 for boys and 0.71-1.24 for girls. Conclusions: (1) The period around the age of 10 appears to be sensitive for developing the explosive power abilities of adolescents; (2) Drop jump from a height of 30 cm is a more suitable speed and power exercise for girls.

Keywords: *track and field, explosive power, adolescents, jumps*

INTRODUCTION

Track and field is one of the most interesting sports to watch, where the athletes compete simultaneously in disciplines with basic movements. In elite sports, these movements are improved at the highest possible level and result from years of practice, the improvement of theory and technique, and the regularities in building motor habits. This process is long and not very well clarified theoretically. For the experts, the question of the development of the explosive power abilities of competitors is of particular importance. This is due to a number of issues related to biological development and the so-called sensitive periods during that time. Explosive power abilities are the basis of achieving high sports results in a number of track and field disciplines, including sprint and jump disciplines.

One way to examine that ability to produce explosive movement is to test the jump height in different jumping exercises. The most used ones are different types of vertical jumps. At the same time, there are well-known tools for developing speed-power qualities such as plyometric exercises. Many authors identify plyometric training as an effective method for improving rebounding abilities, explosive power, speed, and agility (McKay & Henschke, 2012; Miller et al., 2006; Khodaei et al.,2017). One of the most used jumps for that purpose is the drop jump (DJ) (Xu et al, 2023; Owen, 2023). Since the first research on plyometric exercises in 1960, there has been a wide range of scientific reports about it in different sports including football, volleyball, basketball, etc. (Beattie & Flanagan, 2015; Ramirez-Campillo et.al. 2018; Addie et al.,2019; Montoro-Bombú et al., 2023). According to Silva et al. (2019), most of the reports are directed at the effect of plyometric training on vertical jump performance. Others are on strength performance or horizontal jump performance. A few are directed to speed, agility, or flexibility performance. According to Montoro-Bombú et al. (2023), over the last three years, more than 300 research studies about the drop jump have been published.

Sport practitioners are of the opinion that the height from which it is performed is critical since the impact speed increases during the fall, which can lead to a large load. Several authors have focused their attention on the problem of determining the optimal height for performing a drop jump, and there are specific differences in their conclusions. Some studies found that no change in performance was observed when the DJ height was increased, while others believed that the effect increased to an optimal height followed by a plateau and performance decline (Bobbert et al., 1987; Peng et al., 2017; Peng et al., 2019). Decker and McCaw (2012) investigated the influence of the DJ from three different heights (40,60, and 80 cm), finding that there were no significant differences in the eccentric phase, but in the concentric phase, differences were found between the 40 and 60 cm trials. In conclusion, they suggest 60 cm as an adequate height for a drop jump. In a similar study on improving the jumping performance of 15-16-year-old athletes but with heights of 30, 40, and 50 cm, Amara et al., 2015 defined both 40 cm and 50 cm as an effective height to achieve a high level of the explosive power of lower limbs.

In the separate stages of preparation of adolescent athletes, several abilities and skills are modeled to achieve greater power of effort. Largely, explosive power is genetically determined by the presence of fast-twitch muscle fibers. On the other hand, coaches may influence the adolescent's ability to generate power through the methodology. In this regard, finding the potentially more gifted children would help in the selection process, or the selection and sports orientation, in individual disciplines or a group of disciplines in track and field. One way to examine the ability to produce explosive movement is to test the jump height in different exercises.

As we can see, authors have been interested in plyometric exercises in many sports, but there is limited information when we speak about track and field. Therefore, the aim of this research was to establish the periods of the highest age-related increase in explosive power abilities in adolescent athletes.

METHODS

Participants

The study population consisted of 245 children (108 boys and 137 girls) from the "KLASA" Club preparatory groups aged between 7 and 12 years. Their distribution is shown in Table 1. All the study procedures were in accordance with the Declaration of Helsinki. Prior to the study, parental agreement was obtained for all tested children.

Table 1. *Distribution of participants by age and gender*

Age (years) ⇩	**Gender ⇩**	
	Boys	**Girls**
7	10	10
8	24	20
9	28	24
10	20	31
11	10	24
12	16	28

Measurement

The investigated characteristics of jump height and contact time (CT) were recorded with Optojump Next (Microgate, Balzano, Italy) with a recording frequency of 1000 Hz. Optojump Next is an optical platform equipped with a sensor and a receiving beam with a length of 1 meter with 100 LEDs. When the LED light is interrupted, the counter in the device turns on and detects with an accuracy of 1 millisecond. The jump height is measured using the flight time and algorithm with the following formula: $h=((T_f)^2*9.81)/8$, where T_f is flight time.

Test procedures

The jumps were conducted after a preliminary warm-up of the participants, which consisted of non-intensive jogging, general development exercises, skipping exercises, and starts. The competitors were prior informed about the tests and performed them in groups of 5, with a minimum 2-minute rest after performing each jump before performing the next one. The participants were instructed to put maximum effort into the performance, and in the event of incorrect performance, the jump was repeated. Two heights were used to perform the drop jump (20 and 30 cm), which we believe are the most suitable for this age group.

The drop jump test is a double-legged jump test and involves dropping from an elevated platform onto the ground (in our case, a standard athletic track) with both feet, absorbing the drop and immediately rebounding into a maximal vertical jump. In our case, a swing of the arms was used.

Statistical processing

The mathematical and statistical methods used in this study were descriptive statistics and comparative analysis. All statistical procedures were performed using SPSS Statistics v.19 (IBM, Chicago, Illinois, USA).

RESULTS

The results of the tests are presented in Figures 1, 2, and Table 2. The indicators that are displayed are the height of the jump (h), the reactive strength index (RSI), and the contact time of the jump ($t_{con.}$).

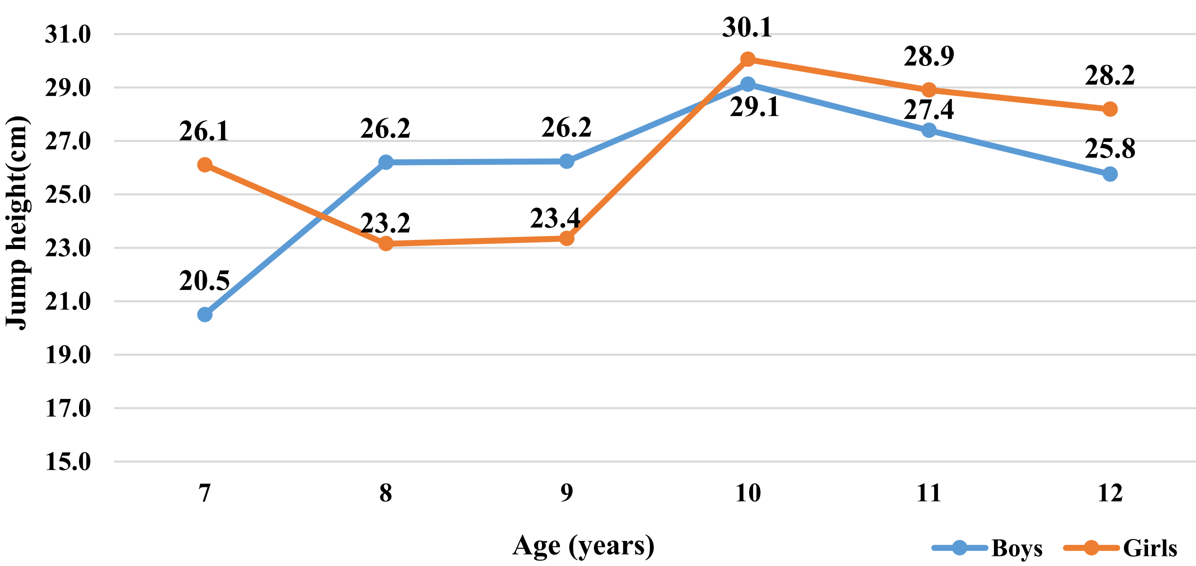

Figure 1. *Age-related difference in jump height for DJ 20*

The table shows that there was a certain heterochronism in terms of the jump height and RSI indicators. Jump height ranged between 20.5 cm and 29.1 cm and RSI 0.50-1.26 for boys, and between 22.6 cm and 31.0 cm and RSI 0.71-1.24 for girls.

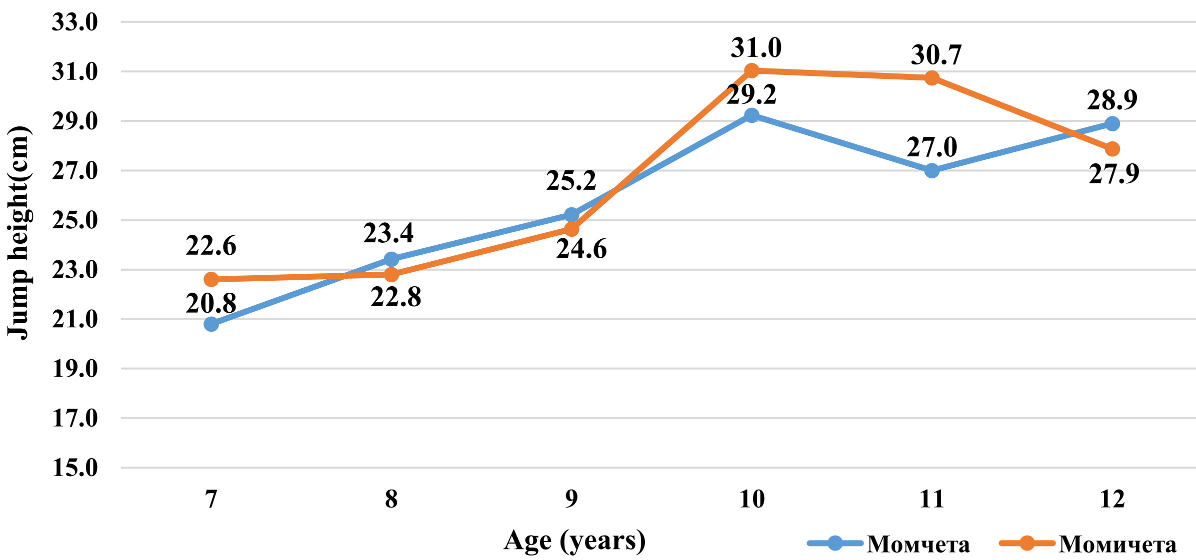

Figure 2. *Age-related difference in jump height for DJ 30*

The reactive strength index typically increases or is close to that of previous years, but in our case, the data did not show this trend. The most linear index was the one that decreased with age or had close values ranging between 0.228 and 0.393 seconds for boys and 0.249 to 0.321 seconds for girls.

Table 2. *Change in the various investigated indicators in terms of age*

Age	Boys						Girls					
	DJ 20			DJ 30			DJ 20			DJ 30		
	Contact time (s)	Jump (cm)	RSI (m/s)	Contact time (s)	Jump (cm)	RSI (m/s)	Contact time (s)	Jump (cm)	RSI (m/s)	Contact time (s)	Jump (cm)	RSI (m/s)
7	0.314	20.5	0.65	0.338	20.8	0.50	0.265	22.8	0.86	0.260	22.6	0.87
8	0.321	26.2	0.82	0.314	23.4	0.54	0.295	23.2	0.78	0.321	22.8	0.71
9	0.386	26.2	0.68	0.393	25.2	0.56	0.249	23.4	0.94	0.276	24.6	0.89
10	0.230	29.1	1.26	0.242	29.2	0.60	0.243	30.1	1.24	0.252	31.0	1.23
11	0.253	27.4	1.08	0.311	27.0	0.58	0.293	28.9	0.99	0.320	30.7	0.96
12	0.228	25.8	1.13	0.242	28.9	0.60	0.254	28.2	1.11	0.308	27.9	0.90

DJ20 – drop jump from height 20 cm; DJ30 – drop jump from height 30 cm

Table 3 presents the results from the Independent sample T-test. It is evident from the results that only two of the selected indicators were statistically different for the boys and girls. Both were for the DJ 20 test. These were the Jump height for the seven-year-olds, where girls jumped higher than boys, and the contact time for the nine-year-olds, where boys had a faster CT than girls.

Table 3. *Independent sample T-test values*

Age	Indicator	DJ 20		DJ 30	
		Mean difference	*p*-value	Mean difference	*p*-value
7 years	Jump height	5.6	**.034**	1.6	.510
	CT	0.05	.568	0.08	.973
	RSI	0.33	.400	0.52	.753
8 years	Jump height	3.0	.212	0.6	.720
	CT	0.03	.464	0.01	.885
	RSI	0.03	.728	0.17	.539
9 years	Jump height	2.8	.421	0.8	.814
	CT	0.14	**.035**	0.12	.065
	RSI	0.26	.141	0.33	.090
10 years	Jump height	1.0	.343	0.8	.414
	CT	0.1	.173	0.01	.918
	RSI	0.0.02	.935	0.63	.214
11 years	Jump height	1.5	.727	3.7	.614
	CT	0.04	.599	0.01	.801
	RSI	0.10	.843	0.39	.750
12 years	Jump height	2.4	.355	1.0	.819
	CT	0.26	.356	0.07	.849
	RSI	0.02	.291	0.31	.629

DISCUSSION

In the scientific literature, there are various methods and tools for measuring the vertical jump, and the authors are united around the opinion that the most popular for scientific research is the method of recording the flight time (Xu et al., 2023; Gadev et al., 2020). This measurement approach has also been validated by some authors (Garcia-Lopez et al., 2005; Glatthorn et al., 2011; Attia et al., 2017; Glatthorn et al., 2011). However, it should be noted that when using the Optojump Next Infrared Contact Platform the sensor is 0.3 cm above the surface on which the beams rest. Despite this, studies by Balsalobre-Fernández et al. (2014) and Magrum et al. (2018) show the validity of this device as a reliable source of information for sports educators.

A number of authors define the maximum power of work as the primary determinant regarding the speed and explosive power abilities of the athlete (Nikolaidis et al., 2016; Nordin et al., 2014; McFarland et al., 2016; Peev, 2014; Rouis et al., 2016; Santiago et al., 2015). Also, a large number of sports specialists use maximum power (explosive power) as a method of control, selection, and prediction of abilities (Cunha et al., 2017; Hedrick Anderson, 1996; Klavora, 2000). Some authors even try to calculate the anaerobic power based on the jump height (Hoffman, Kang, 2002; Nikolaidis et al., 2016; Peev et al., 2017; Theodorou et al., 2013).

Success in sports depends on many factors, such as age, gender, motor abilities, and motor qualities. For many decades, researchers have highlighted the influence of biological age on functional performance, including motor abilities and qualities (Cabral et al., 2016). According to Malina et al. (2004), age development is a crucial diagnostic technique to analyze athletes‘ physical potential, motor abilities, and motor qualities. Eventually, age development appears to be an essential consideration in selecting an athlete. Therefore, based on talent selection or identification, young athletes with better motor qualities and abilities are more likely to be selected (Gantois et al., 2017).

In this paper, our interest is mainly focused on selection in track and field. It is carried out in stages and starts from 7-8 years of age. The presence of genetic predispositions and the level of motor activity should be established. Special qualities are observed in those aged 9-10 years, and general physical fitness is assessed. After the age of 12-13 years, the abilities for realization in a specific discipline are established. During the selection in the speed and power disciplines, genetic predispositions, and morphological and psychological indicators of adolescents are also of great importance. Research in this field among the Bulgarian population has been carried out by a number of authors, whose works help us to more fully understand the processes in the adolescent organism and how they affect sports activity (BSFS, 1982; Nancheva et al., 2012; Petkova, 2016, 2017, 2019; Slanchev, 1992).

With the increasingly higher sports results, even greater demands are placed on athletes' overall preparation. As a consequence of this trend, it would be important to know more fully the functional status indicators and the predisposition of young athletes to display higher-power actions. Knowledge of these values and the processes of physical and functional development will facilitate their selection and, hence, the identification of sports talent along with the optimization of the training process. Our study addresses the period of initial sports preparation and initial sports orientation. In this age group, adolescent athletes exhibit development rates similar to those of the human population (Stratton et al., 2004). According to Philippaerts et al. (2006), the rates of body height increase are most accelerated in the first year after birth and the period of 13-14 years of age. At the same time, the diameter of muscle fibers from childhood to maturity increases 14 times. Therefore, the muscle mass increases gradually to 44-50% of the total body mass (G. Stratton et al., 2004).

Motor skills development at that stage proceeds unevenly and non-simultaneously, with their maximum manifestations occurring at different ages. It also depends on the body's functional abilities and the systems involved in their formation (motor, cardiovascular, respiratory, neuromuscular, etc.), as well as on the training activity. Such a trend is also evidenced by the study data (Figures 1 and 2), namely the drop in the results of boys and girls after 10 years of age. From this point of view, we should note that although muscle strength increases during adolescence, the same cannot be said for explosive power abilities, which depend on the time for which the muscle effort is applied. On this occasion, the data from the height of the drop jump from a 20 cm box are interesting. There are large fluctuations in age aspect for both sexes. At the same time, it is illogical to see a decline in the results of girls of nearly 3 cm at the age of 8 with a subsequent peak at the age of 10. On the other hand, the height of the drop jump of a 30 cm box has a clear tendency to increase the result in the age aspect with the already mentioned declines. These differences are most likely due to the fact that this period coincides with faster rates of growth of the locomotor apparatus, the difficulty of coordination, and the insufficient implementation of neuromuscular effort (BSFS, 1982; Nacheva et al., 2012; Petkova, 2016; Slanchev, 1992).

Contact time is an important variable related to the stretch-shortening cycle (SSC). SSC and contact time can be divided into fast (< 0.25 seconds) or slow (> 0.25 seconds) (Ramirez-Campillo et al., 2018). Generally, DJ is an exercise from the group of fast duration but the athletes in the research showed higher results in this indicator, which is another sign that they were not prepared to execute that kind of exercise properly. In this study, children at the age of 10 years demonstrated the shortest contact time.

Since most of the movements required in sports are plyometric in nature and use the stretch-shortening cycle (SSC), it would be appropriate for the tests to be of the same nature. One such exercise is the depth jump. An RSI index can be derived from it, which is very reliable and can be used by Zota coaches to determine the intensity of plyometric exercises. Another important point with RSI is that it can be used to measure optimal DJ height (Addie et al., 2019). The reactive strength index was developed to measure the explosiveness of athletes and determine how they perform in plyometric exercises (Owen, 2023). Many valid and reliable tests are used to calculate this index, the most common being the drop jump. The purpose of this study was to examine the effect of drop height on drop jump contact time, jump height, and RSI. Scientists must consider the fact that as drop height increased, contact time also increased but jump height did not change. At the same time, RSI decreases when applying a drop height of 60 cm or more (Addie et al., 2019). Contact time at the RSI is an important parameter to consider in athletes' control. It is assumed that athletes must have a good level of technical skill to implement plyometric work. In this study, adolescents showed low RSI values, but considering their age this is normal.

As for the abilities to perform plyometric exercises (measured by RSI), we noticed a tendency for their increase up to the age of 10 years in both sexes, where its peak was also noticeable, which could be defined as an appropriate period for development. During the following year, we saw a slight decline followed by a gradual increase in these abilities. The data also showed almost the same values for the boys for both measured heights of the depth jump in terms of age, which showed their inability to realize plyometric actions from such a height. Meanwhile, higher reactivity was observed in girls from a higher height than in boys from a higher height throughout the study period, while the results of the girls from a lower height were higher than or similar to those of the boys. From all this, we can conclude that girls are more prone to performing plyometric exercises at the age of 7-12 years than boys.

CONCLUSIONS

Based on the obtained results and the observed changes in adolescent athletes, we can outline several points for future research that can help with the selection process. Most of the reports that examine DJ are directed to other sports different from track and field although jump is an athletic exercise. As a whole, the period around the age of 10 appears to be sensitive for the development of adolescents' speed and strength abilities. Young athletes are not prepared to execute this exercise with the required speed, leading to other questions about its usefulness in the selection process. Drop jumps from a height of 30 cm are a more suitable explosive power exercise for girls, which may be due to earlier maturation.

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