IMPACT OF SPORT GAMES AND CYCLIC SPORTS ON MUSCLE STRENGTH AND CERTAIN CARDIOVASCULAR SYSTEM INDICATORS IN BOYS 11–14 YEARS OF AGE – A LONGITUDINAL STUDY

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Abstract:

The aim of the study was to determine the impact of sport games and cyclic sports on certain features of cardiovascular reactions to exercise and to muscular strength enhancement in a cohort of 105 boys at the age of 11–14 years. They were recruited at the age of eleven years: 35 non-athletes, 35 cyclic sports athletes and 35 sport games players. The measurements were performed for four consecutive years. The muscle strength and cardiovascular indices were registered and taken for analysis. The results indicate sport games training sessions are an important external factor affecting the functional parameters of accelerated changes in the cardiovascular system (CVS) of the 11–13-years-old age group. The influence of endogenous factors on a child's growth and development particularly increases at the age of 13–14 years, resulting in significant changes in CVS indices improvement, and non-athletes almost equal peers engaged in sports for those characteristics. Improvement of the muscle capacity indices depends on the nature of the physical load: muscle strength indices increased more in the cyclic sports group.

Key words: *maturation, athletes, non-athletes, sport specificity, specific physical load*

Introduction

Human growth and maturation is determined by the interaction of inherent (endogenous) and acquired (exogenous, environmental) factors (Armstrong & Welsman, 2005). A significant role in this interaction is given to the exogenous factors, i.e. physical activity, the nature of physical load and other physical load characteristics (Szopa & Żychowska, 2001). Activity of the cardiovascular system (CVS) is exceptionally important in the chain of physiological adaptive mechanisms (Winsley, Armstrong, Bywater, & Fawkuer, 2003; Poderys, et al., 2004). A number of epidemiological studies have already highlighted the positive effects of physical exercise on the working capacity and functional state of skeletal muscles and cardiovascular system (Whelton, Chin, Xin, & He, 2002; Strong, et al., 2005; Hilberg, 2008).

Long-term physical load results in heart and vascular system adaptation changes (Pober, Braun, & Freedson, 2004). Regular physical load exposures lead to enhanced CVS functional capability. Cardiac adaptation to maximal physical loads is one of the key factors that determine the overall adaptation of the organism to its environment. During the period of intensive growth of the human body in the first ten to fifteen years of life, heart rate (HR) has the main role in increasing the efficacy of the heart during physical exercise. CVS changes cause activation of different physiological adaptation patterns by different physical loads at different age stages (Poderys, et al., 2004; Vaeyens, Lenoir, Williams, & Philippaerts, 2008). The heart has complex mechanisms that facilitate the maintenance of oxygen supply-demand balance necessary for its contractile function in response to physiological fluctuations during variable workloads exposures (Santos, Anilkumar, Zhang, Brewer, & Shah, 2011). The myocardium is composed of multiple highly specialized myocardial fibers and the specialized conduction system (Evans, Yelon, Conlon, & Kirby, 2010). Myocardial processes from depolarization to repolarization are estimated by evaluating ECG parameters such as HR, QRS complex, rate-corrected QT and JT intervals (Berul, Sweeten, Dubin, Shah, & Vetter, 1994; Crow, Hannan, & Folsom, 2003).

The aim of this study was to examine the long-term training effects of two different groups of sports – sport games and cyclic sports on muscle strength and some CVS indicators in boys throughout early adolescence.

Materials and methods

Subjects

The sample consisted of 105 boys eleven years of age at the beginning of the research, Lithuanian high-school and sports-school students. All subjects were divided into three groups: non-athletes (n=35), cyclic sports athletes – middle distance runners (n=35), and representatives of sports games – basketball, team handball, and soccer (n=35). The study involved boys engaged in the chosen sports for not less than two years and they had attended training session no less than four times per week.

The same cohorts were followed for four years and took part in the study at the age of 12, 13 and 14 years of age (Table 1).

Research methods and organization

The measurements were carried out at the Kinesiology Laboratory, Lithuanian Academy of Physical Education and started in Spring 2006 (April/May). At the start of the research and in each of the next four years follow-up tests and measurements were performed at the same time of day. Four testers having long-term experience in assessments of youth cardiovascular and muscular performance took part at each point of the annual registration of the measured indices. The standard of testing procedure is usual for testing Lithuanian youth athletes. Two days before testing the boys did not perform any all-out exercise. Testing was conducted in a laboratory at a room temperature of 20-21°C, and twenty minutes was intended for adaptation before testing.

At the initial measurements and each year after that the students underwent a fixed load exercise test, i.e. the Rouffier test (thirty squats per 45 seconds) and all-out exercise test, i.e. the vertical jump test in 30 seconds (Poderys, Buliuolis, Poderyté, & Sadzevicienѐ, 2005). The study protocol was approved by the Lithuanian Bio-ethical Committee.

A 12 synchronous lead computerized ECG recording and analysis system (“Kaunas-load”®, developed at the Kaunas University of Medicine, Institute of Cardiology; Vainoras, 2002) was used during and after the testing procedure and the total of 25 intervals of ECG (duration of each was 10 seconds) were registered and analyzed. The changes in HR, JT and rate-corrected JT (JTc) intervals were analyzed. The JT and JTc intervals were analyzed as indices of ventricular repolarization (Hlaing, Dimino, Kowey, & Yan, 2005; Berul, et al., 1994). Its change is closely related to the myocardial metabolic changes (Vainoras, 2002).

Muscle strength was measured by the dynamometer “Nicholas” (Lafayette Instruments Company®, Lafayette, Indiana). The maximum force required for the isometric muscle contraction mode was obtained when the resistance, caused by the investigator, occurred. The dynamometric measurements were performed in order to assess the major muscles strength (results presented in Newtons). The strength of the forearm flexors, femoral flexors, calf extensors and calf flexors was measured on both the right and left side. The measurements were repeated three times and the best score was registered.

Table 1. Basic anthropometric characteristics of subjects

Age	Sport event	Body height, cm	Body mass, kg
11 years	Non-athletes (n=35)	150.3± 2.2	42.6± 3.4
	Cyclic sports athletes (n=35)	149.1± 2.5	40.2± 2.6
	Sport games players (n=35)	154.1± 2.1	43.2± 2.4
12 years	Non-athletes (n=32)	158.6±1.8	46.6± 1.8
	Cyclic sport athletes (n=21)	159.4± 2.2	45.4± 2.4
	Sport games players (n=19)	162.2± 2.4	47.8± 2.4
13 years	Non-athletes (n=30)	165.7± 2.4	54.5± 2.1
	Cyclic sport athletes (n=18)	166.1± 1.9	51.2± 2.2
	Sport games players (n=17)	169.6± 1.9	53.5± 2.2
14 years	Non-athletes (n=26)	171.9± 1.6	61.5± 2.3
	Cyclic sport athletes (n=15)	170.9± 1.9	56.2± 2.0
	Sport games players (n=16)	175.2± 2.4	58.9± 2.5

Data processing methods

The obtained data were processed by descriptive statistics methods. In order to evaluate the significance of the obtained differences between the groups, one-way analysis of variance – ANOVA (Student’s test summary of several independent samples) was used. The differences between the measured values were statistically significant at the level of $p<.05$.

Results

The strength of the examined muscle groups measured throughout the followed period from the subjects' 11 to 14 years of age is presented in Figures 1 to 4 (for the forearm flexors in Figure 1, for the femoral flexors in Figure 2, for the calf extensors in Figure 3 and for the calf flexors in Figure 4). The results suggest that the cyclic sports athletes predominated in strength, whereas the non-athletes scored the worst in the strength tests.

Intergroup significant differences were found in forearm flexors strength at the time point of twelve years of age between the non-athletes and both groups of athletes (both the left and right arms); at the time point of 13 years of age – between the non-athletes and cyclic sport athletes (both the left and right arms); at the time point of 14 years of age – between all the three groups (the right arm) and between both groups of athletes and the non-athletes (the left arm).

Significant differences in femoral flexors strength were found: at the time point of 13 years of age – between the cyclic sport athletes, sport games players and non-athletes (both the left and right leg); at the time point of 14 years of age – between all the three groups (the right leg), between non-athletes and cyclic sport athletes (the left leg).

Calf extensors strength scores showed significant differences: at the time point of 12 years of age between the cyclic sport athletes, sport games players and non-athletes (both the left and right leg); at the time point of 13 years of age – between all the three groups (the right leg), and between the cyclic sport athletes, sport games players and the non--athletes (the left leg); at the time point of 14 years of age – in all the three groups (both the left and right leg). Intergroup comparison of calf flexors' strength showed significant differences: at the time points of 12 and 13 years of age between the cyclic sport athletes, sport games players and the non-athletes (both the left and right leg); at the time point of 14 years – between the groups of cyclic sport athletes and non-athletes (the right leg) and between all the three groups (the left leg).

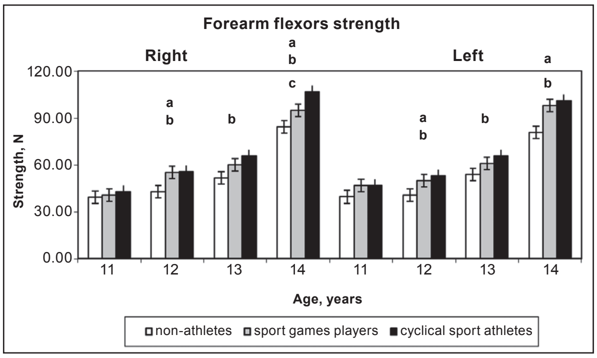

Figure 1. Forearm flexors' strength (in N) in the non-athletes, sport games players and cyclic sport atletes. ***Note****. The difference between: the non-athletes and sport games players – a, the cyclic sport athletes and non-athletes – b, the sport games players and cyclic sport athletes – c; statistically significant at p<.05.*

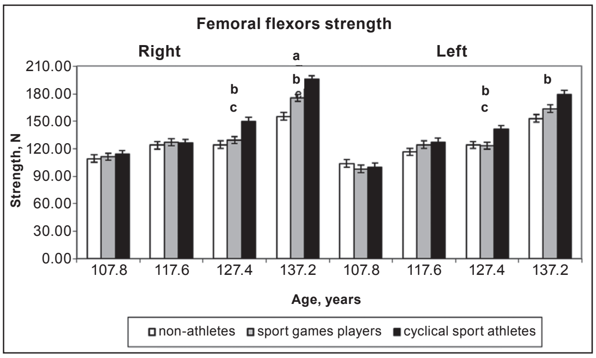

Figure 2. Femoral flexors' strength in the non-athletes, sport games players and cyclic sport atletes. ***Note****. The difference between the non-athletes and sport games players – a, the cyclic sport athletes and non-athletes – b, the sport games players and cyclic sport athletes – c; statistically significant at p<.05.*

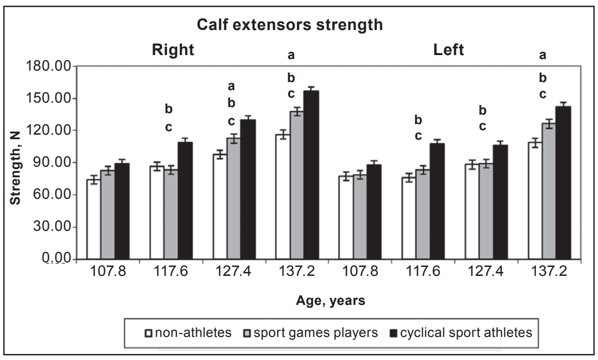

Figure 3. Calf extensors' strength in the non-athletes, sport games players and cyclic sport atletes. ***Note****. The difference between the non-athletes and sport games players – a, the cyclic sport athletes and non-athletes – b, the sport games players and cyclic sport athletes – c; statistically significant at p<.05.*

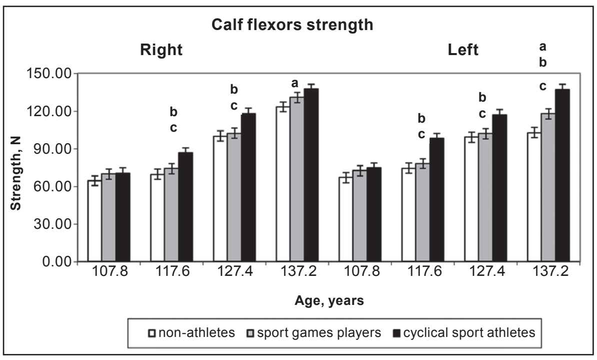

Figure 4. Calf flexors' strength in the non-athletes, sport games players and cyclic sport atletes. ***Note****. The difference between the non-athletes and sport games players – a, the cyclic sport athletes and non-athletes – b, the sport games players and cyclic sport athletes – c; statistically significant at p<.05.*

The dynamics of HR during and after the Rouffier and 30-second vertical jumping tests in the non-athletes, sport games players and cyclic sport athletes aged 11 to 14 years are presented in Figure 5. At the time points of 11, 12 and 14 years of age no significant differences between the athletes and non-athletes were found (only random cases of significant differences in the random ECGs were found). Also, at the time point of 13 years of age the HR results of the non-athletes and cyclic sports athletes did not differ. However, the data of these two groups throughout the entire study showed significant differences in comparison to the sport games players. The results suggest faster energy capacities mobilization and recovery processes in CVS of the sport games players than in the subjects of the other two groups.

Assessment of metabolic changes in myocardium was based on the analysis of the JT interval's dynamics of the non-athletes, sport games players and cyclic sport athletes aged 11 to 14 years before the load application, after the Rouffier test and after the 30-second vertical jumping test. The obtained results are presented in Figure 6. Apparently, no significant differences were found between the athletes and non-athletes at the time points of 11, 12 and 14 years of age, as opposed to the situation at the time point of 13 years of age. The largest range of the JT interval alteration was registered in the sport games players, since at almost all time points significant differences were obtained in comparison to the non-athletes and cyclic sports representatives.

While observing stages of 11, 12 and 14 years of age, no statistically significant differences were found in the rate-corrected JT interval among the non-athletes, sport games players and cyclic sport athletes. At the time point of 13 years the highest JTc interval was registered in the sport games players, although statistically significant differences were not found between them and the non-athletes and cyclic sport athletes (Figure 7).

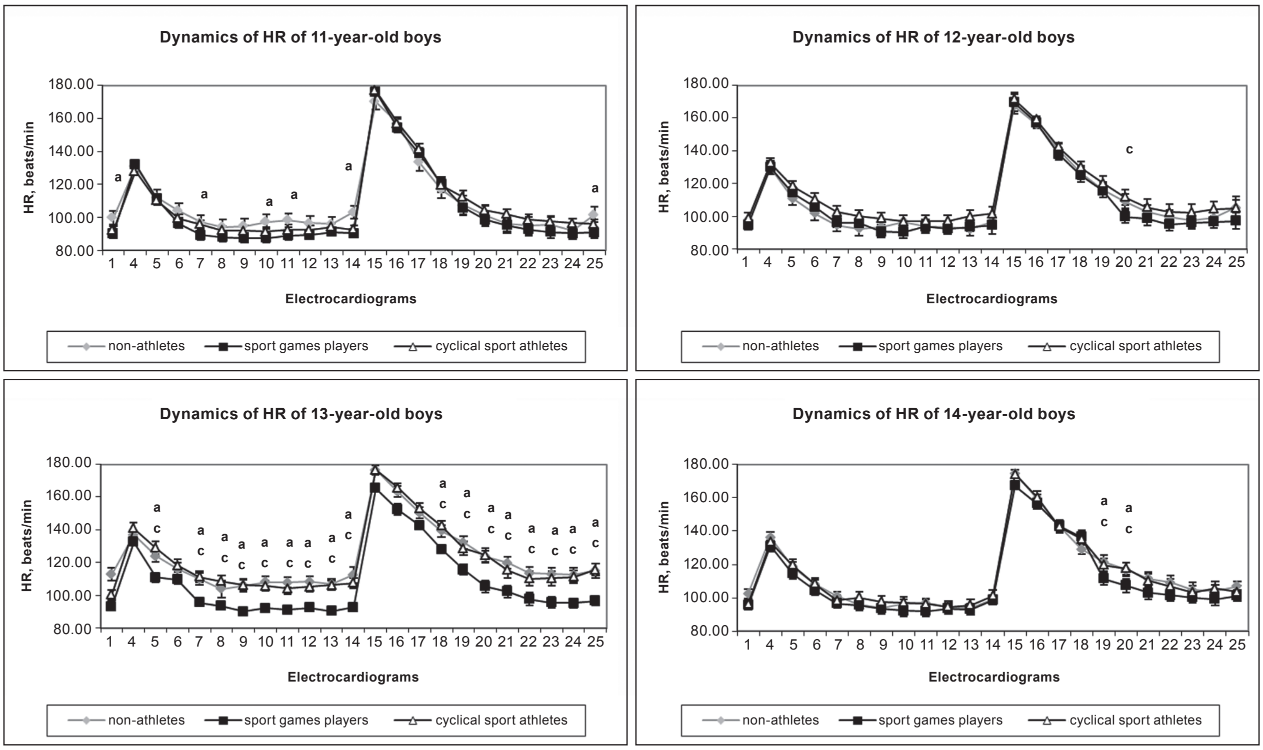

*Figure 5. Heart rate (HR) dynamics of 11 to 14-year-old non-athletes, sport games players and cyclic sport athletes during the Rouffier test and the 30-second vertical jumping test. **Note**. The difference between the non-athletes and sport games players – a, the cyclic sport athletes and non-athletes – b, the sport games players and cyclic sport athletes – c; statistically significant at p<.05. 1 ECG – before load; 4 to 14 ECG – recovery after the Rouffier test; 15 to 25 ECG – recovery after the 30-second vertical jumping test.*

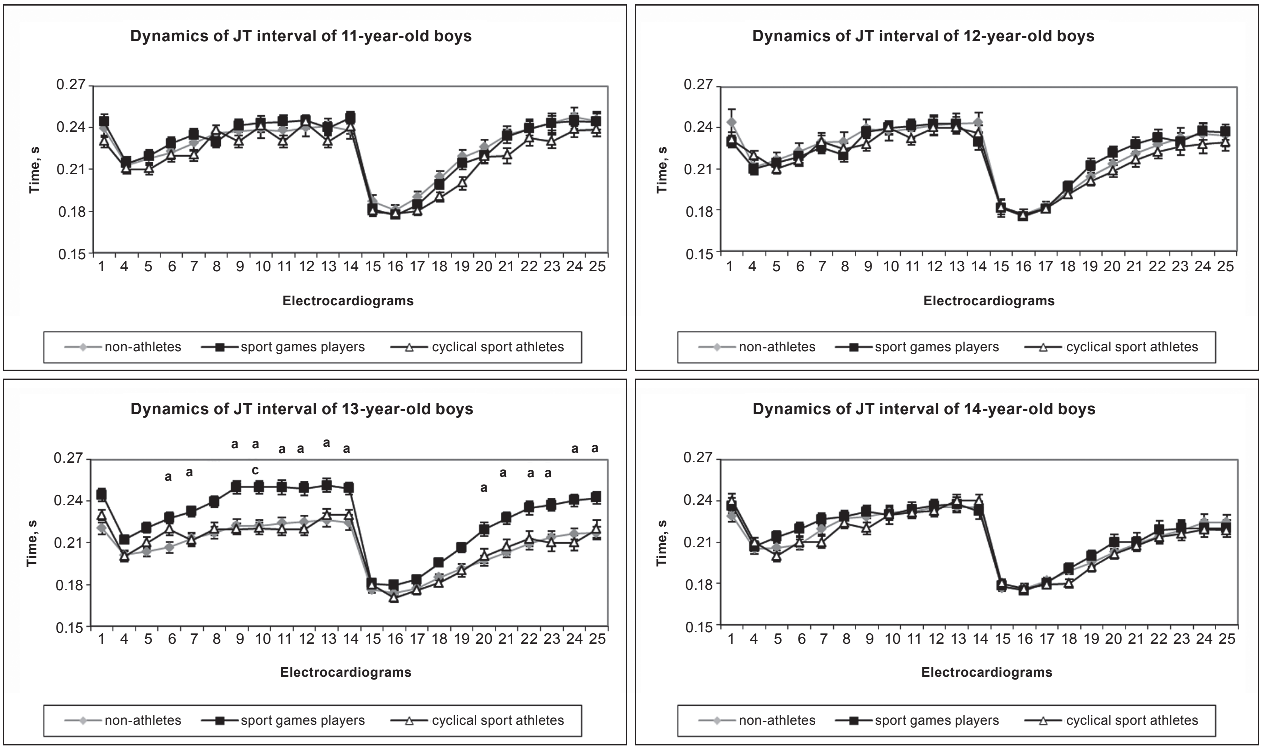

Figure 6. JT interval dynamics of 11 to 14-year-old non-athletes, sport games players and cyclic sport athletes during the Rouffier test and the 30-second vertical jumping test. ***Note****. The difference between non-athletes and sport games players – a, cyclic sport athletes and non-athletes – b, sport games players and cyclic sport athletes – c; statistically significant at p<.05. 1 ECG – before load; 4 to 14 ECG – recovery after the Rouffier test; 15 to 25 ECG – recovery after the 30-second vertical jumping test.*

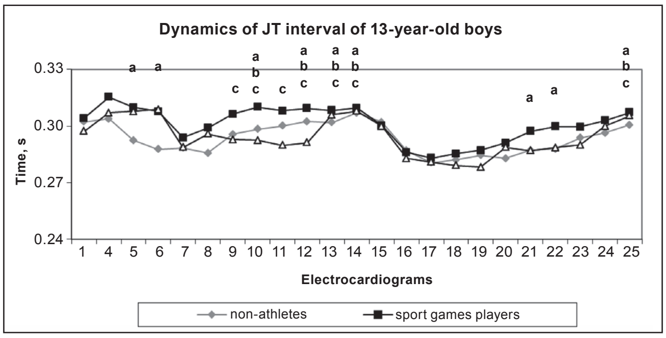

Figure 7. JTc interval dynamics of 13-year-old non-athletes, sport games players and cyclic sport athletes during the Rouffier test and the 30-second vertical jumping test. ***Note****. The difference between the non-athletes and sport games players – a, the cyclic sport athletes and non-athletes – b, the sport games players and cyclic sport athletes – c; statistically significant at p<.05. 1 ECG – before load; 4 to 14 ECG – recovery after the Rouffier test; 15 to 25 ECG – recovery after the 30-second vertical jumping test.*

Discussion and conclusions

Response of the human body to regular physical exercise, affecting the body's growth and development features, manifests itself as impact on the functional and morphological changes (Gilbert, 2000; Lodish, Blobe, & Schiemann, 2000). One of the age periods sensitive to the external influences is the period between 11 and 14 years. Therefore the investigations of this age period in boys engaged in sports may reveal the complex interaction of the endogenous and exogenous factors. Reports and case studies on this issue are still insufficient grounds for drawing conclusions about the safety of intense training or high-level competition in young athletes (AAP, 2010).

The present research was designed to study a longitudinal impact of sport games and cyclic sports on the features of development dynamics of muscular strength and two important ECG indices in boys from 11 to 14 years of age. It is shown that the nature of physical load (*partially regulated in sport-games-specific activities and strictly regulated physical load in cyclic sports training sessions*) differently affects the features of CVS and muscles strength development. Similar differences of various physiological systems in a growing and rapidly evolving body were noted by Pearson, Naughton and Torode (2006).

The comparison of the obtained data showed that the lowest HR values were in 13-years-old sport games players who significantly differed from the non-athletes and cyclic sports athletes. It is well established that due to exercise-induced lowered heart rate, at rest and during exercise, both myocardial blood flow and oxygen consumption per gram of myocardium are lower at any given absolute level of exercise (Laaksonen, et al., 2007; Duncker & Bache, 2008). Thus lower HR values show that boys participating in sport games training programs exhibit longer diastole (heart relaxation) and faster mobilization of CVS at the onset of exercise. This confirms the opinion of the other authors (Buceta & Killik, 2000; Reed, Metzker, & Phillips, 2004; Krustrup, et al., 2010a) that sport-specific exercises, used in the sport games training sessions, that are only partially regulated physical loads, have a considerable impact on the heart adaptation.

The results obtained during the study showed that the dynamics of JT interval was similar at the time points of 11, 12 and 14 years in boys engaged in different sports and no significant difference between the groups were found. However, at the time point of 13 years of age the JT interval values, obtained after the dosed exercise tests, in the sport games players significantly differed from the cyclic sports athletes and non-athletes. When corrected for HR, the highest JTc interval was again observed in the sport games players, although statistically significant differences between them and the non-athletes and cyclic sport athletes were not found. Namely, other studies (Poderytè, Emeljanovas, & Poderys, 2002; Emeljanovas & Poderys, 2010) established that endogenous factors, especially at the age of 13–14 years, have a great influence on the CVS, so that also the non-athletes children' CVS functional indices improved rapidly.

It is difficult to explain or speculate (concerning) all the possible internal physiological mechanisms of the observed changes. Scientific papers present some explanations about the possible common neuro-hormonal influences on myocard reaction during physical load (Chinchilla & Franco, 2006). The muscular hypertrophy with appropriate intracellular changes in skeletal or in cardiac muscle leads us to having more discussion upon it. The changes in both these muscles are more likely to be attributed to a better neuromuscular coordination and neurovegetative adrenergic influence, respectively. Developmental biology of the heart provides a very suitable model to this end.

Within the possible endogenous factors influencing the heart rate at the studied age there could be maturation processes related with neuro-humoral influences and changes of the sympathetic and parasympathetic influences on the cardiac function (Duncker & Bache, 2008), and at least they are parts of the intrinsic modifications (Such, et al., 2008).

Although better results of the CVS dynamics evaluation were specific to the representatives of sports games, the results of dynamometric strength assessments and intergroup comparison showed that muscle strength was more specific to the cyclic sports athletes than to the non-athletes and sport games players. Such significant differences between boys were identified at all the age points and in the assessments of both the right and the left side. Muscle capacity assessment data confirmed findings of a number of other authors claiming that exercise affects the growth and development processes (Macera, Hootman, & Sniezek, 2003; Myers, et al., 2004).

A large number of studies has been done in order to assess growth and development patterns (Munchmeier, 2001; McCarthy, Pozniak, & Agre, 2002) and to find the most appropriate physical load (Kozlowski, et al., 2001; Busso & Benoit, 2002; Docherty, 2002; Wolpert, Doya, & Kawato, 2003). A generalization of the results of previous studies and of this study suggests that interaction of the external and internal factors determine the properties of muscular and CVS functional capacity development and its expression during exercise in the 11–14-year-old boys. Intensity-variable physical load, specific to the exercises of sport games' training sessions, is a significant external factor that facilitates the accelerated changes of cardiovascular functional parameters at the age of 13 years. However, endogenous factors in boys, especially at 13–14 years of age, strongly influence the CVS, so that the non-athletes' CVS functional parameters also improve rapidly. According to these indices, the non-athletic children are almost equal to their peers engaged in sports. Precisely regulated physical load, specific to the cyclic sports, is an external factor that influences boys' muscle strength parameters in the period of 11–14 years of age.

These results are in concordance with previous findings of other authors (Pearson, Naughton, & Torode, 2006; Krustrup, et al., 2010b), where diversely directed physical loads, creating different external and internal stimuli relations, lead to different adaptation properties. Thus, due to regular physical loads exposure, but of a different nature, the functional state of CVS of players in sport games training sessions improves faster, whereas for the cyclic sports representatives improvement is faster for muscular system performance.

To sum up, it is necessary to take into account the fact that the athletes' physical maturity and functional ability indicators are also the outcome of a selection process and adaptation dynamics (Wilmore & Costill, 2001; Philippaerts, et al., 2006; Vaeyens, et al., 2008). It is well known that the initial functional readiness of a child is an important factor in choosing the kind of sporting activities and in sports selection as well. Nevertheless, this study confirms previous research findings (Strong, et al., 2005; Baquet, Twisk, Kemper, Van Praagh, & Berthoin, 2006; Dollman & Olds, 2007; Horst, Paw, Twisk, & Mechelen, 2007; Emeljanovas & Poderys, 2010) that sport activities unquestionably have a considerable influence on the capabilities of the cardiovascular system and skeletal muscles.

Sport games training practice is a significant exogenous factor, affecting the functional parameters of accelerated changes in cardiovascular system (CVS) of the 11–13-years-old age groups. However, the decisive influence of endogenous factors on children's growth and development significantly increases at the age of 13–14 years leading to significant improvement of important cardiovascular system indices, and the non-athletes almost equal their peers in these parameters.

Improvement of the muscle capacity indices depends on the nature of physical load: the muscle strength indices increased more in the cyclic sports group than in the sport games' group.

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UTJECAJ BAVLJENJA SPORTSKIM IGRAMA I CIKLIČKIM SPORTOVIMA NA MIŠIĆNU SNAGU I ODREĐENE POKAZATELJE FUNKCIJE SRČANOŽILNOG SUSTAVA U DJEČAKA DOBI OD 11 DO 14 GODINA – LONGITUDINALNO ISTRAŽIVANJE

Cilj istraživanja bio je utvrditi utjecaj bavljenja sportskim igrama i cikličkim sportovima na određene karakteristike srčanožilne reakcije/adaptacije na tjelesno vježbanje i na povećanje mišićne snage na uzorku od 105 dječaka u dobi od 11 do 14 godina. Dječaci su bili uključeni u istraživanje u dobi od 11 godina: 35 ne-sportaša, 35 sportaša koji se bave cikličkim sportovima te 35 sportaša iz sportskih igara. Mjerenja su provedena tijekom četiri uzastopne godine. Zabilježeni su i analizirani pokazatelji mišićne snage i parametri funkcije srčanožilnog sustava. Rezultati pokazuju da su treninzi sportskih igara važan vanjski čimbenik koji utječe na funkcionalne parametre ubrzanih promjena srčanožilnog sustava u dječaka dobi 11–13 godina. Utjecaj endogenih faktora na rast i razvoj djeteta posebno se povećava u dobi 13–14 godina te rezultira značajnim promjenama u smjeru poboljšanja karakteristika funkcije srčanožilnog sustava, tolikima da su se ne-sportaši u tim karakteristikama gotovo izjednačili sa svojim vršnjacima uključenima u sportske aktivnosti. Poboljšanje pokazatelja mišićnih kapaciteta ovisi o karakteristikama fizičkog opterećenja: pokazatelji mišićne snage više su se povećali u sportaša koji su se bavili cikličkim sportovima.

Ključne riječi: *sazrijevanje, sportaši, ne-sportaši, specifičnost sporta, specifično fizičko opterećenje*

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