CAN THE REGULAR PHYSICAL LOAD CHANGE THE FUNCTIONAL STATE OF PUPILS IN ELEMENTARY SCHOOL?

Renáta Szabóová^{*1}, Natália Škutová², Robert Herich¹

¹ University of Veterinary Medicine and Pharmacy in Košice, Slovak Republic

¹ University of Veterinary Medicine and Pharmacy in Košice, Slovak Republic

² BENU Pharmacy, Slovak Republic

Summary: The functional status of the organism is a cluster of aerobic, cardiorespiratory and cardiovascular ability in co-operation with the muscular ability ensuring physiological activity of myocard and muscles in the form of regular dynamic and static active movement. Nowadays is observed an increasing lack of physical activity in the pediatric population, which is reflected in the increasing number of the civilization diseases. The aim of this work was to show the impact of regular dynamic activity on the functional status of the cardiovascular system and fitness in schoolable children (n = 100) using Ruffier's functional test. The values of the Ruffier index were monitored and compared in groups of girls (n = 25) and boys (n = 25) involved in regular school activity within subject „Physical education“ in comparison with groups of children participating also in regular out-of-school physical activity (girls n = 25, boys n = 25) during 5 months. The most significant result ($p < 0.001$) was observed in functional status of children involved in both regular and after-school activity after 5 months. Presented work showed the significant impact of regular physical activities on circulatory system and muscular work of schoolable children.

Key words: children, load, physical load, cardiovascular system

Introduction

One of the conditions how to maintain health and healthy lifestyle is regular physical activity. The movement is a resource of expressing personality and communication, it is a complex of human behavior that includes all human movement activities (Pastucha et al. 2011). The physical activity is human manifestation including all activities performed by the skeletal

muscle system with the interaction of all physiological functions. The movement is one of the basic demonstration between the body and the external environment as well as is a factor of a child's mental development (Hrabinec et al. 2017).

The functional ability of the organism (aerobic ability, cardiorespiratory or cardiovascular ability) is in cooperation with muscle ability, flexibility and body composition of the aerobic ability of the organism. It is defined as "the body's ability to receive and use oxygen efficiently mainly from physical activity". The content and form of physical activity is important for adaptation to individual variations - biological age, current health status, interests, functional fitness, gender, range of motion of the individual (Pokorný 2004). In the resting phase of the organism, a large part of the total blood flow leads to the digestive tract and kidneys. During exercise the arterioles dilate in the muscle fibers, reduce resistance and redirect more blood flow to the relevant organ systems and also reduce the relative flow to the digestive tract and kidneys, while the blood flow to the brain remains constant. During the physical activity of the body, the sympathetic nervous system is stimulated and the adrenaline is released, subsequently the rate and the contractility of heart increases. This results in an increase of ejecting volume of heart, cardiac output and a decrease in end-diastolic volume. During aerobic exercises, the heart and the heart wall thickness increases with the formation of eccentric hypertrophy, which allows greater ventricular filling and stronger contractions. Thus, a larger ejection volume can be achieved at rest (Labrosse 2018).

The physical load leads to complex of physiological processes allowing striated skeletal muscles to perform increased work performance, the higher muscle load puts higher demands on oxygen intake and on the cardiovascular system, e. g. by increasing of cardiac output, heart rate and heart rate volume. After regular intense and prolonged physical activity are observed physiological changes such as hyponatremia, activation of procoagulant and fibrinolytic mechanisms, oxidative stress. The adaptation of organism to physical regular load/exercise plays important role in suppression of oxidative stress effect, the other symptoms include the higher blood volume, triglycerides level decrease, the HDL cholesterol level increase and the blood pressure decrease after load. The degree and mode of adaptation action to physical load depends on the kind of physical activity as well as on the genetic predisposition of organism (Vančura & Radvanský 2007). The physical exercise is divided into several groups: static/dynamic, eccentric/concentric, isotonic/isometric, strenght/ endurance, light/heavy, continuous/ intermittent (intermittent by rest or very light load), force explosive/force endurance, of small muscle groups/of large muscle groups, postural muscles/phasic muscles

(Radvanský 2006). The physical load dividing into dynamic and static load influences the body adaptation way during exercise, but usually occurs the combination of these two types of physical load (Vančura & Radvanský 2007).

The dynamic load is characterized by cyclic alternating of muscle tension and relaxation resulting of isotonic muscle contraction (Štejfá 2007). According to the power resistance and speed of the active movement is the dynamic load divided into endurance, maximum, explosive and speed load (Zumr 2019). The response of organism to dynamic physical activity has three phases. The initial phase arises before physical activity, tachycardia is observed in the pre-start state of the organism. The accompanying phase is characterized by fast increase of heart rate followed by slower increase and then the heart rate stabilizes at the steady-state value, as long as the intensity of the physical activity does not exceed the level of the anaerobic power of organism. After physical exercise in the final state it shows a rapid heart rate decrease, later a slow decrease of the heart rate is observed (Jančík et al. 2006). During non-physiological dynamic activity is showed the significant increase of lung ventilation compared to oxygen consumption. This difference is related to metabolic acidosis, which is compensated by an increase of CO₂ excretion and a decrease in blood pCO₂. Oxygen consumption as a parameter of total energy production of the organism increases in conjunction with the physical exercise to a physiological maximum (maximum rate of oxygen consumption, VO₂ max.) (Javorka et al. 2014).

The isometric muscle contraction is typical for static load of organism, while the energy needed for performance of static work is converted to heat and the effectiveness of this static work is at zero level (Javorka et al. 2014). The continuous prolonged muscle contraction with superior power is causing muscle fatigue due to increased intramuscular pressure, which compresses the capillaries and narrows the blood supply to the muscles. Muscles obtain oxygen supply from myoglobin through anaerobic glycolysis to form lactic acid and its storage in the muscles is causing exhaustion and pain in the contracted muscle (Radvanský 2006). Muscle activity causes the increasing of lung ventilation via increased respiratory volume and respiratory rate (Javorka et al. 2014).

During short-time exercise is observed hyperglycemia, the blood glucose concentration is increased by 60 %, during long-term exercise is observed hypoglycemia as the response of depletion of the organism due to a general adaptation syndrome. Also the concentration of free fatty acids increases, but after intake of carbohydrate reach food remains physiological value of free fatty acids probably due to increased insulin release inhibiting lipolysis (Javorka et al.

2014). During muscle contraction is formed the heat, while the excessive amount of heat is dissipated by sweating (up to 1 liter of sweat per hour) (Vokurka 2012).

The autonomic nervous system modifies the changes caused by stimulating of the endocrine system activity in pre-start state of physical load and during prolonged exercise. The aerobic exercise stimulates the sympathetic nervous system as well as increases oxygen consumption, the stretching activates the parasympathetic nervous system during unchanged oxygen consumption. The activation of the sympathetic system releases adrenaline/epinephrine and noradrenaline/norepinephrine from the adrenal marrow and mobilizes glycogen and lipids stores and stimulates the production of cyclic adenosine monophosphate (cAMP) and heart function. The intensity of this regulatory process is demonstrated by the urinary excretion of vanilmandelic acid. The pituitary-adrenal neuroendocrine system is participating after the start of exercise by the regulation of secretion of adrenocorticotrophic hormone (ACTH) from the anterior lobe of the pituitary gland, ACTH promotes the glucocorticoids secretion from the adrenal cortex. Glucocorticoids involves in the inhibition of glucose utilization in all tissues except the brain and heart, also have the lipolytic effect in adipose tissue and glycolytic effect of glucagon in the liver, what is beneficial for muscle work (Javorka et al. 2014).

The stimulus/stressor is an action inducing the response/reaction. If stimuli and reactions are regularly repeated for a long time, the adaptation of organism arises. Adaptive changes include the heart and muscle hypertrophy by the transformation of muscle fibers II-A, an increase in the heart ejection volume and VO_2 max. Adaptation to physical activity takes place in a training process in improving of the functional state of the organism (Javorka et al. 2014).

Methods

The aim of this study was to determine the functional state of the cardiovascular system and condition in primary school students aged from 11 to 15 years through Ruffier's functional test by the Ruffier's index (Chuo et al. 2018) expressed, which is a value parameter of the cardiovascular system state as well as the condition of the organism during physical activity. Pupils ($n = 100$) were divided into 4 experimental groups according to gender and the number of regular physical activities for 5 months. The regular physical activity in all tested groups of children was physical education during the standard teaching process at elementary school. The subject – „Physical education“ took place twice a week (for an hour and a half per week). The experimental groups were divided into girls group (GPhE – girls with the subject Physical

education, $n = 25$) and boys group (BPhE – boys with the subject Physical education, $n = 25$), whose regular physical activity consisted only of the „Physical education“ subject and into girls group (GPhEc – girls with the subject Physical education with the combination the other regular physical activity, $n = 25$) and boys group (BPhEc – boys with the subject Physical education with the combination the other regular physical activity, $n = 25$), whose regular physical activity consisted of the physical education with combination of other external sport activities at regular time, such as athletics, dance education, inline skating, floorball etc. The experiment was performed with consent of parents and/or legal representatives. Pupils from elementary school were in good health conditions without the presence of cardiovascular diseases or musculoskeletal disorders.

Measurement of heart rate values was performed in two samplings:

1. measurement - the period when the pupils/children started school after the 2 months of summer holidays (sampling 1: groups GPhE1 – GPhE in the sampling 1, GPhEc1 – GPhEc in the sampling 1, BPhE1 – BPhE in the sampling 1, BPhEc1 – BPhEc in the sampling 1).
2. measurement - the period when children were completed the regular physical activities during 5 months (sampling 2: groups GPhE2 – GPhE in the sampling 2, GPhEc2 – GPhEc in the sampling 2, BPhE2 – BPhE in the sampling 2, BPhEc2 – BPhEc in the sampling 2).

The results of measurements were obtained under the same conditions, on the same day and time. The Ruffier test was repeated in each pupil after 30 minutes during measurements 1 and 2 to obtain an average RI (Ruffier index) value. Based on Ruffier index was determined and compared the functional state of the organism of each pupil and the average functional state of the organism of children in all experimental groups (Baňárová et al. 2015). The statistical analysis of results as well as statistical significance of differences between all experimental groups was determined and compared by one-way ANOVA test and confirmed by Tukey post test (MiniTab, Czech Republic). Level of statistical significance 0.001 was expressed by p value ($p < 0.001$).

Results

Measurement 1

In the experimental group of girls GPhE1 were found after the measurement 1 two girls (8 %) with Ruffier index values in interval from 3.1 to 7.0 and according to evaluation of the functional state of the organism based on the Ruffier test index can be described this result as a good functional state of the organism. Ten girls (40 %) showed an average functional status, 12

girls (48 %) showed poor functional status, one girl (4 %) showed very poor functional condition. In the GPhEc1 experimental group was evaluated the good functional status of 13 girls (52 %) and the average functional status of 12 girls (48 %). In the experimental group BPhE1 was evaluated the functional status as good (n = 7; 28 %), average (n = 11; 44 %), poor (n = 5; 20 %) and very poor (n = 2 ; 8 %). The experimental group BPhEc1 contained 13 boys (52 %) with good and 12 (48 %) boys with moderate functional status of organism.

Measurement 2

The second measurement of this experiment started after 5 months of regular physical activity involving only physical education 2 times every week for 1 and a half hours in groups GPhE2 and BPhE2 as well as in groups GPhEc2 and BPhEc2 with the combination of regular physical education in addition to the other regular physical activity. The experimental group of schoolgirls GPhE2 showed the following functional status: good (n = 4; 16 %), moderate (n = 14; 56 %) and poor (n = 7; 28 %). In the experimental group GPhEc2 was found the good functional status in 21 girls (84 %) and the average functional status in 4 girls (16 %).

In the boys of experimental group BPhE2 was measured an average functional state of 20 pupils (80 %), good of 4 (16 %) and a poor of 1 (4 %). The BPhEc2 group achieved good functional status in 21 pupils (84 %) and average functional status in 4 pupils (16 %). The GPhE experimental group reached the average of the experimental group functional state in measurement 1 (GPhE1) and measurement 2 (GPhE2) as well as the decreasing average RI value results (Table 1) by 1.22 (10.63 %).

The GPhEc group improved the functional status in comparison with measurement 1 (GPhEc1) to measurement 2 (GPhEc2) from average to good functional status by reducing the RI value at 1.03 (14.27 %) (Table 1). The boys of experimental group BPhE demonstrated the average functional state in the measurement 1 (BPhE1) and measurement 2 (BPhE2), the average of RI value decreased by 0.77 (7.95 %). The change of the functional status was achieved in the BPhEc experimental boys group during the measurement 1 (BPhEc1) and measurement 2 (BPhEc2) from the average to good functional state (difference of the RI value: 0.82; 11.15 %) (Table 1).

However, the most significant difference of functional status was observed after 5 months (in measurement 2) of regular physical activity/load of the organism in the girls group GPhEc2 (6.22 ± 0.91) compared to GPhE2 (10.20 ± 2.15) (Figure 1) and in the boys group BPhE2 (8.96 ± 1.55) compared to BPhEc2 (6.46 ± 0.98) at a significance level of $p < 0.001$ (Figure 2). This significant result indicates the fact that the dynamic regular physical activity

of the organism is one of the factors influencing the improvement of the functional state of the organism and participates in increase of the individual condition of pupils regardless of gender. Based on the measurement 2 after 5 months of regular exercise in physical education in all four groups can be stated a positive effect of regular dynamic load as one of the factor influencing the condition and cardiovascular fitness especially in girls and boys who were engaged in free time regular physical activity/load.

Table 1

The average functional state expressed by $RI \pm SD$ (Ruffiers index $\pm$ standard deviation) in all experimental groups after measurement 1 and measurement 2

Experimental group	Measurement 1	Measurement 2
GPhE	11.42 ± 2.58	10.20 ± 2.52
GPhEc	7.25 ± 1.73	6.22 ± 0.92
BPhE	9.73 ± 3.25	8.96 ± 1.56
BPhEc	7.30 ± 1.78	6.48 ± 0.98

Figure 1

*The comparison of average functional state in the girls experimental groups GPhEc2 (measurement 2; 6.22 ± 0.92) and GPhE2 (measurement 2; 10.20 ± 2.52); different letters (a***, b***) meant the significant effect expressed by value $p < 0,001$*

Figure 2

*The comparison of average functional state in the boys experimental groups BPhEc2 (measurement 2; 6.48 ± 0.98) and BPhE2 (measurement 2; 8.96 ± 1.56); different letters (c***, d***) meant the significant effect expressed by value $p < 0,001$*

Discussion

Nowadays, the physical inactivity is part of possible risk factors affecting a lot of health problems/disorders/metabolic diseases e. g. obesity, *diabetes mellitus*, hypertension, the reduction of muscle-skeletal mobility or psychosocial problems (Svobodová 2015). The adequate quantity and quality of movement/exercise/physical activity forms the essence of existence of maintained homeostasis in the body (Kusyn & Kusynova 2018). Aerobic activities have the greatest health benefits especially for the cardiovascular and respiratory systems (Sigmund & Sigmundova 2015). Aerobic fit organisms are able to receive more oxygen during exercise and load, increase muscle work, increase blood volume and the number of oxygen-saturated erythrocytes. The system of blood vessels expands and the possibility of fat storage in blood vessels is reduced (Červinková et al. 2000). If is the physical activity regular and prolonged, the heart and lungs function and oxygen transport is under adaptation of organism thereby ensuring the prevention of civilization diseases is often increased (Dvořáková & Engelthalteová 2017).

The child should have physical activity not only during the school education with regular intervals at the subject of „Physical education“, but also during the free time as well as on holidays, e.g. on the two months lasting summer holiday is necessary to provide suitable regular physical activity/exercise (Škutová 2020). The combination of the lack of physical activity and unhealthy diet eating habits has a negative effect on the development of the cardiovascular system and musculoskeletal system. The results of the functional status in pupils of elementary school obtained from experiment showed a reduced condition in groups of children who have had less regular school physical activity as well as no activity during summer holidays. This can be caused by decreased physical activity and irregular eating. It is necessary to refer to the increased incidence of children with overweight and obesity, the formation of the vertebrogenic disorders, which has had gradual tendency as a consequence of insufficient physical activity (Marko & Bendíková 2019).

Tanha et al. (2011) found the increased risk of cardiovascular system problems in healthy physically inactive children with an average age of 9.8 years. The level of physical activity was evaluated using resting heart rate, blood pressure and maximal oxygen absorption in the group of 223 children. The children physically more active showed a lower risk of occurrence of cardiovascular diseases.

The appearance of overweight and obesity in 20 % of children aged from 11 to 15 years was observed in the Czech Republic (Kalman 2019). The following study showed this result:

64 % of children spent time without physical activity on summer holiday (Roubalová 2015). The physical activity is important in children with *diabetes mellitus* type I., e.g. the asymptomatic increase of carotid artery thickness was observed. Patients with *diabetes mellitus* type I have five times higher risk to die of cardiovascular and cerebrovascular disorders at the ages 20 – 39 years (Järvisalo et al. 2002). Herbst et al. (2007) observed the effect of regular physical activity on cardiovascular risk factors such as blood lipid concentration and blood pressure with the finding that one and more risk factors affect 69 % of pediatric patients with *diabetes mellitus* type I. However the increased physical activity in children diagnosed with *diabetes mellitus* type I is associated with decreased lipoprotein levels of plasma as well as diastolic blood pressure.

Dias et al. (2015) examined the effect of exercise on flow-mediated arterial dilatation (FMD) in overweight and obese children and adolescents and also examined the role of cardiorespiratory parameter (maximum oxygen consumption – VO₂max) in comparison to mean difference between vascular functions (by FMD) and VO₂max between exercise and rest time. The regular exercise improved cardiovascular function in overweight and obese children founding a significant improvement in FMD and VO₂max parameters. However, the occurrence and effect of a one risk factor does not affect the insufficient activity of the cardiovascular system, but the permanent and prolonged action of risk factors (poor lifestyle, smoking, alcoholism, lack of exercise, metabolic diseases) leads to the functional state and condition disorders of organism in children but also in adolescents, e.g. by Baňárovej et al. (2016) based on the Ruffier functional test was classified a below-average value of cardiovascular condition in 39 % of young people under age of 25 years.

Conclusions

Physical education should not be the only way to exercise necessary to the healthy growth and development of school-age children. It is important to lead children to a healthy lifestyle, not only by consuming a healthy food, but especially in connection with sport activities.

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