Original article

INFLUENCE OF PHYSICAL TRAINING ON CARDIORESPIRATORY ENDURANCE IN PREADOLESCENT AGE

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Cardiorespiratory or aerobic endurance is the ability of the whole body to sustain physical activity for an extended period of time, involving relatively large groups of muscles. The attitudes on the possible impact of training on cardiorespiratory endurance in preadolescents are contradictory. Our study enrolled 195 boys aged 11 to 12 years. Experimental group (n=92) consisted of the children who had been involved with planned and programmed water polo training for at least two years. Control group (n=103) consisted of schoolchildren who only had had regular physical education in schools. Our investigation protocol included standardized anthropometric measurements and tests, performed respecting the appropriate protocols. Statistical analysis of the results demonstrated that there were no significant differences in age and relative values of oxygen consumption (VO_{2peak}). Body height and mass, as well as the skinfold thickness, were significantly higher in experimental group subjects. The values of absolute VO_{2peak}, FVC and $FEV_{1.0}$ were also significantly higher in the examinees involved with water polo training. These findings stress the importance of a systematic training process even in this early period of growth and development in order for the trainees to acquire important functional advantages. We believe that a properly planned and programmed physical training can significantly contribute to the development of cardiorespiratory endurance even as early as preadolescent age. *Acta Medica Medianae 2009;48(1):37-40.*

Key words: traininig, endurance, water polo, VO_{2peak}

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Introduction

Biologic development of school age children occurs intensely, unevenly and in a heterochronous way. Sudden changes may be observed with the onset of puberty. In boys, puberty starts at 12 or 13 years of age, with considerable individual variance. That is the reason why biologic age is often not matched with the chronologic one. Development of motor skills is also characterized by uneven development. There are periods when the development of some abilities is accelerated, followed by periods of slower development. The periods during which some specific influences induce stronger reaction, as well as the result of this reaction, may result in optimal effects; they are termed „sensitive periods". Reaction speed and frequency of movement are the abilities with dynamic development in the period from 7 to 11 or 12 years of age (1). The development of endurance changes unevenly, however, with growth tendency. The period of puberty is thought to be very sensitive for the development of aerobic and anaerobic endurance (2).

Pulmonary function develops and increases with ageing. Pulmonary volumes and capacities grow until physical maturation is reached. These increases are directly related to body growth (3). The indicators of function of cardiovascular system are also vary dependent on the body mass. Children have lower stroke volume and blood pressure, but higher heart frequency compared to adults. Younger children are more prone to tachycardia and tachypnea during physical exercise, since thus they adapt their small cardiorespiratory potential to the given level of straining. At submaximal levels of exercise, arteriovenous difference in oxygen in children is higher in children than in adults, compensating for lower stroke volume of the heart (4,5). Improvement of pulmonary and cardiovascular function during growth produces an increase of aerobic capacity. For non-athletes, the highest values are reached in men in the period from 17 to 21 years of age, and in women from 12 to 15 years of age (5,6).

Cardiorespiratory endurance or aerobic endurance is the ability of the whole body to sustain long-lasting physical activity and involves relatively large muscle groups. Cardiorespiratory endurance is associated with the development of ability of cardiovascular and respiratory systems to maintain oxygen supply to the muscles engaged in prolonged physical activity, and with the ability of muscles to obtain the necessary energy via aerobic processes. These facts are the reason why the terms cardiorespiratory endurance and aerobic endurance are often used interchangeably.

Most authors engaged in physical activity studies believe that maximal oxygen consumption (VO_2max), sometimes called maximal aerobic power or maximal aerobic capacity, is the most objective laboratory measure of cardiorespiratory endurance. Maximal oxygen consumption (VO_{2max}) is the maximal quantity of oxygen transported and utilized per minute of maximal physical exercise. The value of VO_{2max} can be directly measured or estimated depending on the technical characteristics of the equipment used, test protocol, time and duration of exercise (7). When maximal oxygen consumption should be estimated, with tests ending at a submaximal level of strain and with results extrapolation up to maximal values, we use the term „highest value" or „peak" of oxygen consumption (VO_{2peak}). In order to get the value of VO_{2peak}, it is necessary to achieve the appropriate intensity of incremental exercise for minimally 3 to 5 minutes, reaching the plateau of oxygen consumption.

With endurance training more oxygen could be transported to and utilized by the active muscles. These improvements enable individuals to perform with higher intensity the physical activities that require endurance (improving overall performance).

Material and methods

Our studied sample was composed of 195 healthy boys, aged 12 years ± 6 months. That sample was futher divided into two subsamples; the first, with 92 examinees, was our experimental group; this group consisted of the examinees who had been involved with planned and programmed water polo training for at least two years in water polo clubs in Belgrade, Zemun and Nis.

The second subsample, with 103 examinees, was our control group, composed of schoolchildren who only had had regular physical education in school as a form of organized physical activity. Potential examinees for this subsample had been questioned first about their possible involvement with sports. Out of four schools from the City of Nis, only those who were not involved in any sports were considered eligible for the control group.

All the examinees, their parents and sports trainers were given all the necessary information about the objectives, course, participation and possible side-effects of the study. All the examinees underwent general physical examination before the enrollment. The whole of the study protocol was executed in the presence of parents and/or trainers. None of the study participants had any anamnestic information or clinical finding of physical exercise-induced bronchoconstriction.

Procedures. The measurements of body height, weight and skinfold thickness were performed according to standardized protocols (8) with anthropometer (GPM, Swiss), electronic weighing scale (Tefal, France) and caliper (GPM, Swiss).

Within the assessment of pulmonary function we measured forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) with computerized spirometer (Spirocomp, Germany). These measurements were performed prior to the test to determine VO2peak. The examinees were required to perform exhalation according to the test standards (9) in three instances in total. The value of the highest FEV1.0 was recorded as the result.

Maximal oxygen consumption was estimated by extrapolation method after standardized continued submaximal test on bicyclergometer (Kettler, Germany) with telemetric monitoring of heart rate (Polar, Finland). Equipment preparation, warm up exercises and test data recording were done in accordance with appropriate standards (7,8).

All tests were done in morning hours, in a room with 21-23°C temperature and 55-60% humidity, so that microclimate conditions were matched to the standards for laboratory functional testings (7,8). We made use of the SPSS statistical package for Windows (Release 10.0, Chicago, IL, USA).

Results

Anthropometric characteristics of the examinees and values of physiologic parameters are presented in Tables 1 and 2. All the results were presented as a mean value ± standard deviation.

Table 1. Anthropometric characteristics for experimental and control group

Variables (unit)	Experimental group (n=92)	Control group (n=103)	P value
Variables (unit)	11.3 ± 0.4	11.4±0.3	p>0.05
Age (years)	156.98±8.36	151.53±8.39	p<0.05
Stature (cm)	51.02±11.19	43.54±11.1	p<0.05
Body weight (kg)	21.15±14.94	17.65±10.58	p<0.05
Abdominal skinfold thickness (mm)	14.33±8.99	11.32±7.82	p<0.05
Subscapular skinfold thickness (mm)	16.81±8.81	13.77±7.98	p<0.05

All results are presented as means±SD.

Table 2. Physiological variables experimental and control group

Variables (unit)	Experimental group (n=92)	Control group (n=103)	P value
FVC (l)	3.73±0.68	3.24±0.63	$p<0.05$
$FEV_{1.0}$ (l)	3.15±0.44	2.74±0.48	$p<0.05$
VO_{2peak} ($l \cdot min^{-1}$)	2.41±0.42	1.99±0.52	$p<0.05$
VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$)	48.09±9.85	46.90±11.39	$p>0.05$

All results are presented as means±SD. FVC - forced vital capacity; FEV1 - forced expiratory volume at one second; VO2peak – peak oxygen consumption;

Discussion

Cardiorespiratory endurance of a person is determined by a large number of factors, most important of which being age, gender, body weight, genotype, physical activity (fitness), acute and some past diseases, and so on (10). Cardiorespiratory endurance is believed to be, according to most published papers and textbooks in the field of sports science, the most important element of physical fitness. At the same time, it is the principal defense of an athlete against exhaustion. Low endurance capacity leads to fatigue, even in low dynamic sports and activities (11).

Starting from the results obtained in our previous study (12) comparing water polo trainees with non-sportists, this study was performed with a significantly larger sample of examinees. Our experimental group enrolled all the children from four water polo clubs involved with water polo training for at least two years, regardless of their individual success in competitions. Water polo training of experimental group children consisted of the improvement of swimming techniques and learning of technical elements of water polo. The trainings took place 3 to 4 times a week and lasted 60-75 minutes (excluding 15 minute stretching exercises before each training session). Moreover, these children participated in a competition system with 10 to 15 matches per season. Our control group consisted of an almost doubled number of age-matched children compared to our previous study.

Statistical analysis of the data obtained by anthropometric measurements demonstrated statistically significant differences in almost all studied variables. Body height differences may be explained by biased selection of candidates for water polo training. Significant differences in body mass and skinfold thickness could be attributed to water polo training process, diet and prolonged immersion in water. Since the examinees are aged 11 to 12 years, these variables and differences among them are subject to significant changes in adolescence. Pulmonary function parameter analysis demonstrates statistically significant differences in both parameters of interest. Differences in FVC are caused partially by body height and mass differences, but are also believed to be the direct consequence of processes of physiologic adaptation of children to water polo training. Statistically significant difference of FEV1 parameter, being a part of FVC utilizable in physical activities of moderate and submaximal intensity, is even more direct indicator of physiological adaptation of this group of examinees.

Absolute values of peak oxygen consumption (VO_2peak) are statistically different among the groups. The explanation of such differences lies in long-term (two years at least) sports activity requiring intense physical strain. It is in accordance with previously reported literature data (13-16). The described findings, with the absence of statistically significant age difference among the groups, represent the ground for the proposition that intense training in a discipline with primarily aerobic demands, produce increased cardiorespiratory endurance even in preadolescent age. We should perhaps mention that there is no unanimous agreement about the optimal intensity, frequency and duration of physical activity which could improve cardiorespiratory endurance in preadolescent children (17). Earlier investigations have even questioned the possibility of improvement of cardiorespiratory endurance in children in view of the difficulties of implementation of required intensity and duration of planned training sessions and usual physical activity in that age (18). Differences in relative VO_{2peak} values are not statistically significant among the groups, which can be attributed to a significantly higher body mass of experimental group subjects. Investigations on a large number of athletes in various sports disciplines have shown that higher values of body mass and fat tissue adversely affect cardiorespiratory endurance (19). The results of our present study are in conflict with the results of our previous study, which could be explained by the sample selection in the previous study. In the past study, only the children more successful in trainings (first team members) were enrolled in the experimental group, while in the present study experimental group contained all the children involved with training for at least two years. Regardless of the fact that there are no statistically significant differences in relative VO_{2peak} values, we can draw the conclusion that physiologic adaptation to training, evident in markedly higher absolute VO_{2peak} values, successfully compensates for increased body mass and percentage of fat tissue. In other words, children involved with water polo training have greater ability to sustain prolonged physical activity of relatively large muscle groups, regardless of higher body mass and skinfold thickness values. We should mention that the results of some big-scale studies have demonstrated that longitudinal skeleton dimensionality positively correlates with swimming speed and, later, with overall success in water polo (20,21).

Conclusion

The results obtained in this study point to the importance of systematic training even in preadolescent period of development as a way to acquire significant functional advantages. Properly planned and programmed training can produce improved cardiorespiratory endurance in children, regardless of body mass values. Practical significance of this study, we believe, lies in the utilization of its results in the process of selection in water polo, in training control, diagnosis and modelling. Similarly, the effects of physical education in schools could be better validated, and modes and guidelines could be suggested in order to improve and innovate the education process. Long-term investigations in that regard could contribute to a higher degree of generalization of results, representing the solid ground for new scientific insights.

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UTICAJ TRENINGA U PREADOLESCENTNOM UZRASTU NA KARDIORESPIRATORNU IZDRŽLJIVOST

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Kardiorespiratorna ili aerobna izdržljivost je sposobnost čitavog tela da održava dugotrajnu fizičku aktivnost i uključuje relativno velike mišićne grupe. Stavovi o mogućem uticaju treninga na kardiorespiratornu izdržljivost kod preadolescenata su oprečni. Prikazano istraživanje je obuhvatilo ukupno 195 dečaka starih između 11 i 12 godina. Eksperimentalnu grupu (n=92) činila su deca uključena u planirani i programirani vaterpolo trening tokom najmanje dve godine. Kontrolnu grupu (n=103) činili su učenici koji su imali samo redovnu nastavu fizičkog vaspitanja u školi. Protokol istraživanja obuhvatao je standardizovana antropometrijska merenja i funkcionalna testiranja, koja su izvedena prema odgovarajućim protokolima. Statistička analiza dobijenih rezultata je pokazala da između grupa nije bilo značajnih razlika u godinama starosti i relativnim vrednostima najveće potrošnje kiseonika (VO_{2peak}). Telesna visina i masa, kao i debljina kožnih nabora bili su statistički značajno veći kod ispitanika eksperimentalne grupe. Vrednosti apsolutne VO_{2peak}, FVC i $FEV_{1.0}$ su takođe bile statistički značajno veće kod ispitanika uključenih u vaterpolo trening. Dobijeni nalazi ukazuju na važnost sistematskog trenažnog procesa već u ovom periodu razvoja kao načina za sticanje značajnih funkcionalnih prednosti. Smatramo da je pravilno planiran i programiran trenažni proces efektivan za razvoj kardiorespiratorne izdržljivosti već u preadolescentnom periodu. *Acta Medica Medianae 2009;48(1):37-40.*

Ključne reči: *trening, izdržljivost, vaterpolo, VO_{2peak}*