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THE EFFECTS OF WATER POLO TRAINING ON AEROBIC POWER AND PULMONARY FUNCTION IN 11 AND 12 YEARS OLD BOYS

SUMMARY

The investigations of the effects of training on aerobic power in children in the prepuberty years have yielded contradictory results. The study aim was to establish the effects of water polo training on aerobic power in 11- and 12-year old boys. The experimental group was composed of 54 boys engaged in water polo for at least 2 years through an organized system of training and competition. The control group was composed of 61 boys of the same age who were not actively engaged in any athletic activity. The investigation included anthropometric measurements and functional assessments. Aerobic power via maximal oxygen consumption (VO_{2max}) was assessed by Astrand test on cycle ergometer. Pulmonary function: forced vital capacity (FVC) and forced expiratory volume at one second (FEV_1) were measured with computerized spirometer. There were no statistically significant differences with regards to age between the two groups. Body weight and height were statistically significantly higher in the experimental group subjects. The results demonstrated statistically significant differences in VO_2max values expressed both in the absolute and in the relative values. There are significant differences between the groups regarding the FVC and FEV_1 values. Our investigation showed that water polo training leads to a significant improvement in aerobic power in boys during prepuberty. These findings point to the importance of systematic training process as early as this developmental stage since that is the way of acquiring significant functional advantages.

***Key words*: children, endurance, oxygen consumption, training, water polo**

INTRODUCTION

A large number of young athletes train for competitive sport before puberty, yet the understanding whether their capabilities benefit from endurance training is limited (1). Water polo training and competition demand high physical and physiological adaptation. Former Yugoslavia and now Serbia and Montenegro have a rich water polo tradition (3 times Olympic Gold Medal Winners, 2 times World Champions, 3 times European Champions, 2 times FINA Cup Gold Medalists, etc.). The foundation of this continuous success is training with young categories of players.

Aerobic power serves as a functional index of the pulmonary, cardiovascular, and hematologic components of oxygen delivery and oxidative mechanisms of the exercising muscles. Maximal oxygen consumption (VO_2max) is the major determinant of endurance exercise performance. An increase in VO_2max improves the athlete's ability to sustain a higher rate of aerobic energy expenditure.

In normal children and adolescents, absolute VO_2max (litres·min^{-1}) increases with growth and maturation. Males exhibit higher values of VO_2max than females, and the sex differences increase as they progress through adolescence (1–3). The difference between males and females has been attributed to the boys' greater muscle mass and hemoglobin concentration. As body size significantly affects the measurement of physiological performance, VO_2max should be normalized to account for the differences in body size. When VO_2max is expressed as ml·kg^{-1}·min^{-1} (indicating that changes in VO_2max are in direct proportion to changes in body mass), sex differences become evident. However, growth in children is not a regular process, and differential or non-isometric changes occur in the proportions of body segments. Therefore, this theoretical exponent may not be appropriate for all age groups (4).

The rate and magnitude of increase in VO_2max resulting from training in adults is related to frequency, duration, and intensity of exercise regimen. Compared with adults there are fewer reports on the response of children to exercise training. Endurance capabilities of children improve as they become older and increase in body size. Genetic heritage seems to play a prominent role in children's endurance capabilities and response to training, and the effects of training may be small (5,6). Some authors suggest that aerobic training does not influence levels of VO_2max before puberty (7). One explanation for the lack of trainability in children is that they have greater levels of habitual physical activity, which maintain them closer to their VO_2max potential. Another explanation is that habitual physical activity that children undertake, although plentiful, is seldom of the duration and intensity believed necessary to improve VO_2max (8).

Some authors have stated that there is limited evidence to suggest that training during prepubescence increases VO_2max (9). Controversially, other authors have concluded that VO_2max responded positively to endurance training in prepubescent children (10,11). Two hypotheses have been presented to explain the relationship between maturation and children's aerobic power (3,4), namely, there is the maturational threshold before which children are unable to elicit physiological changes in response to training, or that adolescence is a critical period during which children are particularly susceptible to aerobic training. Although some disagreement remains as to whether aerobic training in prepubescent children causes improvement in VO_2max, most studies conclude that such an effect does exist.

Sensitivity to aerobic training is largely dependent on genotype: only about 30% of VO_2max can be accounted for training itself (5). Individuals who possess high aerobic power are likely to select themselves for participation in endurance sports (running, swimming, cycling, rowing, etc.).

MATERIAL AND METHODS

The changes in aerobic power and pulmonary function have been investigated in 11- and 12-year old boys. Age was computed from date of birth and date of examination. Fifty-four young water polo players from four clubs, with at least two years of training and competition experience, served as an experimental group (EG). The experimental group of children was engaged in water polo training program (15 min long stretching prior to training lasting 60–75 min, 6 times a week) designed to improve swimming techniques and master the technical elements of the game. Besides, children were included in a competition system with more than 15 contents during the competition season.

Sixty-one boys of the same age from three city schools served as a control group (CG). Children from this group were not involved in any organized sport activity in the last six months. All children volunteered to participate in the study. Before the beginning of the study, the informed consent of both the children and their parents were obtained.

Anthropometric apparatus was calibrated according to the manufacturer's instructions. Stature was measured by using a stadiometer (GPM, Swiss) to the nearest 0,1 cm. Body weight was determined using electronic balance scale (Tefal, M6010, France) to nearest 0,1 kg. Sexual maturity was visually assessed by using Tanner's indexes for pubic hair development (12). Anthropometric and maturity measures were taken once on each measurement occasion due to time and ethical restrictions. However, the same trained research team made the anthropometric measures and maturity assessments throughout the duration of the study.

Subjects were admitted for laboratory examination at 10 A.M. after an overnight rest between 10 and 12 hours. Pulmonary function expressed as forced vital capacity (FVC) and forced expiratory volume at one second (FEV_1) were measured using computerized spirometer (Spircomp, 106F, Germany) before test. VO_2max was assessed by Astrand test (13,14) on cycle ergometer (Kettler, AX1, Germany). Heart rate was determined during the test, using short-range radio telemetry (Polar, M31, Finland). The protocol of investigation was the same for all participants.

The data are expressed as means SD. Statistical analysis was performed using Student's t test. The data were analyzed using statistical package SPSS for Windows (Ver. 8.0).

RESULTS

All results are presented in table 1. There were no significant ($p>0.05$) differences in age between EG and the CG. EG subjects had higher values of body weight and height with respect to the CG subjects (EG vs. CG): stature (156.85±6.94 cm vs. 154.02±5.14 cm; $p<0.05$), body weight (49.18±7.39 kg vs. 45.35±7.22 kg; $p<0.01$).

VO_2 max – maximal oxygen consumption; FVC - forced vital capacity; FEV_1 - forced expiratory volume at one second;

In the EG subjects as compared to the CG subjects, the assessed aerobic power was statistically significantly higher in both the absolute values (2.36±0.2 L vs. 1.93±0.42 L; $p<0.0001$), and the relative values (49.40±6.96 $ml \cdot kg^{-1} \cdot min^{-1}$ vs. 43.52±9.18 $ml \cdot kg^{-1} \cdot min^{-1}$; $p<0.001$).

There were significant differences between the groups with regards to the values of forced vital capacity and forced expiratory volume at one second (EG vs. CG): FVC (3.64±0.51 L vs. 3.29±0.56 L; $p<0.001$), FEV_1 (3.09±0.41 L vs. 2.76±0.45 L; $p<0.001$).

DISCUSSION

Studies in which the effects of training on aerobic power were observed have produced conflicting results. Mirwald et al. (7) suggest that maximal aerobic power cannot be increased by training during the prepubertal years. As a part of an longitudinal investigation, Baxter-Jones and Helms (15) conducted the training of young athlethes (TOYA) study, and found that training increases the aerobic power of prepubertal children above a normal increase attributable to age, physical growth and maturation. This study investigated training effects on a total of 453 athletes from four sports: soccer, swimming, gymnastics and tennis. When age, stature, and body mass were controlled, VO_2max significantly increased with pubertal status. Girls showed a similar trend as well, but significant increases in VO_2max shown by the boys towards the end of puberty were not replicated by the girls. The authors suggested that, in more aerobic sports, as swimming, the aerobic training effects were most noticeable. However, this study was an observational study, and therefore it was not possible to assess the training programs in different sports.

The optimal intensity, frequency, and duration of exercise that increase VO_2max are still unknown. In the present study, we found that two years of water polo training significantly improves VO_2max in 11- and 12-year old prepubescent boys. The differences being statistically significant are present in both the absolute and the relative values. The explanation of the significance of differences is found in a long-term participation in sport activities (at least two years) requiring intensive physical efforts. This

Table 1. Physical characheristics, VO_2max, FVC and FEV_1 results for experimental and control group.

Parameters	Experimental group n = 54	Control group n = 61	P value
Age (years)	11.2±0.4	11.2±0.3	NS
Stature (cm)	156.85±6.94	154.02±5.14	0.0137
Body weight (kg)	49.18±7.39	45.35±7.22	0.0058
Absolute VO_2 max ($L \cdot min^{-1}$)	2.36±0.2	1.93±0.42	< 0.00001
Relative VO_2 max ($ml \cdot kg^{-1} \cdot min^{-1}$)	49.40±6.96	43.52±9.18	0.0002
FVC (L)	3.64±0.51	3.29±0.56	0.0006
FEV_1 (L)	3.09±0.41	2.76±0.45	0.0001

is in accord with the previous literature data (15). The differences in FVC are statistically significant as well, and we consider them partly a physiological adaptation of children engaged in training. A statistically significant difference in FEV_1, presenting a part of FVC usable in intensive physical activity, is even a more direct indicator of the physiological adaptation of these individuals. The described findings, with no statistically significant difference between the groups with respect to age, present us with the starting basis to assert that intensive trainings in a discipline with primary aerobic requirements lead to increased aerobic power in boys as early as in prepuberty years. The differences in body weight and height cannot be considered only with respect to participation in sport activity, for these values result from a complex interaction of several different factors. These differences do not reflect the statistical significance of the investigated values of aerobic power, for the differences are present in the relative values as well. We refer to the results of more extensive studies which have revealed that longitudinal dimensionality of the skeleton positively correlates with the swimming speed and later, with success in water polo as well (16).

CONCLUSION

These results show that prepubescent children with adequate duration and intensity of training regimen can increase VO_2max as much as young adults. On the basis of the above stated conclusions, it can be said that this type of water polo training significantly improves aerobic power and pulmonary function in growing children. From a practical point of view, these findings point to the importance of systematic training regimen as early as at the prepubescent stage as the mode of acquiring significant functional advantages

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EFEKTI VATERPOLO TRENINGA NA AEROBNU MO] I PLU]NE FUNKCIJE DE^AKA STARIH 11 I 12 GODINA

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SA@ETAK

Istra`ivanja uticaja treninga na aerobnu mo} dece prepubertetskog uzrasta pru`aju opre~ne rezultate. Cilj studije bio je utvr|ivanje efekata vaterpolo treninga na aerobnu mo} de~aka starih 11 i 12 godina. Eksperimentalnu grupu ~inilo je 54 de~aka koji se vaterpolom bave najmanje dve godine kroz organizovani sistem treninga i takmi~enja. Kontrolnu grupu ~inio je 61 de~ak istog uzrasta, koji se nisu organizovano bavili fizi~kom aktivno{}u. Istra`ivanje je obuhvatilo antropometrijska merenja i funkcionalna ispitivanja. Aerobna mo} preko maksimalne potro{nje kiseonika procenjivana je Astrandovim testom na biciklergometru. Plu}ne funkcije: forsirani vitalni kapacitet (FVC) i forsirani ekspiratorni volumen u prvoj sekundi (FEV_1) mereni su kompjuterizovanim spirometrom. Izme|u grupa nije bilo statisti~ki zna~ajnih razlika u godinama starosti. Telesna visina i masa bile su statisti~ki zna~ajno ve}e kod ispitanika eksperimentalne grupe. Rezultati su pokazali statisti~ki zna~ajne razlike u vrednostima VO_2max iskazanim kako u apsolutnim, tako i u relativnim vrednostima. Zna~ajne razlike izme|u grupa postoje u vrednostima FVC i FEV_1. Na{e istra`ivanje pokazalo je da vaterpolo trening dovodi do zna~ajnog pobolj{anja aerobne mo}i kod de~aka prepubertetskog uzrasta. Ovi nalazi ukazuju na va`nost sistematskog trena`nog procesa ve} u ovom periodu razvoja kao na~ina za sticanje zna~ajnih funkcionalnih prednosti.

Klju~ne re~i: deca, izdr`ljivost, potro{nja kiseonika, trening, vaterpolo