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COMPARISON OF ANAEROBIC MEAN AND PEAK POWER OUTPUTS IN PREADOLESCENT BOYS AND ADULT MALES

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Summary. *Age related differences in anaerobic mean and peak power outputs were examined in 21 preadolescent (Tanner Stage = 1) boys (age 11.1yrs.±0.3) and 23 male adults (age 20.2yrs.±0.6). The investigation protocol included anthropometric measurements (determination of stature, body weight and fat free mass-FFM by bioelectrical impedence analysis) and the 30-s all-out Wingate anaerobic test on a cycle ergometer. Mean power (boys vs. men) absolute values 300.82W ±74.66 vs. 643.97W ±93.54; relative values 7.06W·kg^{-1} ±1.04 vs. 8.74W·kg^{-1} ±1.66; relative values per kilogram FFM 8.71W·kg^{-1}FFM ±1.48 vs. 10.27W·kg^{-1}FFM ±1.96. Peak power (boys vs. men) absolute values 347.48W±90.75 vs. 755.88W±116.91; relative values 8.16W·kg^{-1}±1.18 vs. 10.26W·kg^{-1}±2.84; relative values per kilogram FFM 10.07W·kg^{-1}FFM±2.14 vs. 12.06W·kg^{-1}FFM±2.78. The mean and peak power output values found during the Wingate anaerobic test were statistically significantly lower ($p<0.05$) in preadolescent boys than in adults even when expressed by total (absolute), body mass (relative) or fat free mass unit. These results show that the adolescents' anaerobic power scores are lower than those in adults which arises the question of the effectiveness of strength and endurance training program during this period of growth and maturation.*

Key words: *Muscle power, anaerobic, preadolescent, strength*

Introduction

There is a difference in relation of the two parts of bioenergetic capacity (aerobic and anaerobic) to chronological age. Namely, when aerobic capacity (VO_{2max}) is expressed in the absolute values (L·min^{-1}), the values are lower in children than in adults. However, when these VO_{2max} values are expressed in relation to body mass, that is, in relative units (ml·kg^{-1}·min^{-1}), little or no differences are found between children and adults (1).

Despite a high VO_{2max}, performance in endurance events is not as high in children as in adults because of lower running economy. In children, cardiovascular responses are characterized by higher maximal and submaximal heart rates, lower systolic stroke volume and arterial blood pressures than in adults. During prolonged exercise, the hormonal adaptation for energy substrate utilization is quite different from adults; a lower decrease in insulin and increases in catecholamine and glucagon to exercise could be responsible for a less effective regulation of glycemia with risk of hypoglycemia (2). In comparison with extensive longitudinal and transversal studies of aerobic function in practically all periods of growth and maturation, the study of very brief high intensity exercise and muscle power has not received the same attention from the researchers.

Power is the product of force and velocity. Muscle power is an explosive aspect of strength. Energy for strong muscle contractions is obtained almost exclusively from anaerobic sources, therefore this type of contraction belongs to the anaerobic part of bioenergetic capacity. Strong muscle contractions are sustained mostly on the basis of fast twitch (white) muscle fibers. This fiber type is rich with myofibrils which show a higher myosin activity for ATP release, and lower amount of sarcoplasm and mitochondria. The contractions of these fibers do not require oxygen since the basic pathways of energy release are anaerobic thus making the amount of mitochondria and blood supply rather poor. The duration of a strong contraction is time limited for the amount of available anaerobic energy is limited. Individuals with a higher percentage of fast twitch fibers are more capable of developing stronger muscle contractions. Muscle power can be conditionally divided into three types: explosive power, maximum power or peak power, and power endurance. Explosive power represents the speed of achieving maximum power. Maximal power understands peak power for a given contraction. Power endurance refers to the ability of maintaining maximum peak as long as possible. Each of these conditionally divided three types can be trained separately, but an increase in any of them leads to the improvement in the others pointing to their interconnection (3). Muscle power depends on the cross-section of muscles, nerve factors, initial muscle fiber length, joint angle, and training.

One of the reasons for a small number of investigations of anaerobic capacity and muscle power in children is the non-existence of the optimal test.

Many tests have been devised to assess anaerobic power and endurance for the evaluation of anaerobic fitness levels and to examine anaerobic training effects. Tests have measured both physiological and performance variables. Physiological parameters examined have included oxygen debt, and post exercise blood and muscle lactate levels. However, the tests are invasive and require sophisticated equipment so they are expensive and mainly inconvenient for use in children. On the other hand, performance tests are non-invasive, simple and inexpensive, but of lower validity i.e. they can not display the maximum anaerobic ability of the subject. Earlier studies of muscle strength with measurements of strength in hand grip, knee flexion and back extension demonstrated low correlation coefficient of strength in other muscle group. For example, hand grip strength is correlated to the strength in the other muscle groups with a low correlation coefficient of 0.25-0.51 (4). After that, investigators have used short term cycle tests with various protocols, and insufficiently investigated sensibility and validity for anaerobic capacity (5). Over the last decade, most laboratories for functional diagnostics have used the Wingate anaerobic sprint test in the investigation of anaerobic capacity. This standardized test presupposes the 30-s all-out maximal effort on a cycle ergometer (6). The way of loading the subjects is in a direct dependence of the manufacturer i.e. the type of cycle ergometer used, but there are standardized and precise testing protocols for all types. During the Wintgate anaerobic test, the recording of the two parameters is compulsory (mean and peak power) whereas the other values can be derived from the basic (fatigue index, speed of achieving peak power values, etc.). Mean power output is the average power output for the entire 30-s test. Peak power output is the highest power output during any 5-s interval during the test. The sensibility and validity of the test have been confirmed by several direct studies (7), and the Wingate test is currently considered the best performance test for determining anaerobic capacity and it is widely used for investigating athletes, children and even children with certain neuromuscular diseases (8). The aim of the present study was to determine and compare the anaerobic mean and peak power values in the subjects of different chronological and biological age.

Subjects and Methods

The first group of subjects was composed of preadolescent boys at the chronological age of 11.1±0.3 years. All subjects were pupils attending the city elementary schools who were not engaged in any sort of organized physical activity at least six months prior to the investigation.

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. The age was computed from date of birth and date of examination. Sexual maturation was classified according to Tanner's indexes of pubic hair (9). All subjects in this group were at Tanner's pre-pubertal stage 1. A total of 21 subjects in this group underwent a protocol of investigation.

The second group of subjects was composed of male adults at the chronological age of 20.2±0.6 years. None of the subjects in this group was engaged in organized physical activity at least six months prior to the investigation. A total of 23 subjects in this group underwent a protocol of investigation.

The subjects were introduced to the protocol of investigation, and before the beginning of the investigation, they gave written informed consent, confirming voluntary participation. The examinees were admitted for laboratory examination at 11 a.m. after at least 8 hours of an overnight rest, and a light breakfast at least 2 hours before the laboratory examination. The examination was performed in a well-ventilated laboratory, under thermo-neutral conditions at 22-23 degrees C, and 55-60% relative air humidity. During the examination, the subjects were using the sports equipment. The investigation protocol included anthropometric measurements and Wingate anaerobic test. 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. Fat mass and fat free mass (FFM) were determined by bioelectrical impedance analysis-BIA (10) using an Omron (Japan) device according to standardized procedure for the type of device used (11).

The Wingate test was conducted on a cycle ergometer interfaced with computer. Data registration was performed using the computer program specially designed according to standards of the author's test and announced technical description of the system for computer data registration (12). The rest of the Wingate standardization elements were applied following the author's recommendation (13). The results obtained during the test were automatically recorded and computed. The investigated parameters of anaerobic capacity were expressed both in absolute (W), and in relative values ($W \cdot kg^{-1}$). The examinees performed Wingate anaerobic test in two series, which were separated by a 45 min break. The protocol of investigation was the same for all participants, and the same ergometer was used for all tests throughout the study. All investigated subjects underwent the Wingate test for the first time. However, the same trained research team made all measures and assessments throughout the duration of the study. Results included the series that revealed parameters with better values of peak power (PP) and mean power (MP). Statistical processing of anthropometric values was evaluated by Student's t-test. The evaluation of differences in estimating fat mass percentage, fat free mass and the values of the peak and mean power between groups was performed by Mann-Whitney U – Wilcoxon Rank Sum W test.

Results

All results are presented in table 1. and table 2. The data are expressed as means±SD.

Table 1. Anthropological variables in subjects under investigation.

	Preadolescent boys (n=21)	Adult males (n=23)	P value
Age (yrs.)	11.10 ± 0.30	20.20 ± 0.60	<0.01
Body height (cm)	149.24 ± 5.36	177.84 ± 6.58	<0.001
Body weight (kg)	42.53 ± 6.62	73.66 ± 7.84	<0.001
Fat mass (%)	18.84 ± 5.52	14.9 ± 4.74	<0.01
Fat free mass (kg)	34.52 ± 4.88	62.69 ± 7.02	<0.001

Table 2. Peak and mean power in subjects under investigation.

	Preadolescent boys (n=21)	Adult males (n=23)	P value
Peak power (W)	347.48 ± 90.75	755.88 ±116.91	<0.001
Mean power (W)	300.82 ± 74.66	643.97 ± 93.54	<0.001
Peak power ($W \cdot kg^{-1}$)	8.16 ± 1.18	10.26 ± 2.84	<0.01
Mean power ($W \cdot kg^{-1}$)	7.06 ± 1.04	8.74 ± 1.66	<0.05
Peak power ($W \cdot kg^{-1}$FFM)	10.07 ± 2.14	12.06 ± 2.78	<0.05
Mean power ($W \cdot kg^{-1}$FFM)	8.71 ± 1.48	10.27 ± 1.96	<0.01

Discussion

Results of our investigation clearly show that anaerobic mean and peak power outputs are lower in preadolescents than in adult males. Certainly, the greatest differences exist in absolute values (MP boys vs. men: 300.82±74.66 vs. 643.97±93.54, p<0.01). However, even when the obtained values are expressed in relative units, i.e. in relation to body weight, the differences remain statistically significant (MP boys vs. men: 7.06±1.04 vs. 8.74±1.66; p<0.01). In order to determine the differences in investigated values of anaerobic capacity even more accurately, the obtained values were expressed in relation to fat free mass, which is not a common case in similar investigations.

Fat free (body) mass represents the body mass devoid of all extractable fat. The differences in mean and peak power outputs between the groups, although lower than in the comparison of absolute and relative values, showed a statistical significance as well (MP boys vs. men: 8.71±1.48 vs. 10.27±1.96; p<0.01). The investigation pursuing a similar concept showed no differences in anthropometric characteristics and values of short term muscle power in the subjects of the same sex aged 8-12 years. A longitudinal investigation of De Ste Croix et al. (14), carried out on the same subjects who underwent two tests within an interval of almost complete two years confirmed that there were no differences in the values of short term muscle power between sexes in the preadolescent period, and the increase in the values of final in relation to initial measurement was the consequence of the increase in body mass, i.e. muscle tissue mass during the period of growth. The results of our and similar investigations undoubtedly point out that in comparison to adult males, preadolescent boys appear to be limited in their ability to perform short-term anaerobic exercise (15).

In comparison of our investigation with similar investigations of this problem worldwide, an interesting finding was that regardless of the type of equipment and protocols used, the subjects included in our study were taller, heavier, and with a higher percentage of fat tissue in relation to both preadolescent and adult male subjects included in those investigations.

The results of investigations in which other tests such as force-velocity and isokinetic cycle ergometers were used also show that children's and adolescent's anaerobic power scores are lower than those in adults (16). Qualitative muscular differences are cited more frequently for this disparity than differences in the quantity of muscle, but conclusive research is lacking in this area. It has been considered that children have a limited ability to perform anaerobic type activities. The results of some investigations showed a lower concentration of phosphofructokinase, the key rate-limiting enzyme of anaerobic glycolysis which indicated that children cannot achieve adults concentrations of lactate in either muscle or blood for maximal and supramaximal rates of exercise (17). However, lactate threshold, when expressed as a percentage of VO_{2max}, does not appear to be a limiting factor in children because children's lactate thresholds are similar if not higher than those in similarly trained adults (18). Some data on children's muscles suggest that their biochemical characteristics are different from young adults muscle. The concentration of ATP in resting muscle and its utilization during intense exercise seem to be similar in preadolescent boys and older males. By contrast, phosphocreatine concentration is somewhat lower at rest in preadolescent boys and has the same or slightly lower rate of utilization than that found in older males. The main age of maturation related difference is in the concentration and utilization of muscle glycogen. Both factors are distinctly lower in preadolescent boys (19). Based on these data, it seems that the biochemical difference in anaerobic characteristics between children and adults is associated with anaerobic glycolysis and less with phosphagen system. There are no data to explain why prepubescent children have a lower glycolytic capacity. There are indications that the development of neural activation of motor units and muscle metabolism during exercise play a significant role. To generate maximum power, muscle must be fully activated, and whether young people can, or do, fully activate their muscles during exercise is difficult to establish with certainty. No longitudinal data are available that examine the issue through adolescence, but it has been reported that 16-year-olds have a greater degree of motor unit activation of the knee extensors than 10-year-olds. Furthermore, Sargeant (20) has pointed out that maturation of the corticospinal tract continues into the second decade with, for example, cortico spinal conduction velocity continuing to increase up to about 15 years.

Conclusion

The mean and peak power output values developed during the Wingate anaerobic test is lower in preadolescent boys than in adults even when it is expressed by total (absolute), body mass or fat free mass unit. Research is still needed on the specific developmental stage at which an individual acquries the adult characteristics for anaerobic exercise. Although the biochemical data mentioned above are in line with lower ability of children to perform anaerobic exercise, they do not explain the mechanism of such a deficiency. Studies at the cellular level are needed to tell wheter there are any age or maturation related differences in muscle fiber types that are recruited during supramaximal exercise. With regards to training exercise planning and dosing in our conditions, from the practical point of view, there is a need to conduct several longitudinal studies on a bigger sample of children of both genders in order to get a broader picture of anaerobic capacity depending on the chronological and biological age. These data would present significant practical directions for the beginning and intensification of strenght and endurance training program during the preadolescent and adolescent period.

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POREĐENJE ANAEROBNE PROSEČNE I MAKSIMALNE SNAGE KOD DEČAKA PREDADOLESCENATA I ODRASLIH MUŠKARACA

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Kratak sadržaj: *Uzrasno zavisne razlike u anaerobnoj prosečnoj i maksimalnoj snazi ispitivane su kod 21 dečaka (starosti 11,1 god.±0,3) u preadolescentnom periodu (prvi stadijum po Taneru) i ko 23 odrasla muškarca (starosti 20,2 god±0,6). Protokol istraživanja sastojao se od antropometrijskih merenja (određivanja telesne visine, telesne mase i mase bezmasnog tkiva-MBT metodom analize bioelektrične impendance) i 30-osekundnog maksimalnog Vingejt anaerobnog testa na bicikl-ergometru. Prosečna snaga (dečaci u odnosu na odrasle muškarce) apsolutne vrednosti 300,82W ±74,66 vs. 643,97W ±93,54; relativne vrednosti 7.06W·kg^{-1} ±1,04 vs. 8,74W·kg^{-1} ±1,66; relativne vrednosti po kilogramu MBT 8,71W·kg^{-1}FFM ±1,48 vs. 10,27W·kg^{-1}FFM ±1,96. Najveća snaga (dečaci u odnosu na odrasle muškarce) apsolutne vrednosti 347,48W±90,75 vs. 755,88W±116,91; relativne vrednosti 8,16W·kg^{-1}±1,18 vs. 10,26W·kg^{-1}±2,84; relativne vrednosti po kilogramu MBT 10,07W·kg^{-1}FFM±2,14 vs. 12,06W·kg^{-1}FFM±2,78. Prosečna i najveća snaga ispoljene tokom Vingejt anaerobnog testa su statistički značajno manje ($p<0,05$) kod dečaka u preadolescentnom periodu, u poređenju sa odraslim muškarcima, u apsolutnim i relativnim vrednostima, kao i u relativnim vrednostima izraženim na masu bezmasnog tkiva. Ovi rezultati pokazuju da je anaerobna moć u preadolescentnom periodu manja u odnosu na zrelo doba što otvara pitanje efektivnosti treninga snage i jačine u ovom periodu rasta i razvoja.*

Ključne reči: *Mišićna snaga, anaerobno, preadolescenti, jačina*