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Original scientific paper

Gender-Related Differences in Maximum Mechanical Power Output in Short-Term Activities in Children and Adolescents

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A B S T R A C T

The study was designed to examine the gender-related differences in maximum mechanical power output in various short-burst activities during growth. The subject sample consisted of four subgroups: 9 boys (14.11±0.6 yr), 9 boys (10.67±0.71 yr), 7 girls (14.29±0.49 yr), 7 girls (10.57±0.54 yr). We meausred peak power (PP), mean power (MP), fatigue index (FI) during 30-s WAnT, squat jump height (SJH) and power (SJP), and counter movement jump height (CMJH) and power (CMJP), maximum speed over 20-metre distance (S20). Lactation concentration was measured in the 3rd and 5th minutes after the WAnT. Ratio normalisation and ANCOVA were used to remove the influence of the differences in muscle (MM) and body mass (BM). Male adolescents had higher absolute values of PP (P<0.05), MP (P<0.05) than female. Ratio normalisation showed that boys had higher PP/BM (P<0.05), PP/MM (P<0.05), MP/BM (P<0.05), MP/MM (P<0.06) than girls. The ANCOVA adjustment for MM showed differences between genders in PP (P<0.001), MP (P<0.001), SJH (P<0.05), SJP (P<0.05) and CMJP (P<0.001), whereas the ANCOVA adjustment for BM showed differences only in PP (P<0.001), MP (P<0.001). Prepubertal boys had higher absolute values only in SJP (P<0.05). We concluded that variations in body composition could not be the only key to gender-related differences in power output in short-burst activities.

Key words: *anaerobic performance, peak anaerobic power, mean anaerobic power, boys, girls*

Introduction

Anaerobic energy production is very important for a growing child. If we observe young boys and girls moving, we can see that their activities consist of short bursts of energy rather than activities of moderate intensity for longer periods of time. On the other hand development of anaerobic function and performance during childhood and adolescence has received less research attention than aerobic function. Moreover, there is a dearth of studies on young girls[1]. More research should be undertaken to understand the anaerobic performances in relation to gender. Some authors tried to solve this puzzle of anaerobic performance with different indirect measuring methods which often include measurement of external power output. The two most frequently used terms for describing anaerobic performance are peak anaerobic power (PP) and mean anaerobic power (MP), measured with cycle ergometry (Wingate test) of different durations. PP and MP are often used to describe gender- and age-related differences in anaerobic performance, but different studies yield different results. Despite the fact that an analogous methodology was used, some studies reported higher absolute and relative values of PP and MP in boys than in girls aged 11 and 12[2,3,4]. The others reported only higher absolute values of PP and MP in boys than in girls aged 11 and 12[4].

Despite recent progress in the understanding of developmental variation in anaerobic function during childhood and adolescence, it is still not clear whether body composition variations are the key to age and gen-

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der-related differences in anaerobic functions during growth or whether there are some other factors contributing more to the differences between genders in short-burst activities. Different studies showed that anaerobic performance differs between genders even after making adjustments for the differences in body mass, fat free mass or cross sectional area in adults[5–7], children[3] and adolescents[8,9].

On the other hand only small-scale studies examined short-burst activities other than cycling with maximum intensity in relation to gender, growth and maturation. If we want to solve the puzzle of developmental characteristics in anaerobic performance overall, we should have in mind that various short-burst activities include different neuromuscular strategies and also different relative contribution of energy systems. For instance, phosphagen pool provides about 60% of the energy needs during a 10-s maximal exercise bout, while about 50% of the energy required in a 90-s maximal effort comes from both the phosphagenic and glycolytic energy systems[10]. We should also have in mind that muscular work during cycle ergometry tests does not involve storage and reuse of elastic energy[11]. Therefore, the measured mechanical power in cycling with maximum intensity represents the majority of the capacity to produce muscular work with the metabolic substrates used to produce high quantities of energy in short time. For complete assessment of all the processes involved in maximum mechanical power production in children and adolescents it is necessary to include both the metabolic and the visco-elastic capacities of human skeletal muscle with maximal exercise involving the stretch-shortening cycle in various functional conditions[12].

There is a paucity of information concerning gender comparison of short-burst activities of children and adolescents. Therefore the present study was designed to examine the differences in maximum mechanical power output in various short-burst activities in relation to age and gender during growth, controlling for variation in muscle mass and body mass.

Materials and Methods

Subjects

The subject sample consisted of four subgroups: the first subgroup included 9 boys (14.11 ± 0.6 yr, 170.7 ± 7.4 cm, 61.9 ± 9.7 kg), the second 9 boys (10.67 ± 0.71 yr, 145.3 ± 6.1 cm, 35.6 ± 4.0 kg), the third 7 girls (14.29 ± 0.49 yr, 167.6 ± 5.8 cm, 56.3 ± 7.9 kg) and the fourth 7 girls (10.57 ± 0.54 yr, 146.1 ± 10.8 cm, 36.6 ± 6 kg). All participants were healthy and capable of performing standard elementary school program. Parents and children gave their informed consent before the experiment. The study was also approved by the National Committee for Medical Ethics.

Antropometry. Anthropometric variables were measured with standard protocol according to EUROFIT (1993). Muscle mass (MM) was estimated trough anthropometry using equation reported by Mateigka[13]. Body mass (BM) was measured with standard protocol according to EUROFIT[14].

Maturational age. Maturational age was assessed through observation according to the standards of Tanner[15].

Experimental design. The subjects performed the standardised warm up, consisted of 10 minutes stepping on a 20 cm high bench with a frequency of 0.5 Hz, with a leg exchange every minute. After the warm-up they performed squat jumps and counter movement jumps three times. The best results of the three trials were analysed. After a 10-minute rest the subjects performed a 20-metre run with maximal speed two times. The rest between two trials lasted for 3 minutes. 10 minutes after the last trial the subjects performed cycling with maximum intensity for 30 seconds.

Procedures for the maximal exercise tests. Muscle peak anaerobic power (PP) and mean anaerobic power (MP) were measured by the Wingate anaerobic test (WAnT) on a Monark cycle ergometer. This test consists of a 30-second »all-out« supramaximal task where after a 4-minute warm-up the subject pedals at maximal rate against a high constant resistance (7.5% of their body weight). PP was taken as the highest mechanical power output at any 1-s period. MP was the average power throughout 30 seconds of cycling with maximum intensity. Blood for lactate sampling after the cycling with maximum intensity was drawn from earlobe. Blood from earlobe was drawn in the third minute (LA3) and the fifth minute (LA5) post exercise. Fatigue index (FI) was calculated from equation 1.

$$FI = \left(100 - \left(\frac{PMI}{PP} \times 100\right)\right) \qquad (1)$$

PP – the highest mechanical power output at any 1-s period; PMI – the lowest mechanical power output at any 1-s period

Maximal speed (S20) was calculated from equation 2. The subject ran 20 metres with maximal speed after an acceleration zone of 10–20 metres. BROWER TIMING SYSTEM (USA) was used for measuring the 20 metres' time.

$$v_{max} = \frac{20}{t}\left(\frac{m}{s}\right) \qquad (2)$$

v_{max} – maximal speed; t – time at 20 metres

Squat jump heights (SJH) and counter movement jump heights (CMJH) were measured with tensiometric platform (Kistler, 9278, Winterhur, Switzerland) in the laboratory environment and calculated from equation 3. Take-off power in squat jump (SJP) and also in counter movement jump (CMJP) was calculated from equation 4. In the squat jump test the subject performs a vertical jump from semi-squat position (knee angle: 90°), with trunk as vertical as possible and hands on hips. The subject executes the test without the counter movement. In counter movement jump the subject started in erect position with hands on hips and executed a vertical jump after a downward counter movement (knee must be flexed at 90° at the end of the counter movement).

$$H = \frac{g\left(\frac{t_f}{2}\right)^2}{2} = \frac{g t_f^2}{8} \qquad (3)$$

H – jump height; t_f – flight time; g – gravity constant

$$P = \frac{W}{t_c} \qquad (4)$$

P – power at take-off; W – work at take-off; t_c – contact time

Data analysis

Descriptive statistics (mean and standard deviations) for measured parameters were calculated for each subgroup. The ratio method for all measured variables and ANCOVA were employed to determine age and gender differences in the measured parameters. Covariates used for the ANCOVA analysis were muscle mass (MM) and body mass (BM). Homogeneity of variance was confirmed ($P>0.05$).When we used the ratio method, we divided each variable with MM and BM. ANOVA was performed to assess the significance of gender differences in absolute and relative values (assessed with the ratio method) in the measured parameters. An alpha level of 0.05 was used for all statistical tests.

Results

Physical characteristics

The physical characteristics of adolescent boys (14.11 ± 0.6 yr) and adolescent girls (14.29 ± 0.49 yr) are shown in Table 1. The physical characteristics of prepubertal boys (10.67 ± 0.71 yr) and prepubertal girls (10.57 ± 0.54 yr) are shown in Table 2.

There were no significant differences between adolescent boys and girls in terms of physical characteristics, with the exception of the difference in the values of adipose tissue that was nearly significant ($P=0.055$). There were also no significant differences between prepubertal boys and girls in terms of physical characteristics, with the exception of the difference in the values of adipose tissue that was nearly significant ($P=0.054$).

Based on the assessment of sexual maturation the group of adolescent boys and girls was rated in stage 4 of a five-stage scale described by Tanner[15], meanwhile the group of prepubertal boys and girls was rated in stage 1 of the same pubertal growth chart reported by Tanner[15].

Tanner's[15] pubertal growth chart showed no significant gender differences in terms of chronological or biological age of adolescent and prepubertal subjects.

Anaerobic performance in adolescent boys and girls

The first five variables in Table 3 show the differences between adolescent boys and girls in anaerobic performance measured with the Wingate test. There were no significant differences in the absolute values of post-exercise lactate production in the 3rd and 5th minutes, despite the fact that girls in the 3rd and also in the 5th minute attained only 85% of the boys' absolute value. There were neither any significant differences in post-exercise values of lactate production – when BM or MM were used as covariates. When we normalised the absolute post-exercise lactate values after the 3rd and 5th minutes with BM, girls attained 92% and 94% of the boys' values. When we normalised the absolute post-exercise lactate values after the 3rd and 5th minutes with MM, girls attained 97% of the boys' values in both cases.

On the other hand the absolute values for PP in adolescent boys were significantly higher than those in adolescent girls (Table 3). Girls attained 81% ($P<0.05$) compared to the boys' values. When we used BM and MM as covariates the differences in PP between adolescent boys and girls were also significant (Table 3). When we normalised the absolute PP with BM, girls attained 88% ($P<0.05$) and when we normalised the absolute PP with MM, girls attained 91% ($P<0.05$) of the boys' values.

There were also significant differences between adolescent boys and girls in MP (Table 3). Girls attained 80% ($P<0.05$) of the boys' values. If BM and MM were used as covariates, the differences in MP between adolescent boys and girls were also significant (Table 3). When the absolute MP was normalised with BM, girls attained 88% ($P<0.05$) and when the absolute MP was normalised with MM, girls attained 90% ($P<0.06$) of the boys' values.

TABLE 1
PHYSICAL CHARACTERISTICS OF ADOLESCENT BOYS AND ADOLESCENT GIRLS

	BOYS (14–15)		GIRLS (14–15)		
	A	SD	A	SD	ANOVA
BH (cm)	170.7	7.4	167.6	5.8	0.364
BW (kg)	61.9	9.7	56.3	7.9	0.234
MM (kg)	29.5	4.7	26.1	4.1	0.159
FM (kg)	7.8	3.3	11.4	3.5	*0.055*

Legend: A – arithmetic mean; SD – standard deviation; ANOVA – statistical significance of analysis of variance, BH – body height, BW – body weight, MM – muscle mass, FM – fat mass

TABLE 2
PHYSICAL CHARACTERISTICS OF PREPUBERTAL BOYS AND PREPUBERTAL GIRLS

	BOYS (10–11)		GIRLS (10–11)		
	A	SD	A	SD	ANOVA
BH (cm)	145.3	6.1	146.1	10.8	0.844
BW (kg)	35.6	4.0	36.6	6.0	0.714
MM (kg)	19.9	10.0	16.9	3.1	0.456
FM (kg)	4.0	1.7	6.3	2.6	*0.054*

Legend: A – arithmetic mean; SD – standard deviation; ANOVA – statistical significance of analysis of variance, BH – body height, BW – body weight, MM – muscle mass, FM – fat mass

TABLE 3
DIFFERENCES IN ANAEROBIC PERFORMANCE OF ADOLESCENT BOYS AND GIRLS ASSESSED WITH ANOVA AND ANCOVA

	BOYS (14–15)		GIRLS (14–15)		Statistical significance of differences		
	A	SD	A	SD	ANOVA	ANCOVA	
						MM	BM
LA3 (ml/l)	8.11	2.07	6.96	1.33	0.221	0.256	0.389
LA5 (ml/l)	8.82	2.09	7.55	1.05	0.163	0.204	0.298
PP (W)	477.56	72.58	385.29	67.34	*0.021*	*0.000*	*0.022*
MP (W)	406.67	55.41	326.85	57.20	*0.014*	*0.000*	*0.014*
FI	31.73	8.10	33.87	10.08	0.645	0.210	0.285
SJH (cm)	24.74	3.58	26.92	2.85	0.326	*0.050*	0.402
SJP (W)	1336.7	189.91	1418.1	139.08	0.737	*0.036*	0.447
CMJH (cm)	28.43	4.12	27.00	4.67	0.601	0.789	0.531
CMJP (W)	1415.1	189.60	1390.8	221.57	0.868	*0.001*	0.534
CMJH/SJH	1.11	0.14	1.07	0.07	0.658	0.870	0.787
S20 (ms^{-1})	7.24	0.75	6.91	0.26	0.285	0.513	0.347

Legend: A – arithmetic mean; SD – standard deviation; ANOVA – statistical significance of analysis of variance; ANCOVA – statistical significance of analysis of covariance (MM – muscle mass as covariate; BM – body mass as covariate)

There were no significant differences between adolescent boys and girls in absolute values of anaerobic performance measured with squat jumps and counter movement jumps (Table 3). Girls attained 108% of the boys' squat jump heights and 94% of the boys' counter movement jump heights. On the other hand girls' results in squat jump heights and power were better than those of boys, when we normalised for BM and MM. Girls attained 119% of the boys' squat jump height value, when BM was used, and 123% of the boys' values, when MM was used for normalisation. The differences were not significant but when BM and MM were used as covariates, the differences were significant (Table 3).

Girls also attained better results than boys, when we normalised CMJH values for BM (104%) and MM (107%). In CMJP girls attained 98% of the boys' values and when we normalised for BM, girls attained 108% of the boys' CMJP. When MM was used, girls attained 111% of the boys' values and the differences were significant when MM was used as covariate (Table 3).

Adolescent boys were faster than adolescent girls but the differences were not significant. Girls attained 95% of the boys' speed in a 20-metre run, while after normalisation for BM and MM girls attained 104% and 107% of the boys' values.

Anaerobic performance in prepubertal boys and girls

The first five variables in Table 4 show the differences between prepubertal boys and girls in anaerobic performance measured with the Wingate test. There were no significant differences in the absolute values of post-exercise lactate production in the 3rd and 5th minutes. Girls attained 94% of the boys' absolute value in the 3rd minute and 95% in the 5th minute. There were neither any significant differences in post-exercise values of lactate production, when BM or MM were used as covariates (Table 4). When we normalised the absolute post-exercise lactate values after the 3rd and 5th minutes with BM, girls attained 97% and 98% of the boys' values. When we

TABLE 4
DIFFERENCES IN ANAEROBIC PERFORMANCE IN PREPUBERTAL BOYS AND GIRLS ASSESSED WITH ANOVA AND ANCOVA

	BOYS (10–11)		GIRLS (10–11)		Statistical significance of differences		
	A	SD	A	SD	ANOVA	ANCOVA	
						MM	BM
LA3 (ml/l)	6.74	1.19	6.41	1.44	0.622	0.719	0.687
LA5 (ml/l)	7.07	1.38	6.78	2.04	0.747	0.710	0.842
PP (W)	242.55	27.14	237.71	46.14	0.796	0.573	0.658
MP (W)	220.22	24.61	207.71	37.93	0.437	0.341	0.368
FI	21.18	5.57	29.53	25.97	0.360	0.638	0.418
SJH (cm)	21.95	3.37	21.65	4.06	0.872	0.369	0.982
SJP (W)	753.96	45.17	665.03	87.27	*0.039*	0.114	0.097
CMJH (cm)	22.48	3.17	23.69	4.42	0.534	0.627	0.453
CMJP (W)	764.33	60.03	693.77	110.19	0.177	0.422	0.443
CMJH/SJH	1.03	0.08	1.10	0.14	0.188	0.327	0.209
S20 (ms^{-1})	6.36	0.42	6.02	0.41	0.197	0.189	*0.066*

Legend: A – arithmetic mean; SD – standard deviation; ANOVA – statistical significance of analysis of variance, ANCOVA – statistical significance of analysis of covariance (MM – muscle mass as covariate; BM – body mass as covariate)

normalised the absolute post-exercise lactate values after the 3rd and 5th minutes with MM, girls attained 111% and 113% of the boys' values.

There were no significant differences in absolute values for PP between prepubertal boys and girls (Table 4). Girls attained 98% compared to boys. When BM and MM were used as covariates, the differences in PP between prepubertal boys and girls were not significant. However, when the absolute PP was normalised with MM, girls attained 115%, and when the absolute PP was normalised with BM, girls attained 95% of the boys' values.

Similar results were obtained for MP (Table 4). Girls attained 94% of the boys' absolute MP value. Meanwhile, when we used BM and MM as covariates, the differences in MP between prepubertal boys and girls were not significant (Table 4). However, when the absolute MP was normalised with MM, girls attained 111%, and when the absolute MP was normalised with BM, girls attained 91% of the boys' values.

There were significant differences between prepubertal boys and girls in the absolute values of anaerobic performance measured with squat jump (Table 4). Girls attained 88% of the boys' squat jump power. On the other hand, there were no significant differences among them in other jumping parameters. Girls scored better results than boys, when we normalised their jumping results with MM. Girls attained 116% of the boys' SJH value, 103% of the SJP value, 124% of the CMJH value and 106% of the CMJP value. Girls' CMJH/SMJ index was better than that of boys but the differences were not significant.

Prepubertal boys were faster than adolescent girls, but the differences were not significant. Girls attained 94% of the boys' speed in a 20-metre run. When we used BM for normalisation, girls attained 92% of the boys' speed. On the other hand girls were better when we used MM for normalisation, as they attained 111% of the boys' speed value. The differences were not significant.

Discussion

The main findings of this study were: (1) gender differences between adolescent boys and girls were even more obvious after anthropometric normalization, especially when muscle mass was used as covariate; (2) gender differences between prepubertal boys and girls were less obvious, before and after using muscle mass and body mass as covariates.

Gender differences between adolescents were obtained in absolute PP and MP measured with 30-s WAnT. Girls PP and MP were about 19% and 20% lower than those of boys, respectively. Similar results were obtained in various studies on anaerobic power and endurance, where significant gender differences in absolute and relative values appeared since the age of 13[8,16,17]. The gender difference in relative anaerobic power (W kg^{-1}) during puberty and adolescence may be due to a greater absolute and proportional increase in the fat mass in females and to a proportionately greater increase in the muscle mass in males[3,18]. However, when we normalised our data for muscle mass and body mass, girls' PP and MP were still lower than those of boys by about 12% and 10%, respectively. It seems that variation in body composition (proportional increase in fat mass in females and proportional increase in muscle mass in males) was not the only factor of gender differences in PP and MP production measured with 30-s WAnT. Therefore, we suggest that muscle mass could explain part of variability in PP and MP but as such cannot fully account for the deficiency in girls PP and MP measured with WAnT. There might be other factors that contribute to gender-related differences in anaerobic power measured with WAnT. The first one could be the rate of energy turnover through anaerobic pathways. Maximal performance of such duration (30-s) depends predominately on the anaerobic glycolitic system[19]. Control of glycolysis is determined largely by the catalytic and regulatory properties of two enzymes, namely phosphofructokinase (PFK) and phosphorylase[19]. One of the reasons for gender differences could probably be the glycolitic enzyme activity. The activity of PFK in human skeletal muscle is about 25% lower in sedentary adult females than in sedentary adult males[20]. A more pronounced glycolitic enzyme profile in males was found in an investigation of older adolescents (mean age: 17 and 19 years for males and females, respectively)[21]. On the other hand, gender differences in glycolytic enzyme activities among children have not been entirely evaluated[22]. Differences in glycolytic enzyme activities could probably be reflected in different lactate (LA) production by gender. However, our data showed that differences between genders in LA production were not significant, especially when we normalised the post-exercise lactate values with muscle mass in the 3rd and 5th minutes. Adolescent girls attained 97% of the boys' values. Yet, we should have in mind that post-exercise LA values did not result only from production but also consumption of LA in the organism. LA levels might be best interpreted as an index of the balance between the process of production and consumption (clearance). Other factors may significantly influence LA levels as well, including rate of release from the muscle cell, rate of lactate utilization by organs such as the liver and heart, and volume of distribution within the body fluids[22].

The second causative factor for greater anaerobic power, measured with WAnT, in adolescent boys could be hormonal changes prior and in puberty. Hormonal differences between the genders could probably be the reason for significantly greater PP and MP in adolescent boys. Gender differences in anaerobic performance between adolescent boys and girls could probably be related to different hormonal influences, especially by oestrogen and testosterone. In boys, testosterone probably plays the critical anabolic role in the growth and development of muscle mass during adolescence[23], while in girls, oestrogen increases adipose tissue levels, has a retarding effect on lean mass as well as reduces glycogenolysis[9].

However, different studies yield different results. In the longitudinal study[24] circulating testosterone levels began to rise one year before peak height velocity and then increased steadily, reaching adult levels around three years after peak height velocity[25]. However, in the same study data for girls showed that the strength of the muscle quadriceps is proportional to height and total body mass, while for boys there is an additional factor that can be fully attributed to increasing levels of testosterone[25]. On the other hand, Falgairette et al.[26] reported only a moderate correlation of mean and peak anaerobic power with salivary testosterone in their cross-sectional study of 6–15 year old boys.

The third causative factor for gender-related differences in PP and MP during WAnT could be the biomechanical changes in musculoskeletal organisation during growth. In particular, changes in muscle pennation with increased muscle size during growth may influence force output and contribute to age and gender differences in power[25]. Females' greater Q angle may result in reduction of the proportion of quadriceps muscle force that is transmitted through the patellar tendon, putting females at a disadvantage in power generation[9] during cycling with maximal intensity.

The fourth causative factor for gender-related differences in PP and MP during WAnT could be the contractile properties of muscle fibres. Boys seem to have a potential advantage over girls during the adolescent period because of their significantly higher type IIb areas[25]. Fast motor units (consisting of IIb muscle fibres) in adult quadriceps had 10 times greater maximum shortening velocity than slow motor units (consisting of type I muscle fibres[27]). This difference between slow and fast muscle fibres might be expected to influence the velocity dependent force and power relationship, which set boys before girls.

Whereas adolescent boys dominate in WAnT, girls dominate in squat jump and counter movement jump. In contrast, adolescent girls' squat jump heights were 8% better than those of boys, when the absolute values were compared. When we normalised for MM, girls were 23% better than boys. Adolescent girls were also better than boys in CMJH, namely by 7%. We should have in mind that muscular work during cycle ergometry and squat jumps were not the same. During a 30-s WAnT the glycolytic energy system was more prominent, while during a squat jump and counter movement jump the phosphagenic energy system and the ability to store and reuse elastic energy were in the foreground. New research methods such as PNMRS[31] showed that no gender differences existed in resting phosphagen concentration (ATP and CP) or in creatin kinase activity[20,28]. This could help explain why girls were equal to boys in squat jump heights and power. Yet, adolescent girls were better than adolescent boys! If adolescent boys really have a higher proportion of IIb areas[25], why were their SJH and SJP results poorer than those of girls. The answer to this question could lie in different neuromuscular strategies and inter- and intra-muscular co-ordination which was dominant both in cycling with maximum intensity and in squat jumps. The pattern and percentage of muscle fibre activation must also be considered as contributing factors to gender-related differences in squat and counter movement jumps. When vertical jump is accepted as an estimation of anaerobic power, changes in neuromuscular co-ordination per se and the timing of the growth spurt might influence power independent of muscular potential[29].

In contrast to adolescent boys and girls, anaerobic power of prepubertal children showed little gender difference prior and after using antropometric normalisation or BM and MM as covariates. Similar results were obtained in various studies, where no significant differences were observed in absolute leg anaerobic power between boys and girls of 9–11 years of age[8,16,17]. The first and probably the most important causative factor could lie in maturity-associated variation by gender in thigh muscle mass. Girls appear to have greater thigh muscle mass per unit body mass in childhood[30]. If we look at the data presented by Maresh[30] more carefully we can see that at the age of ten there are no differences between genders in the ratio of the products of estimated mid-thigh muscle area and femur length per unit body mass. Power is the end product of force and velocity characteristics of skeletal muscle tissue. Force generated with a muscle is related to cross-sectional area of the active muscle, whereas velocity of muscle contraction is related to the number of sarcomeres in a series. This equality in thigh muscle mass per unit body mass between genders in prepubertal children could be the reason for no significant differences in the measured parameters.

Conclusion

Our measuring methods showed that adolescents differ by gender in terms of their ability to produce anaerobic power, while gender differences in the ability to produce anaerobic power were much less obvious in prepubertal children. Although the maturity effects were probably mediated through the influence of maturity status of the body size and muscle mass, this could not be the only reason. There were gender differences in the ability to produce anaerobic power in adolescents, when measured parameters were normalised with muscle mass or muscle mass and body mass used as covariates, which may suggest that variations in body composition could not be the only reason for gender-related differences in short-term power output in adolescents. Meanwhile, equality of prepubertal boys and girls implied that maturity not relating only to structural but also to qualitative changes of the body (different hormonal structures, different neuromuscular strategies, etc.) were probably the most important factors for gender differences in short-term power output, measured with our experimental protocol.

Nevertheless, we should have in mind that the main limitations of our study were small sample size, superficial assessment of sexual maturation, indirect measurements of anaerobic power and cross-sectional evaluation. Although gender and age related differences in the anaerobic power might be related to the maturation of muscle metabolic pathways and different neuromuscular strategies, future studies should focus on underlying mechanisms with new non-invasive research tools, which will be used in a much greater study sample with appropriate control group.

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SPOLNE RAZLIKE U MAKSIMALNOJ MEHANIČKOJ SNAZI TIJEKOM KRATKOTRAJNIH AKTIVNOSTI KOD DJECE I ADOLECENATA

S A Ž E T A K

Ovo istraživanje oblikovano je tako da proučava spolne razlike u maksimalnoj mehaničkoj snazi kod različitih kratkotrajnih eksplozivnih aktivnosti tijekom razvoja. Uzorak ispitanika sastojao se od četiri podgrupe: 9 dječaka (14,11 ± 0,6 god), 9 dječaka (10,67 ± 0,71 god), 7 djevojčica (14,29 ± 0,49 god) i 7 djevojčica (10,57 ± 0,54 god). Mjerili smo maksimalnu snagu (engl. peak power (PP)), srednju snagu (engl. mean power (MP)), index umora (engl. fatigue index (FI)) tijekom 30-s WAnT-a, visinu i snagu skoka iz čučnja (engl. squat jump height (SJH) and power (SJP)), visinu i snagu skoka uz brojenje pokreta (engl. counter movement jump height (CMJH) and power (CMJP)), i maksimalnu brzinu na udaljenost od 20 metara (S20). Koncentracija laktata bila je izmjerena u 3. i 5. minuti nakon WanT-a. Omjer normalizacije i ANCOVA korišteni su kako bi se odbacile razlike uvjetovane razlikama u mišićnoj i tjelesnoj masi (engl. muscle mass (MM), body mass (BM)). Muški adolescenti imali su više vrijednosti PP-a (P<0,05), MP- a (P<0,05) u odnosu na adolescentice. Omjer normalizacije je pokazo kako dječaci imaju viši PP/BM (P<0,05), PP/MM (P<0,05), MP/BM (P< 0,05) i MP/MM (P<0,06) u odnosu na djevojčice. The ANCOVA prilagodba za MM pokazala je razlike između spolova u PP (P<0,001), MP (P<0,001), SJH (P<0,05), SJP (P<0,05) i CMJP (P<0,001), dok je za BM pokazala razlike samo za PP (P<0,001) i MP (P<0,001). Predpubertetski dječaci imali su više apsolutne vrijednosti samo za SJP (P<0,05). Mi zaključujemo kako razlike u tjelesnoj građi i sastavu ne mogu biti jedini ključ spolnih razlika u maksimalnoj snazi kratkotrajnih eksplozivnih aktivnosti.