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Changes in maximal oxygen uptake during growth and development in girls who actively participate in basketball and non-athletes girls: a longitudinal study

Promene u maksimalnoj potrošnji kiseonika tokom rasta i razvoja devojčica koje igraju košarku i devojčica koje se ne bave sportom: longitudinalna studija

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Abstract

Background/Aim. It is well known that continuous engagement in physical activity is important for normal growth and development of children. Maximal oxygen uptake (VO_{2max}), as a measure of functional state of the organism, is largely affected by level of physical activity, but it remains unclear to what extent it can be improved during childhood. The aim of the study was to evaluate dynamics of changes in aerobic capacity, anthropometric and body composition characteristics in active and non-active girls over a period of 3 years. **Methods.** A total of 48 young girls were included in the study. Girls were divided into 2 groups: training group consisted of 25 girls who played basketball (age 13.84 ± 0.94) and non-training group of 23 girls who were not involved in any organized sports (age 13.83 ± 0.98). Anthropometric and body composition characteristics were measured in order to monitor somatic growth during the study. VO_{2max}values were obtained by performing cardiopulmonary exercise testing on a treadmill. All parameters were measured every 6 months during 3-years period. **Results.** ANOVA analysis showed a significant time and group interaction effect on VO_{2max} ($p < 0.001$), body mass index (BMI) ($p < 0.001$) and fat percentage (FAT%) ($p < 0.01$). Also, there was an obvious increase in VO_{2max} within both groups due to growth and development itself ($p < 0.001$). **Conclusion.** The main finding of the study was an increase in VO_{2max} due to growth and development. The girls who actively participated in basketball had higher level of aerobic capacity compared to non-active girls. Furthermore, continuous basketball training led to maintaining normal body composition in terms of FAT% and BMI, which altogether may imply that organized physical activity has a positive influence on evaluated characteristics.

Key words:
exercise; oxygen consumption; growth and development; basketball; adolescent; women.

Apstrakt

Uvod/cilj. Poznato je da je redovna fizička aktivnost važna za normalan rast i razvoj dece. Maksimalna potrošnja kiseonika (VO_{2max}), kao mera funkcionalnog stanja organizma, u velikoj meri zavisi od nivoa fizičke aktivnosti, ali nije jasno u kojoj meri ova vrednost može biti unapređena tokom detinjstva. Cilj rada bilo je praćenje dinamike promene aerobne sposobnosti i antropometrijskih karakteristika devojčica koje treniraju košarku i onih koje se ne bave sportom u periodu od tri godine. **Metode.** U studiji je učestvovalo 48 devojčica podeljenih u dve grupe: grupa od 25 devojčica (uzrasta 13,84 ± 0,94) koje su trenirale košarku i grupa od 23 devojčice (uzrast 13,83 ± 0,98) koje se nisu bavile sportom. U cilju praćenja somatskog rasta tokom studije vršena su antropometrijska merenja i procena telesne kompozicije. Vrednosti VO_{2max} dobijene su izvođenjem maksimalnog ergospirometrijskog testa opterećenja pokretnoj traci. Svi parametri mereni su na svakih 6 meseci tokom perioda od 3 godine. **Rezultati.** ANOVA analiza pokazala je značajan efekat interakcije između vremena studije i grupa u pogledu VO_{2max} ($p < 0.001$), indeksa telesne mase (BMI) ($p < 0.001$) i procenta telesne masti (FAT%) ($p < 0.01$). Takođe, uočen je i očigledan porast VO_{2max} u obe grupe tokom studije kao rezultat rasta i razvoja ($p < 0.001$). **Zaključak.** Glavni zaključak studije je porast u VO_{2max} kao posledica rasta i razvoja. Takođe, redovna fizička aktivnost omogućila je održavanje normalne telesne kompozicije u pogledu BMI i FAT%, što sve zajedno može da implicira da organizovana fizička aktivnost ima pozitivan uticaj na praćene parametre.

Ključne reči:
vežbanje; kiseonik, potrošnja; rast i razvoj; košarka; adolescenti; žene.

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Introduction

Physical activity is an important factor for normal growth and development of children since continuous exercise enhances the functional state of entire organism and has beneficial effects on body composition and basic motor skills [1]. It is essential to adopt proper habits in terms of physical activity during childhood in order to prevent sedentary lifestyle and, consequently, all the concomitant diseases (cardiovascular diseases, type 2 diabetes, obesity, etc.) [1–4].

Aerobic capacity represents the functional state of the entire organism, but largely depends on the ability of the heart and lung to deliver an adequate amount of oxygen to our muscles in order to produce energy for work. Maximal oxygen uptake (VO_{2max}) is the measure of aerobic capacity and cardiorespiratory fitness per se. It is significantly affected by genetic factors, gender, age, and level of physical activity. Although it is predominantly genetically determined, active participation in sports can lead to full expression of genetic potential and subsequently to an increase in aerobic capacity, especially in period between age 18 and 25 [5]. On the other hand, VO_{2max} values are increasing during growth and development of children due to increase in body size, but it remains unclear to what extent aerobic capacity can be improved by engaging in continuous physical activity in such early and sensitive period of life [2, 3, 6, 7]. There are limited data available on changes in VO_{2max} during growth and development of both active and inactive children, especially longitudinal data are lacking for young girls.

Therefore, the study was designed to evaluate dynamics of changes in aerobic capacity, anthropometric and body composition characteristics in 2 groups of girls over a period of 3 years. The obtained results should provide the basis for a discussion on the individual influence of growth and development as well as basketball training on the evaluated parameters.

Methods

Subjects

A total of 48 young girls were included in the study. Girls were divided into 2 groups: the training group consisted of 25 girls who played basketball (age 13.84 ± 0.94 at the beginning of the study; age 16.32 ± 1.21 at the end of the study) and the non-training group of 23 girls who were not involved in any organized sports (age 13.83 ± 0.98 at the beginning of the study; age 16.65 ± 0.88 at the end of the study). The girls from the training group were recruited from 3 local basketball teams in Belgrade, Serbia. At the baseline of the study they have already played basketball 3.65 ± 1.67 years on average and had 5.7 ± 2.13 h of training per week. The non-training group consisted of girls who attended the same elementary schools as their peers in the training group. Both groups were homogeneous in terms of age, gender and socioeconomic status.Written informed consent was obtained through a letter given to parents explaining study goals, procedures, and methods. The protocol was in accordance with the Declaration of Helsinki for research on human subjects and was approved by the Ethical Committee of Sports Medicine Association of Serbia.

Measurements

Participants were evaluated at outpatient sports medicine clinic, under the auspice of the Sports Medicine Association of Serbia, every 6 months (April/October) during a period of 3 years (total of 6 tests were carried out).

Physical/somatic growth of the young girls was estimated by obtaining anthropometric and body composition characteristics. Height was measured by Seca stadiometer to the nearest 0.1 cm. Arm span was obtained by using tape measure technique. Tanita Body Composition Analyzer BC-418MA was used to measure body weight, body mass index (BMI), body fat percentage (FAT%), and free fat mass (FFM).

VO_{2max} values were obtained by performing cardiopulmonary exercise testing (CPET) on a treadmill (H-P-COSMOS). Before the CPET, participants passed sports medical examination and were eligible for carrying out maximal progressive test. The subjects were equipped with a face mask, heart rate monitor (COSMED Wireless HR Monitor) and ECG device (Quarck T 12x, Wireless 12-lead ECG) in order to perform the test. The initial speed and inclination were set at 2.5 km/h and 3°, respectively. Every 30 seconds treadmill speed was increased by 0.5 km/h, while the inclination remained constant throughout the test. The protocol was created, as described above, taking into account the age of participants and the fact that most of them did not use the treadmill before. A very low speed at the beginning of the test, with only 0.5 km/h of increase in 30 sec, has provided enough time to get familiar with the treadmill and walking and running technique. The treadmill inclination was set in order to amortize steps on a treadmill and avoid local muscle fatigue and aches. Oxygen consumption kinetics was measured continuously by using breath-by-breath analysis technique (Quark CPET system manufactured by Cosmed). Heart rate was monitored by both COSMED Wireless HR Monitor and ECG device. A test was considered maximal if participants achieved 90% or more of predicted maximal heart rate for age and gender. The 220 – age equation was used in order to calculate maximal heart rate predicted values (Tanaka, 2001). Furthermore, a plateau in oxygen consumption despite increased workload, a respiratory exchange ratio grater than 1.00 and reached volitional exhaustion were also criteria for the end of the test. All the tests were performed by trained personnel and the test equipment were routinely calibrated with both volume and gas calibration every fifth test.

Statistical analysis

Statistical analysis was performed with the software IBM SPSS Statistic version 20.0. All data were assessed for normality (one-sample Kolmogorov-Smirnov test). Paired samples *t*-test was used to compare measured characteristics within the groups at the beginning and the end of the study. The subject's baseline and final characteristics between the groups were compared using independent-sample *t*-test. A comparison of continuous variables was performed by general linear model 2-way analysis of variance (ANOVA) with repeated measures, with group (research group vs. control group) as the between-subjects effects, and time (baseline vs. end of the observational period) as within-subjects effects. Descriptive statistics of data for both groups were given as r ± SD. A p-value ≤ 0.05 was considered statistically significant.

Results

The anthropometric and body composition characteristics for both groups are presented in Tables 1 and 2 respectively.

Within the group changes

Main effects of time on anthropometric and body composition parameters are shown in Table 2. A significant increase in FAT% was noticed in the non-training group after 3-years follow-up in comparison to baseline values (paired samples t-test, $p < 0.01$), while there were no significant changes in the training group in terms of this parameter (paired samples t-test, $p > 0.05$). Furthermore, Figure 1 shows an obvious increase in VO_{2max} values within the both groups throughout the study (ANOVA repeated measures; main effect of time, $p < 0.001$). In addition, Figure 2 and 3, respectively, present trend changes in BMI, FAT% and VO_{2max} values within the training and non-training group over time.

Between the group changes and time and group interaction effects on measured anthropometric and body composition parameters are shown in Table 2. At the baseline of the study, there was no differences between the active and inactive girls regarding FAT% ($p > 0.05$), but final measurements revealed significant difference in terms of this characteristic (independent sample t-test, $p < 0.01$). Furthermore, ANOVA analysis also showed a significant time and group interaction effect on VO_{2max} ($p < 0.001$).

Table 1

Anthropometric and body composition characteristics of the training group / non-training group during the study period

Parameters	Test I	Test II	Test III	Test IV	Test V	Test VI
	r ± SD	r ± SD	r ± SD	r ± SD	r ± SD	r ± SD
Height (cm)	169.3 ± 6.48/ 165.0 ± 7.39	170.1 ± 6.26/ 166.0 ± 6.89	170.6 ± 6.04/ 166.8 ± 6.93	171.2 ± 5.94/ 167.2 ± 6.71	171.6 ± 5.92/ 167.2 ± 6.72	172.0 ± 5.88/ 168.2 ± 6.30
Arm span (cm)	167.5 ± 8.20/ 163.6 ± 8.88	168.8 ± 7.96/ 164.0 ± 8.82	169.4 ± 7.62/ 165.4 ± 8.23	169.9 ± 7.97/ 166.0 ± 7.92	170.1 ± 7.97/ 166.0 ± 7.94	170.4 ± 7.84/ 166.6 ± 7.84
Weight (kg)	59.76 ± 7.67/ 56.52 ± 9.22	61.7 ± 7.63/ 58.19 ± 9.80	62.03 ± 7.30/ 59.25 ± 9.67	62.23 ± 6.60/ 60.27 ± 10.60	62.88 ± 6.51/ 60.32 ± 10.61	63.24 ± 6.58/ 61.74 ± 10.05
Body mass index (kg/m^2)	20.95 ± 2.50/ 20.59 ± 2.74	21.31 ± 2.67/ 21.13 ± 2.96	21.44 ± 2.55/ 21.17 ± 2.49	21.34 ± 2.35/ 21.98 ± 2.59	21.62 ± 2.35/ 22.07 ± 3.19	21.74 ± 1.98/ 23.05 ± 2.95
Body fat percentage (%)	25.38 ± 3.37/ 26.57 ± 4.35	25.53 ± 4.01/ 26.18 ± 4.63	25.81 ± 3.84/ 26.89 ± 4.47	25.0 ± 3.63/ 27.34 ± 4.97	25.64 ± 4.01/ 27.42 ± 4.98	25.28 ± 4.01/ 28.59 ± 4.21
Free fat mass (kg)	44.44 ± 4.82/ 41.32 ± 5.25	45.23 ± 5.18/ 42.53 ± 5.56	45.58 ± 4.48/ 43.02 ± 4.93	46.40 ± 4.22/ 43.78 ± 4.90	46.75 ± 4.52/ 43.84 ± 4.90	47.42 ± 4.15/ 44.69 ± 4.75

Test I – Test VI: performed measurements during period of 3 years on every 6 months (April/October).

Table 2

Within and between the group changes in terms of anthropometric and body composition characteristics and VO_2max values during the study

Parameters	Training group		Non-training group		ANOVA p values		
	baseline	final	baseline	final	time[a]	group[b]	time *group[c]
Height (cm)	169.3 ± 6.48	172.0 ± 5.88	165.0 ± 7.39	168.2 ± 6.30	< 0.001	< 0.05	ns
Arm span (cm)	167.5 ± 8.20	170.4 ± 7.84	163.6 ± 8.08	166.6 ± 7.84	< 0.001	ns	ns
Weight (kg)	59.76 ± 7.67	63.24 ± 6.58	56.52 ± 9.22	61.74 ± 10.05	< 0.001	ns	ns
Body mass index (kg/m^2)	20.95 ± 2.50	21.74 ± 1.98	20.59 ± 2.74	23.05 ± 2.95	< 0.001	ns	< 0.001
Body fat percentage (%)	25.38 ± 3.37	25.28 ± 4.01	26.57 ± 4.35	28.59 ± 4.21	< 0.05	ns	< 0.01
Free fat mass (kg)	44.44 ± 4.82	47.42 ± 4.15	41.32 ± 5.25	44.69 ± 4.75	< 0.001	< 0.05	ns
VO_2max (mL/kg/min)	41.62 ± 4.57	49.85 ± 4.20	35.13 ± 2.59	39.03 ± 2.66	< 0.001	< 0.001	< 0.001

[a]Time (baseline vs. end of the observational period) refers to within-subjects effects.
[b]Group (training vs. non-training group) refers to between-subjects effects.
[c]Time*group refers to time and group interaction effects.
VO_2max – maximal oxygen uptake.

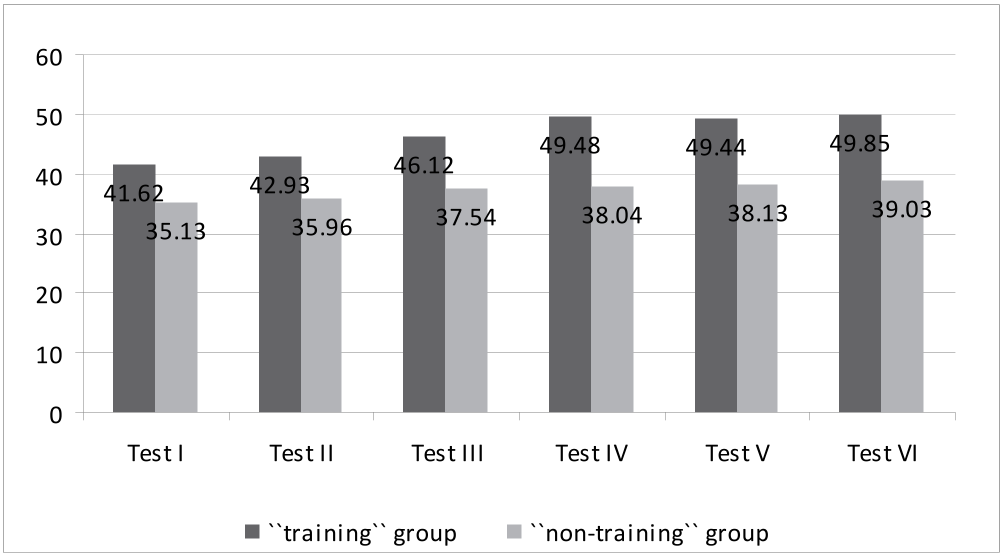
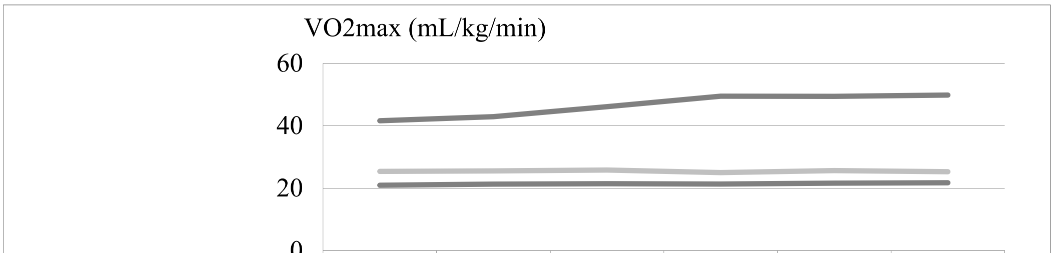
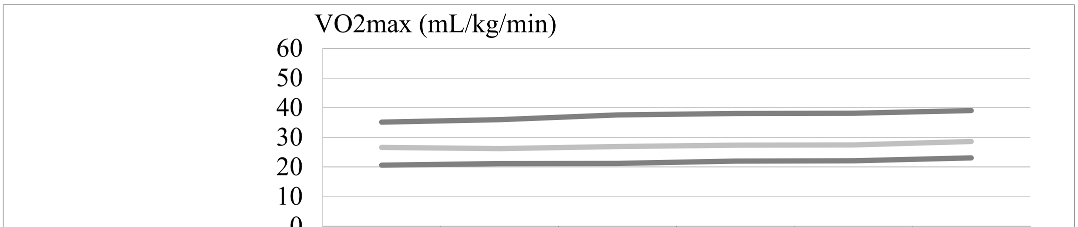


Fig. 1 – Changes in VO_{2max}values (mL/kg/min) in the training and non-training group measured on every 6 months over a period of 3 years.
VO_2max – maximal oxygen uptake.



	Test I	Test II	Test III	Test IV	Test V	Test VI
BMI (kg/m2)	20.95	21.31	21.44	21.34	21.62	21.74
FAT %	25.38	25.53	25.81	25	25.64	25.28
VO2max (ml/kg/min)	41.62	42.93	46.12	49.48	49.44	49.85

Fig. 2 – Trend changes in BMI, FAT% and VO_{2max} values within the training group over time.
BMI – body mass index; FAT – body fat percentage; VO2max – maximal oxygen uptake.



	Test I	Test II	Test III	Test IV	Test V	Test VI
BMI (kg/m2)	20.59	21.13	21.17	21.97	22.07	23.05
FAT %	26.57	26.18	26.89	27.34	27.43	28.59
VO2max (ml/kg/min)	35.13	35.96	37.54	38.04	38.13	39.03

Fig. 3 – Trend changes in BMI, FAT% and VO_{2max} values within the non-training group over time.
BMI – body mass index; FAT – body fat percentage; VO2max – maximal oxygen uptake.

Discussion

The main finding of the present study was an increase in VO_{2max} in both study groups over time. Furthermore, the participants from the training group achieved higher VO_{2max} values compared to their non-active peers.

Representative data of VO_{2max} values in the young girls were scarce, presented within a wide range of age (i.e. 13–19), and vary among studies depending on sample size and measurement methods [3, 8]. Our data are highly comparable with those reported in a study including 92 active and 75 non-active Spanish girls (41.85 mL/kg/min and 39.03 mL/kg/min in 12 to 18-years-old active and non-active girls, respectively) [4]. On the other hand, higher VO_{2max} values were obtained among Indian girls (54.4 ± 5.00 and 48.70 ± 3.21 ml/kg/min in 12 to 17-years-old active and non-active girls, respectively) [9] and yet, lower in 6 to14-years-old Serbian girls (30.4 ± 9.6 mL/kg/min) probably due to younger age of evaluated participants [10]. Compared for normative data for VO_{2max}, the training group girls were graded as excellent (39.0–41.9 mL/kg/min) at the beginning of the study and as superior (> 41.9 mL/kg/min) by the end of the observational period. Aerobic capacity of the non-training group was graded as good (35.0–38.9 mL/kg/min) throughout the entire study.

Earlier studies reported a gradual increase in VO_{2max} through childhood and adolescence due to growth, development, and a subsequent increase in body size and muscle mass, which enhances oxygen utilization. Accordingly, maturation, age, and body composition may account for most of differences in VO_{2max} values in pre-pubertal and pubertal children [3, 11], with only weak to moderate training-induced increase inVO_{2max} during this sensitive period of life [3, 7, 8, 11]. In line with our findings, a gradual increase in aerobic capacity goes in favor to growth and development. The continuous increase in body height, arm span, body weight, BMI and FFM over time clearly contributed to better oxygen utilization and an increase in VO_{2max} values. On the other hand, the recent research on this matter [7, 9, 12, 13] showed a strong association between regular engagement in physical activity and aerobic capacity in children, which might explain higher VO_{2max} values in training group compared to non-training one. The higher level of aerobic capacity in the trained group of girls could be associated with an increased respiratory volumes, stroke volume and cardiac output, which are in favor of both morphological and functional adaptations of heart and lungs to organized and continuous physical activity [7].

Furthermore, being involved in regular basketball training led to maintaining normal body composition in terms of FAT% and BMI during growth and development [10]. It is well known that lower FAT%, with normal BMI and greater FFM are also correlated with higher cardiorespiratory fitness [14]. In addition, athletic training at a non-elite level did not affect growth in somatic sense [15]. Growth spurt and changes in weight were the same for both groups, since there was no significant time and group interaction effect on these parameters by the end of the observational period.

In addition, according to Robbins et al. [15], by the age of 13, only about 22% of girls meet World Health Organization recommendations of at least 60 min of physical activity every day [1, 16, 17] and almost 28% are already overweight or obese. These findings indicate that young girls would benefit from continuous involvement in exercise programs, such as those designed to increase physical activity [15, 18, 19]. The obtained results could be in a favor of positive effects of physical activity on aerobic capacity, body composition and consequently cardiorespiratory system of young girls itself.

Limitations

Although the present study has certain advantages such as direct measurement of VO_{2max} and evaluation of a large number of parameters over a period of 3 years, it also has some limitations. At the beginning of the study there was already statistically significant difference in terms of VO_{2max}, body weight and FFM between the two evaluated groups. The complex interaction between basketball training and growth and development could be properly evaluated only if there were no significant differences between the groups in terms of baseline measurements. The results obtained by this comparative longitudinal study design might only imply that active participation in basketball led to an increase in aerobic capacity beside growth and development. In addition to frequency of basketball training (hours/week of training) obtained for the training group, the level and intensity of physical activity could have been measured by accelerometers and heart rate monitors for both evaluated groups in order to get better insight into influence of organized physical activity on monitored parameters.

Conclusion

According to the results presented in the study, maximal oxygen uptake gradually improves with an increase of body size due to growth and development in young girls. It is demonstrated that girls actively engaged in basketball training have higher aerobic capacity and maintain normal values of FAT% and BMI during growth and development. These findings may imply that organized physical activity has a positive influence on evaluated characteristics.

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