

## REDUCTION OF RELATIVE MAXIMUM OXYGEN UPTAKE IN GIRLS OF ADVANCED SEXUAL MATURATION

Margit Mäll, Kalle Karelson, Mehis Viru and Atko-Meeme Viru

*Institute of Exercise Biology, University of Tartu, Tartu, Estonia*

Original scientific paper

UDC 576.8.095-053.6-055.2

### Abstract

The purpose of this study was to verify the previous results indicating reduced peak  $\text{VO}_2$  normalized to body mass in girls of advanced sexual maturation. 31 girls aged 11 to 15 years were divided by Tanner's sexual maturation stages into groups of prepubertal (stage I), pubertal (stages II, III, IV) and postpubertal (stage V) girls. The peak  $\text{VO}_2$  and the ventilatory threshold were assessed with the aid of a cycloergometric incremental exercise test. Peak  $\text{VO}_2$  (l/min) was higher in pubertal than prepubertal girls ( $1.89 \pm 0.44$  vs.  $1.72 \pm 0.32$ ,  $p < 0.05$ ). The difference between pubertal and postpubertal girls was insignificant. Relative maximum  $\text{VO}_2$  did not differ between prepubertal and pubertal girls. In postpubertal adolescents this value was 13% lower than in pubertal girls ( $p < 0.05$ ). An increase of the body mass index showed that in sexual maturation stage V the gain of body mass was relatively more pronounced than the increase in body height. The ventilatory threshold did not differ between the maturation groups.

*Key words:* body height, body mass, maximum oxygen uptake, sexually mature girls

### DIE VERMINDERUNG VON RELATIVER MAXIMALER SAUERSTOFFAUFNAHME BEI GESCHLECHTSREIFEN MÄDCHEN

#### Zusammenfassung:

Das Ziel dieser Studie war, die früheren Forschungsergebnisse, die die Verminderung von relativer maximaler Sauerstoffaufnahme bei geschlechtsreifen Mädchen zeigten, zu überprüfen. 31 Mädchen (im Alter 11-15 Jahre) wurden laut Tanners Stufen der Geschlechtsreife in drei Gruppen, nämlich, Vorpubertät (Stufe I), Pubertät (Stufen II, III, IV) und Nachpubertät (Stufe V), geteilt. Die maximale Sauerstoffaufnahme und die ventilatorische Schwelle wurden mit Hilfe des Fahrradergometer-Stufenübung-Testes bestimmt. Maximale Sauerstoffaufnahme (l/min) war bei den Mädchen, die in der Pubertätsgruppe waren, höher als bei Mädchen, die sich in der Vorpubertätsgruppe befanden ( $1,89 \pm 0,44$  und  $1,72 \pm 0,32$ ). Der Unterschied zwischen den Mädchen, die in der Pubertätsphase waren, und Mädchen in der Nachpubertätsphase, war nicht bedeutend. Relative maximale Sauerstoffaufnahme ist kein Kriterium, das die Mädchen, die in der Vorpubertätsphase sind, und Mädchen in der Pubertätsphase, voneinander unterscheidet. Bei Mädchen, die sich in der Nachpubertätsphase befinden, war dieser Wert 13% niedriger als bei Mädchen in der Pubertätsphase ( $p < 0,05$ ). Der erhöhte Körpermassenindex zeigte, dass in der fünften Stufe der Geschlechtsreife die Körpermassenzunahme größer war als Körperhöhenzunahme. Die ventilatorische Schwelle war kein Kriterium, das die verschiedenen Geschlechtsreifengruppen voneinander unterscheidet.

*Schlüsselwörter:* Körperhöhe, Körpermasse, maximale Sauerstoffaufnahme, geschlechtsreife Mädchen

### Introduction

In several studies the values of peak  $\text{VO}_2$  max have been examined relative to sexual maturation. More mature teenagers of both sexes demonstrate significantly higher absolute  $\text{VO}_2$  max (Armstrong

et al., 1991; Baxter-Jones, Goldstein, & Helms, 1993, Falgairette et al., 1991; Krahenbuhl, Skinner, & Kohrt, 1985). Relative maximum  $\text{VO}_2$  is independent of sexual maturation in boys (Armstrong et al., 1991; Falgairette et al., 1991;

Krahenbuhl, Skinner, & Kohrt, 1985). Comparison of regression standards indicated that for a given body mass more mature boys had a greater peak  $\text{VO}_2$  than immature boys (Williams et al., 1992). In girls, according to a previous study performed in our laboratory, peak  $\text{VO}_2$  may decrease in the final stages of sexual maturation in association with the increased adipose tissue (Laaneots, Karelson, & Viru, 1996). The purpose of the present study was to verify the possibility that peak  $\text{VO}_2$  reduces at the advanced sexual maturation in girls. The additional research task was to compare the  $\text{VO}_2$  changes concomitant with maturation with any possible alterations of the anaerobic threshold, an index of skeletal muscles oxidative capacity (Madar, 1991).

## Methods

Thirty-one girls, of the age range of 11 to 15 years, volunteered to participate in the study and gave their informed consent. The school physician considered all girls healthy. Any physical activity of the subjects was mainly related to the physical education classes twice a week.

Body height and body mass were measured and the stage of sexual maturation was assessed according to Tanner (1962). The girls were divided into three sexual maturation groups: prepubertal girls – sexual maturation stage I, pubertal girls – sexual maturation stage II, III or IV, and postpubertal girls – sexual maturation stage V. All prepubertal girls and three pubertal girls of stage II were premenarcheal. Pubertal girls of stage III and IV, as well as all postpubertal girls menstruated regularly.

The peak  $\text{VO}_2$  and the ventilatory threshold were determined in the incremental bicycle ergometer test (Pärnat, Viru, & Nurmekivi, 1975). At the first 3-min exercise stages the power output

was 50 and 100 W. Later the power output increased by 20 W every three-minutes. The pedalling rate was 60 revolutions per minute. After each girl had reached her highest intensity level that she was able to maintain during three minutes, a one-minute spurt followed at the highest possible rate of pedalling. During the spurt the resistance for pedalling was the same as at the power output stage of 120 W, when the pedalling rate was 60 revolutions per minute. Oxygen uptake, lung ventilation and heart rate were recorded using a gas analyzer AG 0011-0012 (Võru, Estonia) and sport-tester Polar P-3000 (Finland). The ventilatory threshold was calculated according to the studies of Caiozzo and associates (1992) and Wasserman and associates (1973). The point of breakdown of linearity between the exercise intensity and lung ventilation (the onset of pronounced incline in lung ventilation) was considered to be the ventilatory threshold.

The statistical analysis of the results was performed using one-way ANOVA with a post hoc evaluation of differences between the groups. The differences were considered statistically significant at  $p < 0.05$ .

## Results

Prepubertal, pubertal and postpubertal girls differed by age, body height and body mass (Table 1). Peak  $\text{VO}_2$  (l/min) was higher in pubertal vs. prepubertal girls, but not in postpubertal vs. pubertal girls. Relative  $\text{VO}_2$  max did not differ between the prepubertal and pubertal girls but was decreased in the postpubertal in comparison with other groups.

Power output, lung ventilation and heart-rate at the ventilatory threshold did not differ between the groups of diverse sexual maturation status.

Table 1. Body measures and work capacity indices in prepubertal, pubertal and postpubertal girls (mean  $\pm$  SD)

	Prepubertal girls N=10	Pubertal girls N= 10	Postpubertal girls N=11
Sexual maturation (stage by Tanner)	I	II - IV	V
Age (years)	12.1 $\pm$ 0.6	13.7 $\pm$ 0.5*	14.8 $\pm$ 0.3*
Body height (cm)	153 $\pm$ 6.6	161 $\pm$ 10.7	167 $\pm$ 5.6
Body mass (kg)	40.3 $\pm$ 8.8	49.2 $\pm$ 8.5*	56.8 $\pm$ 7*
Body mass index	17.2	18.8	20.4
Peak $\text{VO}_2$ (l/min)	1.72 $\pm$ 0.32	1.89 $\pm$ 0.44*	1.88 $\pm$ 0.46
Relative $\text{VO}_2$ max (ml/min· kg)	43 $\pm$ 7.3	39 $\pm$ 9.8	34 $\pm$ 5.9*
<i>At the ventilatory hreshold:</i>			
Power output (W)	123 $\pm$ 2	130 $\pm$ 14.2	131 $\pm$ 10.2
Lung ventilation (l/min)	39.4 $\pm$ 7.0	44.0 $\pm$ 7.9	43.5 $\pm$ 8.6
Heart rate (bpm)	189 $\pm$ 17.4	180 $\pm$ 22.1	176 $\pm$ 20.8

\* Statistically significant difference from the value of the previous group ( $>0.05$ )

## Discussion and conclusion

The obtained results confirmed the outcome of a previous study (Laaneots, Karelson, & Viru, 1996) that peak values of  $\text{VO}_2$  reduce during the late stages of sexual maturation. In girls, when age, body height and body mass were controlled, the significant increase in peak  $\text{VO}_2$  found in male adolescent athletes was not observed in young female athletes (Baxter-Jones, Goldstein, & Helms, 1993). Obviously, in female athletes the training effect on aerobic capacity compensates the reduction of peak  $\text{VO}_2$  due to the influence of gain in body mass at advanced sexual maturation. The present results confirmed that the reduction of peak  $\text{VO}_2$  coincides with the pronounced increase in body mass. At the sexual maturation stages IV results of Cooper 12-min running test were worse than at stage III in association with the increased body mass (Volver & Viru, 1995) and subcutaneous adipose tissue (Volver & Viru, 1997). In the pre-

sent study, the computed body mass index (body mass/body height) increased with maturation (mean index for prepubertal girls 17.2, for pubertal girls 18.8, and for postpubertal girls 20.4), indicating that the gain of body mass was more pronounced than the increase of stature.

We failed to establish a sexual maturation effect on the ventilatory threshold. It is assumed that the anaerobic threshold depends first of all on the oxidative capacity of skeletal muscles (Madar, 1991). Consequently, the decreased aerobic capacity was not related with any impairment of the oxidative capacity of muscles.

To conclude, in girls, advanced sexual maturation may be associated with a reduction of the relative maximum  $\text{VO}_2$  when their gain of body mass is more pronounced than an increase of body height. According to the constant values of the anaerobic threshold, decreased  $\text{VO}_2$  in female adolescents is, obviously, not related to impairment of the oxidative capacity of skeletal muscles.

## References

- Armstrong, N., Williams, J., Balding, J., Gentle, P., & Kirby, B. (1991). The peak oxygen uptake of British children with reference to age and sexual maturation. *European Journal of Applied Physiology*, *62*, 369-375.
- Baxter-Jones, A., Goldstein, H., & Helms, P. (1993). The development of aerobic power in young athletes. *Journal of Applied Physiology*, *75*, 1160-1167.
- Caiozzo, V.J., Davil, J.A., Azus, J.L., Vandagriff, R., Prietto, C.A., & McMaster, W.C. (1982). A comparison of gas exchange indices used to detect the anaerobic threshold. *Journal of Applied Physiology*, *53*, 1184-1189.
- Falgairrette, G., Bedu, M., Fellman, N., Van-Praag, E., & Coudert, J. (1991). Bioenergetic profile in 144 boys aged 6 to 15 years with special reference to sexual maturation. *European Journal of Applied Physiology*, *62*, 151-156.
- Krahenbuhl, G.S., Skinner, J.S., & Kohrt, W.M. (1985). Development aspects of maximal aerobic power in children. *Exercise and Sport Sciences Reviews*, *13*, 503-538.
- Laaneots, L., Karelson, K., & Viru, A. (1996). Relation of aerobic capacity to stage of sexual maturation. *Biology of Sport*, *13*, 137-144.
- Mader, A. (1991). Evaluation of the performance of marathon runners and theoretical analysis of the test results. *Journal of Sports Medicine and Physical Fitness*, *31*, 1-19.
- Pärnat, J., Viru, A., & Nurmekivi, A. (1975). Repeated assessment of aerobic and anaerobic work capacity of runners. *Journal of Sports Medicine and Physical Fitness*, *15*, 13-19.
- Tanner, J.M. (1962). *Growth at Adolescence*. 2<sup>nd</sup> edition Oxford: Blackwell Sci Publ.
- Volver, A., & Viru, A. (1995). Improvement of motor fitness in relation to sexual maturation in 10 to 14 year old girls. *Biology of Sport*, *12*, 91-102.
- Volver, A., & Viru, A. (1997). Motor development related to sexual maturation in 11- to 14-year-old girls. *Biology of Sport*, *14*, 205-211.
- Wasserman, K., Whipp, B., Koyal, S.N., & Blaver, W.I. (1973). Anaerobic threshold and respiratory gas exchange during exercise. *Journal of Applied Physiology*, *35*, 236-243.
- Williams, J.R., Armstrong, N., Winter, E.M., & Crichton, N. (1992). Changes in peak oxygen uptake with age and sexual maturation in boys: Physiological fact or statistical anomaly. In J. Coudart, & E. Van Praag (Eds.), *Children and Exercise XVI* (pp. 35-37). Paris: Mason.

## SMANJENJE RELATIVNOG MAKSIMALNOG PRIMITKA KISIKA KOD DJEVOJČICA U KASNIJOJ FAZI SPOLNOG SAZRIJEVANJA

### Sažetak

#### Uvod

Neka su istraživanja pokazala da vrijednost relativnog  $VO_2$ max ne ovisi o spolnom sazrijevanju dječaka. Međutim, opažanja te pojave u djevojčica pokazala su da je vrijednost  $VO_2$ max niža u kasnijim fazama spolnog sazrijevanja nego li u spolno manje zrelih djevojčica (Laaneots i sur., 1996). Cilj ovog istraživanja bio je provjeriti smanjuje li se relativni maksimalni primitak kisika s napredovanjem spolnog sazrijevanja u djevojčica.

#### Metoda

Uzorak ispitanica činila je 31 djevojčica u dobi od 11 do 15 godina. Uzorak je prema Tannerovoj ljestvici podijeljen na podgrupu prepubertetskih (faza I), pubertetskih (faza II, III, IV) i postpubertetskih djevojčica (faza V). Maksimalni  $VO_2$  i ventilacijski prag procjenjivani su progresivnim testom na biciklergometru.

#### Rezultati

Vrijednost maksimalnog  $VO_2$  (l/min) bila je viša u pubertetskih nego prepubertetskih djevojčica ( $1.89 \pm 0.44$  nasuprot  $1.72 \pm 0.32$ ). Razlika između pubertetskih i postpubertetskih djevojčica ( $1.88 \pm 0.46$ ) nije bila statistički značajna. Nije se pokazala statistički značajna razlika

u vrijednosti relativnog maksimalnog primitka kisika između prepubertetskih ( $43 \pm 7.3$ ) i pubertetskih ( $39 \pm 9.8$ ) djevojčica. Međutim, ta vrijednost u postpubertetskih djevojčica ( $34 \pm 0.46$ ) bila je oko 13% niža nego u djevojčica u pubertetu ( $p < 0.05$ ). Povećanje indeksa tjelesne mase (sa 18.8 na 20.4 u prosjeku) pokazalo je da je u petoj (V) fazi spolnog sazrijevanja povećanje tjelesne mase relativno više istaknuto nego tjelesni rast u visinu. Tako je vidljivo da korelacija između veličine tijela i maksimalnog  $VO_2$  nakon ulaska u petu fazu spolnog sazrijevanja prestaje. Ne postoji statistički značajna razlika između grupa ispitanica s obzirom na vrijednost ventilacijskog praga. Dok je anaerobni prag prije svega određen oksidativnim kapacitetom mišića, smanjenje relativnog maksimalnog  $VO_2$  u djevojčica u kasnijoj fazi spolnog sazrijevanja nije bilo povezano s promjenama oksidativnog mišićnoga kapaciteta.

#### Zaključak

U djevojčica se spolno sazrijevanje povezuje sa smanjenjem relativnog maksimalnog primitka kisika, što se javlja paralelno s povećanjem tjelesne mase u odnosu na povećanje visine. Prema konstantnim vrijednostima anaerobnog praga, smanjenje relativnog  $VO_2$ max u djevojčica u naprednoj fazi spolnog razvoja očigledno nije bilo povezano sa smanjenjem oksidativnog mišićnoga kapaciteta.

Submitted: May 10, 2003

Accepted: December 2, 2003

Correspondence to:

Prof. Atko-Meeme Viru, Ph.D.

Institute of Exercise Biology, University of Tartu

Ylikooli 18,

51014 Tartu, Estonia

Phone: +372 5 115132

Fax: +372 7 375367

E-mail: viru@ut.ee