

AEROBIC PERFORMANCE IN YOUNG GIRLS DURING A MAXIMAL LABORATORY TREADMILL TEST: DIFFERENCES BETWEEN ATHLETES AND NON-ATHLETES

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RESUMO

O objetivo do estudo foi analisar as diferenças no Pico VO₂ entre nadadoras jovens em comparação com raparigas sem prática desportiva. O grupo de nadadoras foi composto por 6 raparigas pré-púberes (9,8 anos) e 10 púberes (11,3 anos), e o grupo de controlo por 6 raparigas pré-púberes (9,8 anos) e 10 púberes (11,2 anos) não-atletas. O Pico VO₂ foi mensurado com análise direta de gases, respiração-por-respiração (Cosmed K4b2, Roma, Itália), durante um protocolo incremental em passadeira até a exaustão. A normalidade (Shapiro-Wilks) e homogeneidade (Levene) foram assumidas. O One-Way análise de variância (ANOVA) e LSD Post-Hoc foram usados (SPSS, versão 17.0), com um nível de significância de $p < 0,05$. O Pico VO₂ relativo foi significativamente superior ($p = 0,010$) nas nadadoras pré-púberes comparativamente com as não-atletas pré-púberes ($60,6 \pm 9,1 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ vs. $43,6 \pm 8,9 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$; $p = 0,003$), e nas nadadoras púberes comparativamente com as não-atletas púberes ($60,9 \pm 5,0 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ vs. $49,5 \pm 7,7 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$; $p = 0,010$). Esses resultados foram consistentes com as observações de valores superiores de Pico VO₂ em raparigas envolvidas num desporto comparativamente com os seus pares não treinados. Assim, o Pico VO₂ superior nas nadadoras pré-púberes e púberes poderá dever-se às diferenças na prática desportiva entre os grupos.

Palavras Chave: Desempenho aeróbio, Pico VO₂, nadadoras jovens.

ABSTRACT

The aim of the study was to analyse the differences in the Peak VO_2 between young girls swimmers compared with girls without sport practice. The swimmers group was composed by 6 prepubertal (9.8 years) and 10 pubertal (11.3 years) girls, and the control group by 6 prepubertal (9.8 years) and 10 pubertal (11.2 years) girls non-athletes. The Peak VO_2 was measured during an incremental treadmill protocol until exhaustion with direct gas analysis, breath-by-breath (Cosmed K4b², Rome, Italy). Normality (Shapiro-Wilks test) and homogeneity (Levene's test) were assumed. The one-way analysis of variance (ANOVA) and LSD Post-Hoc was used (SPSS, version 17.0), with a significance level of $p < 0.05$. Relative Peak VO_2 was significantly higher in prepubertal swimmers compared with the prepubertal non-athletes ($60.6 \pm 9.1 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ vs. $43.6 \pm 8.9 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$; $p = 0.003$), and in pubertal swimmers than in pubertal non-athletes ($60.9 \pm 5.0 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ vs. $49.5 \pm 7.7 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$; $p = 0.010$). Those results were consistent with the observations of higher values of Peak VO_2 in young girls involved in sport compared with their untrained peers. Thus, the higher Peak VO_2 in prepubertal and pubertal swimmers might be due to the differences in sport practice.

Keywords: Aerobic performance, Peak VO_2 , young girl swimmers.

INTRODUCTION

The aerobic fitness can be defined as the blood ability to carry the oxygen (O_2) to the muscles and its use to generate the energy that enables muscle contraction during exercise (Armstrong & Fawcner, 2007; Armstrong & Welsman, 2008; Armstrong, McManus, & Welsman, 2008; Armstrong, Tomkinson, & Ekelund, 2011; Armstrong, 2014). One of the most important indicators of the aerobic fitness is the maximal aerobic power, which is related to the maximum amount of chemical energy that can be transformed, by oxidative processes in the muscle mitochondria per unit time (Malina, Bouchard, & Bar-Or, 2004; Kenney, Wilmore, & Costill, 2012).

The maximal oxygen uptake ($\text{VO}_{2\text{m}\acute{\text{a}}\text{x}}$) is the highest rate at which an individual can consume O_2 during exercise and is known as the best measure of maximal aerobic power in adults (e.g., Petot, Meilland, Moyec Le Mille-Hamard, & Billat, 2012), limiting the rate at which O_2 can be used during aerobic exercise (Armstrong *et al.*, 2011). However, the Peak VO_2 is the highest VO_2 value obtained during a maximal test and is considered the best indicator of

aerobic fitness, more specifically of maximal aerobic power in children and adolescents (Dencker, Thorsson, Karlsson, Lindén, Wollmer, & Andersen, 2008; Armstrong *et al.*, 2008, 2011; Armstrong, 2013).

In one hand the Peak VO₂ in children and adolescents is well documented (Armstrong & Fawkner, 2007; Armstrong *et al.*, 2008, 2011) and a higher Peak VO₂ is a prerequisite of elite performance in various sports (Armstrong & Welsman, 2008; Armstrong *et al.*, 2011; Barker & Armstrong, 2011). On the other hand, a low Peak VO₂ is associated with the prevalence of diseases (Loftin, Sothorn, Warren, & Udall, 2004; Carvalho *et al.*, 2013; Wijnstok, Hoekstra, van Mechelen, Kemper, & Twisk, 2013).

The Peak VO₂ is highly correlated with body mass, so it is generally expressed per unit of body mass, in relative terms (kg·mL⁻¹·min⁻¹), being relevant in the context of sport in which the weight is supported or moved during exercise (Armstrong, 2013, 2014).

The absolute Peak VO₂ (L·min⁻¹) increases with age around 80% in girls between 8 and 16 years, although the relative Peak VO₂ showed a decrease from 45 mL·kg⁻¹·min⁻¹ to 35 mL·kg⁻¹·min⁻¹ approximately, in the same period (Armstrong & Welsman, 1994; Bar-Or & Rowland, 2004; Malina *et al.*, 2004; Armstrong *et al.*, 2008; Armstrong, 2013, 2014).

The participation of prepubertal and pubertal female athletes in sport raises questions about the understanding of the physiological responses to training (McManus & Armstrong, 2011). There is a scarcity of studies that analyze the maximal aerobic power in girls athletes than in boys. Thus, the aim of this study was to evaluate the peak VO₂ in prepubertal (S1) and pubertal (S2) girls swimmers and in prepubertal (C1) and pubertal (C2) girls not involved in any regular sport practice. Cross-sectional studies have reported that young athletes possessed a higher relative Peak VO₂ (mL·kg⁻¹·min⁻¹) than their untrained peers (Barker & Armstrong, 2011; Armstrong *et al.*, 2011; Barker, Williams, Jones, & Armstrong, 2011; Armstrong, 2014), specifically in young girls swimmers (McNarry, Welsman, & Jones, 2011).

METHOD

Participants

Participated in the study thirty-two young girls divided in two groups according to the sport practice. The swimming group was formed by 6 prepubertal (S1) and 10 pubertal (S2) girls swimmers, with an average of 2.2±0.4 and 2.7±0.5 years of training practice and competition, respectively. The control group was composed by 6 prepubertal (C1) and 10

pubertal (C2) girls without regular sport practice. The physical characteristics of the participants are shown in Table 1.

After being informed about the objectives and procedures involved, parents or guardians of the participants signed an informed consent and all participants were volunteers giving their assent to participate in the study (Jago & Bailey, 2001).

The study was approved by the scientific committee of the University of Madeira and the Sport Sciences School of Rio Maior, Polytechnic Institute of Santarém. The study was conducted in accordance with the Declaration of Helsinki, fulfilling the ethical principles for research on humans (World Medical Association, 2013).

Table 1. Physical characterization of the participants.

Variables	S1 (n=6)	S2 (n=10)	C1 (n=6)	C2 (n=10)
Age (yr)	9.8 ± 0.6	11.3 ± 0.7	9.8 ± 0.4	11.2 ± 0.8
Height (cm)	140.4 ± 3.9	152.7 ± 5.4	141.8 ± 5.5	150.0 ± 6.8
Weight (kg)	33.0 ± 4.4	46.4 ± 6.8	37.2 ± 9.5	41.1 ± 7.2
Tanner's stage	1 ± 0	3.4 ± 0.5	1 ± 0	3.5 ± 0.5

Note. yr – years; cm – centimetres; kg – kilograms; m – meters.

Experimental Procedures

The data collections were performed at the Laboratory for Research in Sports of the Sport Sciences School of Rio Maior – Institute Polytechnic of Santarém, with a room temperature around 20° C and 50% of humidity (Gore, Tanner, Fuller, & Stanef, 2013). The study was a quasi-experimental design with non-equivalent groups (Trochim, 2006).

The protocols proposed by the International Society for the Advancement of Kinanthropometry (ISAK), described by Fragoso and Vieira (2011) and Slater, Woolford, and Marfell-Jones (2013) were used for the anthropometric evaluation.

The assessment of biological maturation of the participants, through self-rating (Baxter-Jones, Eisenmann, & Sherar, 2005; Baxter-Jones & Sherar, 2007; Malina & Beunen, 2008), was done based on the developmental stages of pubic hair described by Tanner (1962), using the schematic illustrations and descriptive criteria for each stage (adapted from Malina *et al.*, 2004).

Instructions were given to participants about the objectives, protocol and experimental procedures, including safety rules. There was also a period for testing the instruments and

encouragement during the test, mainly during the last few minutes (Malina *et al.*, 2004; Gore *et al.*, 2013).

The Peak VO_2 was measured with direct gas analysis, breath-by-breath (Cosmed K4b², Rome, Italy), during an incremental treadmill protocol (modified Balke), where the participants ran until exhaustion (volitional fatigue or maximum criterion was achieved), on the Technogym Runrace Treadmill HC1200 (Italy). The modified Balke test (Heyward, 2006), consisted of a warm-up performed at $3 \text{ km}\cdot\text{h}^{-1}$ of velocity and 0% grade during 3 minutes. Stage 1 was set at $6 \text{ km}\cdot\text{h}^{-1}$ and 4% grade during 2 minutes, and the following stages were increasing $2 \text{ km}\cdot\text{h}^{-1}$ and 2% of grade until exhaustion. The recovery stage was set at $3 \text{ km}\cdot\text{h}^{-1}$ and 0% of grade during 3 minutes.

The calibration procedures of the gas analyzer Cosmed K4b² were as follows (according to manufacturer's guidelines): room air; reference gas (16% O_2 and 5% CO_2); delay (gas transition time); and turbine (with a 3000 ml syringe).

The criteria used to guarantee the attainment of Peak VO_2 was: a respiratory exchange ratio value greater than 1.0; achieve the maximal heart rate estimated (using the formula of Tanaka, Monahan, & Seals, 2001); plateau in VO_2 (increase of not more than $2 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) despite an increase in work rate; and the volitional fatigue of the participant, that is, if cannot follow the required speed despite continuous encouragement of the investigators (Malina *et al.*, 2004; Dencker *et al.*, 2008; Armstrong & Welsman, 2008; Hebestreit & Beneke, 2008; Gore *et al.*, 2013).

Data was recorded using a telemetric system. After each test, the data was filtered (program Cosmed K4b², version 9.1b) and values averaged every 15 seconds (Barker *et al.*, 2011; Barker, Day, Smith, Bond, & Williams, 2014), and the maximum values were selected for analysis.

Statistical Analysis

Descriptive data are presented as mean \pm standard deviation. Normality (Shapiro-Wilks test) and homogeneity (Levene's test) were satisfied for a significance level of 0.05. The one-way analysis of variance (ANOVA), with the Tukey HSD post-hoc, was used to compare the groups. Statistical analysis was performed in the Statistical Package for Social Sciences (SPSS) version 17.0, and the level of significance was set at 5%.

RESULTS

Table 2 presents the dependent physiological variables on the prepubertal and pubertal girls swimming and girls non-athletes.

Table 2. Variables of the maximal oxygen consumption test.

Variables	S1 (n=6)	S2 (n=10)	C1 (n=6)	C2 (n=10)	F	p
Absolute Peak VO ₂	2.0 ± 0.5	2.8 ± 0.2	1.6 ± 0.2	2.0 ± 0.4	16.324	<0.001
Relative Peak VO ₂	60.6 ± 9.1	60.9 ± 5.0	43.6 ± 8.9	49.5 ± 7.7	9.486	<0.001
Peak RER	1.2 ± 0.1	1.1 ± 0.1	1.0 ± 0.1	1.1 ± 0.1	2.383	0.091
Peak HR	201 ± 4.5	195 ± 7.9	196 ± 15.5	198 ± 9.1	0.577	0.636

Note. Absolute Peak VO₂ – absolute peak oxygen consumption (L·min⁻¹); Relative Peak VO₂ – relative peak oxygen consumption (mL·kg⁻¹·min⁻¹); Peak RER – peak respiratory exchange ratio; Peak HR – peak heart rate (bts·min⁻¹).

The absolute Peak VO₂ (L·min⁻¹) was significantly higher in S2 compared with S1 ($p=0.002$), C1 and C2 ($p<0.001$), but no differences were found between S1 and C1 ($p=0.156$) and between S1 and C2 ($p=1.000$), and between C1 and C2 ($p=0.086$).

The S1 obtained a significantly higher relative Peak VO₂ (mL·kg⁻¹·min⁻¹) compared with C1 ($p=0.003$) and C2 ($p=0.036$). The S2 presents a significantly higher relative Peak VO₂ compared with C1 ($p=0.001$) and C2 ($p=0.010$). In this variable, no differences were found between S1 and S2 ($p=1.000$), neither between C1 and C2 ($p=0.432$).

No significant differences were found in the peak respiratory exchange ratio and peak heart rate between the groups (Table 2).

DISCUSSION

This study was made to analyze the differences in the maximal aerobic power between children and adolescent girls swimmers with children and adolescent non-athletes. The main finding of this study was that prepubertal and pubertal girls swimmers showed a significantly higher relative Peak VO₂ (mL·kg⁻¹·min⁻¹), compared with prepubertal and pubertal girls non-athletes. Those results were in agreement with the fact that children and young girls involved in sport generally obtain a higher Peak VO₂ than their untrained peers (Armstrong *et al.*, 2011; Barker & Armstrong, 2011; Barker *et al.*, 2011; Armstrong, 2014). Those results might be due to the differences in sport practice between the groups, more specifically with the years of training practice and competition in the swimmers groups.

However, this study is limited to the fact that the sample was not representative of all the girls swimmers in the population (Trochim, 2006). In addition, as it is a cross-sectional study was limited to the knowledge of those differences in Peak VO₂ were associated with training or may be due to the initial selection for that sport (Armstrong, 2014).

In prepubertal swimmers the results from the absolute Peak VO₂ (L·min⁻¹) were smaller and in pubertal girls were higher than the results from the study of McNarry *et al.* (2011), although in that study this variable was evaluated in a cycle ergometer test.

Analyzing the results of the relative Peak VO₂ (mL·kg⁻¹·min⁻¹) with the literature, the present results were higher than those observed by Sperlich *et al.* (2010) in prepubertal girls and boys swimmers (analyzed as a single group), and by McNarry *et al.* (2011) in prepubertal and pubertal girls swimmers, but in those studies that variable was also evaluated in a cycle ergometer test.

The prepubertal and pubertal girls without sport practice presented similar results when compared with the literature of girls with the same age (Winsley, Fulford, Roberts, Welsman, & Armstrong, 2009; McGawley, Leclair, Dekerle, Carter, & Williams, 2012) or the same maturational status (McNarry *et al.*, 2011) derived from a cycle ergometer test. The results were also similar with results of the prepubertal and pubertal girls not involved in any sport practice from the treadmill assessment of the maximal aerobic power (McManus, Armstrong, & Williams, 1997; Williams, Armstrong, & Powell, 2000; Welsman & Armstrong, 2000; Armstrong & Welsman, 2001). Prepubertal and pubertal girls non-athletes might benefit from a regular sport practice to improve their Peak VO₂ (Balyi & Williams, 2009).

CONCLUSION

We may conclude that it was observed a higher relative Peak VO₂ (mL·kg⁻¹·min⁻¹) in the prepubertal and pubertal girls swimmers than in the non-athlete girls, however no significant differences were found in the relative Peak VO₂ by maturational status when considering the same group. Those differences seem to be due to the distinct sport practice between the groups.

The variables of the maximal oxygen consumption test and the findings of the study bring valuable information for the coach as a general measure of the maximal aerobic power. Although, future studies should evaluate the maximal aerobic power from sport specific

tests, considering the differences in maturational status and the differences across the season.

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