Peak oxygen uptake of healthy Iranian adolescents

Babak Amra[1], Roya Kelishadi[2], Mohammad Golshan[3]

[1]Respiratory Research Centre, Isfahan University of Medical Sciences, Isfahan, Iran
[2]Preventive Paediatric Cardiology, Isfahan Cardiovascular Research Centre, Isfahan University of Medical Sciences, Isfahan, Iran
[3]Isfahan University of Medical Sciences, Bamdad Respiratory Research Centre, Isfahan, Iran

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Corresponding author:
Babak Amra, MD
Respiratory Research Centre
Isfahan University
of Medical Sciences
Isfahan, Iran
Bamdad Building No. 11
Sheikh Mofid St
8164763831
Phone: +98 311 66 37 177
Fax: +98 311 66 23 967
E-mail:
amra@med.mui.ac.ir

Abstract

Introduction: Maximal oxygen uptake (VO_{2max}) has an important place in the assessment of cardiopulmonary fitness. Currently there is insufficient normative data for Iranian adolescents. With this preliminary study, we aimed to set up the first normative data for our laboratory which may also serve as a basis for future large population-based studies in Iran.
Material and methods: We assessed the peak oxygen consumption of 95 healthy Iranian adolescents, aged 13-17 years, and examined the cardiopulmonary responses to exercise test in relation to their age, sex and body size. Between June and September 2007, the level of aerobic capacity was evaluated by maximal oxygen consumption (VO_{2max}), which was calculated using the exercise test on a bicycle ergometer.
Results: During a four-month period, the cardiopulmonary exercise test was conducted on a population-based sample of 95 adolescents (44 boys and 51 girls). The mean age and body mass index were 15.59 ±1.85 years and 23.46 ±5.05 kg/m^2, respectively. The VO_{2max} of boys was significantly higher in boys than in girls (16.71 ±8.72/12.48 ±6.25 ml/kg/min respectively, p = 0.001).
Conclusions: The current study presents normal data for a small representative sample of healthy Iranian adolescents. VO_{2max} in our study was in the poor to average range when compared to the standard values of other populations. This information should prompt policy makers and medical educators to address this problem, and to consider promoting exercise and integrating physical fitness into the school curriculum.

Key words: maximal oxygen uptake, adolescents, cardiopulmonary exercise test, Iran.

Introduction

Maximal oxygen uptake (VO_{2max}) is considered to be the best index of cardiopulmonary fitness [1]. It is the highest rate of oxygen consumption by the body in a given period of time during vigorous dynamic exercise involving a large portion of muscle mass [2]. Pulmonary, cardiovascular and haematological components of oxygen delivery and the oxidative mechanisms of the exercising muscle are the main factors for VO_{2max}. Regular physical activity is generally considered to be an important factor in the growth and the development of both healthy children and those affected by chronic disease [3].

It is documented that ethnic differences are important determinants of cardiopulmonary function. Applying adequate reference values is essential for the correct interpretation of the data from functional tests. Deriving an appropriate reference equation requires inclusion of anthropometric parameters and age [4]. This problem is of considerable significance in the paediatric age group because of the great dynamics in anthropometric characteristics and the corresponding functional parameters [4].

During the period of transition from adolescence to adulthood, many structural, hormonal and biochemical changes to physiology take place which interfere with VO_{2max} [5]. Hence it is necessary to establish specific VO_{2max} values for this population. The international literature offers reference values for healthy children and adolescents [5]. Nevertheless, data for classifying this parameter, sourced from the Iranian population, are still lacking.

In consideration of the importance of VO_{2max} measurement for the classification of physical fitness, and also for advice on exercise, this study aimed to establish mean VO_{2max} values from a representative population-based sample of Iranian adolescents and to assess its differences in terms of gender.

Material and methods

Participants

This cross-sectional study was carried out between June and September 2007, with schoolchildren selected by multistage random cluster sampling from public schools in Isfahan (Iran), within the age range of 13 to 17 years. History taking and a physical examination with careful notation excluded those children with any chronic disease or disability that would limit their activity.

The selected adolescents were invited to take part in the study. All tests were conducted in the Cardiopulmonary Testing Laboratory at the Bamdad Respiratory Research Centre, Pulmonary Function Test Department in Isfahan.

Oral consent was obtained from adolescents and written informed consent from their parents. The consent included details of benefits, risks and procedures involved. The study protocol was approved by the Research Ethics Committee of Isfahan Cardiovascular Research Centre, Isfahan University of Medical Sciences. The adolescents' chronological ages were determined centesimally, with date of data collection and date of birth as references.

Anthropometric measurements

Body weight (Wt) was measured with light clothing using an anthropometric balance, accurate to 100 g and with a maximum capacity of 150 kg, while barefoot height (Ht) was measured with a stadiometer with 0.1 cm divisions, in accordance with accepted standards. These two variables were then used to calculate body mass index (BMI) as Wt (kg)/Ht^2 (m).

Cardiopulmonary exercise testing (CPET) protocol

Exercise testing

The instructions given to participants were similar to the routine instructions sent to patients coming to the cardiopulmonary exercise laboratory of Bamdad Respiratory Research Centre for clinical exercise testing [6]. Symptom-limited CPET was performed using an electrically braked cycle ergometer (model 800; Zan, Germany). Cardiopulmonary exercise testing was performed under pulmonologist supervision by an experienced technician with defined criteria for stopping, such as serious cardiac arrhythmias, hypotension and electrocardiogram (ECG) changes or severe oxygen desaturation. Resuscitation equipment and a defibrillator were always available during tests.

An incremental exercise protocol was used in which the work rate was increased by a fixed amount between 10 and 30 Watts (w) every minute after an initial 3 min of unloaded pedalling. The work rate increment for each individual was selected to enable the subject to reach his or her estimated VO_{2max} in 10 min. Standard 12-lead ECGs (Zan, Germany) were obtained at rest, every 3 min during exercise, at peak exercise and for 5 min into the recovery phase, while blood pressures were measured using a standard cuff sphygmomanometer at similar intervals. Participants wore a tight-fitting facemask connected to a turbine volume transducer. Measurements of mixed expired oxygen, mixed expired carbon dioxide and expired volume were determined at rest and for each breath throughout exercise using a metabolic cart (Zan, Germany). The gas analyzer (Zan, Germany) was calibrated for both accuracy and linearity prior to each test. Oxygen uptake (VO_2 in ml/min, standard temperature and pressure, dry), carbon dioxide production (VCO_2 in ml/min), gas exchange ratio, minute ventilation (VE in l/min, BTPS), respiratory rate (RR), tidal volume (VT) and the ventilatory equivalent for carbon dioxide (V E/VCO_2) were determined and averaged every 30 s. Oxygen saturation (SaO_2) and heart rate were recorded *via* pulse oximetry (Zan, Germany) and ECG, respectively, continuously throughout exercise and during recovery. Maximal exercise was defined as the fulfilment of at least two of the following three conditions:

(i) failure of VO_2 to rise with increasing work load of exercise,

(ii) respiratory gas exchange ratio greater than 1.15, or

(iii) heart rate within 15 b.p.m. of the predicted maximal heart rate (HR_{max}).

The VO_{2max}, maximal expired ventilation (VE_{max}), HR_{max} and maximal oxygen pulse (VO_{2max}/HR_{max}) were selected as the highest values obtained from any 30 s measurement period [7].

Statistical analysis

Data were stored in a computer database, and were analyzed with SPSS statistical software (SPSS, Inc. Chicago, IL) version 15.

The covariates considered in the proposed equations for VO_{2max} and WR_{max} were age (years), gender, height (cm) and weight (kg).

All statistical tests were conducted at a 5% level of significance.

Results

The anthropometric measures of study participants are shown in Table I. They ranged from 157 to 180 cm in height (mean: 163.85 ±9.01) and from 58 to 74 kg in weight (mean: 63.36 ±16.01) and with mean age of 15.59 years. Height and weight were found to be normally distributed in the study population. The VO_{2max} and VE_{max} (l/min) were significantly higher in boys than in girls (p = 0.001 and p = 0.04 respectively). Whereas HR max was higher in girls than boys (p = 0.03). Systolic and diastolic blood pressure had no significance difference in terms of gender (p = 0.31 and p = 0.39 respectively) (Table II).

Prediction formulae were derived for VO_{2max}, HR_{max} and VE_{max} (Table III). Figure 1 presents changes in VO_{2max} of boys and girls with respect to age changes, and Figure 2 presents these changes according to height changes.

Discussion

Since many factors such as, age, sex, height and habitual physical activity influence $V'_{O2,peak}$, it is recommended that the normalcy (or otherwise) of the measured exercise capacity be judged by comparing with reference values for matched healthy populations. Values smaller than the prediction by more than 1.96 times the SD should be considered abnormal with a confidence of 95%. Values less than 40% predicted indicate severe impairment [8].

Normal values for important variables derived from clinical non-invasive cycle ergometer testing of Iranian adolescents were obtained for the first time in the present study.

The peak VO_2 of the Iranian adolescents was found to be lower than those reported for Indian and Western countries [9].

Most studies of maximum exercise performance in healthy populations have quantified age, gender and body size. However, when comparing equations that include these covariates, marked differences in predicted values may occur and the impact of different sets of reference values on maximal CPET interpretation can be considerable [10]. Discrepancies may result from analytical bias, different weighting in the population of the variables or the contribution of other variables not included in the analysis and, often, the cause

Table I. Anthropometric characteristics of participants

Characteristics	Boys (n = 44)	Girls (n = 51)	Total (n = 95)	p-value
Age [year]	15.62 ±2.06	15.57 ±1.71	15.59 ±1.85	0.91
Weight [kg]	66.21 ±18.43	61.47 ±14.05	63.36 ±16.01	0.21
Height [cm]	168.06 ±11.01	161.04 ±6.03	163.85 ±9.01	< 0.001
BMI [kg/m^2]	23.27 ±5.49	23.59 ±4.78	23.46 ±5.05	0.78

Values are expressed as mean ± SD, BMI – body mass index, n – number

Table II. Cardiopulmonary responses at maximal exercise in adolescents

	Boys	CV [%]	Girls	CV [%]	p value
VO_{2max} [l/min]	1.11 ±0.51	46	0.77 ±0.36	47	< 0.001
VO_{2max} [ml/kg × min]	16.71 ±8.72	52	12.48 ±6.25	50	0.02
HR_{max} [b.p.m]	149.21 ±20.95	14	159.67 ±22.28	14	0.03
SBP	109.85 ±12.30	11	105.42 ±16.01	15	0.31
DBP	70.75 ±9.07	13	67.83 ±13.24	20	0.39
VE_{max} [l/min]	30.45 ±13.18	43	24.37 ±12.94	53	0.04

Values are expressed as the mean ± SD, VO_{2max} – maximal oxygen uptake, BW – body weight, HR_{max} – maximal heart rate, VE_{max} – maximal minute ventilation, SBP – systolic blood pressure, DBP – diastolic blood pressure, CV – coefficient of variance of these differences is not clear [10]. The difference in predicted values of exercise capacity derived from studies conducted in Western countries and studies on Iranian subjects requires further elucidation. One possibility is that the differences in predicted values are due to differences in methodology of testing as used by different centres. Given that predictions

Table III. Predictive equations for maximal oxygen uptake, maximal heart rate, maximal minute ventilation

Coefficients (SEM)			
Covariates	VO_{2max} [ml/kg × min]	HR_{max} [b.p.m]#	VE_{max} [l/min]
Age [years]	–0.004 (0.47)	–0.09 (426.10)	0.06 (0.85)
Gender: 1) boy 2) girl	–0.17 (1.68)	0.24 (153.49)*	–0.09 (3.05)
Height [cm]	0.43 (0.12)*	0.11 (110.15)	0.35 (0.22)*
Weight [kg]	–0.39 (0.06)*	–0.35 (51.22)*	–0.006 (0.10)
Constant	–28.94 (17.11)	20007.23	–59.73 (30.95)
R square	0.22	0.16	0.17

*VO_{2max} – maximal oxygen uptake, HR_{max} – maximal heart rate, VE_{max} – maximal minute ventilation, #quadratic transformation for outcomes, *p-value < 0.05*

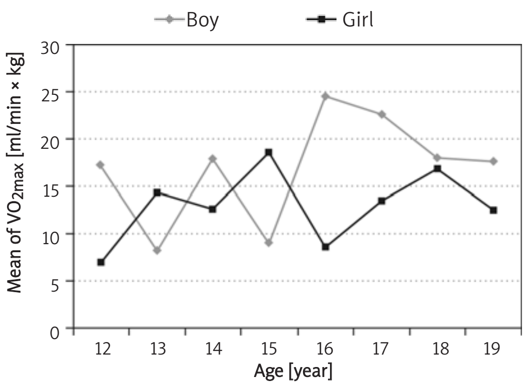

Figure 1. Changes in VO_{2max} of boys and girls according to changes in age

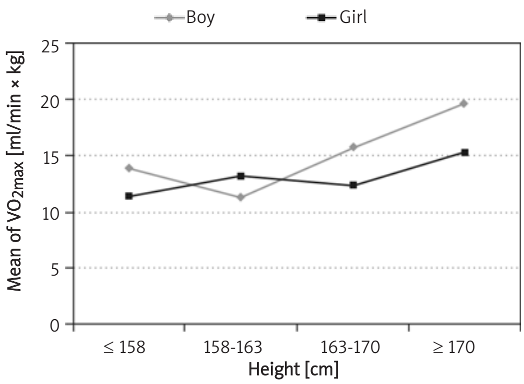

Figure 2. Changes in VO_{2max} of boys and girls according to changes in height

of VO_{2max} are seldom more precise than ±20% (2 SD) and that there can be large differences in measurement accuracy of different CPET systems, the observed difference in VO_{2max} between different populations may be accounted for by these differences alone. In addition to differences in methodology and equipment, factors not included in the analysis may also account for the observed difference in predicted values of exercise capacity. Two such factors are level of habitual activity and the weight status of the subjects [10].

The level of physical fitness or physical training and the measured VO_{2max} are correlated in children, and physical activity should lead to a higher VO_{2max} that can be reached even in ill children [11].

In many studies, normative data for healthy children of different ethnic groups have been obtained, and different methods were used for exercise stress testing [9]. It is advisable, however, that each laboratory evaluate its own method, since the characteristics of those commercially available instruments may differ, and normative data may differ due to the ethnic differences [4].

These controversial results also indicate the necessity of normative data based on ethnicity, age and gender. In our study the correlation of peak VO_2 was stronger with height than weight in boys, but when corrected for age the correlation became insignificant. Exercise time was also strongly correlated with increasing age.

The maximum observed VO_2 values in our study were 12.48 ml/kg × min for girls and 16.71 ml/kg × min for boys. Armstrong *et al*. offer typical values for boys of 48 to 50 ml/kg × min during adolescence, while for girls, their figures are 39 to 45 ml/kg × min [12]. Our study results are much lower than the VO_2 peak values of adolescents reported in previous studies [2, 4, 5, 9].

Children demonstrate a greater ventilatory efficiency during exercise as they grow, with a progressive decline in sub-maximal and at least in boys maximal Ve/VO_2 [13].

We observed that boys' maximum VO_2 values were greater than girls. This was to be expected, bearing in mind that, in our community, cultural factors encourage physical activity and the resultant muscular development for boys more than girls [14].

However, beyond the age of 12 years, boys' peak VO_2 was higher than girls' peak VO_2, Similarly, Lenk *et al*. [11] found longer endurance times in boys than girls in older ages (10-15 years). The difference between boys and girls has been attributed to differences in haemoglobin concentration and body size [7]. Another explanation is based on the girls' greater accumulation of subcutaneous body fat during the circumpubertal years [15].

It is worth pointing out that none of the adolescents we studied were athletes, and that any differences in daily physical activity levels, if present, were predominantly due to cultural factors.

This study has been the first of this kind to provide mean maximum VO_2 values to be used as a parameter for the classification of cardiorespiratory fitness in Iranian adolescents. This classification is a contribution to the definition of values to define normality.

It is not possible to draw any conclusions concerning racial differences in exercise capacity from the present study. A multicentre study using standardized procedures and rigorous quality control and aimed at generating appropriate sets of reference values to be used in different populations may throw further light on race-related differences in predictive values for CPET.

VO_{2max} in our study was in the poor to average range when compared to the standard values of other populations. This information should prompt policy makers and medical educators to address this problem, and to consider promoting exercise and incorporating physical fitness into the school curriculum.

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