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The peak oxygen uptake of healthy Turkish children with reference to age and sex: a pilot study

Yeşim Gürsel, Birkan Sonel, Haydar Gök, Peyman Yalçın

Department of Physical Medicine and Rehabilitation, Ankara University Faculty of Medicine, Ankara, Turkey

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Maximal oxygen uptake (VO_2max) has an important place in the assessment of cardiopulmonary fitness. Currently there is insufficient normative data for Turkish children. With this preliminary study, we aimed to set up a normative data for our lab which may also serve as a basis for future large population based studies in Turkey. We assessed the peak oxygen consumption of 80 healthy Turkish children aged 5-13 years and examined the cardiopulmonary responses to exercise test in relation to their age, sex and body size. Dynamic lung functions were positively and significantly correlated with age. A similar correlation was observed for the peak VO_2. A significant positive correlation between peak VO_2 and body size was demonstrated only in boys for height. There were no differences in all of the test parameters with reference to sex except in the age group of 13 years. Boys who were 13 years old had higher mean values of maximal voluntary ventilation (MVV), oxygen uptake at anaerobic threshold, peak VO_2, and exercise test duration than those of girls of the same age ($p<0.05$). VO_2 plateau was detected only in 25%, and when two groups with and without VO_2 plateau were compared, there were no differences regarding the age, sex, weight, height and exercise test results. Assessment of VO_2 by graded exercise stress testing by treadmill is accepted as a safe and effective method of evaluating the physical fitness of children. Current study presents normal data for a limited subpopulation of healthy Turkish children.

Key words: maximal oxygen uptake, healthy children, treadmill exercise test.

Maximal oxygen uptake (VO_2 max) 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, hematologic components of oxygen delivery and the oxidative mechanisms of the exercising muscle are the main limiting factors for VO_2 max. 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 diseases. The physiologic adaptations of normal children to exercise provide insight into the abnormalities found in children with various diseases. Exercise stress testing is an accepted mode of evaluating the peak oxygen consumption and cardiopulmonary status of children[3]. Obtaining useful and accurate laboratory measurements and interpreting test results of children with diseases depend on an understanding of normal physiological responses[3]. Currently, there is not sufficient normative data for Turkish children. Herein, we provide normal data on the peak oxygen consumption of a limited sample of healthy Turkish children aged 5-13 years and examine the cardiopulmonary responses to exercise test in relation to their age, sex and body size.

Material and Methods

Subjects

All of the children entering the study were from the same state primary school and aged between 5-13 years. Children were selected by a random number list. Twenty-five children from each age group were invited and those whose parents gave written informed consent were accepted for the study. No attempt was made to select the children who were particularly active, and all of the subjects were attending the regular physical education class at school. Age, weight and height profiles of the study population are presented in Table I. All were healthy and taking no medications that would affect exercise performance. Children with infections were not allowed to participate in the laboratory test.

Table I. Age and Anthropometrical Data of Children by Sex (Mean±SD)

	Boys (n=43)	Girls (n=47)
Age (years)	8.84±2.88	9.70±2.64
Height (cm)	132.12±17.65	139.40±16.15
Weight (kg)	30.40±12.46	33.45±11.30

Exercise Test

All tests were conducted in the Cardiopulmonary Testing Laboratory at the University of Ankara, Department of Physical Medicine and Rehabilitation. Testing was done at various times during the day considering the school hours of each child. The children were given adequate explanation of the proposed protocol and objectives and asked to try as hard as they could. Prior to the exercise test, pulmonary function tests were performed. Flow-volume curves were obtained by forced expiratory maneuvers using Vmax29 ergospirometry (Sensormedics®, Yorbda Linda, California). Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC, and maximal voluntary ventilation (MVV) were measured in three consecutive trials and the best trial was accepted.

In our laboratory, most of the ergospirometric exercise tests are performed on treadmill using the Bruce walking treadmill protocol. For some patients who are known to have serious cardiopulmonary or musculoskeletal limitations, modified Bruce or Naughton protocols are preferred. We wanted to standardize the test protocol for the healthy children group as already done for the adult group. Before the study, five children of different ages were tested using several treadmill test protocols (Bruce, modified Bruce, Naughton, and Oslo) on separate days. Bruce protocol was thought to be an appropriate test to achieve a maximal test for children. However, children who were at the age of 5-6 years tolerated modified Bruce protocol better than the Bruce protocol. So we adhered to the original Bruce walking protocol for the children aged 7-13 and to the modified Bruce protocol for those who were 5-6 years old on a treadmill with 12-lead electrocardiographic monitoring (Marquette Case I: Marquette, Milwaukee, WI). Systolic and diastolic blood pressures were recorded as well. During the test, VO_2 and VCO_2 were measured continuously and analyzed with the use of a Sensormedics metabolic cart (Sensormedics®, Yorbda Linda, California). Before each test session, the gas analyzers were calibrated with certified gases of known standard concentrations. The children were permitted to hold onto the guard rails of the treadmill slightly to fell safe. They were encouraged to walk to their limit. The test was terminated when fatigue was expressed by the subject or when observed by the testing staff as sweating, hyperpnea, facial flushing and unsteady gait and considered to be consistent with an exhaustive effort.

Three criteria were used to determine whether a successful maximal test had been performed: 1. a leveling or plateauning of VO_2 (defined as an increase of VO_2 <2 ml/kg/min), 2. heart rate >195 beats/min, 3. respiratory exchange ratio >1.0[4]. Maximal heart rate attained at the end of the exercise, peak oxygen uptake or maximal oxygen uptake (VO_2 plateau) and ventilatory anaerobic threshold (VAT) were evaluated. Peak oxygen uptake was defined as the average value during the final minute of exercise. A plateau of VO_2 was defined as a less than 2 ml/kg/min increase in the average value during the final minute of the last stage, and if a plateau had been detected, the average value was accepted as maximal oxygen uptake.

Ventilatory anaerobic threshold was determined by Wasserman method[5]. Minute ventilation volume (VE)/VO_2 and VE/VCO_2 were plotted against time. The VAT occurred when there was an isolated increase in the slope for VE/VO_2 with no change in the slope for VE/VCO_2. If this point occurs then the slope for R and the slope for VE abruptly increase. The point where the VAT occurred was expressed as a percent of VO_2 maximum.

Statistical Analysis

All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS for Windows v.9.0). Values were presented as means and standard deviations. Univariate association between age, sex, height, weight and all test parameters was assessed by Mann Whitney U test. Correlations between age and dynamic lung functions, VO_2 and body size were measured by Pearson correlation test.

Results

All of the children completed the test without any complication, and all tests were terminated upon development of fatigue in a subject. Dynamic lung functions of the children are presented in Table II in relation to age and sex groups, and in Table III, the peak cardiopulmonary responses of the children are displayed in relation to age groups and sex. Forty percent of the children tested did not meet the criteria for a successful maximal test. Dynamic lung functions were positively and significantly correlated with age: r=0.884, p<0.001 for FVC; r=0.834, p<0.001 for FEV_1; r=0.905, p<0.001 for vital capacity (VC); r=0.714, p<0.01 for MVV). A similar correlation was observed for the peak VO_2 (r=0.337, p<0.001). A significant positive correlation between peak VO_2 and body size was demonstrated only in boys for height (r=0.422, p<0.05) (Table IV). There were no significant differences in all of the test parameters with reference to sex expect the age of 13 years. Boys who were 13 years old had significantly higher mean values of MVV, oxygen uptake at anaerobic threshold, peak VO_2, and exercise test duration than those of girls of the same age.

A plateau of VO_2 was detected in 23 children. NO significant difference was found between the two groups who displayed a plateau of VO_2 and those who did not in relation to age, sex, height and weight. Various properties of the two groups are presented in Table V. Ventilatory anaerobic threshold was not detected in five children (one was 9 years old, one was 13 and the rest were 5).

Table II. Dynamic Lung Function Test Results by Age Groups and Sex (Mean±SD)

Age (years)	Sex	FVC[a] (L/min)	FEV1[b] (L/min)	FEV1/FVC[c]	VC[d] (L/min)	MVV[e] (L/min)	Z	P
	Boys	35.2±7.82	19.65±5.17	169.38±3.07	12.17±3.85	8.80±2.46	-0.507[a]	0.650
5-6							-0.781[b]	0.475
	Girls	36.68±8.65	21.92±4.01	178.86±17.04	11.21±1.34	7.93±1.57	-1.767[c]	0.088
							-0.213[d]	0.837
							-1.173[e]	0.250
	Boys	38.06±7.41	20.58±6.39	190.13±6.78	9.79±3.94	8.50±1.77	-1.540[a]	0.139
7-8							-0.742[b]	0.470
	Girls	37.37±7.23	20.46±5.67	188.89±19.61	10.67±3.52	10.31±1.77	-0.958[c]	0.351
							-1.541[d]	0.139
							-1.540[e]	0.139
	Boys	43.82±9.48	26.82±8.76	178.83±22.84	10.67±2.10	12.90±2.25	-0.271[a]	0.792
9-10							-0.613b	0.594
	Girls	38.96±6.45	24.07±7.71	186.18±10.35	10.23±2.46	11.54±1.87	-0.866[a]	0.440
							-0.118[d]	0.995
							-0.108[e]	0.958
	Boys	46.29±6.41	27.71±5.97	181.00±10.76	12.55±1.67	14.73±2.06	-1.446[a]	0.152
11-12							-0.775[b]	0.468
	Girls	41.41±8.18	27.01±6.46	192.09±15.75	12.55±1.67	14.73±2.06	-0.953[c]	0.349
							-1.066[d]	0.295
							-1.409[e]	0.173
	Boys	47.95±5.66	30.14±3.33	198.67±6.38	14.09±1.53	16.56±1.81	-0.471[a]	0.689
13							-1.414[b]	0.181
	Girls	40.47±5.99	22.96±4.59	189.33±13.21	10.99±1.66	13.08±1.71	-1.419[c]	0.181
							-0.510[d]	0.683
							-3.064[e]	0.001

FVC: forced vital capacity; FEV1: forced expiratory volume in 1 second; VC: vital capacity; MVV: maximal voluntary ventilation.

Table III. Peak Cardiopulmonary Responses to Treadmill Exercise by Age Groups and Sex (Mean±SD)

Age (years)	Sex	VO_2[a] Peak (ml/kg/min)	VO_2[b] at Vat (ml/kg/min)	Peak[c] heart rate (beat/min)	Systolic[d] BP (mmHg)	Diastolic[e] BP (mmHg)	Exercise[f] test time (min:sec)	Z	P
								-0.307[a]	0.765
	Boys	35.23±7.82	19.65±5.17	169.38±13.07	118.08±14.94	70.00±11.55	12.17±3.85	-1.171[b]	0.270
5-6								-1.071[c]	0.311
		36.68±8.65	21.92±4.01	178.86±17.04	138.57±16.76	81.43±12.15	11.21±1.34	-2.368[d]	0.019
	Girls							-1.852[c]	0.097
								-0.119[f]	0.938
								-1.637[a]	0.114
	Boys	38.06±7.41	20.58±6.39	190.13±16.78	125.00±10.69	78.75±3.54	9.79±3.94	-1.540[b]	0.139
7-8								-0.337[c]	0.743
								-0.247[d]	0.815
	Girls	37.37±7.23	20.46±5.67	188.89±19.61	130.56±23.24	80.00±8.66	10.67±3.52	0.000[e]	1.000
								-0.481[f]	0.673
								-0.251[a]	0.808
	Boys	43.82±9.48	26.82±8b76	178.83±22.84	123.33±13.66	80.00±6.32	10.67±2.10	-0.977[b]	0.368
9-10								-0.352[c]	0.733
								-0.052[d]	0.961
	Girls	38.96±6.45	24.07±7.71	186.18±10.35	124.55±12.93	78.18±8.74	10.23±2.46	-0.800[e]	0.525
								-0.704[f]	0.525
								-1.338[a]	0.197
	Boys	46.29±6.41	27.71±5.97	181.00±10.76	136.00±13.50	83.00±9.40	12.55±1.67	-0.247[b]	0.809
11-12								-1.766[c]	0.085
	Girls	41.41±8.18	27.01±6.46	192.09±15.75	128.18±13.28	76.36±11.20	12.55±1.67	-1.292[d]	0.223
								-1.462[e]	0.173
								-0.916[f]	0.387
								-2.123a	0.036
	Boys	47.95±5.66	30.14±3.33	198.67±6.38	144.17±19.60	80.00±6.32	14.09±1.53	-2.670[b]	0.004
13								-1.183[c]	0.272
	Girls	40.47±5.99	22.96±4.59	189.33±13.21	128.89±10.54	75.00±10.00	10.99±1.66	-1.901[d]	0.066
								-1.268[e]	0.272
								-2.946[f]	0.002

VO_2: oxygen uptake; VAT: ventilatory anaerobic threshold.

Table IV. Correlation Between Dynamic Lung Functions, Peak VO_2, Age and Body Size

		FVC (L/min)	FEV1 (L/min)	MVV (L/min)	VC (L/min)	VO_2 Peak (ml/kg/min)	Exercise test time (min:sec)
Age (years)	All	0.884 (0.000)	0.834 (0.000)	0.714 (0.000)	0.905 (0.000)	0.337 (0.000)	0.126 (0.235)
	Boys	0.902 (0.000)	0.901 (0.000)	0.798 (0.000)	0.910 (0.000)	0.554 (0.000)	0.203 (0.191)
	Girls	0.850 (0.000)	0.768 (0.000)	0.562 (0.000)	0.895 (0.000)	0.253 (0.089)	0.076 (0.610)
Height (cm)	All	0.887 (0.000)	0.845 (0.000)	0.751 (0.000)	0.926 (0.000)	0.233 (0.028)	0.119 (0.265)
	Boys	0.884 (0.000)	0.902 (0.000)	0.812 (0.000)	0.902 (0.000)	0.422 (0.005)	0.258 (0.095)
	Girls	0.892 (0.000)	0.791 (0.000)	0.631 (0.000)	0.950 (0.000)	0.218 (0.145)	0.033 (0.826)
Weight (kg)	All	0.908 (0.000)	0.879 (0.000)	0.786 (0.000)	0.923 (0.000)	0.209 (0.049)	0.121 (0.258)
	Boys	0.924 (0.000)	0.948 (0.000)	0.846 (0.000)	0.932 (0.000)	0.285 (0.064)	0.218 (0.160)
	Girls	0.886 (0.000)	0.823 (0.000)	0.709 (0.000)	0.920 (0.000)	0.249 (0.095)	0.075 (0.616)

Values show correlation coefficients, and p values are presented in parenthesis.

FVC: forced vital capacity; FEV1: forced expiratory volume in 1 second; MVV: maximal voluntary ventilation; VC: vital capacity; VO_2: oxygen uptake.

Table V. Comparison of Physical and Test Parameters Between Children with and without VO_2 Plateau (Mean±SD)

	Children with VO_2 plateau (n=23)	Children without VO_2 plateau (n=67)	Z	P
Age (years)	8.61±2.84	9.52±2.73	-1.417	0.157
Height (cm)	131.04±17.48	137.31±17.24	-1.620	0.105
Weight (kg)	30.30±12.30	33.42±11.81	-1.329	0.184
Peak oxygen uptake (ml/kg/min)	40.02±8.27	40.61±8.17	-0.143	0.887
Exercise test time (min:sec)	12.16±1.86	11.10±3.01	-1.739	0.082

VO_2: oxygen uptake.

Discussion

Exercise can be useful as a physiologic stress to elicit findings and abnormalities that are not evident at rest. So exercise testing is often used as a stress test. Breath-by-breath analysis for measuring respiratory gas exchange during exercise has been shown to be valid and reproducible to an acceptable degree also for children[6]. In many studies, normative data for healthy children of different ethnic groups have been obtained, and different methods were used for exercise stress testing[4,7-10]. It is advisable, however, that each laboratory evaluate its own method, since the characteristics of those commercially available may differ, and normative data may differ due to the ethnical differences[10]. In a former study[11], cardiovascular responses to Bruce treadmill test of healthy Turkish children were reported, but our study is the first reporting the respiratory gas analysis during exercise test in Turkish children. The former study assessed the mean endurance time, heart rate and blood pressure responses to exercise in children aged 4-15 years. However, they did not measure the maximal oxygen uptake, and since the age range of all children and grouping range were different from that of our subjects, it is inappropriate to compare the results.

The results show that peak VO_2 values of Turkish children 7-8 years of age were lower than those of North American children[8], but the values were similar for the children 9-13 years old. Children of 11-13 years of age of both sexes have better peak VO_2 values than those of British children[7], who were tested by cycle ergometer. Since the testing methods were not similar, it is difficult to compare the results.

In a Norwegian study in which peak VO_2 of healthy children and children with congenital heart diseases was compared, a different treadmill testing protocol (Oslo protocol) was used[9]. Norwegian healthy children have higher peak VO_2 than Turkish children, but anthropometrical measures also differed. Their mean height and weight were more than those of Turkish children. These differing results also indicate the necessity of normative data for each ethnic, age and sex group.

The peak VO_2 of both sexes increased with age and this is in accord with reports from other laboratories[7-9,12,13]. In this population group 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.

There were no significant differences in the test results between boys and girls, as was expected on the basis of previous results. 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 hemoglobin concentration and body size[7]. Another explanation is based upon the girls' greater accumulation of subcutaneous body fat during the circumpubertal years. In this study, neither hemoglobin concentrations nor pubertal evaluation were assessed, so it is hard to make any further comment on this difference in light of the existing data.

The appearance of a VO_2 plateau indicates that the subject has provided a sufficient exercise effort to identify a true VO_2. Secondly, the presence of a VO_2 plateau has served as a cornerstone for the argument that oxygen delivery and/or utilization is the limiting factor in progressive endurance exercise tests. Studies in children, however, have consistently indicated that a VO_2 plateau is not typical during "maximal" exercise tests, appearing as infrequently as 30-50% in some reports[3,8,14-16]. In this study population, VO_2 plateau was detected only in 25%, and when two groups with and without VO_2 plateau were compared, there were no significant differences as to age, sex, weight, height and exercise test results. There seemed to be on predictive factors for the appearance of VO_2 plateau, and both groups had similar peak VO_2.

Graded exercise stress testing by treadmill is a safe and effective method of evaluating the physical fitness of children. The current study presents normal data only for a limited subpopulation of healthy Turkish children, hence one should be careful before applying these preliminary results to the entire population. However, the data obtained may serve as laboratory reference values in the evaluation of children with various heath problems affecting physical fitness.

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