Reference Values for Cardiopulmonary Exercise Testing for Sedentary and Active Men and Women

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Abstract

Background: The reference values for cardiopulmonary exercise testing (CPET) available in Brazil were derived from a cycle ergometer in a sedentary and relatively small population.

Objective: Provide reference values for CPET in Brazilians of both sexes, either sedentary or active.

Methods: From 2006 to 2008, 3,992 CEPT of healthy individuals were selected from our laboratory. Athletes, smokers, patients with any known pathology, users of continuous medication and obese patients were excluded. Peak VO_2 was considered max VO_2. We also analyzed the anaerobic threshold VO_2, maximum ventilation and oxygen pulse according to sex, age, sedentary and active patients. Age groups were divided as follows: G1 (15-24), G2 (25-34), G3 (35-44), G4 (45-54), G5 (55-64) and G6 (65-74).

Results: According to age groups, the mean values of VO_2 in ml/kg/min with their standard deviations were: Active man: G1-50.6 ± 7.3, G2-47, 4 ± 7.4, G3-45, 4 ± 6.8, G4-40.5 ± 6.5; G5-35.3 ± 6.2; G6-30.0 ± 6.1. Active woman: G1–38.9 ± 5.7; G2–38.1 ± 6.6; G3–34.9 ± 5.9; G4–31.1 ± 5.4; G5–28.6 ± 6.1; G6–25.1 ± 4.4. Sedentary man: G1–47.4 ± 7.9; G2–41.9 ± 7.2; G3–39.0 ± 6.8; G4–35.6 ± 7.7; G5–30.0 ± 6.3; G6–23.1 ± 6.3. Sedentary woman: G1–35.6 ± 5.7; G2–34.0 ± 4.8; G3–30.0 ± 5.4; G4–27.2 ± 5.0; G5–23.9 ± 4.2; G6–21.2 ± 3.4.

Conclusion: This article provides reference values of max VO_2, among other parameters, in the Cardiopulmonary Exercise Testing performed on the treadmill in individuals of both sexes, either active and sedentary. (Arq Bras Cardiol 2011; 96(1): 54-59)

Keywords: Pulmonary ventilation/physiology; reference values; exercise test; sedentary lifestyle.

Introduction

Maximum oxygen consumption (max. VO_2) reflects the maximum capacity of a person to absorb, carry and consume O_2[1]. It is the most important parameter of individual fitness and an objective and independent parameter cardiovascular disease prognosis[2-5]. It is defined as the point at which VO_2 increases less than 50 ml/min or 2.1 ml/kg/min in spite of increased stress, i.e., when in the chart, the VO_2 curve reaches the plateau. It is recommended that it be expressed in ml/kg/min and the predicted value (%) for age, weight and sex[6]. Max. VO_2, in practice, is considered to be equivalent to VO_2 obtained at peak stress[1,5,6], because in most tests, the criteria above to determine max VO_2 are not obtained.

To date, studies published to provide population benchmarks for the cardiopulmonary exercise testing used small samples and most of them were run on a cycle ergometer. The vast majority of centers that performed the stress test in our field have executed it on a treadmill.

This study aims to provide reference values for VO_2 max and other exercising parameters through the analysis of a large sample of treadmill exercise tests performed in a healthy population in southern Brazil.

Methods

Population

Between Jan/2006 and Oct/2008, we analyzed 9,250 cardiopulmonary exercise tests performed in a large referral center for cardiology exercise and sports medicine in Southern Brazil. We excluded individuals with any symptom of disease or pathology reported, athletes, smokers, on any medication, obese patients (BMI ≥ 30) and tests with RER (VCO_2/VO_2) < 1.1.

The tests selected totaled 3,922. The groups were primarily divided into active men (n = 1818), active women (n = 1019), sedentary men (n = 570) and sedentary women (n = 515). The degree of physical activity was determined by pre-test questionnaire. Active individuals were those who practiced regular physical activity at least three times a week

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for more than 30 minutes. Sedentary individuals performed the cardiopulmonary exercise testing as a routine initial assessment for the start of regular physical activity. Active individuals were mostly those who performed physical activity and sought medical evaluation and/or advice.

Max VO_2 values, anaerobic threshold (AT), O_2 pulse, maximal ventilation (VE), respiratory exchange ratio - maximum VCO_2/VO_2 (RER) and maximum heart rate (HR) were analyzed considering gender, age and physical activity. Age groups were divided into 6 groups: G1 (15-24 years old), G2 (25-34 years old), G3 (35-44 years old), G4 (45-54 years old), G5 (55-64 years old) and G6 (65-74 years old).

All patients signed an informed consent, where they allowed the use of test data anonymously for use in research. This study was approved by the local ethics and research committee.

Cardiopulmonary exercise testing and statistical analysis

All examinations were performed by cardiologist experienced and qualified in exercise testing and cardiopulmonary exercise testing. All patients performed the treadmill test on a ramp protocol according to guidelines of the Brazilian Cardiology Society of Cardiology for Cardiopulmonary Testing[7].

The examinations were performed on a treadmill ergometer Inbrasport - ATL™, Brazil, 1999. ErgoPC Elite Software Version 3.3.6.2, Micromed™, Brazil, 1999. We used mixing chamber gas analyzer, MetaLyzer II, Cortex™, Germany, 2004. The determination of max VO_2 was the highest VO_2 achieved during the exercise. The anaerobic threshold was identified by the chart of ventilatory equivalent of oxygen and carbon dioxide (chart VE/VCO_2 - VE/VO_2). The oxygen pulse was found by dividing the max VO_2 by max HR. Max VE was found with the highest ventilation per minute obtained during the exercise.

Statistical analysis was performed by the program Microsoft™ Excel 2002 through descriptive analysis and comparison between the average values through nonparametric t test, considering significant any values smaller than 0.05.

Findings

We analyzed the examinations of 2,388 men and 1,534 women, where 4.0% of this population were African descendants. Max VO_2 max, AT, O_2 Pulse, VE, RER and HR values found were separated by sex, age and physical activity level (Tables 1 and 2). VO_2 values have declined across all age groups (Figure 1).

Maximum VO_2

For max VO_2 values, a highly significant difference ($p < 0.01$) was found among nearly all age groups. There was no significant difference between mean values of groups 1 and 2 of active women ($p = 0.17$) and sedentary men and women in group 6 ($p = 0.38$). Among sedentary women in groups 1 and 2, the mean values were close, however, the difference was significant ($p = 0.03$). There was an approximation of values of sedentary men and active women of group 5 and 6, and the difference was not significant ($p = 0.30$ and 0.39 respectively).

Anaerobic threshold

There was a statistically significant difference in all age groups among active men, but in groups 5 and 6 there was no difference ($p = 0.07$). In active women, there was no difference in AT values between groups 1 and 2 as well as in sedentary women in groups 1 and 2, 5 and 6 ($p = 0.88$, $p = 0.69$, $p = 0.12$, respectively).

Table 1 - Average max VO_2 values, AT, O_2 pulse, VE, max RER and max HR of active individuals

Active patients		1	2	3	4	5	6
Men	Max VO_2	50.6 ± 7.3	47.4 ± 7.4	45.4 ± 6.8	40.5 ± 6.5	35.3 ± 6.2	30.0 ± 6.1
	AT	33.3 ± 7.4	30.9 ± 6.8	30.1 ± 6.4	27.0 ± 6.1	23.3 ± 5.2	19.9 ± 4.8
	O_2 pulse	19.6 ± 3.7	20.0 ± 3.6	19.9 ± 3.4	18.3 ± 3.2	16.8 ± 3.2	15.6 ± 3.4
	VE	115.6 ± 25.0	115.6 ± 25.6	113.3 ± 23.2	103.2 ± 22.4	91.2 ± 20.9	81.0 ± 18.4
	RER	1.22 ± 0.4	1.20 ± 0.2	1.19 ± 0.3	1.20 ± 0.4	1.18 ± 0.4	1.15 ± 0.5
	HR	194 ± 9	184 ± 10	178 ± 9	171 ± 11	161 ± 12	150 ± 13
	n	343	597	427	285	134	32
Women	Max VO_2	38.9 ± 5.7	38.1 ± 6.6	34.9 ± 5.9	31.1 ± 5.4	28.6 ± 6.1	25.1 ± 4.4
	AT	24.9 ± 5.9	24.8 ± 6.2	22.5 ± 5.6	20.2 ± 4.8	18.9 ± 4.4	17.4 ± 3.1
	O_2 pulse	12.0 ± 2.3	12.1 ± 2.5	11.7 ± 2.4	11.1 ± 2.0	11.0 ± 2.2	9.9 ± 1.5
	VE	76.3 ± 17.0	74.8 ± 16.9	71.9 ± 15.4	66.1 ± 14.4	61.2 ± 13.9	49.9 ± 13.4
	RER	1.24 ± 0.4	1.20 ± 0.2	1.22 ± 0.3	1.18 ± 0.2	1.16 ± 0.4	1.16 ± 0.5
	HR	193 ± 9	184 ± 9	179 ± 11	169 ± 11	163 ± 13	154 ± 14
	n	177	300	229	206	81	26

Max VO_2 - maximum oxygen consumption (ml/kg/min). AT - anaerobic threshold (ml/kg/min). O_2 Pulse - oxygen pulse (ml/beat). VE - ventilation per minute (L/min), max RER - respiratory exchange ratio - maximum VCO_2/VO_2 and max HR - maximum heart rate.

Table 2 - Average max VO_2 values. AT, O_2 pulse, VE, max RER and max HR of sedentary individuals

Sedentary individuals		1	2	3	4	5	6
Men	Max VO_2	47.4 ± 7.9	41.9 ± 7.2	39.0 ± 6.8	35.6 ± 7.7	30.0 ± 6.3	23.1 ± 6.3
	AT	30.4 ± 6.9	25.8 ± 6.3	24.5 ± 6.2	22.6 ± 5.9	19.1 ± 4.0	15.9 ± 4.5
	O_2 pulse	17.9 ± 3.8	17.8 ± 3.4	17.3 ± 3.4	16.2 ± 3.2	14.0 ± 3.1	11.8 ± 3.2
	VE	107.8 ± 23.4	108.3 ± 23.7	102.1 ± 22.1	92.7 ± 24.3	81.0 ± 21.3	57.8 ± 14.7
	RER	1.24 ± 0.3	1.23 ± 0.2	1.20 ± 0.3	1.16 ± 0.2	1.20 ± 0.4	1.16 ± 0.5
	HR	193 ± 12	188 ± 12	180 ± 12	171 ± 13	163 ± 14	145 ± 15
	n	85	188	157	100	30	10
Women	Max VO_2	35.6 ± 5.7	34.0 ± 4.8	30.0 ± 5.4	27.2 ± 5.0	23.9 ± 4.2	21.2 ± 3.4
	AT	21.5 ± 5.2	21.3 ± 4.4	19.1 ± 4.3	17.8 ± 3.8	16.1 ± 2.8	14.9 ± 2.9
	O_2 pulse	10.9 ± 2.1	10.7 ± 1.8	10.2 ± 2.0	9.9 ± 1.9	9.6 ± 1.7	9.3 ± 1.3
	VE	70.7 ± 17.6	69.9 ± 15.7	64.8 ± 15.0	60.1 ± 14.7	51.6 ± 10.5	45.1 ± 11.3
	RER	1.22 ± 0.3	1.22 ± 0.2	1.20 ± 0.3	1.18 ± 0.3	1.18 ± 0.4	1.14 ± 0.5
	HR	194 ± 8	185 ± 10	179 ± 12	169 ± 13	158 ± 14	144 ± 18
	n	85	149	108	108	40	25

Max VO_2. maximum oxygen consumption (ml/kg/min). AT - anaerobic threshold (ml/kg/min). O_2 Pulse - oxygen pulse (ml/beat). VE - ventilation per minute (l/min), max RER - respiratory exchange ratio - maximum VCO_2/VO_2 and max HR - maximum heart rate.

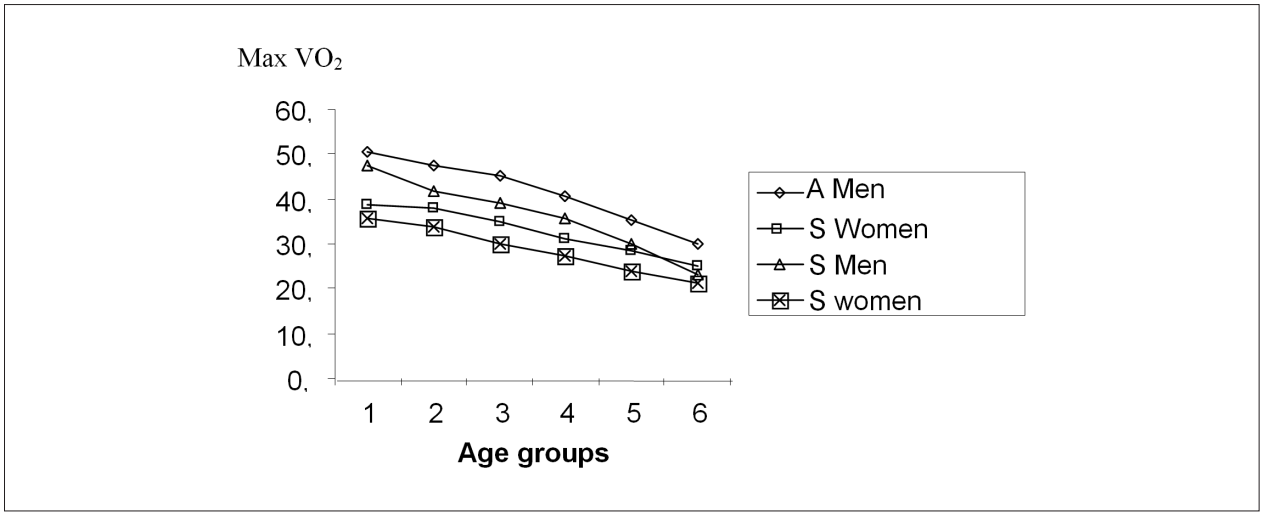

Fig. 1 - *Max VO_2 values. (ml/kg/min) according to age. A - active patients, S - sedentary patients.*

O_2 Pulse

Only from group 4 to 5 and from 5 to 6 there was a significant decline in O_2 pulse in active men. In sedentary patients, there was only a significant difference between groups 4 and 5. Among women, no significant difference was found in O_2 pulse values across all age groups.

Maximum ventilation

Among men and women in groups 1 and 2, there were differences as well as among active men in groups 2 and 3 ($p = 0.14$). In all other groups of men and women, values were significantly different ($p < 0.05$).

Respiratory exchange ratio

The values found show that the tests have met maximality criteria and that there is a clear downward trend of this parameter over the ages and among men and women, either active or not.

Maximum heart rate

As expected, there was a decrease in max HR between groups by age with no differences between sexes and physical activity level.

Discussion

Max VO_2 values vary with age, sex, weight, daily physical activity level and type of exercise[6]. Smokers and sedentary patients present smaller values[6,8]. VO_2 values obtained by cycle ergometer are 5 to 11.0% lower than those obtained with treadmill[8]. Studies (Table 3) to determine reference values for max VO_2 generally did not take into account all these factors, plus the fact that most formulas used to predict max VO_2 derive from studies with too small samples[6].

Most studies were conducted on cycle ergometers, including studies by Hansen[12] and Jones[13], which are recommended by the ATS/ACCP guidelines - 2003 as reference studies for cardiopulmonary exercise testing. In Brazil, most centers perform cardiopulmonary exercise testing on a treadmill, and our population is less familiar with physical activities on bicycles.

This study gathered the largest number of individuals so far and it only used data from tests on a treadmill.

As to the level of physical activity practiced by individuals, there is enough difference between the studies. Bruce[9] separated sedentary individuals from actives one, but in others, such as studies by Blackie[16], Fairban[19] and Koch[23], there was no clear distinction. The studies by Froelicher[10] and Vogel[14] evaluated highly conditioned individuals (military). Some studies, such as by Neder[21] and Ong[22], studied only sedentary individuals[19].

Making a comparison of our results with those of other studies, we see small increase or reduction variations in the max VO_2 found[19,24,25] (Table 4). Comparing our sample of sedentary individuals with the national study carried out by Neder[24], we observed higher values of max VO_2 in our work. Neder's study[24] employs a cycle ergometer, which may justify lower values. On the other hand, when comparing our findings with Fairbarn[19] Canadian study, composed of non-athlete volunteers, which stratified age groups similar to ours, the values were higher than those of our sample. Perhaps, this is due to the difference in physical activity profile between the two populations.

We believe that VO_2 values vary depending on the population studied as we can see in the Brazilian study by Neder et al[24] and the Chinese study by Ong[22], who found lower values when compared with European and North American studies.

The greatest strength of our study lies in its large sample, including healthy individuals of both sexes, either sedentary or active. Our data regarding the other ventilatory parameters were used to complement the values that can be expected in tests on a treadmill in our population. Many authors present data on VO_2 with little information on other parameters. We saw that the maximality of our tests, with RER and max average HR of the groups is within the range expected for the age groups, regardless of gender and physical activity level.

This study did not aim to draw comparisons between the values found among the groups, but present them as completely as possible so it can be compared by other laboratories in different individuals. Knowing the average values of our population, we can establish proper physical fitness scales not requiring the classifications made in other countries.

Although the retrospective nature of the study can be considered a limitation, we have values that represent the real world of a great laboratory of cardiopulmonary exercise testing. The Brazilian population is very heterogeneous in its various regions, and the South of Brazil is predominantly colonized by Europeans and the number of African descendants is smaller than in the Southeast and Northeast. The presence or absence of disease was based solely on a questionnaire. Common limitations[7] to other studies, such as inclusion of smokers, limited number of individuals, physical activity level, did not occur in our study.

This study is the first one in the literature to combine a large sample, inclusion of both sexes, wide age range, division

Table 3 - Major studies for reference values of cardiopulmonary exercise testing

Studies	Ergometer	n (M/W)	Population	Age
Bruce, 1973 [9]	Treadmill	295 (138 - 157)	sedentary/active individuals	29-73
Froelicher, 1974 [10]	Treadmill	710 (519 - 191)	military individuals	20-53
Drinkwater,1975 [11]	Treadmill	109 (0 - 109)	general population	10-68
Hansen, 1984 [12]	Cycle	77 (77 - 0)	shipyard worker	34-74
Jones, 1985 [13]	Cycle	100 (50 - 50)	general population	15-71
Vogel, 1986 [14]	Treadmill	1,889 (1,514 - 375)	military individuals	17-55
Jones, 1989 [15]	Cycle	1,071 (732 - 339)	general population	20-70
Blackie, 1989 [16]	Cycle	128 (47 - 81)	general population	55-80
Storer, 1990 [17]	Cycle	231 (115 - 116)	Sedentary Individuals	20-70
Blackie, 1991 [18]	Cycle	231 (111 - 120)	general population	20-80
Fairban, 1994 [19]	Cycle	231 (111 - 120)	general population	20-80
Inbar, 1994 [20]	Treadmill	1,424 (1,424 - 0)	general population	20-70
Neder, 1999 [21]	Cycle	120 (60 - 60)	Sedentary Individuals	20-80
Ong, 2002 [22]	Cycle	95 (48 - 47)	Sedentary Individuals	20-70
Koch, 2008 [23]	Cycle	534 (253 - 281)	general population	25-80

Table 4 - Comparative analysis of our study with the results of Neder[24], Fairbarn[19] and AHA[25] and their variations in percentage. Neder's[24] and Fairbarn's[19] max VO_2 values are presented in l/min

Age	Men		%	Women		%
	Neder (SM)	SM	%	Neder (SW)	SW	%
20-39	2,621 ± 366	3,332 ± 608	+ 27	1,679 ± 228	1,971 ± 362	+ 17
40-59	2,085 ± 345	2,825 ± 626	+ 35	1,319 ± 143	1,706 ± 333	+ 29
>60	1,585 ± 210	1,855 ± 508	+ 17	1,052 ± 116	1,368 ± 292	+ 30
	Fairbarn (M)	AM		Fairbarn (M)	AW	
20-29	3,58 ± 0,77	3,73 ± 0,65	+ 4	2,67 ± 0,50	2,25 ± 0,42	– 16
30-39	3,42 ± 0,71	3,65 ± 0,60	+ 7	2,58 ± 0,38	2,20 ± 0,46	– 15
40-49	3,33 ± 0,80	3,37 ± 0,56	+ 1	2,20 ± 0,42	1,96 ± 0,35	– 11
50-59	3,03 ± 0,50	2,91 ± 0,53	– 4	1,77 ± 0,40	1,84 ± 0,34	+ 4
60-69	2,44 ± 0,43	2,52 ± 0,52	+ 3	1,58 ± 0,32	1,64 ± 0,35	+ 4
	Fairbarn (M)	SM		Fairbarn (M)	SW	
20-29	3,58 ± 0,77	3,44 ± 0,63	– 4	2,67 ± 0,50	2,01 ± 0,36	– 25
30-39	3,42 ± 0,71	3,26 ± 0,58	– 5	2,58 ± 0,38	1,93 ± 0,36	– 25
40-49	3,33 ± 0,80	2,99 ± 0,59	– 10	2,20 ± 0,42	1,80 ± 0,33	– 18
50-59	3,03 ± 0,50	2,48 ± 0,56	– 18	1,77 ± 0,40	1,56 ± 0,28	– 12
60-69	2,44 ± 0,43	1,89 ± 0,51	– 23	1,58 ± 0,32	1,42 ± 0,28	– 10
	AHA (M)	AM		AHA (M)	AW	
20-29	43 ± 22	48,6 ± 7,5	+ 13	36 ± 21	38,4 ± 5,9	+ 7
30-39	42 ± 22	46,6 ± 7,1	+ 11	34 ± 21	37,1 ± 6,6	+ 9
40-49	40 ± 22	43,4 ± 6,7	+ 8	32 ± 21	33,0 ± 5,3	+ 3
50-59	36 ± 22	37,9 ± 6,4	+ 5	29 ± 22	30,0 ± 5,8	+ 3
60-69	33 ± 22	31,9 ± 5,7	– 3	27 ± 22	25,5 ± 4,8	– 5
	AHA (M)	SM		AHA (M)	SW	
20-29	43 ± 22	44,5 ± 7,2	+ 4	36 ± 21	34,6 ± 4,9	– 4
30-39	42 ± 22	40,7 ± 7,2	– 3	34 ± 21	32,5 ± 5,4	– 4
40-49	40 ± 22	37,7 ± 6,7	– 6	32 ± 21	28,7 ± 5,3	– 10
50-59	36 ± 22	31,7 ± 7,1	– 12	29 ± 22	25,4 ± 4,3	– 13
60-69	33 ± 22	25,2 ± 7,2	– 24	27 ± 22	22,7 ± 3,3	– 16

M - men, W - women, SM - sedentary men, SW - sedentary women, AM - active men, AW - active women.

of active and sedentary individuals, exclusion of smokers in cardiopulmonary exercise testing performed on a treadmill.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

This study is not associated with any post-graduation program.

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