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Changes in the Cardiorespiratory Fitness of Men and Women in Various Age Groups

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ABSTRACT

Bara CLBP, Alves, DL, Ruy-Barbosa MA, Palumbo DP, Sotomaior BB, da Silva L, Leitão MB, Osiecki R. Changes in the Cardiorespiratory Fitness of Men and Women in Various Age Groups. **JEPonline** 2019;22(1):1-10. The purpose of this study was to compare the VO_2 max between the sexes and in different age groups in the Brazilian population. A total of 6,590 cardiopulmonary tests were performed of healthy individuals, regardless of physical activity level, of both sexes between 11 and 45 yrs of age (3,482 women and 3,108 men, respectively). The tests were performed between January 2012 and December 2017, and the oxygen consumption was measured directly with a gas analyzer. The subjects of both sexes were divided into 7 age groups: G1 (11 to 15 yrs old); G2 (16 to 20 yrs old); G3 (21 to 25 yrs old); G4 (26 to 30 yrs old); G5 (31 to 35 yrs old); G6 (36 to 40 yrs old); and G7 (41 to 45 yrs old). The results showed a main effect of sex ($F_{(1)}$ = 16665.5, P<0.001; ES = 0.157), age group ($F_{(6)}$ = 75.4, P<0.001; age ($F_{(4)}$ = 4.7, P = 0.003, ES = 0.003). Significant reductions were found in males between groups G2 and G3, G4 and G5, and G5 and G6 (P<0.01). Comparing the sexes, men showed higher values of VO_2 max in all age groups (P<0.001). In summary, although VO_2 max values are higher in males, the decline in this group was more pronounced over time. We recommend that physical activity should be promoted in the Brazilian population, especially among males.

Key Words: Cardiopulmonary Test, Physical Activity, VO_2 max

INTRODUCTION

Cardiorespiratory fitness is usually expressed as maximal oxygen uptake (VO_2 max) or metabolic equivalent (MET), which can be estimated through a variety of maximum or submaximal running tests performed in the field or in the laboratory (21). Cardiorespiratory fitness is also an important marker of cardiovascular health (16,30), in addition to being classified as the fourth risk factor for cardiovascular disease (14). It is more strongly associated with all-cause mortality than risk factors such as obesity, smoking, hypertension, dyslipidemia and diabetes (5). Consequently, there is considerable interest in studying factors that lead to differences in cardiorespiratory fitness.

Several studies describe changes in VO_2 max through aging in men and women (6,17,33). It is suggested that VO_2 max may decline approximately 10% per decade from the age of 25 to 30 in active and sedentary adults of both sexes (6,12,13,18,27). On average, men have a higher VO_2 max than women, which is primarily due to their higher ventricular ejection volume, hemoglobin concentration, muscle mass, and lower body fat (9).

In a recent systematic review, Lamoureux et al. (21) estimated temporal trends in cardiorespiratory fitness of more than 2.5 million apparently healthy adults between 1967 and 2016 and the associations with health, socioeconomic, and environmental indicators. The study found a significant decline in adult VO_2 max since 1980 that suggested a decline in population health. Declines were higher for men than for women, and for young adults (<40 yrs old) than for middle-aged adults (≥40 yrs old). However, the data were obtained in the population of eight high- and upper-middle-income countries, indicating the inexistence of these analyzes in low- and middle-income countries. In another study, Ekblom-Bak et al. (11) described trends in the estimated VO_2 max (from 1995 to 2017) of a submaximal cycle ergometer test of Swedish workers, aged between 18 and 74 yrs old and variations between women and men of different age groups. The authors found a steady and pronounced decline in mean cardiorespiratory fitness in Swedish adults with greater reductions in males and young age.

Considering the importance of the contribution of studies with outcome variables directly related to cardiovascular health, the purpose of this study was to compare VO_2 max between the sexes and in different age groups to provide a better understanding of the differences in cardiorespiratory fitness in the Brazilian population.

METHODS

Subjects

This study was conducted using data from 6,590 cardiopulmonary tests of 3,108 healthy male subjects and 3,482 female subjects (regardless of their level of physical activity) between 11 and 45 yrs of age. The tests were performed between January 2012 and December 2017 in a private clinic in the city of Curitiba-PR. All the tests were supervision of a medical specialist in sports medicine and cardiology in a temperature-controlled room. This study was carried out in accordance with the ethical standards established by the Declaration of Helsinki (3).

Procedures

The subjects underwent a cardiopulmonary exercise test in an Inbrasport - ATL® treadmill exercise treadmill. Oxygen consumption (VO_2) was directly measured with a Metalyzer II gas analyzer. The data were analyzed using data from the software Metasoft (Cortex Leipzig, Germany) and ergo PC Elite (Micromed Brasilia, Brazil).

The tests were interrupted when the individual reached maximum heart rate (220-age), voluntary exhaustion, or any other abnormalities that were observed during the test. All the test were carried out in accordance with the method established in the Guideline of the Brazilian Society of Cardiology (15). The subjects of both sexes were divided into 7 age groups: G1 (11 to 15 yrs old); G2 (16 to 20 yrs old); G3 (21 to 25 yrs old); G4 (26 to 30 yrs old); G5 (31 to 35 yrs old); G6 (36 to 40 yrs old); and G7 (41 to 45 yrs old).

Statistical Analyses

Descriptive data were reported as mean, standard deviation (±SD), and confidence interval (95% CI). The normality of the data was verified through the Komogorov-Sminorv test. The analysis of variance (ANOVA) was used to verify the difference in VO_2 max (dependent variable) between sexes and age groups (independent variables). When a significant difference was found, the Tukey *post hoc* test was used for multiple comparisons. All analyzes were performed using Statistica® software (version 7.0). Statistical significance was set at an alpha level of $P<0.05$.

RESULTS

Table 1 shows the descriptive values of VO_2 max (mean ± SD, 95% CI) in females and males in different age groups.

The ANOVA showed interaction between sex and age group ($F_{(4)} = 4.7$, $P = 0.003$, ES = 0.003). In females, *post hoc* tests showed a tendency to significant reductions in VO_2 max between G1 and G2 ($P = 0.052$) and G6 and G7 ($P = 0.053$). In the male sex, significant reductions were found between G2 and G3 ($P<0.001$), G4 and G5 ($P = 0.003$), G5 and G6 ($P = 0.002$), and a significant reduction between G6 and G7 ($P = 0.051$). Comparing the sexes, men showed higher values of VO_2 max in all age groups ($P<0.001$).

The main effect of sex was found ($F_{(1)} = 16665.5$, $P<0.001$; ES = 0.157), in which men presented higher VO_2 max values when compared to women ($P<0.001$). In addition, the main effect of the age group ($F_{(6)} = 75.4$, $P<0.001$; ES = 0.048) was found with significant reductions in VO_2 max between groups G2 and G3 ($P<0.001$), G4 and G5 ($P=0.008$), G5 and G6 ($P<0.001$), and G6 and G7 ($P<0.001$).

Table 1. Descriptive Values of VO_2 max in Females and Males in Different Age Groups.

Sex	Age Group	N	VO_2 max Mean	± SD	CI (95%)	
Females	**G1 (11-15)**	125	38.79	± 0.73	37.35	40.22
	G2 (16-20)	165	35.55	± 0.64	34.30	36.80
	G3 (21-25)	300	34.92	± 0.47	34.00	35.85
	G4 (26-30)	601	35.48	± 0.33	34.82	36.13
	G5 (31-35)	782	34.66	± 0.29	34.09	35.24
	G6 (36-40)	797	33.29	± 0.29	32.72	33.86
	G7 (41-45)	712	31.93	± 0.31	31.33	32.53
Males	**G1 (11-15)**	302	48.26	± 0.47	47.34	49.18
	G2 (16-20)	431	47.28	± 0.39	46.51	48.06
	G3 (21-25)	451	43.78	± 0.39	43.02	44.53
	G4 (26-30)	779	44.04	± 0.29	43.47	44.61
	G5 (31-35)	1145	42.48	± 0.24	42.00	42.95
	G6 (36-40)	1260	41.06	± 0.23	40.61	41.52
	G7 (41-45)	1127	39.94	± 0.24	39.46	40.42

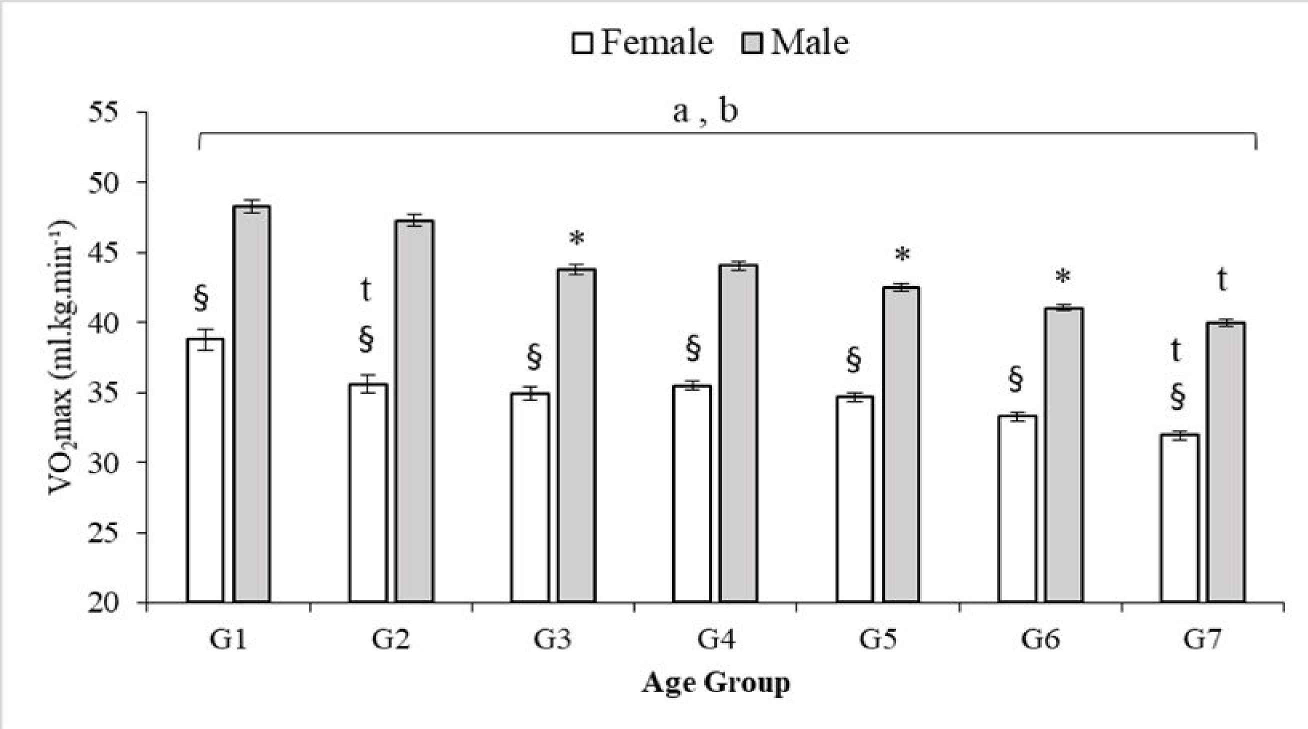

Figure 1. VO_2 max ($mL·kg^{-1}·min^{-1}$) **in Female and Male in Different Age Groups.** [*]Significant difference for the previous age group (P<0.01); [t] Significant difference for the previous age group; [§] Significant difference for males (P<0.01); [a]Main effect of age group; [b]Main effect of sex

DISCUSSION

The purpose of the study was to compare the cardiorespiratory fitness in both sexes and in different age groups. The main findings demonstrate that VO_2 max in men is higher than in women in all age groups. We also found that VO_2 max decreased over time, which was more pronounced in the male subjects at 30 yrs of age.

The results demonstrate a significant difference between the sexes, where men presented higher values of VO_2 max than the women in all age groups. These findings corroborate previous findings, as in the study by Herdy and Uhlendorf (19) that analyzed Brazilian men and women and found significant differences in VO_2 max between the sexes in all age groups. Another study performed with the Brazilian sedentary population also found a significant difference between the VO_2 max values between men and women for all age groups analyzed (20 to 80 yrs of age) (P<0.01) (25). The pattern seems to be repeated also in trained individuals (19-23).

The differences in VO_2 max between genders are attributed to the higher percentage of fat and lower level of hemoglobin found in the female subjects (7,31). In fact, a previous study with Hockey players identified that variation in VO_2 max values between the sexes was caused by body fat percentage (27.6%) and body mass index (31.91%) (32). Also, in relation to the morphological and body composition aspects, studies indicate that other factors can also be responsible for the VO_2 max differences between the sexes, such as a greater amount of lean mass and lower blood volume (2,20). In addition, a study conducted with marathon runners in a 1-hr run test on treadmill identified that 25% of the difference in VO_2 max results were caused by the lower percentage of lean mass found in the female subjects (23).

Another morphological factor that seems to influence VO_2 max is related to the females' heart size, which is smaller than in the males. The females' smaller heart size is responsible for the lower maximum systolic volume and, consequently, a lower cardiac output (20). One study reported that heart size (i.e., left ventricular mass) was responsible for 68.3% of the difference in VO_2 max levels between males and females with the same training level. Thus, it is evident how morphological aspects and body composition are important determinants of VO_2 max.

Another factor related to the VO_2 max difference between genders is the hemoglobin levels. In fact, a study conducted with elite cross-country skiers demonstrated that hemoglobin level was 10% lower in female athletes, which resulted in lower VO_2 max values when compared to the male athletes (31). In agreement, Sharma and Kailashiya (32) also demonstrated that approximately 10% of the difference in VO_2 max between the sexes was related to a lower concentration of hemoglobin in females.

Studies suggest that after 30 yrs of age, VO_2 max values decline progressively as individuals age (1,6). Arena et al. (1) and Bortz et al. (6) indicate significant differences were found in the VO_2 max values between the age groups in both sexes. They also reported a sharp fall at 30 yrs of age. Likewise, in a meta-analysis performed with 13,828 individuals divided into 6 age groups (from 20 to <70 yrs old) and 3 levels of physical activity (sedentary, active, and athletes), reductions in VO_2 max values were also observed with the increase in the subjects' age.

The physiological mechanisms underlying the decrease in VO_2 max appear to be central (e.g., cardiovascular) and peripheral (e.g., oxygen extraction) (34). Studies have reported a reduction in maximal cardiac output in healthy individuals and athletes with advancing age (4), resulting in declines in maximal heart rate and maximal ejection volume (34). Carrick-Ranson et al. (8) demonstrated that healthy subjects had a lower maximum cardiac output and a lower maximum heart rate with an increase in age, thus reducing VO_2 max.

In addition, a restriction in blood circulation to the active muscles contributes to a lower VO_2 max (28,29). Lawrenson et al. (22) evaluated the effect of age on the blood circulation of the quadriceps muscle during incremental knee extension exercise. The results demonstrated a decrease in blood circulation (by approximately 500 $mL \cdot min^{-1}$) in the older subjects compared to the younger subjects (22). The arteriovenous oxygen difference (a-vO_2 diff), characterized as the ability of the skeletal and respiratory muscles to extract and consume oxygen (O_2) from the blood to produce energy during maximal exercises (34), can also contribute to the decline of VO_2 with advancing age. In a study of 110 sedentary and trained subjects aged 18 to 72 yrs of age, a lower a-vO_2 diff was reported in the older subjects regardless of gender and level of physical activity. When the data were normalized by body mass, Ogawa (26) found that differences in VO_2 max were related to the increase in age and also to the decrease in oxygen extractions (72% and 28%, respectively). In another study, healthy subjects also had lower a-vO_2 diff values with advancing age (8).

Based on the findings of this study, we suggest that differences between sexes and ages should be considered during the cardiorespiratory fitness assessment. In addition, we recommend the promotion of physical activity in males to avoid a marked decrease in VO_2 max after 30 yrs of age.

CONCLUSIONS

Although VO_2 max values are higher in males, the decrease in this group is more pronounced over time. We recommend that regular physical activity should be promoted in the Brazilian population, especially among males.

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