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Behavior of indirect maximal oxygen uptake on users of the PROSA Program at Universidad de Antioquia, Medellín, Colombia

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SUMMARY

Objective: This research work sought to describe the behavior of maximal oxygen uptake (VO_{2max}) in a population of adults who performed regular physical activity and classify the level of cardio-respiratory fitness.

Methods: 819 results were analyzed with the estimated 2000-m VO_{2max} test from 2001 to 2009 of 125 subjects who exercise regularly in the PROSA program at Universidad de Antioquia and were discriminated by decade and gender.

Results: The results showed that VO_{2max} reached its peak between 30 and 39 years of age in men ($52.0 \pm 2.5 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) and women ($42.9 \pm 3.5 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$). There were significant differences between the VO_{2max} of men and women and the decline in all age groups, except for those over 70 years of age. The VO_{2max} of men in the study was maintained between the 70 and 90 percentiles, while that of women was between 70 and 80 percentiles.

Conclusion: The decline in VO_{2max} associated with age is different for men and women and it is different in almost all age groups

Keywords: Maximal oxygen uptake; Cardio-respiratory fitness; Aging.

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Comportamiento del consumo máximo de oxígeno indirecto en los usuarios del Programa PROSA de la Universidad de Antioquia, Medellín, Colombia

RESUMEN

Objetivo: Describir el comportamiento del consumo máximo de oxígeno ($VO_{2Máx}$) en una población de adultos que realiza actividad física regular y clasificar el nivel de fitness cardiorrespiratorio.

Métodos: Se analizaron 819 resultados del $VO_{2Máx}$ estimado con la prueba de 2000 metros entre los años 2001 a 2009 de 125 sujetos que realizan ejercicio físico regular en el Programa PROSA de la Universidad de Antioquia y se discriminaron por década y sexo.

Resultados: Se mostró que el $VO_{2Máx}$ alcanzó su pico máximo entre las edades de 30 a 39 años en hombres ($52 \pm 2.5 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) y mujeres ($42.9 \pm 3.5 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$). Se encontraron diferencias significativas entre el $VO_{2Máx}$ de hombres y mujeres y en la disminución en todos los grupos etarios, excepto en los mayores de 70 años. El $VO_{2Máx}$ de los hombres del estudio se mantiene entre los percentiles 70 y 90; el de las mujeres entre los percentiles 70 y 80.

Conclusión: La disminución del $VO_{2Máx}$ asociada con la edad es diferente para hombres y mujeres y también en casi todos los grupos etarios.

Palabras clave: Consumo máximo de oxígeno; Fitness cardiorrespiratorio; Envejecimiento.

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There is sufficient evidence to support that levels of cardio-respiratory fitness are inversely associated with all-cause mortality, heart disease, cancer, and other chronic diseases and that cardio-respiratory fitness is related to health, independence, and functional capacity¹⁻⁴ and there is interest in the investigation of the decline in age-related $\text{VO}_{2\text{max}}$ ⁵; although there are differences in the studies, these generally reported a decrease of 0.4-0.5 ml/kg/min/year (9%-10% per decade) for men and women, regardless of the level of activity^{5,6}. High-intensity regular exercise can reduce this loss to 50% in young or middle-aged men but not in older adults; women do not seem to be able to reduce it to less than 10% per decade. The loss of age-related $\text{VO}_{2\text{max}}$ appears to occur non-linearly in association with decreased physical activity. In sedentary individuals, this occurs between 20 and 30 years of age, and in athletes after reducing or completing training⁵.

Measuring or estimating $\text{VO}_{2\text{max}}$ can be performed with direct and indirect standardized assessments^{7,8}. Direct assessments are those that measure $\text{VO}_{2\text{max}}$ and other physiological variables by using, for example, respiratory gas analyzers. Indirect assessments are those designed to estimate $\text{VO}_{2\text{max}}$ without the need for special equipment and are based on equations with variables such as gender, age, height, weight, and distance traveled and can be performed on a running track, a treadmill, etc.; these include the Cooper test, Balke test, the Rockport 1-mile test, 1.5-mile running test, and the 2000-m Ukk test⁹.

In our environment, we know of no published research on the subject and because of the variability of results, the aim of this study was to describe the behavior of maximal oxygen intake in a population of adults who perform regular physical activity and secondarily, to classify the level of cardio-respiratory fitness.

MATERIALS AND METHODS

This descriptive study was conducted by reviewing digital records from the 2000-meter Test of PROSA program users from 2001-2009.

PROSA is the psychophysical health program of Universidad de Antioquia and it employs physical activity and exercise as a means for disease prevention and health promotion. It is directed to employees, teachers, and retirees of Universidad de Antioquia,

regardless of gender and age. The program works year round, with a frequency of 5 days per week and with a 1-h duration per session. The 380 individuals are divided into 13 groups who exercise mornings, noon, and evenings. Each of the users participating in the program has a sports medical follow-up seeking to prescribe and monitor exercise (the execution and exercise prescription is to be individualized and follow the American College of Sports Medicine (ACSM) recommendations)⁶.

Secondary sources were used (digital records) of 125 subjects intentionally selected from a total population of 380 individuals. Subjects who had at least three assessments of indirect maximal oxygen intake between 2001 and 2009 were considered as inclusion criterion. We excluded subjects who had less than three assessments to consider only people who have had greater participation in the program.

Estimation of $\text{VO}_{2\text{max}}$. To estimate the indirect maximal oxygen uptake of users of the PROSA program, we calculated the time spent in the 2000-m test by using the following parameters: For individuals who can only perform the test by walking, we consider the following variables and formulas, respectively: time: duration of the run in minutes and seconds; heart rate: at the end of the test (in beats per minute); body mass index (BMI): (weight divided by the square of height in meters); age: years old; $\text{VO}_{2\text{max}} = 84.9 - 4.65 * \text{time} - 0.22 * \text{heart rate} - 0.26 * \text{age} - 1.05 * \text{BMI}$ (for men). $\text{VO}_{2\text{max}} = 116.2 - 2.98 * \text{time} - 0.11 * \text{heart rate} - 0.14 * \text{age} - 0.39 * \text{BMI}$ (for women). For individuals who take the test by jogging, we have accounted the time spent in minutes and seconds and used the following formula: $\text{VO}_{2\text{max}} = 11.6 + 0.176 * (2000/\text{time})$.

Statistical analysis. For statistical analysis, data collected from digital files were entered into the Excel[®] spreadsheet and we calculated the mean, standard deviation, and coefficient of variation. $\text{VO}_{2\text{max}}$ data were grouped into 10-year intervals in both men and women, and were placed into percentiles and compared with ACSM reference tables (Table 1 and 2)⁶. We also applied the Student t test to establish significant differences between the values of $\text{VO}_{2\text{max}}$ for men and women, as well as by age groups. ANOVA was applied and a Tukey test was applied to determine significant differences between age groups of men and between age groups of women.

Table 1
VO_{2max} (ml/kg/min) in male non-athletes, according to American College of Sports Medicine

Percentile	Age (years)				
	20-29	30-39	40-49	50-59	≥60
90	55.1	52.1	50.6	49.0	44.2
80	52.1	50.6	49.0	44.2	41.0
70	49.0	47.4	45.8	41.0	37.8
60	47.4	44.2	44.2	39.4	36.2
50	44.2	42.6	41.0	37.8	34.6
40	42.6	41.0	39.4	36.2	33.0
30	41.0	39.4	36.2	34.2	31.4
20	37.8	36.2	34.6	31.4	28.3
10	34.6	33.0	31.4	29.9	26.7

Table 2
VO_{2max} (ml/kg/min) in women non-athletes, according to American College of Sports Medicine

Percentile	Age (years)				
	20-29	30-39	40-49	50-59	≥60
90	49.0	45.8	42.6	37.8	34.6
80	44.2	41.0	39.4	34.6	33.0
70	41.0	39.4	36.2	33.0	31.4
60	39.4	36.2	34.6	31.4	28.3
50	37.8	34.6	33.0	29.9	26.7
40	36.2	33.0	31.4	28.3	25.1
30	33.0	31.4	29.9	26.7	23.5
20	31.4	29.9	28.3	25.1	21.9
10	28.3	26.7	25.1	21.9	20.3

RESULTS

We analyzed the records of the 2000-m test of 125 subjects, 50 men (40%) and 75 women (60%) with mean age of 57.7±9.1 years and 54.7±11.6 years, respectively.

Table 3 shows the number of follow-up evaluations conducted between 2001 and 2009. It is noted that subjects with 6, 7, 8, and 9 assessments represent 73% of the study population.

In whole, we analyzed 819 data of VO_{2max}, 338 (41.3%) from men and 481 (58.7%) from women. Table 4 adds the evaluations between 2001 and 2009. It is observed that between 50 and 59 years of age, 305

evaluations were analyzed for men and women.

Table 5 presents changes in VO_{2max} with age in men and women. It is noted that the best average was between 30 and 39 years for both men (52 ml * kg⁻¹ * min⁻¹) and women (49.2 ml * kg⁻¹ * min⁻¹); thereafter, there is a decrease of VO_{2max}. Significant differences were found between maximal oxygen uptake for men and women and there were also differences between age groups, except for those older than 70 years of age (p=0.30).

According to the results presented in Table 6, in the group of men there are significant differences from 40 years of age; in that of women, although differences existed between 30 and 40 years of age, the differences

Table 3
Number of evaluations per subject between 2001 and 2009

Total assessments between 2001-2009	Assessments						Total
	9	8	7	6	5	4 and 3	
Subjects	14	27	24	26	17	17	125
Population (%)	11.2	21.6	19.2	20.8	13.6	13.6	100%

Table 4
Assessments of maximum oxygen uptake
between 2001 and 2009

Ages (years)	Assessments		
	Men	Women	Percentage by age
≥70	20	33	6.5
60-69	72	100	21.0
50-59	150	155	37.2
40-49	82	125	25.3
30-39	14	50	7.8
<29	NA	18	2.2
Total assessments	338	481	819
Percentage of assessments	41.3	58.7	100.0

become more well-known and constant from 50 years of age.

Table 7 shows the VO_{2max} expressed in $ml \cdot kg^{-1} \cdot min^{-1}$ and Mets per decade in men and the location

Table 6
p value for the Tukey test in the ANOVA
procedure to compare age groups for
men and women

Age groups (years)	Men	Women
(30 - 39) - (40 - 49)	0.99	0.02*
(40 - 49) - (50 - 59)	0.00*	0.21
(50 - 59) - (60 - 69)	0.00*	0.00*
(60 - 69) - (≥70)	0.00*	0.00*

* significant, $p < 0.05$

in percentiles according to the ACSM. It is noted that the average VO_{2max} with age in men is between the 70th and 90th percentiles. For men over 70 years of age, percentiles were not found because ASCM tables do not report accurate data for that age range.

Table 8 describes the VO_{2max} expressed in $ml \cdot kg^{-1} \cdot min^{-1}$ and at Mets per decade in women and their location in percentiles according to the ACSM. It is noted that the average VO_{2max} according to age in women is between the 70th and 80th percentiles.

Table 5
Mean maximum oxygen uptake by age group and gender

Age decade for men and women	30 - 39	40 - 49	50 - 59	60 - 69	≥70
Average VO_{2max} in men	52.0 ± 2.5	50.6 ± 4.9	44.8 ± 7.0	40.6 ± 8.5	31.3 ± 6.5
Average VO_{2max} in women	42.9 ± 3.5	39.0 ± 5.1	37.0 ± 6.7	31.8 ± 7.3	29.1 ± 7.1
T test among age groups	0.00*	0.00*	0.00*	0.00*	0.30
T test between men and women			0.00*		

p value for Student t to compare the data by gender in the same age range. *significant, $p < 0.05$; p value for Student t to compare the data by gender regardless of age. * significant, $p < 0.05$.

Table 7
Location in $\text{VO}_{2\text{max}}$ percentiles of men according to American College of Sports Medicine

Age (years)	$\text{VO}_{2\text{max}}$ average ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)	Equivalence in Mets	Percentile according to ACSM
30 - 39	52.0 ± 2.5	14.9	90
40 - 49	50.6 ± 4.9	14.5	90
50 - 59	44.8 ± 7.0	12.8	80
60 - 69	40.6 ± 8.5	11.6	70
≥ 70	31.3 ± 6.5	8.9	NA

Table 8
Location in $\text{VO}_{2\text{max}}$ percentiles of women according to American College of Sports Medicine

Age (years)	$\text{VO}_{2\text{max}}$ average ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)	Equivalence in Mets	Percentile according to ACSM
≤ 29	41.5 ± 4.3	11.9	70
30 - 39	42.9 ± 3.5	12.3	80
40 - 49	39.0 ± 5.1	11.1	70
50 - 59	37.0 ± 6.7	10.6	80
60 - 69	31.8 ± 7.3	9.1	70
≥ 70	29.1 ± 7.1	8.3	NA

DISCUSSION

This study describes changes in $\text{VO}_{2\text{max}}$ associated with age over a period of nine years. The direct comparison with other cross-sectional or longitudinal studies is not the most accurate because there are differences in methodology and population, but, in general, in these, the trend is the decline of $\text{VO}_{2\text{max}}$ with age in men and women^{5,10-16} starting from 25 to 30 years of age, once physical maturity has been reached^{5,13,17}.

There is controversy on the impact of physical activity in the rate of loss of aerobic power^{10,18,19,20,21}. The meta-analysis of cross-sectional studies found no association between increased physical activity with decreased $\text{VO}_{2\text{max}}$ ^{10,19}, longitudinal studies suggest that regular vigorous exercise may slow to 50%, but the reduction or suspension of training with the elderly may result in a misleading acceleration in that decline¹⁰; a study recently reported decreased $\text{VO}_{2\text{max}}$ of 1% per annum after 25 years in subjects who do not perform physical activity and of 0.5% per annum for adult athletes; for other researchers, aerobic capacity declines 5-15% per decade^{5,17}, an equivalent reduction of as

much as 60% from 30 to 70 years of age; a recent review reported an average 5 ml/kg/min per decade for all age groups and reported that progressive aerobic training can improve $\text{VO}_{2\text{max}}$ at least 5-6ml/kg/min²² and others report that the annual rate of decline in $\text{VO}_{2\text{max}}$ expressed in relative terms varies from 0.25 to 1.04ml/kg/min, depending on gender and level of physical activity¹⁷.

In our study population, the decrease of $\text{VO}_{2\text{max}}$ behaves indifferent form between every decade of life and significant differences between age groups exist ($p=0.00$); therefore, it would be suitable to express the $\text{VO}_{2\text{max}}$ and its decrease during the course of time, according to age groups in men and women.

Multiple studies suggest that age-associated decline is greater in men than in women when expressed in absolute terms such as l or ml/min, but when expressed per decade, the apparent gender difference disappears¹⁰. Although cross-sectional studies show a linear decrease of $\text{VO}_{2\text{max}}$ through life, a decline nonlinear acceleration of about 20% after 70 years of age was reported in longitudinal studies^{5,13,17}.

In our study and in a longitudinal study¹³, the rate of decline in $\text{VO}_{2\text{max}}$ varies among decades and has a

considerable increase after 60 years of age. Also, there is an accelerated decrease per decade independent from the level of physical activity in men and women; comparatively, women have lower $\text{VO}_{2\text{max}}$; this has also been reported in another study in individuals 60-92 years of age¹⁴.

For all the foregoing, it is proposed that the percentage or the annual change in $\text{VO}_{2\text{max}}$ can not be generalized but expressed in terms of age and gender of the individuals.

$\text{VO}_{2\text{max}}$ loss is due to central and peripheral adaptations^{5,17} and the decline in vigorous physical activity and age-related sarcopenia exacerbate the process^{13,17}; related to these changes and to improve health, ACSM and other organizations recommend aerobic and strength training since early stages of life⁶.

Vigorous aerobic training can produce a 25% improvement of $\text{VO}_{2\text{max}}$ (5-6 ml/kg/min) in the elderly, potentially delaying the loss of independence by 10 to 12 years^{6,22}. Controlled programs of regular exercise could contribute to the attenuation of the decline in age-related $\text{VO}_{2\text{max}}$ ^{6,14}.

A recent meta-analysis²³ reported that those with the best cardio-respiratory fitness ($\text{VO}_{2\text{max}} \geq 7.9$ Mets vs. $\text{VO}_{2\text{max}} \leq 7.9$ Mets) is associated with lower risk of mortality from all causes and cardiovascular events in healthy men and women. The lowest level of $\text{VO}_{2\text{max}}$ (8.3 Mets) -70th percentile- was for women over 70 years of age, but this value is classified as highly fitting into percentiles based on the location. This may mean they would get those benefits associated with the level of fitness and reduced risk of coronary heart disease, cancer, other chronic diseases, and better health and independence^{1-4, 22,23}.

Although a limitation of the study was measured by indirect $\text{VO}_{2\text{max}}$ 2000-m UKK test, a 0.85 correlation was found with laboratory tests, along with a prediction error of 0.05 ml*min⁻¹*kg⁻¹²⁴; similarly, the 2000-m running test has a correlation of 0.71 (p<0.0001) with respect to ergospirometric evidence²⁵. It should also be noted that the ACSM $\text{VO}_{2\text{max}}$ data are from the United States population, but they are now the world reference⁶.

On the other hand, physical activity should ideally be assessed to stratify the groups and get more specific results from the age groups. Therefore, it would be important to perform prospective longitudinal studies that allow easily controlling multiple variables.

CONCLUSIONS

$\text{VO}_{2\text{max}}$ had its peak in individuals between 30 and 39 years of age; in men it was 52±2.5 ml * kg⁻¹ * min⁻¹ and 42.9±3.5 ml * kg⁻¹ * min⁻¹ in women; thereafter, decreasing over the years. The decline in $\text{VO}_{2\text{max}}$ associated with age is different for men and women and also different in almost all age groups.

In comparison with the ACSM tables, the population of individuals in the PROSA program remain at least at the 70th percentile, therefore, their cardio-respiratory fitness - $\text{VO}_{2\text{max}}$ - for age is high.

Conflict of interest. None of the authors has conflicts of interest related to this study.

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