International Journal of Cardiovascular Sciences. 2019;32(4):343-354

ORIGINAL ARTICLE

Classification System for Cardiorespiratory Fitness Based on a Sample of the Brazilian Population

Antonio Eduardo Monteiro de Almeida,[1,2] Igor Rafael Miranda Ferreira Santander,[3] Maria Izabel Macedo Campos,[2] Jorge René Garcia Arévalo,[1] João Agnaldo do Nascimento,[2] Luiz Eduardo Fonteles Ritt,[4,5] Karlyse Claudino Belli,[6] Jorge Pinto Ribeiro,[†6] Ricardo Stein[6,7]

Cardio Lógica Métodos Gráficos,[1] João Pessoa, PB - Brazil
Universidade Federal da Paraíba (UFPB),[2] João Pessoa, PB - Brazil
Faculdade de Ciências Médicas da Paraíba,[3] João Pessoa, PB - Brazil
Escola Bahiana de Medicina e Saúde Pública,[4] Salvador, BA - Brazil
Hospital Cárdio Pulmonar,[5] Salvador, BA - Brazil
Universidade Federal do Rio Grande do Sul (UFRGS),[6] Porto Alegre, RS - Brazil
Hospital de Clínicas de Porto Alegre (HCPA),[7] Porto Alegre, RS - Brazil

Abstract

Background: Peak oxygen consumption (VO_{2peak}) is an important prognostic marker and its classification helps the cardiologist in the therapeutic decision-making process. The most commonly used cardiorespiratory fitness (CRF) classification has not been validated for the Brazilian population.

Objective: To elaborate a CRF classification using a Brazilian sample and to compare it with the American Heart Association (AHA), Cooper and UNIFESP classifications.

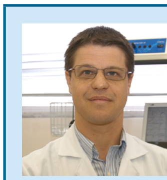
Methods: A total of 6,568 healthy subjects were analyzed through cardiopulmonary exercise testing (CPET). They were distributed by sex and the following age groups (years): 7-12, 13-19, 20-79 (per decades) and > 80 years. After measurement of the VO_{2peak}, participants were distributed into quintiles of CRF in very poor, poor, moderate, high and very high (AEMA Table). The CRF classifications by AEMA, AHA, Cooper, and UNIFESP were compared using the Wilcoxon, Kappa and concordance percentages.

Results: VO_{2peak} presented an inverse and moderate correlation with age considering both sexes (R = -0.488, p < 0.001). All paired comparisons between CRF classification systems showed differences (p < 0.001) and disagreement percentage - AEMA versus AHA (k = 0.291, 56.7%), AEMA versus Cooper (k = 0.220, 62.4%) and AEMA versus UNIFESP (k = 0.201, 63.9 %).

Conclusion: The AEMA table showed important discrepancies in the classification of CRF when compared to other tables widely used in our setting. Because it was obtained from a large sample of the Brazilian population, the AEMA table should be preferred over other classification systems in our population. (Int J Cardiovasc Sci. 2019;32(4):343-354)

Keywords: Exercise Tests; Oxygen Consumption; Respiratory Function Tests; Exercise; Cardiorespiratory Fitness; Population Health.

Mailing Address: Ricardo Stein
Hospital de Clínicas de Porto Alegre (HCPA), Universidade Federal do Rio Grande do Sul (UFRGS) - Largo Eduardo Zaccaro Faraco, Rua Ramiro Barcelos 2350 - Serviço de Fisiatria,Térreo. Postal Code: 90035-903, Porto Alegre, RS - Brazil.
E-mail: rstein@cardiol.br



Ricardo Stein, PhD
Professor Adjunto da Faculdade de Medicina da UFRGS
Coordenador do CardioEx-HCPA
rstein@cardiol.br

DOI: 10.5935/2359-4802.20190057

Manuscript received on February 05, 2018; reviewed on March 17, 2019; accepted on April 01, 2019.

† Note: Deceased on August 23, 2012.

Introduction

Cardiorespiratory fitness (CRF) is one of the main factors associated with general health, and a valuable predictor of cardiovascular morbidity and mortality and all-cause mortality.[1-4] Maximal oxygen uptake (VO_2 max) may be considered a "vital sign" in the CRF scenario.[2] A low CRF is associated with noncardiovascular clinical conditions such as depression, dementia,[5,6] breast cancer and digestive tract cancer.[7,8] Considering the importance of evaluating CRF, the American Heart Association (AHA) launched the principles for the construction of a national registry of the American population.[9]

The gold-standart method for CRF evaluation is the direct measurement of expired gases through the cardiopulmonary exercise testing (CPET), that evaluates the VO_2 max or peak VO_2 (VO_{2peak}). Since this instrument is not always available, VO_{2peak} may be estimated from the duration and/or maximal load reached during the treadmill or cycle-ergometer test and is expressed as metabolic equivalents (METs).[9-15] Classification of VO_2 max or VO_{2peak} is important in clinical practice, and may help health professionals to associate individuals' CRF with cardiovascular risk, and to encourage the practice of physical exercise/activity.

In Brazil, two classification system have been usually used in exercise test software, the Cooper[16] and the AHA systems.[17] The classification proposed by the Exercise and Sports Medicine Center (*Centro de Medicina de Atividade Física e Desporto*) of São Paulo Federal University (UNIFESP),[18] derived from a regional Brazilian sample, has been not widely used in our setting. Few years ago, Herdy and Caixeta[19] published a table from a population sample of physically active, healthy individuals from southern Brazil. In a retrospective study including 2,930 residents of Rio Grande do Sul State, Brazil, Belli et al.,[20] using a treadmill test for estimating VO_2max (Bruce protocol), observed discrepancies in the classification of CRF between Cooper, AHA and UNIFESP tables.

In this context, the aims of the present study were: (1) to evaluate to evaluate the concordance between AHA, Cooper and UNIFESP systems, taking VO_{2peak} measured by CPET as comparison reference value, and (2) to propose a classification table, by sex and age range, based on a Brazilian sample.

Methods

Population

A total of 11,350 individuals referred for diagnosis and assessment of functional capacity was prospectively evaluated. CPET was performed in a referral center in Joao Pessoa, Paraiba State, Brazil, between February 2007 and December 2017. Eighty percent of the patients were residents of Paraiba State, and 16% were from other states. Flow chart of patients' recruitment is depicted in Figure 1. A total of 4,448 subjects were excluded; 407 due to the absence of a total blood count and a echocardiogram. And the other 4,041 for the following criteria: hypertension and use of anti-hypertensive agents with cardiovascular action (36.5%), coronary artery disease (26.9%), vasculopathy (8.9%), valvular heart disease (7.1%), heart failure (8%), anemia (0.7%), chronic obstructive pulmonary disease (7.1%) and asthma (0.5%). Also, we excluded another 311 patients who did not meet the criteria of maximal CPET or due to disagreement regarding the VO_{2peak} value between the two observers, and 23 due to technical problems (electrical power failure). Thus, the final sample was composed of 6,568 asymptomatic individuals; none of them was using medication with cardiovascular action, and all of them had normal total blood count, resting 12-lead electrocardiogram, two-dimensional color flow doppler echocardiography, and pre-test spirometry, in addition to a CPET without any finding of pathological significance.

Physical activity level was determined according to the ACSM guidelines,[11] modified by the authors, as follows: a) physically inactive subjects were those who did not practice any physical exercise regularly, those who practiced exercise less than three times a week, and those who participated in household and occupational activities that generated energy expenditure lower than 3.2 METs; b) physically active were those individuals who practiced exercise regularly three-six times a week for at least three months, and those who participated in household and occupational activities that generated energy expenditure of 3.2-10.2 METs; c) athletes were those individuals who practiced sports at a competitive level, had daily training sessions, and energy expenditure greater than 10.3 METs. Participants were classified in one of these categories, based on their answers in the pre-CPET questionnaire on past practice of physical

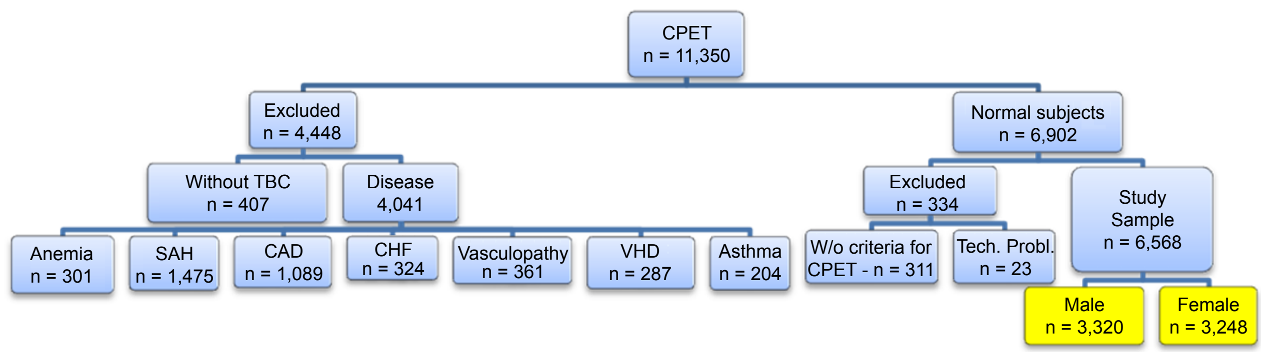


Figure 1 - Flow chart of patients' recruitment.
CPET: cardiopulmonary exercise testing; TBC: total blood count; SAH: systemic arterial hypertension (use of drugs with cardiovascular action); CAD: coronary artery disease; CHF: congestive heart failure; VHD: valvular heart disease; COPD: chronic obstructive pulmonary disease; W/o: without; Tech. probl.: technical problems.

exercise/activity (time, regularity, frequency, duration and intensity), past household and occupational activities focusing on energy expenditure.

All participants signed the informed consent form. The study was approved by the ethics committee of *Hospital de Clínicas de Porto Alegre*, approval number 13-0474).

Cardiopulmonary exercise testing

A CPET device (Metalyzer 3B; Cortex, Leipzig, Germany) combined with ErgoPC Elite (Micromed, Brasília, Brazil), was used with breath-by-breath measurements. All CPET procedures were performed in the same room, with environmental conditions monitored by an Oregon Scientific BAR 208 HGA advanced weather station - mean temperature of 24.47º C, relative humidity of 61.33 and atmospheric pressure of 1009.25 kPa (757 mmHg). Ventilation was regularly calibrated using a 3L-syringe, to apply the correction factor for respiratory volume. Measurements of the oxygen fraction in the expiratory gas (FEO_2) were made through highly accurate (0.1 Vol.%), fast-response electrochemical cells, and the expired fraction carbon dioxide ($FECO_2$) was measured using a highly-sensitive, ND infrared gas analyzer. Calibration of gas analyzers was made weekly (or according to the software recommendations), using a known gas mixture of O_2 (12%) and CO_2 (4.99%) balanced with nitrogen. Ventilatory variables were immediately recorded, and the means were subsequently calculated every 10 seconds with electrocardiographic monitoring. All tests were performed using a treadmill ergometer (Centurion-200 Micromed, Brasilia, Brazil), by the same cardiologist, specialized in exercise testing from the Brazilian Society of Cardiology. A ramp protocol was used, adapted to each participant according to the medical history, biomechanical analysis and physician's expertise, with a planned CPET duration of 8-12 minutes. The subjects were instructed about the test protocol and performed a symptom-limited exercise testing. A modified 10-point Borg scale and the respiratory quotient > 1.10 were used as criteria for maximal exercise.[21-24]

Oxygen uptake

Oxygen uptake was determined based on the agreement between the two specialists in CPET, both independent and blind to study. Test results were sent to the investigators, who identified the peak VO_2 point on the graph. Peak VO_2 was measured at the highest point reached during final stages of maximum effort, considering a sampling interval of two ten-second consecutive periods, and one-minute extrapolation for most participants. For this reason, the term VO_{2peak} was adopted throughout the article.[21,23,24] It is worth mentioning that most individuals reached the highest VO_2 value at the plateau of the curve, regardless of the increase in workload (VO_2 max).[22,24,25]

Study Classification

After analysis of CPET results, the 6,568 apparently healthy subjects were separated by sex and age ranges (7-12, 13-19, ten-year intervals from 20 to 70, and > 80 years). After the VO_{2peak} was measured, individuals were allocated into percentiles and classified into very poor, poor, moderate, good and excellent CRF and then compared. This classification was called the AEMA table.

Statistical analysis

All data were registered in a database by the same trained, independent investigator. Analysis of these data was performed using the IBM SPSS statistics 23 (IBM Company, USA). Continuous variables were described as mean ± standard deviation and categorical variables in percentage. The Student's t-test and the chi-square test were used for comparisons between the distributions of continuous and categorical variables, respectively. Correlations of VO_{2peak} with continuous and categorical variables were made using the Pearson's test and the Spearman's test, respectively. Percentage variation was calculated by VO_{2peak} values of all individuals by sex and age range. Subjects were compared for each table's (AEMA, AHA, Cooper and UNIFESP) criteria using the Wilcoxon test, Kappa (k) and percentage of agreement (%). An error probability (α) < 5% was set as statistically significant.

Results

The group of patients excluded from the study (n = 4,782) did not show any differences regarding sex, age, anthropometric data as compared with the study population. Demographic data (Table 1) showed a predominantly urban population, of pardo ethnicity for both sexes. Regarding educational attainment, most patients had some high school education, and the family income ranged from 250 to 750 American dollars. Table 2 shows a uniform sex distribution (50.5% of men), with mean age of 40 ± 14 years for men and 43 ± 15 years for women. Overweight was predominant in both sexes, and 53.9% of the individuals were physically inactive (44.9% of men and 63.1% of women). Table 3 describes total blood count, ejection fraction (by doppler color flow mapping with two-dimensional echocardiography), spirometry and CPET results, which guided the selection of this healthy sample population, and pointed out maximal CPET results (mean R of 1.23 and 1.21 in men and women, respectively).

In average, women (49.5% of the sample) showed lower VO_{2peak} than men (24.42 ± 6.7 vs. 33.70 ± 9.0 $mL.kg^{-1}.min^{-1}$, $p < 0.001$). There was an inverse, moderate correlation between VO_{2peak} and age in both sexes ($R = -0.488$, $p < 0.001$). Correlation of VO_{2peak} with family income, educational attainment and place of residence was $R = 0.236$; $R = 0.293$ and $R = -0.180$, respectively. Table 4 shows mean VO_{2peak} in different age ranges and its percentage variation; a 16.2% increase and 4.0% increase in VO_{2peak} is observed for men and for women, respectively in the two first age ranges, with a descending trend as age increases in both sexes. Interestingly, such decrease is attenuated in the two last age ranges among women.

Table 5 shows the comparison between CRF tables, describing the number and percentage of individuals with lower, similar and higher CRF. As compared with the AEMA table, there was an overestimation of CRF by the AHA, Cooper and UNIFESP classification.

We found a significant difference, and low agreement between the CRF tables. Table 6 shows the proposed CRF classification (very poor, poor, moderate, high and very high) of the AEMA table, with VO_{2peak} intervals distributed by age and sex.

Discussion

This is an important population-based study reporting the functional capacity evaluated by CPET (VO_{2peak}) of Brazilian individuals and its relationship with demographic variables, and that proposes a genuinely national classification of CRF. The findings of the study revealed high discrepancies in CRF classification when AEMA table was compared with AHA, Cooper, and UNIFESP tables. According to these three classifications, individuals were classified as having higher CRF, with disagreement rates of 57%, 62% and 64% when AEMA was compared with the AHA, Cooper and UNIFESP tables, respectively. The AEMA table distinguishes from these three tables, as it includes the age ranges - 7-12, 70-79 and > 80.

Most CRF tables were composed with international sample data. For this reason, there may be ethnical and social differences that may affect the classification of the Brazilian population by these tables. We believe that external validity of data collected from foreign

Table 1 - Characteristics of the sample

Variables		Male n = 3,320	Female n = 3,248
Educational attainment	None	1.6%	2.1%
	Elementary school	11.4%	10.8%
	High school	42.4%	43.5%
	Higher education	41.8%	41.5%
	Postgraduate education	2.8%	2.0%
Family income	< 1 MW	2.1%	2.8%
	1 - 3 MW	32.5%	39.6%
	> 3 - 5 MW	29.5%	36.3%
	> 5 - 10 MW	27.3%	15.1%
	> 10 - 20 MW	4.7%	4.7%
	> 20 MW	4.0%	1.5%
Place of residence	City	95.0%	94.2%
	Rural area	5.0%	5.8%
Ethnicity	White	41.3%	43.0%
	Pardo	52.5%	50.1%
	Black	6.2%	6.9%

Minimun Wege: ~ 250 American dollars.

Table 2 - Characteristics of the sample

Characteristics		Male n = 3,320	Female n = 3,248	p value
		Mean ± SD or n (%)	Mean ± SD or n (%)	
Age (years)		40.30 ± 13.90	42.67 ± 14.55	0.001
Weight (kg)		81.44 ± 15.87	67.60 ± 13.41	0.001
Height (m)		1.71 ± 0.08	1.58 ± 0.07	0.001
BMI		27.74 ± 4.77	26.88 ± 5.07	0.001
Physical activity	Inactive	1,490 (44.9)	2,050 (63.1)	
	Active	1,620 (48.8)	1,140 (35.1)	0.001
	Athletes	210 (6.3)	56 (1.7)	

BMI: body mass index; SD: standard deviation; n: number of individuals.

Table 3 - Total blood count, doppler color flow mapping with two-dimensional echocardiogram, spirometry and cardiopulmonary exercise testing variables

Variables	Male (n = 3,320)				Female (n = 3,248)			
	Mean	±SD	Minimum	Maximum	Mean	±SD	Minimum	Maximum
Hemoglobin (g/dl)	13.8	0.98	12.00	16.90	13.60	0.96	12.00	16.90
Hematocrit (%)	42.7	3.31	37.00	53.10	42.27	3.40	37.10	51.80
Ejection fraction (%)	67.5	6.35	55.00	83.00	66.90	5.90	55.00	85.00
FVC (L)	4.33	1.01	1.76	8.00	3.17	0.85	1.65	6.42
VEF1 (L)	3.69	0.76	1.66	5.81	2.71	0.64	1.36	4.58
VEF1/FVC (%)	86.5	6.64	80.11	104.53	86.68	6.74	81.09	95.85
Speed (km/h)	8.43	1.72	3.60	17.20	7.11	1.83	2.5	16.90
Slope (%)	11.3	3.15	1.00	18.50	9.07	2.61	0.5	16.50
Stress duration (s)	572.3	124.6	313	1,139	530.63	111.2	312	1169
Max HR (bpm)	177.6	14.4	131	210	175.12	14.95	125	210
Max SBP (mmHg)	187.9	23.9	121	259	181.26	21.16	131	256
Max DBP (mmHg)	87.6	12.0	61	132	84.82	10.08	64	126
R	1.23	0.07	1.10	1.71	1.21	0.06	1.10	1.60
Max VE (L/min)	77.6	18.5	33.10	160.30	58.12	18.80	27.80	147.7
VO_{2peak} ($mL.kg^{-1}.min^{-1}$)	33.7	9.0	10.86	71.52	24.42	6.67	10.13	62.69

FVC: forced vital capacity; FEV1: forced expiratory volume in one second; Max HR: maximum heart rate; max SBP: maximum systolic blood pressure; max DBP: maximum diastolic blood pressure; R: respiratory quotient; Max VE: maximum ventilation; SD: standard deviation.

Table 4 - Distribution of peak oxygen consumption (mean and percentage variation) in 6,568 individuals by age and sex

Age range (years)	Men			Women		
	n	VO_{2peak} (Mean ± SD)	Variation (%)	n	VO_{2peak} (Média ± DP)	Variation (%)
07 - 12	32	36.92 ± 7.4	-	25	28.86 ± 5.8	-
13 - 19	151	42.90 ± 9.1	16.2	107	30.00 ± 7.1	4.0
20 - 29	543	37.54 ± 8.3	-12.5	471	28.24 ± 6.5	-5.9
30 - 39	969	35.78 ± 9.0	-4.7	874	26.70 ± 6.4	-5.5
40 - 49	853	33.03 ± 7.7	-7.7	759	24.00 ± 6.0	-10.1
50 - 59	440	30.10 ± 7.1	-8.9	551	21.84 ± 5.1	-9.0
60 - 69	229	26.10 ± 6.4	-13.3	322	19.30 ± 3.9	-11.6
70 - 79	77	22.06 ± 4.7	-15.5	123	17.41 ± 3.7	-9.8
> 80 years	26	19.20 ± 3.4	-13.0	16	16.56 ± 2.9	-4.9

VO_{2peak}: peak oxygen consumption; SD: standard deviation.

Table 5 - Comparison between cardiorespiratory fitness tables with the number of individuals classified as having higher, lower, or similar fitness

Comparison	Lower n (%)	Similar n (%)	Higher n (%)	Total n	Wilcoxon	Kappa
AEMA vs AHA	1,286 (21.41)	2,604 (43.29)	2,121 (35.30)	6,011	< 0.001	0.291
AEMA vs COOPER	458 (7.32)	2,354 (37.55)	3,457 (55.13)	6,269	< 0.001	0.220
AEMA vs UNIFESP	0 (0.00)	1,968 (36.04)	3492 (63.96)	5,460	< 0.001	0.201
AHA vs COOPER	782 (13.60)	2,426 (42.18)	2545 (44.23)	5,753	< 0.001	0.274
AHA vs UNIFESP	288 (5.84)	1,199 (24.26)	3457 (69.91)	4,944	< 0.001	0.112
COOPER vs UNIFESP	324 (6.23)	2,738 (52.62)	2,140 (41.14)	5,202	< 0.001	0.361

populations or from small samples should be tested in Brazilian people, since the mere extrapolation of data may lead to serious errors.[26] In addition, different methods used for VO_{2peak} estimation (mostly by mostly by treadmill test rather than CPET), the criteria used for CRF classification, and different ages of the populations may have contributed to the discordant results of our study. In Cooper's classification,[16] proposed with data from individuals aged older than 13 years, regardless of physical activity level, oxygen consumption was estimated by the maximal duration of the modified Balke protocol. This classification was based on small studies that reported a correlation between test duration and oxygen consumption of 0.92 for men[27] and 0.94 for women.[28] The UNIFESP classification[18] was based on physically inactive, apparently healthy individuals (311 men and 187 women) aged between 20 and 59 years, with adjustment of the curve VO_{2peak} vs. age and direct measurement of oxygen consumption by CPET.

It is of note that, despite its wide use, there is no original publication in the literature demonstrating that the AHA classification table was actually developed by the AHA. After an exhaustive search in the literature, and even making contact with members of the Association, we did not find any original article published in indexed journals or any document issued by the AHA. All we know is that the supposed AHA classification for CRF was developed with individuals of both sexes, aged between 20 and 69 years.

More recently, a nationwide classification system was published by Herdy and Caixeta.[19] The authors studied only individuals described as physically active, with no correlation with demographic data, which made it impossible to compare their data with ours. Also, generalization of results was limited due to the fact that the authors excluded physically active subjects as well as healthy obese individuals, since these characteristics (sedentary lifestyle and obesity) are present in a large proportion of the Brazilian population.

The AEMA table derived from a sample predominantly (84% of the sample) composed of residents of the northeast region of Brazil, with proportional representation of variables such as sex and physical activity level, comparable to the general population. Clear and strict criteria used in the methodology and the measurement of the VO_{2peak} by the CPET (individualized ramp protocol), make this classification system an attractive instrument, with high potential to be used in clinical practice. It is of note that not only the differences observed in the study group but also the method used in the study seem to explain the different results obtained in comparison with those of the other tables.[16-18]

The AEMA table include children aged between 7 and 12 years old; this age range is not included in the other tables, and hence a direct comparison in this age group was not possible. It is worth pointing out that in this age group, there was a high percentage of physically inactive (62.5%), overweight children, and with a family income of three minimum wages (67.5%). Rodrigues et al.,[29] evaluated 380 school children aged 10-14 years attending public schools. Mean VO_{2peak} in children aged between 10 and 12 years was 43 $mL.kg^{-1}.min^{-1}$ (boys) and 38 $mL.kg^{-1}.min^{-1}$ (girls); mean BMI was 17 for boys and 18 for girls. In our study, in children aged 10-12 years, mean VO_{2peak} was 37 and 29 $mL.kg^{-1}.min^{-1}$ for boys and girls, respectively. A possible explanation for such difference may be related

Table 6 - Classification of cardiorespiratory fitness - AEMA table

Men										
Classification	Percentile	7 - 12 years (n = 32)	13 - 19 years (n = 151)	20 - 29 years (n = 543)	30 - 39 years (n = 969)	40 - 49 years (n = 853)	50 - 59 years (n = 440)	60 - 69 years (n = 229)	70 - 79 years (n = 77)	≥ 80 years (n = 26)
Very poor	≤ 20	< 28.77	< 34.76	< 29.79	< 28.57	< 26.53	< 24.23	< 20.61	< 18.26	< 16.11
Poor	40	28.78 - 35.30	34.77 - 39.73	29.80 - 34.41	28.58 - 32.73	26.54 - 30.43	24.24 - 27.75	20.62 - 23.79	18.26 - 20.64	16.12 - 17.20
Moderate	60	35.31 - 38.21	39.74 - 44.60	34.42 - 38.51	32.74 - 37.08	30.44 - 34.30	27.76 - 31.29	23.80 - 27.08	20.65 - 22.22	17.21 - 19.04
High	80	38.22 - 44.64	44.61 - 50.10	38.52 - 42.76	37.09 - 42.58	34.31 - 39.07	31.30 - 35.56	27.09 - 31.00	22.23 - 25.64	19.05 - 22.76
Very high	100	> 44.65	> 50.10	> 42.76	> 42.58	> 39.07	> 35.56	> 31.00	> 2 5.64	> 22.76
Women										
Classification	Percentile	7 - 12 years (n = 25)	13 - 19 years (n = 107)	20 - 29 years (n = 471)	30 - 39 years (n = 874)	40 - 49 years (n = 759)	50 - 59 years (n = 551)	60 - 69 years (n = 322)	70 - 79 years (n = 123)	≥ 80 years (n = 16)
Very poor	≤ 20	< 23.00	< 24.90	< 23.15	< 21.61	< 19.22	< 17.63	< 15.95	< 14.18	< 13.97
Poor	40	23.01 - 26.20	24.91 - 27.80	23.16 - 26.05	21.62 - 24.42	19.23 - 21.92	17.64 - 20.16	15.96 - 18.13	14.19 - 15.95	13.98 - 15.87
Moderate	60	26.21 - 29.23	27.81 - 30.44	26.06 - 29.00	24.43 - 27.10	21.93 - 24.54	20.17 - 22.33	18.14 - 20.04	15.96 - 17.78	15.88 - 17.25
High	80	29.24 - 35.15	30.45 - 35.0	29.01 - 33.00	27.11 - 30.51	24.55 - 27.92	22.34 - 25.25	20.05 - 22.29	17.79 - 20.90	17.26 - 19.11
Very high	100	> 35.15	> 35.00	> 33.00	> 30.51	> 27.92	> 25.25	> 22.29	> 20.90	> 19.11

to higher rates of physically inactive subjects, and a higher BMI in our sample.

A Norwegian study[22] including 759 physically active individuals aged from 20 to 85 years reported higher VO_{2peak} values compared with our results. Again, this could be explained by the greater proportion of inactive and overweight/obese subjects in our population. However, in a Canadian study by Nelson et al.,[21] involving 816 active men, VO_{2peak} was similar to our study group classified as physically active.

When individuals in the age group of 7-12 years were compared with those in the age range immediately above, there was a mean VO_{2peak} increase (positive percentage variation - Table 4). This seems to be associated with the lower capacity of young individuals in performing work, due to structural limitations of cardiorespiratory system (lower height), and lower anerobic production of ATP.[28,29] Analysis of VO_{2peak} in ten-year periods showed an expressive decrease from 50 years old on among men. Such decrease occurred from 40 years on among women and attenuated at the age of 80. We also observed a regular, inverse correlation between age and VO_{2peak} in our study (r = -0.488), which are similar to the findings reported by Jae et al. (r = -0.501).[30] In an AHA document, Arena et al.,[31] reported that VO_{2peak} can decline approximately 10% per decade in nonathletic subjects, varying from 3% to 6% per decade in individuals aged between 20 and 30 years. In our study, we observed an average decrease of 10.8% in male and 8.1% in female subjects in individuals older than 20 years, with faster decline in men, as shown by Weiss et al.[32]

It is important to highlight that data of more than 18,000 CPETs have been recently published. In this large retrospective study, all tests were performed in a chain of a Brazilian laboratory in the state of São Paulo.[33] CPET had been performed for check-up examination and all individuals had normal resting and exercise electrocardiography tests. Despite a robust sample, Rossi Neto et al.,[33] studied a highly selected group of patients as reported by the authors themselves in their manuscript.[33] Thus, these data may not represent the actual CRF of the Brazilian population.

Considering the CRF classification per se, each classification system has its own particularities. Cooper classification system included individuals aged older than 13 years, regardless of the physical activity level.[15] The AHA table was composed of subjects aged between 20 and 69 years, physically active or not.[16] Finally, the UNIFESP table selected only physically inactive individuals aged between 20 and 59 years.[17] In the AEMA table, 6,011 individuals were allocated to different age ranges and compared with the AHA´s table. A discrepancy of 56.7% (higher or lower CRF) was found, in addition to a low agreement (Kappa 0.291). When the AEMA classification was compared with the Cooper classification, 6,269 subjects were allocated, with a disagreement of 62.4% and low agreement (kappa 0.220). Finally, in the UNIFESP classification, 5,460 individuals were allocated, with disagreement of 63.9% and kappa of 0.201. It is of note the high percentage of disagreement in the CRF level of the three tables compared with the AEMA classification (56.7 - 63.9%, $p < 0.001$). These findings seem to be explained by the difference between study populations and by the presence of genetic factors.[11,34-38] Regarding ethnicity, our sample was characterized by a mixed population, representing white, black and Indian ethnicities, comparably to IBGE (Brazilian Institute of Geography and Statistics) data.[39] No difference between the sexes was found regarding educational attainment, family income, place of residence, physical activity level. In addition, different methods to estimate VO_{2peak} were used between the CRF classification systems. While VO_{2peak} was estimated by exercise duration in Cooper and AHA tables, in our study, this parameter was measured during CPET, and was not estimated by formulas. Previous data published by our group showed that oxygen consumption equations, such as Wasserman's and Jones' equations, may overestimate the oxygen consumption by 11.3% and 31.4%, respectively. UNIFESP classification included physically inactive individuals aged between 20 and 59 years. Although this table was also composed using data from the Brazilian population, comparison between this table with the AEMA table revealed the greatest revealed the greatest discrepancy (63.9%). Discrepancy (63.9%). This may be explained by the fact that, in the age ranges of 40-49 and 50-59 years, the values of oxygen consumption were the same for the classification scale, affecting the agreement between the CRF levels.[40] Therefore, considering the distribution of our study population by CRF levels, there was disagreement in CRF classification by the AEMA table compared with the AHA, Cooper and UNIFESP classifications.

It is worth mentioning that the treadmill or cycle-ergometer test evaluates clinical, hemodynamic, autonomic, electrical and metabolic responses to exercise. Information about CRF guides the medical staff to inform patients and family members about aerobic fitness of the subjects, prescribe exercise and evaluate their prognosis.[10] Since the present study showed a great discrepancy in CRF classification between the AHA, Cooper and UNIFESP tables compared with the AEMA table, our findings may be relevant for clinical practice in different ergometric laboratories in Brazil. Our proposed table provides a more accurate classification of CRF compared with other tables derived from foreign populations, since it was developed with Brazilians' data, thereby eliminating possible biases of international tables.

Limitations

Since data collection was not performed in all federated states of Brazil, the possibility that our findings may not have external validity throughout the country cannot be ruled out. However, the sample was composed of individuals coming from all the country (84% from Paraiba State and 16% from other states), of different ethnicities and multiracial background, which we known as a mixed-race, national sample. It is worth pointing out that comparison of our data with data matched by IBGE age groups, we did not find any difference ($p = 0.401$), including a similar distribution by sex.[39] Our sample showed a higher prevalence of overweight subjects, which is in accordance with data reported by 2012 Vigitel[41] (i.e., 51% of the Brazilian population). Also, the prevalence of individuals that practice regular physical exercise or exercise on the way to work is 47.7%,[41] which is similar to our population.

The low number of individuals aged between 7 and 12 years may be explained by the low frequency of clinical indication of CPET at this age range. On the other hand, at the age of 80's, there were few people who were healthy and met all inclusion and exclusion criteria of the present study. Nevertheless, despite this limitation, we believe that it is important for the clinician to have initial reference values for this age group. Finally, all CPETs were performed using a treadmill, and the applicability of our findings to a cycle ergometer should be tested.

Conclusion

The AEMA table showed important discrepancies when compared with the AHA, Cooper and UNIFESP tables, which are widely used instruments for CRF classification in our setting. We propose the use of the AEMA table, which was constructed with data from a large sample (predominantly regional, though) of the Brazilian population in centers and laboratories where the treadmill exercise testing is test is performed throughout the country.

Author contributions

Conception and design of the research: Almeida AEM, Ribeiro JP, Stein R. Acquisition of data: Almeida AEM, Santander IRMF, Nascimento JA, Agnaldo do Nascimento J, Stein R. Analysis and interpretation of the data: Almeida AEM, Santander IRMF, Campos MIM, Nascimento JA, Agnaldo do Nascimento J, Stein R. Statistical analysis: Almeida AEM, Campos MIM, Nascimento JA, Agnaldo do Nascimento J, Stein R. Writing of the manuscript: Almeida AEM, Ritt LEF, Belli KC, Stein R. Critical revision of the manuscript for intellectual content: Almeida AEM, Ritt LEF, Belli KC, Stein R.

Potential Conflict of Interest

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

Sources of Funding

There were no external funding sources for this study.

Study Association

This study is not associated with any thesis or dissertation work.

Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

References

1. Kodama S, Saito K, Tanaka S, Maki M, Yachi Y, Asumi M, et al. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: a meta-analysis. JAMA. 2009;301(19):2024-35.
2. Franklin BA, McCullough PA. Cardiorespiratory fitness: an independent and additive marker of risk stratification and health outcomes. Mayo Clin Proc. 2009;84(9):776-9.
3. Gulati M, Pandey DK, Arnsdorf MF, Lauderdale DS, Thisted RA, Wicklund RH, et al. Exercise capacity and the risk of death in women: the St James Women Take Heart Project. Circulation. 2003;108(13):1554-9.
4. Myers J, Prakash M, Froelicher V, Do D, Partington S, Atwood JE. Exercise capacity and mortality among men referred for exercise testing. N Engl J Med. 2002;346(11):793-801.
5. Sui X, Laditka JN, Church TS, Hardin JW, Chase N, Davis K, et al. Prospective study of cardiorespiratory fitness and depressive symptoms in women and men. J Psychiatr Res. 2009;43(5):546-52.
6. Liu R, Sui X, Laditka JN, Church TS, Colabianchi N, Hussey J, et al. Cardiorespiratory fitness as a predictor of dementia mortality in men and women. Med Sci Sports Exerc. 2012;44(2):253-9.
7. Holmes MD, Chen WY, Feskanich D, Kroenke CH, Colditz GA. Physical activity and survival after breast cancer diagnosis. JAMA. 2005;293(20):2479-86.
8. Peel JB, Sui X, Matthews CE, Adams SA, Hébert JR, Hardin JW, et al. Cardiorespiratory fitness and digestive cancer mortality: findings from the Aerobics Center Longitudinal Study. Cancer Epidemiol Biomarkers Prev. 2009;18(4):1111-7.
9. Kaminsky LA, Arena R, Beckie TM, Brubaker PH, Church TS, Forman DE, et al. The importance of cardiorespiratory fitness in the United States: the need for a national registry: a policy statement from the American Heart Association. Circulation. 2013;127(5):652-62.
10. Meneghelo RS, Araújo CGS, Stein R, Mastrocolla LE, Albuquerque PF, Serra SM, et al. III Diretrizes da Sociedade Brasileira de Cardiologia sobre Teste ergométrico. Arq Bras Cardiol. 2010;95(5 supl.1):1-26.
11. Whaley MH, Brubaker PH, Otto RM, Armstrong LE. ACSM's guidelines for exercise testing and prescription . 7th ed. Philadelphia: Lippincott Williams & Wilkins; 2006.
12. Strath SJ, Kaminsky LA, Ainsworth BE, Ekelund U, Freedson PS, Gary RA, et al. Guide to the assessment of physical activity: Clinical and research applications: a scientific statement from the American Heart Association. Circulation. 2013;128(20):2259-79.
13. Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Basset Jr DR, Tudor-Locke C, et al. 2011 Compendium of physical activities: a second update of codes and MET values. Med Sci Sports Exerc. 2011;43(8):1575-81.
14. Myers J, Nead KT, Chang P, Abella J, Kokkinos P, Leeper NJ. Improved reclassification of mortality risk by assessment of physical activity in patients referred for exercise testing. Am J Med. 2015;128(4):396-402.
15. Artero EG, Jackson AS, Sui X, Lee DC, O´Connor DP, Lavie CJ, et al. Longitudinal algorithms to estimate cardiorespiratory fitness: associations with nonfatal cardiovascular disease and disease specific mortality. J Am Coll Cardiol. 2014:63(21);2289-96.
16. Blair SN, Kohl HW 3rd, Paffenbarger RS Jr, Clark DG, Cooper KH, Gibbons LW. Physical fitness and all-cause mortalitya prospective study of healthy men and women. JAMA. 1989;262(17):2395-401.
17. Marins JCB, Giannichi RS. Avaliação & prescrição de atividade física: guia prático. 3ª ed. Rio de Janeiro: Shape; 2003.
18. Barros Neto TL, Cesar MC, Tambeiro VL. Avaliação da aptidão física cardiorrespiratória. In: Ghorayeb N, Barros Neto TL. O exercício: preparação fisiológica - avaliação médica - aspectos especiais e preventivos. São Paulo: Atheneu; 1999. p. 15-24.

19. Herdy AH , Caixeta A. Brazilian cardiorespiratory fitness classification based on maximum oxygen consumption. Arq Bras Cardiol. 2016;106(5):389-95.

20. Belli KC, Calegaro C, Richter CM, Klafke JZ, Stein R, Viecili PRN. Cardiorespiratory fitness of a brazilian regional sample distributed in different tables. Arq Bras Cardiol 2012;99(3):811-7

21. Guazzi M, Adams V, Conraads V, Halle M, Mezzani A, Vanhees L, et al. Clinical recommendations for cardiopulmonary exercise testing data assessment in specific patient populations. Circulation. 2012;126(18):2261-74.

22. Edvardsen E, Hansen BH, Holme IM, Dyrstad SM, Anderssen SA. Reference values for cardiorespiratory response and fitness on the treadmill in a 20- to 85- year-old population. Chest. 2013:144(1):241-8.

23. Nelson MD, Petersen SR, Dlin RA. Effects of age and counseling on the cardiorespiratory response to graded exercise. Med Sci Sports Exerc. 2010;42(2):255-64.

24. Wasserman k, Hansen JE, Sue DY, Stringer WW, Whipp BJ. Principles of exercise testing and interpretation. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2005.

25. Aspenes ST, Nilsen TI, Skaug EA, Bertheussen GF, Ellingsen O, Vatten L, et al. Peak oxygen uptake and cardiovascular risk factors in 4631 healthy women and men. Med Sci Sports Exerc. 2011;43(8):1465-73.

26. Vilaró J, Resqueti VR, Fregonezi GAF. Clinical assessment of exercise capacity in patients with chronic obstructive pulmonary disease. Rev Bras Fisioter. 2008;12(4):249-59.

27. Pollock ML, Bohannon RL, Cooper KH, Ayres JJ, Ward A, White SR, et al. A comparative analysis of four protocols for maximal treadmill stress testing. Am Heart J. 1976;92(1):39-46.

28. Pollock ML, Foster C, Schmidt D, Helmann C, Linnerud AC, Ward A. Comparative analysis of physiologic responses to three different maximal graded exercise test protocols in healthy women. Am Heart J. 1982;103(3):363-73.

29. Rodrigues AN, Perez AJ, Carletti L, Bissoli NS, Abreu GR. The association between cardiorespiratory fitness and cardiovascular risk in adolescents. J Pediatr. 2007;83(5):429-35.

30. Jae SY, Heffernan KS, Fernhall B, Lee MK, Choi YH. Cardiorespiratory fitness is inversely associated with inflammatory and fibrinolytic markers in patients with type 2 diabetes. Circulation. 2007;116 (Suppl 16):800.

31. Arena R, Myers J, Williams MA, Gulati M, Kligfield P, Balady GJ, et al. Assessment of functional capacity in clinical and research settings: a scientific statement from the American Heart Association Committee on Exercise, Rehabilitation, and Prevention of the Council on Clinical Cardiology and the Council on Cardiovascular Nursing. Circulation. 2007;116(3):329-43.

32. Weiss EP, Spina RJ, Holloszy JO, Ehsani AA. Gender differences in the decline in aerobic capacity and its physiological determinants during the later decades of life. J Appl Physiol. 2006;101(3):938-44.

33. Rossi Neto JM, Tebexreni AS, Alves ANF, Smanio PEP, de Abreu FB, Thomazi MC, et al. Cardiorespiratory fitness data from 18,189 participants who underwent treadmill cardiopulmonary exercise testing in a Brazilian population. PLoS One. 2019:14(1):e0209897.

34. Cooper KH. Correndo sem medo. Rio de Janeiro: Nórdica; 1985.

35. Fleg JL, Piña IL, Balady GJ, Chaitman BR, Fletcher B, Lavie C, et al. Assessment of functional capacity in clinical and research applications: an advisory from the committee on exercise, rehabilitation, and prevention, council on clinical cardiology, American Heart Association. Circulation. 2000;102(13):1591-7.

36. Steene-Johannessen J, Kolle E, Anderssen SA, Andersen LB. Cardiovascular disease risk factors in a population-based sample of Norwegian children and adolescents. Scand J Clin Lab Invest. 2009;69(3):380-6.

37. Davis JA, Storer TW, Caiozzo VJ, Pham PH. Lower reference limit for maximal oxygen uptake in men and women. Clin Physiol Funct Imaging. 2002;22(5):332-8.

38. Jones NL, Summers E, Killian KJ. Influence of age and stature on exercise during incremental cycle ergometry in men and women. Am Rev Respir Dis. 1989;140(5):1373-80.

39. Instituto Brasileiro de Geografia e Estatística. (IBGE) [internet]. Censo Demográfico 2010 [acesso em 27 jul 2018]. Disponível em: https://ww2.ibge.gov.br/home/estatistica/populacao/censo2010/default.shtm

40. Almeida AEM, Stefani CM, Nascimento JA, Almeida NM, Santos AC, Ribeiro JP, et al. An equation for the prediction of oxygen consumption in a brazilian population. Arq Bras Cardiol. 2014;103(4):299-307.

41. Brasil. Ministério da Saúde. Secretaria de Vigilância em Saúde. Departamento de Vigilância de Doenças e Agravos Não Transmissíveis e Promoção de Saúde. Vigitel Brasil 2012: vigilância de fatores de risco e proteção para doenças crônicas por inquérito telefônico. Brasília; 2013.

Appendix I - General characteristics of the sample by age range

Variables	Age Range								
	07 - 12	13 - 19	20 - 29	30 - 39	40 - 49	50 - 59	60 - 69	70 - 79	≥ 80
Sex	**Male**								
N	32	151	543	969	853	440	229	77	26
Age	10.65 ± 1.4	16.66 ± 1.9	25.40 ± 2.9	34.52 ± 2.8	44.04 ± 2.8	53.74 ± 2.8	63.70 ± 2.8	73.58 ± 2.8	82.67 ± 2.5
Weight (kg)	51.87 ± 10.5	72.93 ± 18	81.90 ± 16	84.20 ± 16	83.47 ± 14	80.49 ± 12	76.75 ± 15	68.98 ± 10	66.9 ± 11
Height (cm)	151.0 ± 0.08	173.6 ± 0.7	174.5 ± 0.1	172.9 ± 0.1	171.1 ± 0.1	168.4 ± 0.1	165.5 ± 0.1	162.3 ± 0.1	161.8 ± 0.1
BMI	22.64 ± 3.21	24.10 ± 5.3	27.05 ± 5.1	28.22 ± 4.8	28.42 ± 4.3	28.45 ± 4.6	27.90 ± 4.6	26.27 ± 3.6	25.45 ± 3.6
Inactive (%)	52.20	28.70	37.10	45.00	43.80	47.40	43.20	54.90	54.20
Active (%)	47.80	57.40	54.50	44.90	50.20	48.30	54.70	43.70	45.80
Athlete (%)	-	13.90	8.40	10.10	6.00	4.30	2.10	1.40	-
VO_{2peak}	36.92 ± 7.4	42.90 ± 9.1	37.54 ± 8.3	35.78 ± 9.0	33.03 ± 7.7	30.10 ± 7.1	26.10 ± 6.4	22.06 ± 4.7	19.20 ± 3.4
Sex	**Female**								
N	25	107	471	874	759	551	322	123	16
Age	9.82 ± 1.7	16.73 ± 1.8	25.19 ± 2.9	34.53 ± 2.9	44.42 ± 2.8	54.23 ± 2.8	64.21 ± 2.8	73.44 ± 2.7	83.40 ± 2.9
Weight (kg)	51.69 ± 12.9	61.43 ± 18	65.62 ± 14	67.46 ± 13	69.25 ± 12	69.03 ± 12	64.82 ± 10	62.90 ± 10	57.13 ± 10
Height (cm)	147.7 ± 0.11	163.1 ± 0.8	162.8 ± 0.6	160.6 ± 0.1	158.5 ± 0.1	156.3 ± 0.1	152.8 ± 0.1	151.5 ± 0.1	152.1 ± 0.0
BMI	23.58 ± 4.5	23.01 ± 6.1	24.83 ± 5.1	26.14 ± 5.0	27.59 ± 5.0	28.23 ± 5.0	27.85 ± 4.6	27.39 ± 4.2	24.73 ± 4.0
Inactive (%)	76.50	68.80	61.00	61.00	62.50	61.00	62.90	71.60	46.70
Active (%)	23.50	27.50	36.00	35.80	34.60	37.50	37.10	28.40	53.30
Athlete (%)	-	3.80	2.90	3.20	2.90	1.50	-	-	-
VO_{2peak}	28.86 ± 5.8	30.00 ± 7.1	28.24 ± 6.5	26.70 ± 6.4	24.00 ± 6.0	21.84 ± 5.1	19.30 ± 3.9	17.41 ± 3.7	16.56 ± 2.9

BMI: body mass index; VO_{2peak}: peak oxygen consumption.