Assessment of Functional Capacity through Oxygen Consumption in Patients with Asymptomatic Probable Heart Disease

Luiz Oswaldo Carneiro Rodrigues, Emerson Silami-Garcia, Maria da Consolação Vieira Moreira, Giane Amorim Ribeiro

Belo Horizonte, MG - Brazil

Purpose – *To compare peak exercise oxygen consumption (VO_{2peak}) of healthy individuals with asymptomatic individuals with probable heart disease.*

Methods – *Ninety-eight men were evaluated. They were divided into two groups: 1) 39 healthy individuals (group N) with an age range of 50±4.6 years; and 2) 59 asymptomatic individuals with signs of atherosclerotic and/or hypertensive heart disease (group C) with an age range of 51.9±10.4 years. In regard to age, height, body surface area, percentage of fat, lean body mass, and daily physical activity, both groups were statistically similar. Environmental conditions during the ergometric test were also controlled.*

Results – *Maximal aerobic power (watts), VO_{2peak}, maximal heart rate, and maximal pulmonary ventilation were lower in group C ($p<0.01$) than in group N; weight, however, was lower in group N ($p=0.031$) than in group C. Differences in the respiratory gas exchange index, heart rate at rest, and the maximal double product of the two groups were not statistically significant.*

Conclusion – *Signs of probable heart disease, even though asymptomatic, may reduce the functional capacity, perhaps due to the lower maximal cardiac output and/or muscle metabolic changes.*

Key words - functional capacity, oxygen consumption, heart disease

Universidade Federal de Minas Gerais – UFMG
Mailing address: Luiz Oswaldo Carneiro Rodrigues - Laboratório de Fisiologia do Exercício – Campus da Pampulha – UFMG - Av. Presidente Carlos Luz, 4664 – 31310-250 - Belo Horizonte – MG - Brazil

Maximal oxygen consumption (VO_{2max}) has been considered the best indicator of the human capacity for tolerating prolonged effort [1]. Its assessment, however, has some technical difficulties, especially in individuals with lower physical fitness or those limited by heart disease [2]. Therefore, the greatest oxygen consumption during exercise, called peak exercise oxygen consumption (VO_{2peak}), is considered an objective indicator of functional capacity. It may also provide an indirect and accurate assessment of cardiac reserve [3]. VO_{2peak} is considered particularly reliable in functional assessment when associated with measurement of anaerobic metabolism[4], either through measurement of blood lactate [5,6] or through recording ventilatory variables [2], in young and middle-aged individuals [7].

Several authors have shown a strong correlation between exercise capacity assessed through VO_{2peak} and the prognosis and severity of congestive heart failure (CHF): the one-year mortality rate is higher in patients with VO_{2peak} below 10 mL/kg.min; this group of patients can benefit from heart transplantation [8,9]. VO_{2peak} may also reveal changes in exercise capacity due to the use of medicines, reflecting, more precisely, the compensatory adjustments and the prognosis of the CHF than any other hemodynamic and clinical indicator [2,10-14].

VO_{2peak}, therefore, has become an important prognostic tool in the evaluation and selection of candidates for cardiac transplantation. All patients with stable terminal CHF should have their functional capacity evaluated through the direct measurement of oxygen consumption, as part of the mandatory procedures for selection for cardiac transplantation [15]. Most of the patients with VO_{2peak} higher than 14mL/kg.min^{-1} can wait longer for transplantation even though VO_{2peak} is only one of the criteria to be considered in each patient [13].

Although VO_{2peak} provides an indicator for cardiac output (CO) and cardiac reserve, factors, such as age, sex, level of physical fitness, muscle mass, and angina, can influence its results[2]. For example, a VO_{2peak} of 14mL/kg.min^{-1} accounts for approximately 60% of the maximal exercise capacity expected in an active 60-year-old man, but only 30% of the capacity of an active 20-year-old man; such a low exercise capacity would be an unacceptable quality of life for a young adult [16].

On the other hand, despite the recognized usefulness of the VO_{2peak} in measuring symptomatic heart diseases, its value in asymptomatic or poorly symptomatic (NYHA class I) heart diseases is still being discussed [17]. This study aimed to approach this question through a comparison of healthy individuals with asymptomatic individuals with signs of atherosclerotic and/or hypertensive heart disease.

Methods

This study was approved by the Ethics Committee of the Hospital das Clínicas of the Federal University of Minas Gerais (UFMG). The sample comprised 98 male volunteers, who signed a consent form, agreeing with the methodology of the study. They were divided into two groups: one with 39 healthy individuals (group N) and the other with 59 asymptomatic individuals with indicative (57.6%) or suggestive (43.2%) electrocardiographic signs of heart disease (group C). The indicative electrocardiographic signs of heart disease were the following: depression of the ST segment >2mm, during effort; complete bundle-branch block; left ventricular overload; and frequent ventricular extrasystoles triggered by effort. The electrocardiographic signs suggesting heart disease were the following: straightening and depression of the ST segment >1mm and <2mm, during effort; unspecific disorders of intraventricular conduction; unspecific alterations of repolarization; arrhythmias, such as nonsustained paroxysmal supraventricular tachycardia and isolated ventricular extrasystoles. In addition, group C also showed evidence of heart disease on coronary angiography (13.5%) and/or echocardiogram (11.8%). Group C, as a whole, comprised individuals with probable atherosclerotic and/or hypertensive heart disease; there was no suspicion of Chagas' cardiomyopathy, valvar disease nor any other disease.

Both groups underwent direct assessment of the VO_{2peak} through the direct method of spirometry with the use of an Ergopneumotest metabolimeter. Indirect determination of the anaerobic metabolism was also performed, as well as the determination of other metabolic, cardiovascular and ventilatory variables during standard exercise until exhaustion [12], in a electronically braked bicycle ergometer (Monark), at a speed of 18 km/h. All patients underwent an ergometric test until exhaustion, characterized as the moment at which the predetermined potency and/or velocity could no longer be maintained. The examiners did not interrupt the tests. The maximal aerobic power (POW) was equivalent to the highest value observed during at least 3 minutes of exercise and VO_{2peak} was obtained during this period. Exercise was subjectively evaluated through the rating of perceived exertion (REP) (from 0 to 10) scale [18]. Electrocardiogram (ECG) and heart rate (HR) were continuously monitored during rest and exercise until exhaustion and also for 10 minutes during recovery. Blood pressure (BP) was obtained through a sphygmomanometer graduated in mmHg. Bicycle ergometetric tests were performed in an environment with air conditioning to maintain temperature (between 21 and 24°C) and relative humidity (between 50 and 75%) levels so that heat stress was unlikely [19]. The impact of heat stress was calculated through the wet bulb globe temperature index (WBGTI) [20,21]. Tests comparing the mean of variables with normal distribution were performed, as well as nonparametric tests, when necessary, adopting the significance level of $p<0.05$.

Results

Table I shows that groups N and C were similar in regard to the following variables: age, usual physical activity, HR at rest, maximal cardiac work, ventilatory equivalent for oxygen, BP variation during exercise, respiratory gas exchange index, REP at the potency of 100 watt, dry environmental temperature, humid environmental temperature, relative humidity of the air.

Table I also shows that group C had greater weights,

Table I – Values (mean ± standard deviation) obtained in the group of healthy individuals (group N) and the group of asymptomatic individuals with signs of probable heart disease (group C) for the following parameters: age, weight, usual physical activity (UPA), systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR) at rest and during exercise, peak exercise oxygen consumption (VO_{2peak}), ventilatory equivalent (VE/VO_2), respiratory gas exchanges index (R), rating of perceived exertion scale (REP), double product (DP), maximal aerobic power (POW), dry environmental temperature (DT), humid environmental temperature (HT), relative humidity of the air (RHA), and the wet bulb globe temperature index (WBGTI).

	Group N	Group C	p
Age	50.0±4.6	51.9±10.4	0.221
Weight	71.5±10.1	76.4±12.1	0.031
UPA	3.5±1.9	4.1±2.6	0.207
HRrest	68.4±11.1	71.0±11.4	0.273
SBPrest	125.9±11.1	147.7±17.5	<0.001
DBPrest	81.6±6.0	94.1±12.0	<0.001
DPrest	8612.1±1597.1	10533.8±2341.6	<0.001
HRmax	165.0±11.9	150.3±16.8	<0.001
SBPmax	195.1±26.1	215.3±29.2	<0.001
DBPmax	92,9±11,7	107.7±17.1	<0,001
DPmax	32203.4±4732.3	32431.0±6176.1	0.837
VO_{2peak}	31.7±7.4	25.1±5.6	$1.2x10^{-5}$
P_{oxy}	21.1±4.9	16.7±3.5	<0.001
POW	2,67±0.56	2.11±0.44	$1.3x10^{-6}$
VE/VO_2	31.5±5.1	30.2±5.5	0.256
R	1.06±0.13	1.05±0.18	0.728
REP	8.9	9.8	0.157
DT	20.6±2.1	20.0±2.1	0.125
HT	16.5±2,1	15.9±2.0	0.169
RHA	60.9±6.7	61.5±7.4	0.698
WBGTI	17.7±2.0	16.4±3.5	0.024

Where: weight in kg; age in years; UPA in multiples of the basal metabolism, MET; SBP and DBP in mmHg; DBP in mmHg; HR in min^{-1}; DP in $mmHg.min^{-1}$; VO_{2peak} in $ml/kg.min^{-1}$; VE/VO_2 and R in absolute figures; REP in the power of 100 watt in the Borg scale; POW in watt/kg; DT, HT and WBGTI in °C; RHA in %.

higher BP at rest and during exercise, and a higher cardiac work at rest than the healthy individuals of group N. On the other hand, group C shows a lower maximal HR, lower peak exercise oxygen consumption, lower oxygen pulse (P_{oxy}) and lower POW during exercise. In addition, the environmental heat stress of group C was lower during exercise.

Table II shows that, when group C was subdivided in regard to the presence or absence of hypertension and use of medication there were no differences in the peak exercise oxygen consumption and oxygen pulse. In the subgroup of hypertensive patients, however, the use of medication reduced the maximal aerobic power and maximal HR.

Discussion

The measure of VO_{2peak} in healthy individuals in this study showed results consistent with those obtained in previous studies [22] in regard to the age of the volunteers[2,16,23].

The lower VO_{2peak} in group C, when compared with that of healthy individuals in the same age range, suggests that the presence of signs of heart disease, even though the patient is asymptomatic, can reduce functional capacity [24]. In the present study, this decrease was 2 METs, representing a significant reduction in the physical capacity for work, leisure and daily activities, corresponding to 14 to 16 years of early aging[16]. A decrease of 3 METs was also observed in a group of individuals with Chagas' heart disease, when compared with healthy individuals in the same age range [17].

Findings of the present study also suggest that both the direct measure of oxygen consumption (VO_{2peak}, in mL/kg.min^{-1}) and the measure of the maximal aerobic power (POW, in watt/kg) can identify the reduction in functional capacity, even for those asymptomatic individuals with signs of heart disease (Table I). POW, however, was statistically 10 times more sensitive than VO_{2peak} for detecting a reduction in the functional capacity of group C participants, when compared with the healthy individuals. In addition, POW revealed some significant differences due to hypertension and use of medication in group C, which did not occur with VO_{2peak} (Table II). These findings are not in accordance with that which has been postulated for the diagnosis of the functional capacity in patients with heart disease [25] and also for the prescription of exercise[7]. However, the highest sensitivity of POW in the assessment of the functional capacity has also been observed for women [26].

Some mechanisms may be involved in the decrease of the functional capacity in group C, for example a reduction in the maximal CO (Q_{max}) due to the probable heart disease, hypertension or the use of medication; muscle metabolic alterations; and the iatrogenic sedentary lifestyle caused by the diagnosis.

At the beginning, the simple presence of signs of heart disease as a criterion of inclusion in group C could suggest that the limiting factor in the functional capacity would be a reduction in Q_{max}. Even though this study did not assess Q_{max} directly, the maximal cardiac work of group C (Table I) was similar to that of the healthy group, and this similarity of the maximal double product (DP_{max}) occurred due to a lower HR_{max} in group C, resulting from a higher BP in this group. This implies that when the same maximal cardiac work is reached with a lower HR, there is a smaller Q_{max} in group C, even though the stroke volume is kept constant [27].

When group C, however, is subdivided into normotensive and hypertensive individuals (Table II), one observes that peak exercise oxygen consumption (VO_{2peak}) and oxygen transportation per cardiac beat (P_{oxy}) are not different in the two groups, indicating that the presence of hypertension is not the main cause of the lower capacity of oxygen uptake and transportation among individuals in group C. Hypertension, however, caused a reduction in POW in this group, suggesting the existence of a peripheral reducing factor.

Observation of P_{oxy} shows that less oxygen was consumed and/or less blood was transported per cardiac beat in group C (Table I), which could result from the lower stroke volume or from the smaller peripheral extraction of oxygen. It is known that chronic heart failure renders the skeletal muscle function difficult, independently from blood flow and from the availability of oxygen [28,29]. It is also known that individuals with symptomatic heart diseases can have metabolic dysfunctions of the skeletal muscles, which reduce their functional capacity [30]. Observation of the respiratory gas exchange index and of the ventilatory equivalent for oxygen (V_E/VO_2) shows that group C reached the same relative level of lactic metabolic acidosis, but with absolute lower efforts than healthy individuals. This

Table II – Values (mean ± standard deviation) of peak exercise oxygen consumption (VO_{2peak}), maximal aerobic power (POT), maximal heart rate (HR_{max}) and oxygen pulse (P_{oxy}) obtained for groups N and C, the latter subdivided into two subgroups: CNS- normotensive individuals without medication; CNM- normotensive individuals with medication; CHS- hypertensive individuals without medication; CHM- hypertensive individuals with medication.

	Group N (n=39)	CNS (n=11)	CNM(**) (n=3)	CHS (n=26)	CHM (***) (n=19)	P
VO_{2peak}	31.7±7.4	25.8±4.5	22.4±10.6	24.7±5.2	25.6±6.1	*
POW	2.66±0.55	2.10±0.43	1.88±0.44	2.24±0.41	1.94±0.45	* ψ
HRmax	165.0±11.9	153.0±19.7	151.3±16.5	155.5±14.6	141.4±15.4	* ψ
P_{oxy}	21.1±4.99	1.71±3.0	14.9±7.1	16.5±3.4	17.0±4.0	*

Where: VO_{2peak} in ml/kg.min^{-1}; POW in watt/kg; HR_{max}: maximal heart rate, in min^{-1}; P_{oxy}: in ml O_2. min^{-1}; (*): significant differences ($p<0.05$) comparing the subgroups of individuals with heart disease with healthy individuals. (ψ): significant differences only between CHS and CHM ($p<0.05$). (**) medication: nitrates and beta-blockers; (***) medication: mainly diuretics, beta-blockers, alpha methyl dopa and nitrates but also individual use of digitalis, minoxidil, angiotensin-converting enzyme inhibitor, tranquilizers or calcium channel blocker. The doses of the medicines used were those recognized as effective.

finding indicates the precocious predominance of the anaerobic glycolysis, strengthening the hypothesis that the best functional capacity can result either from the lowest blood supply to the muscles (smaller stroke volume) or from the smallest peripheral extraction of oxygen (muscle metabolic dysfunction) in group C.

The use of some medicines, especially those blockers of the sympathetic activity upon the heart, may decrease the capacity of adequately adjusting CO during exercise, reducing the blood supply to tissue, resulting in a smaller physical capacity in group C. In this group, 57% of the patients used medicines that were potential cardiac capacity reducing agents, resulting in some degree of chronotropic block and reduction in the maximal power in the hypertensive patients during exercise. There were, however, no significant differences in regard to VO_{2peak} and no significant repercussion on the response of BP during exercise (Table II). These data do not support the hypothesis that group C would have a smaller Q_{max} due to the use of medicines, even though the drugs caused a reduction in maximal power.

Lack of physical fitness is one of the most important factors in the reduction of functional capacity at any age [23]. Medical and/or cultural factors could contribute to resistance of patients to becoming involved in physical activities more effective in promoting fitness. In the present study, group C had an usual mean physical activity similar to that of healthy individuals (Table I), i.e., they do not have a more sedentary lifestyle than healthy individuals, not justifying the smallest functional capacity observed in group C. The coefficient of variation of usual physical activity in this study, however, was very high, indicating the need for further studies.

The REP, measured in the power of 100 watt and reached by all the individuals, was not statistically different between the two groups N and C, showing that the REP scale was not sensitive to the reduction in the functional capacity. Perhaps this may occur because the individuals in group C were still at a higher functional level than that described as a threshold (18 mL/kg.min^{-1}) for the subjective perception of their own dysfunction [31].

Finally, the room temperature during the tests was slightly cold [19]. In such an environment, possible cardiovascular overload resulting from heat stress was statistically higher than that of environmental conditions in which the healthy individuals underwent ergometric tests. This would not explain, however, the reduction in the functional capacity observed in group C. Nevertheless, the magnitude of the increase observed in the WBGTI between the two environments does not seem to cause significant variations in performance during physical activity [31].

In conclusion, the lower VO_{2peak} and POW found in group C indicate that signs of heart disease, even though asymptomatic, can significantly decrease functional capacity. The measure of POW seems to be more sensitive than that of VO_{2peak} for detecting a reduction in functional capacity caused by the asymptomatic probable heart disease. The mechanisms of this decrease have not yet been well clarified and reduction in the maximal CO and/or peripheral metabolic changes are suggested as hypotheses.

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