Evaluation of Cardiopulmonary Fitness in Individuals with Hemiparesis after Cerebrovascular Accident

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Abstract

Background: Due to the hemiparesis, the assessment of cardiorespiratory fitness on individuals after cerebrovascular accident (CVA), using exercise tests with conventional protocols, has become a challenge.

Objective: Perform cardiopulmonary test (CPT) in hemiparetic patients to a pre-participation evaluation aimed at a careful prescription of aerobic exercise.

Methods: The study included eight individuals with chronic hemiparesis who underwent CPT performed with individualized ramp protocol, developed from information on the gait speed of individuals previously evaluated in the track test. We considered the proposal of inclination ranging from 0 to 10.0%, initial speed corresponding to 70.0% of comfortable walking speed rhythm and 40.0% higher than the maximum speed on the track test, expecting that the CPT with this gradual and steady increase in intensity, lasted from 6 to 8 minutes.

Results: In 100.0% of the sample, the reason for discontinuation was peripheral fatigue. The peak VO_2 achieved was 20.6 ± 5.7 ml/kg.min. The threshold I was identified in all tests, standing at 82.64 ± 4.78% of peak HR and 73.31 ± 4.97% of peak VO_2. The respiratory quotient (R) of the group was 0.96 ± 0.09, and three out of eight individuals (37.5%) reached R higher than 1.00, and the Threshold II was identified in these individuals. We found positive relationships between CPT variables and balance scores, performance in the 6-minute walking test and running speed on the ground.

Conclusion: The test proved to be useful for prescribing physical activity in these individuals. (Arq Bras Cardiol 2011; 96(2): 140-147)

Keywords: Physical fitness; paresis; exercise test; stroke; respiratory function tests.

Introduction

Cardiovascular diseases, including the cerebrovascular accident (CVA), is one of the most important health problems of our times[1]. A common characteristic among individuals affected by a CVA is the presence of risk factors such as sedentary lifestyle, high blood pressure (hypertension), obesity, smoking and distress, which can be modified through the intervention on lifestyle. Such factors, if untreated, maintain a high risk of recurrence of CVA in this population[2].

Traditionally, after a CVA, rehabilitation by means of conventional physiotherapy prioritizes the evaluation and treatment of primary neurological damage, including muscle weakness of the hemibody contralateral to the brain damage (hemiparesis) and the presence of abnormal synergism impairing the control of movements. The recovery of gait has been the main goal in the rehabilitation of such patients[3], and the inclusion of such population in programs of cardiorespiratory fitness is still an uncommon practice in Brazil.

Lack of physical fitness may be a secondary factor that limits the transfer of locomotor skills gained in rehabilitation to the community environment. Decreased walking resistance was the most prominent functional limitation observed in a sample of individuals with one year of post-CVA, and its recovery significantly associated with the reintegration of these individuals to community life[4].

The assessment of cardiorespiratory fitness in individuals with CVA is difficult because the specific disadvantages of hemiparesis, muscle weakness, fatigue, lack of balance, contractures and spasticity can interfere in effective testing with standard protocols[5]. Therefore, developing reliable methods for a truthful evaluation of cardiorespiratory fitness in those individuals becomes important.

New studies involving aerobic training[6-7] and physical fitness assessment using submaximum and maximum testing[5,8-13] have recently emerged, contributing with further information on physical fitness alterations and the efficiency of training programs in this population. There are several protocols for ergospirometry evaluation and there are reports of using the modified Balke protocol[14], modified Harbor protocol[15,16], or treadmill test at constant speed and progressive increase of slope[17]. There are no studies that have used an individualized ramp protocol with simultaneous increments of slope

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and treadmill speed. Moreover, none of these studies was conducted in Brazil, where there is a lack of studies involving the assessment of cardiorespiratory fitness on a treadmill in patients with chronic sequel of CVA.

Therefore, this study is designed to investigate the application of an adapted protocol for cardiopulmonary test (CPT) in individualized ramp for individuals with hemiparesis with a variety of walking abnormalities. We investigated the hypothesis that individuals with hemiparesis due to CVA sequel, even the older ones with motor limitations affecting their walking performance, could achieve appropriate exercise intensity for cardiopulmonary evaluation through a stress test with individualized ramp protocol with concurrent increments of speed and treadmill on slope.

Thus, this study sought to describe a protocol for submaximal exercise test on a treadmill that could be performed in clinical practice, and evaluate its effectiveness for a pre-participation evaluation, aiming at a careful prescription of aerobic exercise.

Methods

Sample

This study included eight individuals with chronic hemiparesis (9-34 months after the CVA), aged 21-74, with light to mild motor impairment in lower limbs (20 to 31 points) according to test scores of Fugl-Meyer, and comfortable walking speed on the ground between 0.3 to 1.15 m/s (Table 1).

The sample included individuals with chronic unilateral sequel of a single CVA, (for at least 6 months from the event), with a minimum score of 20 on 34 on Fugl-Meyer scale of

Table 1 - Characteristics of participants and performance in clinical tests

Characteristics	Values (average and standard deviation)
Age (years)	53 ± 17
Chronicity (months)	18 ± 11
Body mass index (Kg/m^2)	27.1±2.7
Use of beta blockers	N = 4 (50.0%)
Hemorrhagic CVA	N = 3 (62.5%)
Ischemic CVA	N = 5 (37.5%)
Motor recovery (0-34 points - Fulg-Meyer Scale)	25 ± 4.5
Balance (0-56 points - Berg Balance Scale)	49 ± 7.7
Comfortable walking speed 10 m (m/s)	0.9 ± 0.3
Fast walking speed 10 m (m/s)	1.26 ± 0.4
Comfortable walking speed on 100 m track (m/s)	0.88 ± 0.3
Fast walking speed on 100 m track (m/s)	1.23 ± 0.6
Human activity profile - MSA	68 ± 7
Human activity profile - AAS	45 ± 12.3

CVA - cerebrovascular accident; MSA - maximum score activity; AAS - adjusted activity score.

lower limbs and independent walking, even under use of any assistive device for ambulation, with no cognitive impairment. Exclusion criteria were the diagnosis of congestive heart failure, unstable angina, peripheral vascular disease with claudication, limiting orthopedic conditions or other conditions (other than CVA sequel) which would prevent participation in a CPT.

Besides the CPT, the evaluation included clinical examination, physical therapy evaluation, with the application of clinical tests to assess motor function and application of a questionnaire on the current level of physical activity - Human Activity Profile[18]. Clinical assessments were performed at intervals of one week before the procedure on the treadmill.

This study was approved by the Ethics and Research Committee (Opinion No. 88/2007). The usual medication was maintained throughout the period of selection and assessment of individuals.

Clinical trials to assess motor function

Before the collection, all participants signed an informed consent. The next step was filling an individual identification sheet and motor function tests that were used to characterize the sample. All tests were performed by an experienced physiotherapist. Lower limb motor impairment was assessed by the motor session of the lower limb in Fugl-Meyer Scale[19], which evaluates voluntary movements in and out of abnormal synergies, with scores ranging from 0 to 34, where a 34 score characterizes normal movement.

The dynamic equilibrium of the individuals was evaluated using the Berg Balance Scale[20], which consists of 14 dynamic balance tasks requested to the patient. The examiner evaluates the patient for each task, scoring from 0 (zero) to 4, where 0 means inability to perform the proposed activity and 4 means the ability to perform the activity without difficulty. The maximum score is 56 points, showing lack of balance disorders, and scores smaller than 36 points means severe impairment of balance[20].

A comfortable walking speed, expressed in m/s, was assessed by requesting participants to walk at a "comfortable" speed using shoes with which they were used to, a distance of 14 meters, and the time to walk 10 meters was recorded. At fast walking speed (10 m), the same procedure was performed, but the individual was asked to walk as fast as possible[21]. Walking resistance was assessed by the 6-minute walk test (TC6min)[21], where individuals were asked to walk from one end to the other of a 30-meter long corridor walking the longest distance possible in 6 minutes[22].

The Human Activity Profile (HAP)[18] was used to assess the level of activity and involves the application of a questionnaire in which the individual answers 94 questions regarding the functional level and physical activity. The HAP examines, among other primary scores, two scores, the MSA (maximum score of activity) related to the numbering of the activity with the highest demand for oxygen that an individual still does, and the AAS (adjusted activity score), which corresponds to the MPE subtracting the number of items that the individual has stopped doing. The MSA is considered a measure of physical activity level, while AAS, a measure of physical fitness. The AAS provides a more accurate estimate of daily activities, as it represents the average metabolic equivalent level spent on a typical day. The classification is obtained by the AAS number, where an individual is considered active (AAS > 74), moderately active (53 ≤AAS ≤ 74) or weak or inactive (AAS < 53).

Protocol for evaluation of stress test on treadmill

We used a ramp protocol based on the protocol used by Mackay-Lyons and Makrides[15] in individuals with hemiparesis. Initially, we performed a walking speed test on a 100m track. Each individual performed two walking tests on the track, one at a comfortable speed, and another at maximum speed, which served to establish the speeds used for the CPT as well as to check the individual's tolerance to a faster speed walking.

Before the CPT, an initial test was performed on a treadmill, with no inclination, to evaluate walking stability and familiarize patients with the equipment, allowing to check whether the fast speed observed on the track could be maintained on the treadmill. In this test, the individuals walked for at least two minutes without interruption, at their comfortable speed determined by the track test, no inclination, and thereafter, for at least 30 seconds at their fast speed. The next step was the CPT, held one week after the clinical and track tests. Before starting the CPT, the patients laid down for about five minutes in a quiet environment, with temperature maintained at around 22ºC, while resting ECG was performed.

For the performance of CPT, we used a treadmill (Imbrasport KT ATL) with a computerized system (Elite Metasoft) and a system of metabolic gas analysis (Metalyzer) to obtain simultaneous respiratory and metabolic parameters, through the direct analysis of gases (O_2 and CO_2) expired and metabolic measures. For electrocardiographic recording, we used specific equipment and software of digital electrocardiogram (ErgoPC Elite version 3.2.1.5, Micromed, Brazil). The initial speed of the CPT used on the treadmill was 70.0% of the comfortable speed on the track test. The final speed of the test was 40.0% higher than the maximum speed of the individual on the ground, as defined in the 100-meter track test. The test was gradual, lasting approximately eight minutes and a maximum inclination of the treadmill set to be 10.0%.

All tests were conducted by the same cardiologist. As the individuals presented great walking instability, they were allowed to rest their hands on the handle. A physical therapist stood behind the patient, for safety reasons, but no assistance was offered if no difficulties were observed as the patients walked during the test.

The test was interrupted at patients' request, or when unsteady walking was observed, or in the presence of any relevant clinical, hemodynamic or ECG abnormalities[23]. The peak oxygen consumption (peak VO_2) was considered the highest VO_2 achieved during exercise. We calculated the inclination of ventilation course (VE) vs. the production of carbon dioxide (VCO_2) by the linear regression model, using data obtained during the entire test.

Statistical analysis

Data were expressed as mean and standard deviation. The t test for one sample was used to compare the walking speed and the VE/VCO_2 inclination in this study with reference values in literature. The Spearman correlation was used to check the relationship between the variables of cardiopulmonary exercise test with the variables of clinical testing. The tests were performed with SPSS software version 17.0, adopting a significance level of 5.0% ($p \leq 0.05$).

Results

We evaluated 8 individuals with mean age 53 ± 17 years, including six men. Five individuals were former smokers (stopped smoking after the CVA), one was diabetic and six individuals were hypertensive patients under pharmacological treatment. None of the individuals had been diagnosed with associated heart diseases, or had participated in a cardiopulmonary or metabolic rehabilitation program.

There were no differences in the speed on the 100m track test and the 10 m walking speed test, both for comfortable speed and for fast speed. Electrocardiographic parameters at rest and stress were considered within normal limits in seven individuals (87.5%), and one (12.5%) had right bundle branch block and isolated polymorphic ventricular extrasystoles. All individuals remained asymptomatic during the test and the reason for discontinuation in 100.0% of the tests was tiredness, especially the lower limbs, influenced by motor difficulties arising from CVA sequel.

The results of the main CPT variables are shown in Table 2. Peak heart rate reached 78.24 ± 13.7% predicted for age, and 25.0% of individuals (n = 2) reached > 95.0% predicted for age and 75.0% of individuals (n = 6) achieved > 75.0% predicted for age. Out of these, four were on beta-blockers. The anaerobic threshold (threshold I) was identified in all examinations, reaching to 82.64 ± 4.78% of peak HR and 73.31 ± 4.97% of peak VO_2. Only three out of eight individuals (37.5%) reached R exceeding 1.00. The respiratory compensation point (Threshold 2) was identified in these individuals. Peak O_2 pulse was considered normal, with average values of 15.46 ± 2.96 ml/b. The VE/VCO_2 inclination behaved near the reference values found in literature in healthy individuals of similar age and sex, with a tendency to be higher in this study ($p = 0.05$)[24].

The results of the CPT performance can be seen in Table 3. The test duration ranged from 3.6 to 8.2 minutes and only one individual completed the test in more than eight minutes. The walking speed of individuals, as evaluated by the walking speed test on the ground at 10 m, was significantly lower when compared with reference values of healthy individuals of similar age and sex[25] ($p = 0.001$). The distance walked in the 6-minute walking test was 400.9 ± 136m and only one person could cover a distance exceeding 500 m.

The balance scores correlated with the speed at the end of the CPT ($\rho = 0.74$, $p = 0.03$) and with motor impairment ($\rho = 0.83$, $p = 0.01$). The initial rate of CPT also correlated with a fast and comfortable walking speed ($\rho = 0.83$, $p = 0.01$, $\rho = 0.92$, $p < 0.001$, respectively).

There were no correlations between peak VO_2 and performance in the walking speed test. However, we observed a positive correlation between the ability to increase walking speed (difference between maximum and comfortable speed) and peak VO_2 ($\rho = 0.71$, $p = 0.04$). Peak

Table 2 - Individual results of the main cardiorespiratory variables at peak CPT

Individual	Peak VO_2 (ml/kg.min)	% of VO_2 predicted	Max HR % predicted	Max VE (l/min)	Max VE % predicted	R	VE/VCO_2 inclination	Peak blood pressure (mmHg)	Maximum score on Borg Scale
1	15.56	46.30	57.80	49.90	36.20	1.02	29.07	130/70	13
2	19.60	65.40	68.75	48.30	40.60	0.94	29.20	160/70	13
3	18.57	63.90	99.40	36.80	53.00	0.90	29.24	180/65	16
4	25.54	47.50	71.40	56.00	32.55	0.92	29.50	150/55	13
5	17.21	75.20	93.20	37.20	69.00	1.03	34.08	170/80	14
6	23.38	81.30	77.80	59.00	56.94	0.82	36.00	160/70	15
7	18.85	47.90	77.40	52.50	30.40	1.02	33.00	160/60	14
8	25.88	83.00	80.20	53.20	49.20	0.98	26.80	180/85	15
Average	20.60	64.00	78.24	49.11	46.00	0.96	30.86	160/70	14
SD	5.70	15.30	13.30	8.10	13.40	0.07	3.10	-------	1

VE - pulmonary ventilation; SD - standard deviation.

Table 3 - Individual results of CPT performance

Individual	Initial speed (m/s)	Final speed (m/s)	Final inclination (%)	Test duration (min)	Distance walked (m)
1	0.40	1.07	6.0	4.93	220.09
2	0.67	1.39	6.5	5.36	372.46
3	0.18	0.54	9.5	7.88	186.23
4	0.76	1.34	9.5	8.20	558.69
5	0.67	1.12	4.0	3.60	220.09
6	0.72	1.12	6.5	5.50	321.67
7	0.58	1.39	8.5	7.10	440.18
8	0.63	1.56	8.0	7.66	490.97
Average	0.60	1.20	7.3	6.30	351.30
SD	0.20	0.30	2.0	2.46	138.06

DP - standard deviation.

VO_2 results were correlated with the walking performance observed by the 6MWT ($\rho = 0.71$, $p = 0.04$). The maximum scores of activity (MSA) and adjusted activity score (AAS) assessed by HAPs were positively correlated with walking speed at the start of the CPT ($\rho = 0.84$, $p < 0.01$ and $\rho = 0.77$, $p = 0.02$, respectively) and peak VO_2 correlated positively with MSA ($\rho = 0.73$, $p = 0.04$).

Discussion

This study evaluated the cardiorespiratory fitness of individuals affected by CVA through an individualized ramp protocol and related its performance to motor impairment, balance deficits, walking performance and physical activity level. With the protocol used, the test was characterized as submaximal, since all individuals reached Threshold 1. Thus, it is clear that the test was useful for a careful prescription of aerobic physical activity.

The proposed duration of the maximum effort in the ramp protocol should be between 8 and 12 minutes[26]. In this study, the initial forecast was that the test would last between 6 and 8 minutes, characterizing a submaximal test, which was seen in 50.0% of individuals. Out of these, two had mild motor impairments, one had moderate motor impairment and one had severe motor impairment. It is likely that the maximum speed to be achieved (40.0% higher than the fast track walking speed) in the test has been overestimated, reducing individual's time spent on the treadmill.

A previous study[27] reported that elderly individuals with CVA sequel presented symptoms of intolerance to physical activity, such as dyspnea, weakness on lower limbs, exaggerated increase of heart and respiratory rate, besides subjective fatigue after walking, even over short distances, such as 50 meters for example. Fatigue is a common sequel in these patients, significantly impacting daily activities, especially those with higher metabolic demand[28]. In most studies involving CPT, generalized fatigue, or fatigue of affected leg, emerges as the main reason for CPT interruption[10,15,17,29,30], suggesting that motor impairment limits peak exercising capacity in this population.

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In this study, three out of the group of individuals reached the respiratory compensation point during the test. Difficulties in obtaining a maximum stress test in this population can be seen in other studies, such as Dobrovolny et al[17], also performed on a tread mill, where only 9.0% reached a respiratory rate (Q) ≥ 1.1, averaging 0.96 ± 0.09, similar to our study. In the study by Kelly et al[29], with a cycle ergometer cardiopulmonary exercise assessment, the average Q was 0.9, and only three of 17 individuals evaluated exceeded the value of 1, and none reached 1.1.

The findings showed that cardiorespiratory fitness and walking performance were markedly impaired in patients studied. Our results also suggest that the walking performance can be reduced because of a poor cardiorespiratory fitness. In the general population of individuals affected by CVA, this deficit is probably even higher, considering that our study excluded severely affected individuals, unable to withstand a treadmill test. The results of this study corroborate previous studies that assessed cardiorespiratory fitness in this population.

In the study by Pang et al[10], with individuals who had had CVA 6 months before (chronic), aged 50-87, peak VO_2 was 23.5 ± 4.0 ml/kg/min for men and 20.1 ± 5.1 ml/kg/min for women, represented losses of 25.0% for men and 20.0% for women compared to healthy population. Kelly et al[29] observed a peak VO_2 between 15.8 to 16.1 $ml.kg^{-1}.min^{-1}$ in 17 individuals with hemiparesis and a mean age of 66 years, evaluated in maximal exercise on a cycle ergometer 30 days after the CVA event. Potempa et al[8], in their pre-intervention evaluation in chronic individuals, found peak VO_2 of 16.6 ± 1 $ml.kg^{-1}.min^{-1}$ in 19 individuals in an experimental group and 15,1 ± 1 $ml.kg^{-1}.min^{-1}$ in other 23 individuals in a control group.

In this study, peak VO_2 was associated with 6MWT. Our data corroborate the study by Kelly et al[29], which evaluated cardiorespiratory fitness on a cycle ergometer in underacute individuals, e found a correlation between peak VO_2 and 6MWT. Another study[10], however, found a low correlation between peak VO_2 measured by a cycle ergometer with the distance run on the 6MWT in chronic patients, and the authors suggest that factors other than cardiorespiratory fitness influenced the walking ability analyzed by the test. Therefore, they do not recommend such testing as the only way to evaluate physical fitness in this population.

There were no correlations between peak VO_2 and performance in the walking speed test on the ground. However, we observed a positive correlation between the ability to increase walking speed (difference between maximum and comfortable speed) and peak VO_2. While the primary impairments that hinder walking are related to loss of strength and coordination[31], loss of cardiorespiratory fitness can be considered a secondary contributor for poor motor performance after a CVA.

The initial speed of CPT was positively correlated with fast and comfortable walking speed measured by walking speed test over 10 meters. As no statistical differences were found between the walking speed test over 10 meters and the test track over 100 meters, used to establish the speed of the treadmill, it is suggested that the walking speed test over 10 meters is used in clinical practice to establish the initial and final speed of the ramp protocol, making daily practice easier, because this test is simple and can be performed on any corridor with 14 meters[21].

The balance scores were highly correlated with the final speed of CPT, which is a sign that the better the balance, the higher the speed progression on CPT. According to Michael et al[32], the balance is a strong predictor of levels of locomotor activity of individuals after CVA in the chronic phase, but it is also related to peak VO_2, showing a relationship between balance and poor physical fitness. The ratio of deficits in balance with the speed achieved in CPT in this study demonstrates that, for such individuals, it may be difficult to increase walking speed sufficiently to induce na effective maximum CPT.

Not all studies evaluating physical fitness in this population have made an assessment of balance or showed a relationship between balance and performance on CPT, however, all of these studies included independently walking individuals making use of any walking assistive device. Considering that locomotor activity levels are strongly associated with balance scores[32], it can be said that studies have evaluated, in general, individuals with mild to moderate deficits in balance, excluding individuals with severe deficits, which would be dependent walking[10] and have difficulties in performing a maximal test.

Although the population in this study is independent for walking, we found a weak physical activity level assessed by the score adjusted by the HAP. Furthermore, we observed a positive correlation between peak VO_2 and maximum scores of HAP, indicating that individuals with better cardiorespiratory fitness perform more activities that require a higher energy expenditure. Physical inactivity is common after a CVA, but patients spend more than 70.0% of their day carrying out activities not related to improvement of their functional status, being involved in activities potentially beneficial for their motor performance in less than 20.0% of their day[33]. In addition, motor activity performed in physiotherapy or occupational therapy is not of sufficient intensity to induce na effective cardiorespiratory training[34].

After a CVA, exercising capacity may be impaired by the presence of cardiovascular comorbidities in up to 75.0% of patients, and it is an important clinical problem that affects both rehabilitation as well as the achievements in the long run[35]. Therefore, concomitant to conventional physical therapy rehabilitation, with a view to recover motor sequels, cardiopulmonary and metabolic rehabilitation must occur with emphasis on physical activity, addressing both functional recovery and the control of these risk factors.

The CPT, however, is not systematically used to diagnose coronary artery disease or even as a basis for prescription of metabolic or cardiopulmonary rehabilitation in individuals with hemiparesis[36]. The different factors that contribute to this reality probably include the constant concern about the risk of falls or even lack of knowledge by health professionals in general, that patients with neurological deficits affecting their walking ability and balance can perform a test on a treadmill, since the protocol is adapted to their limitations.

Although this study presents results with a sample of eight individuals, we can make some statements when it comes to the performance of CPT for evaluation and prescription of physical activity for individuals with chronic hemiparesis. The literature does not report the superiority of using a cycle ergometer or treadmill, both of which have their individual considerations. The cycle ergometer has the advantage of being safer in terms of risk of falls. However, it involves assessment and task-specific training on walking, primary target in the rehabilitation of this population. Literature reports the beneficial effect of aerobic exercise on a treadmill to improve both physical fitness and locomotor function after a CVA[37]. Therefore, its use should be encouraged, both as a form of evaluation and treatment.

This study showed that it is possible to establish a training through a submaximal test, however, some limitations may have affected the results of the study. These limitations include the low number of individuals studied, the testing time, which did not correspond largely to what is recommended in the literature, suggesting that the protocol to be used could be less intense. Another limitation could be failure to compare individuals who underwent testing with individuals who have their prescription based only on subjective forms of prescription and field tests. Future studies with larger samples, investigating if smaller increments in treadmill speed would achieve higher R values, can answer these questions.

Conclusion

In individuals with chronic hemiparesis who can walking independently, CPT on a treadmill with individualized ramp protocol was characterized as submaximal and has proved useful in determining the ventilatory threshold in all individuals evaluated, allowing a careful prescription of aerobic exercise in the context cardiopulmonary and metabolic rehabilitation.

Potential Conflict of Interest

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

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Study Association

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