

ORIGINAL ARTICLE

Relationship between motor-cognitive functions and hemodynamic response of individuals with chronic stroke during and after an acute bout of aerobic exercise

Samantha Helena do Carmo^a, Laércio da Silva Paiva^b, Fernando Adami^b, Francisco Naildo Cardoso Leitão^c, Cleide Maria de Paula Rebouças^d, Vitor Engracia Valenti^e, Rodrigo Daminello Raimundo^f

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^aDepartamento de Fisioterapia, Centro Universitário FMABC, Santo André, São Paulo, Brazil;

^bLaboratório de Epidemiologia e Análise de Dados do Centro Universitário FMABC, Santo André, São Paulo, Brazil;

^cLaboratório Multidisciplinar de Estudos e Escrita Científica em Ciências da Saúde da Universidade Federal do Acre (UFAC), Rio Branco, Acre, Brazil;

^dLaboratório de Delineamento de Estudos e Escrita Científica-LABDEEC da UNINORTE, Rio Branco, Acre, Brasil. reboucas;

^eCentro de Estudos do Sistema Nervoso Autônomo (CESNA), Departamento de Fonoaudiologia, Faculdade de Filosofia e Ciências, UNESP, Marília, São Paulo, Brazil;

^fLaboratório de Delineamento e Escrita Científica do Centro Universitário FMABC, Santo André, São Paulo, Brazil.

Corresponding author
rodrigo.raimundo@fmabc.br

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Abstract

Background: Individuals post-stroke commonly presents functional and cardiorespiratory deficits besides a physical inactivity lifestyle in the chronic phase of disease. Considering this, there is a hypothesis that hemodynamic responses could be affected by motor, cognitive and cardiorespiratory deficits during the aerobic exercise. In order to identify functional conditions that can influence the aerobic performance of these individuals, correlations between functional variables and hemodynamic responses during and after the aerobic exercise were studied. As a secondary purpose, the ability of return to hemodynamic resting state were also analyzed.

Methods: In this experimental study, after being evaluated about their motor and cognitive function, balance and prognosis, forty participants underwent a 30-minute aerobic exercise session on a treadmill. Training heart rate, arterial blood pressure, oxygen pulse saturation, heart rate, and respiratory rate were measured before begin the exercise session, every five minutes during the exercise and five minutes after it.

Results: Cardiorespiratory parameters within normality limits in all phases of the exercise and the capacity of returning to the resting state were observed. Moderate inverse correlations were found between Berg Scale and oxygen pulse saturation ($r = -0.401$, $p = 0.01$), between MMSE and diastolic blood pressure ($r = -0.406$, $p = 0.009$), age and diastolic blood pressure ($r = -0.435$, $p = 0.005$) and between injury time and RR ($r = -0.454$, $p = 0.003$). Relationship between the lesion side and the 20 minutes phase of aerobic exercise was also observed ($p = 0.042$).

Conclusion: Post- stroke individuals present moderate correlation between hemodynamic and respiratory responses during aerobic exercise and balance, muscle strength, injury time, age and side of lesion. They also have the capacity to return to their cardiorespiratory and cardiovascular resting state right after the activity besides their cardiorespiratory deficits.

Keywords: stroke, aerobic exercise, heart rate, blood pressure, respiratory rate.

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Authors summary

Why was this study done?

Considering the deficits that these individuals have in the motor and cardiorespiratory system and the lack of information about the influence that one capacity can exert on the other, the authors decided to assess whether there were correlations between the characteristics of the lesion, sociodemographic, anthropometric and functional characteristics of individuals with stroke and its hemodynamic response when submitted to aerobic training.

What did the researchers do and find?

After being evaluated for motor and cognitive functions, individual characteristics and brain damage, and anthropometric variables, forty participants underwent a 30-minute aerobic exercise session on a treadmill, and had their cardiorespiratory responses recorded. With these data, correlation measures were applied and showed that post-stroke individuals have a moderate correlation between cardiorespiratory responses during aerobic exercise and balance, muscle strength, injury time, age and side of the injury, in addition to the ability to return to the state of rest soon after activity, despite their cardiorespiratory deficits.

What do these findings mean?

Through the results of this study, it is possible to observe that characteristics of brain injury, balance capacity, muscle strength and age are variables that influence the cardiorespiratory performance of these individuals during aerobic exercise. Thus, deficits in these abilities may indicate a worse performance during aerobic activity and should be considered by professionals in the rehabilitation process, as well as aiming to improve these abilities during therapy can promote better performance in this task.

INTRODUCTION

Stroke is the second largest cause of death worldwide, reaching about 6.2 million deaths/year and only standing behind of cardiovascular disease. Every year, in all world, 15 million people are affected by stroke, of these individuals, 5 million are permanently physically incapacitated, according to WHO^{1,2}. In Brazil, is the major cause of motor incapacity in adults³.

The consequences of stroke in the brain tissue are severe, lead to neurological deficits and, as a result, to the sensory, motor and cognitive impairment, and may vary according to the affected brain area and degree of complexity^{4,5}. Cardiovascular and respiratory deficits are very common and may be serious in individuals post-stroke⁶⁻⁸, moreover, people one year post-stroke seems to remain not being active enough to improve or maintain their physical health⁹ while this physical inactivity can increase the risk of recurrent stroke and cardiovascular events¹⁰.

Considering the deficits that this individual has in both motor and cardiorespiratory system and the lack of information about the influence that one capacity could be on each other, the research questions were: Is there a correlation between prognosis, balance, motor, cognitive functions and the cardiorespiratory performance during and after aerobic exercise? Can chronic individuals post-stroke be able to perform aerobic exercise and return to their resting cardiorespiratory parameters in a proper time despite the deficits and physical inactivity lifestyle that they commonly present?

METHODS

Design

Experimental study with one time intervention.

Participants, therapists, centers

Forty individuals of both sexes, aged 40 to 65 years with stroke, both hemorrhagic and ischemic types, confirmed by image exam and medical report, injury time over one year and adequate score on the motor and cognitive applied scales were included in the study. Individuals without gait conditions, not included the ones due to stroke, or clinical conditions for the proposed

exercises and tests, association of other neurological diseases, weight above 150kg, and without medical authorization to perform physical exercise were excluded of the survey.

The number of participants was determined by convenience sample, the participants were recruited and underwent evaluation into Faculdades Metropolitanas Unidas (São Paulo, Brazil) and the methods used were applied by the first and senior authors. The study was approved by the Ethics Committee in Research of the School of Medicine of ABC (Protocol No. 33353) and all volunteers signed an informed consent form.

Intervention

Outcomes measures

For the measurement of the anthropometric variables weight and height, the participants were weighed without shoes, and with the minimum of possible clothes, in electronic scale, with capacity of up to 150kg and subdivisions of up to 10g. For the measure of height, participants pressed the heels, calves, buttocks and shoulders to the wall, positioning the head according to the Frankfurt plan. A stadiometer fixed to the wall was used, with subdivisions in centimeters and millimeters. Based on these data, the Body Mass Index (BMI) was measured by weight (kg)/height (m), and data such as time, type and brain injury side lesion, the latter were collected with a medical report.

Primary outcomes

For functional conditions characterization of these individuals, four scales were applied: Mini-Mental State Examination (MMSE)¹¹, Berg scale¹², Fugl Meyer¹³ and Orpington Scale¹⁴.

Mini-Mental State Examination

The MMSE is a validated instrument to evaluate the individual's cognitive capacity. It is composed of 7 specific cognitive functions categories: time orientation, space orientation, word register, attention and calculation, memory of words, language and visual constructive capacity. The score range from 0 to 30 points.

Berg Scale

The participants were analyzed for their balance through the Berg Scale, an also validated scale composed by 14 commands that evaluate the static and dynamic balance, according to the proposed activities, and measure the performance of the individual tested on a scale of 0 to 4 points for each one of the 14 commands. The maximum score is 56 points, the results below 45 points are considered as predictive of fall, being this the necessary score to consider adequate the balance ability of the individual.

Fugl Meyer

Physical performance will be qualified through the Fugl-Meyer scale. This scale evaluates five dimensions of impairment for motor control aspects: bone articulation range of motion, pain, motor impairment of upper and lower limbs and balance. The data are scored from 0 to 3 points for each item, with a total 226 points score, and considering motor impairment at 100 points as result.

Orpington Scale

In order to evaluate the incapacities due to the cerebrovascular event, this scale evaluates activities of daily living through motor deficits in the upper limb, proprioception, balance and cognition. Its score ranges from 1.6 to 6.8; characterizing the vascular event in mild, moderate or severe.

Secondary outcomes

Systolic (SBP) and diastolic blood pressure (DBP), heart rate (HR), respiratory rate (RR) and oxygen pulse saturation (SAT) measurements were initially collected. The SAT data were collected by visualizing the Onim-Indumeda model 9500 portable finger oximeter Nonin, SBP and DBP data were obtained by a single measurement indirectly verified by means of a WelchAllyn brand sphygmomanometer positioned on the left arm of the subject and Littmann-3M Classic II stethoscope on the median region of the antecubital fossa. For RR a timer was used to count how many thoracic incursions the individual could make in one minute. The heart rate was recorded by the Polar brand S810i cardiofrequencymeter.

After obtaining the resting heart rate (RHR) and maximum heart rate (HRmax) by age, through the formula ($HR_{max} = 220 - \text{age}$), the training heart rate (HRT) was calculated given by the Karvonen formula = $RHR (SD (HR_{max} - RHR) \times \% \text{ training})$. The percentage of training (% training) stipulated was 50 and 70%, as recommended in American Heart Association's guideline for physical activity in stroke survivors¹⁵.

All the measurements were collected by one single examiner with over 10 years of experience.

Exercise protocol

Having calculated training heartrate, the participants were instructed to walk on a treadmill RT250pro of the Movement brand (treadmill model containing anterior and lateral armrest) for aerobic exercise. During the session, support of the arms on the treadmill was allowed, as the individual felt safer.

The aerobic exercise session had a total duration of 30 minutes. In the first 5 minutes a warm-up was played, then, the individuals were instructed to perform 25 minutes of exercise reaching 70% of HRT, considered the peak of exercise. For this, the speeds of treadmill were constantly changed during the experiment to reach the FR training Five minutes after the end of the exercise was considered the recovery time. At the resting state, considered the initial phase (before begin the session), every 5 minutes of the exercise and 5 minutes after it, at the recovery phase, the measurements SBP, DBP, HR, RR and SAT were collected.

This aerobic session occurred around 01h30 and 3h30 p.m. and all the participants were instructed to abstain from caffeine for 8 hours prior, food (2 hours prior) and vigorous exercise prior to testing.

Data analysis

Qualitative variables were presented in absolute frequency and relative frequency. The quantitative variables were presented by mean and median measures, standard deviation and 25th and 75th percentiles measures and respective 95% confidence intervals (95% CI), according to the Shapiro-Wilk normality test.

To analyze the moments of the hemodynamic parameters of post-stroke individuals submitted to aerobic training was performed by linear regression and extracted: the angular coefficient (β), significance (p), predictive capacity of the model (r^2 and r^2 -adjusted). The dependent variables was time (exercise time in minutes) and the independent variables were heart rate, oxygen saturation, systolic blood pressure, mean blood pressure and respiratory rate. The variables that did not present normal distribution were normalized by the criterion suggested by the statistical program: square, cubic, square root, 1/square, 1/cubic, log and inverse.

The Pearson and Spearman correlation test was used to correlate the variables related to functional conditions and hemodynamic parameters at rest and at the time of 20 minutes.

In order to correlate and to associate the anthropometric characteristics and clinical conditions with the hemodynamic parameters at rest and at the moment of 20, the Pearson and Spearman correlation test, the student t test and the Mann-Whitney test were used.

Correlations were classified as null ($r = 0$ to 0.03), weak ($r = 0.03$ to 0.35), moderate ($r = 0.35$ to 0.65), strong ($r = 0.65$ to 0.95), very strong ($r = 0.95$ to 0.99) and perfect ($r = 1$), and direct and indirect (positive and negative, respectively).

The confidence level considered was 95% and the statistical program used was the Data Analysis and Statistical Software for Professionals (Stata) version 11.0®.

Source of support

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Role of the Funding Source

The funders played no role in the design, conduct, or reporting of this study.

RESULTS

Flow of participants, therapists, centers through the study

Figure 1 presents the flow of participants through the study. Anthropometrics and sociodemographic characteristics of the participants are summarized in table 1. The sample was composed by 27 (67,5%) male individuals, 21 (52,5%) of ischemic lesion type and 29 (72,5%) had lesion on the left side.

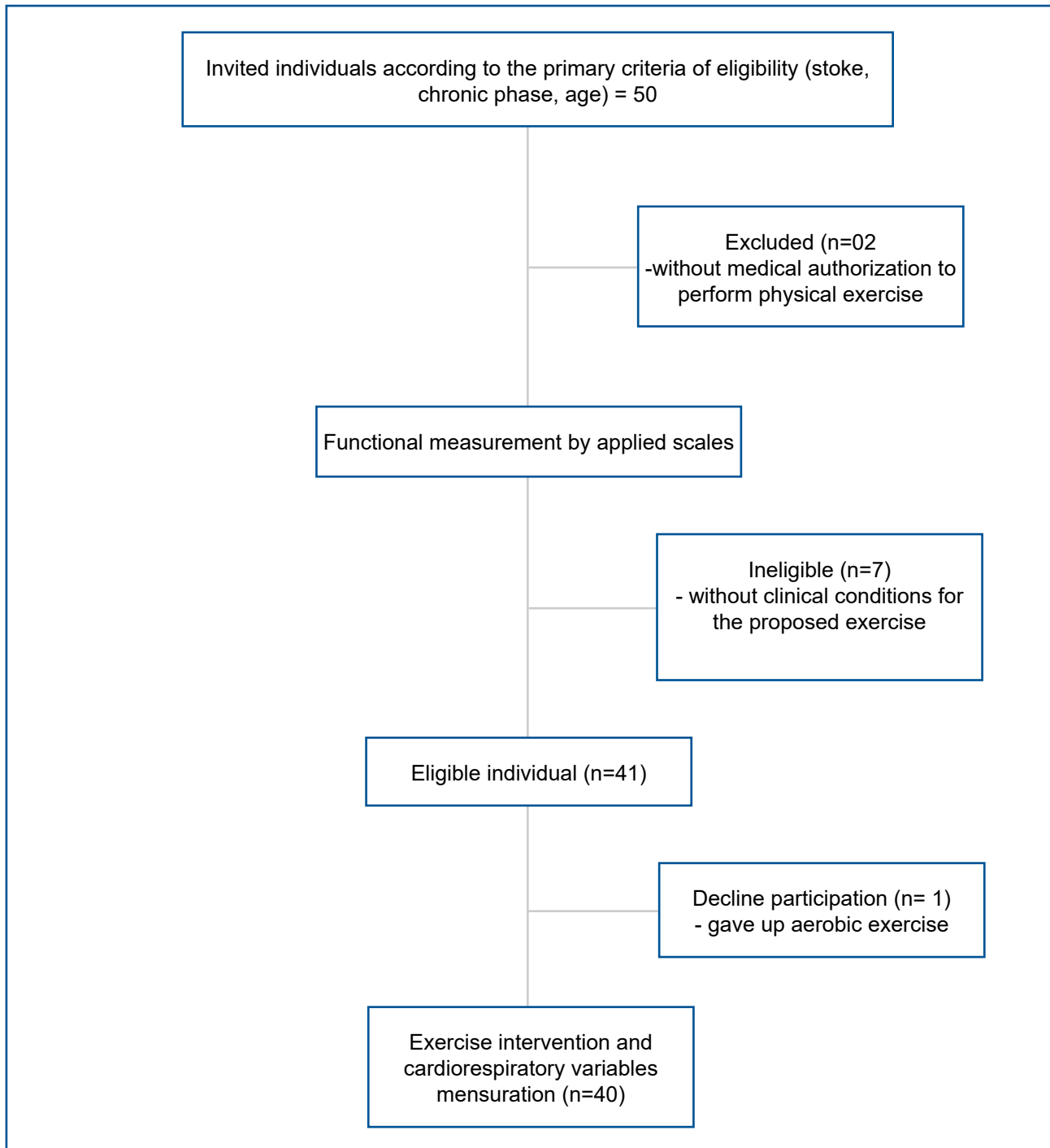


Figure 1: Flow of the participants

Table 1: Description of the sociodemographic, anthropometric and functional variables of patients with stroke submitted to aerobic training

Variables	n	%
Sex		
Male	27	67.5
Female	13	32.5
Lesion type		
Hemorrhagic	19	47.5
Ischemic	21	52.5
Side of lesion		
Right	11	27.5
Left	29	72.5
	Mean (SD)	Median (p.25 – p.75)
Age	60.77 (6.35)	60.5 (56 – 64)
Weight	69.37 (5.55)	70 (67 – 73.5)
Height	1.65 (0.07)	1.65 (1.60 – 1.70)
BMI	25.48 (3.19)	25.14 (23.52 – 27.68)
Injury time	5.27 (1.50)	6 (4- 6)
MMSE	21.55 (5.13)	22 (20 – 24)
EU-FM	26.02 (5.69)	25 (22 – 26)
LE-FM	19.35 (4.59)	18,5 (18 – 22)
Balance-FM	9 (1.03)	9 (8 – 10)
Sensory-FM	19.8 (3.91)	22 (16 – 22)
Joint range-FM	35.55 (4.16)	34 (32 – 38)
Pain-FM	41.95 (1.53)	42 (40 – 44)
Total-FM	151.67 (10.49)	151 (144.5 – 159)
Orpington Prognostic Score	2.82 (0.59)	2.8 (2.2 – 3.6)
Berg Balance Scale	47.75 (5.08)	48 (44 – 52)

SD: Standard Deviation; p25-p75: Percentiles 25 and 75; BMI: Body Mass Index; MMSE: Mini Mental State Examination; FM: Fugl Meyer. EU-FM: Upper-Extremity portion of the Fugl-Meyer Scale; LE-FM: Lower-Extremity portion of the Fugl-Meyer Scale.

Hemodynamic response and breathing frequency behavior during aerobic exercise

Hemodynamic variables presented during the aerobic exercise was HR 69.15 bpm (SD 9.11) at the initial phase, reaching 114.25bpm (SD 19.02) at the peak of exercise, and returning to 73.42bpm (SD 8.47) at the end of the it. In relation to SAT, its onset was 95.42% (SD 1.27), reached 96.22% (SD 1.09) and returned to 95.62% (SD 1.19). The SBP measure was 127.5mmHg (SD 9.26) in the initial phase, reached 135.0mmHg (SD 10.62) and decreased to 119.87mmHg (SD 8.95). The DBP, initiated at 79.25mmHg (SD 5.72), reached 83.25mmHg (SD 6.55) and decreased to 79.00mmHg (SD 6.22). The MBP (mean blood pressure) was 95.26mmHg (SD 5.68) initially for 100.50mmHg (SD 6.94) and 92.65mmHg (SD 6.82). Finally, the RR of these individuals started at 20.17rpm (SD 3.97) went to 28.77rpm (SD 3.56) at 25 minutes of exercise and reached 21.82rpm (SD 11.53) at recovery. These data are described and detailed in table 2.

The results presented in table 3 demonstrate the

relation of time in function of hemodynamic parameters and their influence on them through a linear regression analysis. It can be observed that for the hemodynamic parameters (heart rate, oxygen saturation, systolic blood pressure, mean blood pressure and respiratory rate) there was an increase in the parameters as the exercise time increased (time in minutes), except for the recovery time.

There are no statistically significant differences between the initial and recovery phases. Between the aerobic exercise time, which is subdivided in measurements collected each 5 minutes, to the final 30 minutes, statistically significant differences were found for each phases, except for the phases and parameters mentioned below: between the 15 minutes phase versus initial time there were no significant changes to the SAT; between the 5 minutes phase versus initial time also no significant changes were found for SBP, DBP and MBP. Among the variables, we found weak correlations for SAT, SBP, DBP, MBP, RR and time; and moderate for HR and time (table 3). Correlations between variables

Table 2: Values of central tendency and dispersion of hemodynamic variables between the moments of aerobic training in post-stroke patients

Variables	Inicial		5'	
	Mean (SD)	Median (p.25-p.75)	Mean (SD)	Median (p.25-p.75)
Heart Rate	69.15 (9.11)	70 (64 - 73)	99.62 (22.34)	98.5 (86.5 - 110)
Oxygen saturation	95.42 (1.27)	95.5 (95 - 96)	96.02 (1.38)	96 (95 - 97)
Systolic Blood Pressure	127.5 (9.26)	130 (120 - 130)	129.25 (10.91)	130 (120 - 140)
Diastolic Blood Pressure	79.25 (5.72)	80 (80 - 80)	81.25 (5.15)	80 (80 - 80)
Mean Blood Pressure	95.26 (5.68)	96.66 (93.33 - 101.66)	97.33 (5.96)	96.66 (93.33 - 101.66)
Respiratory Rate	20.17 (3.97)	21 (16 - 23)	22.82 (3.12)	22 (20.5 - 24)

Variables	10'		15''	
	Mean (SD)	Median (p.25-p.75)	Mean (SD)	Median (p.25-p.75)
Heart Rate	107.62 (17.78)	104.5 (99 - 116.5)	109.17 (23.30)	112 (99.5 - 124.5)
Oxygen saturation	96.12 (1.30)	96 (95 - 97)	95.82 (1.10)	96 (95 - 96)
Systolic Blood Pressure	132.5 (10.80)	130 (125 - 140)	134.25 (12.38)	130 (125 - 140)
Diastolic Blood Pressure	82.75 (6.40)	80 (80 - 90)	83.5 (5.79)	80 (80 - 90)
Mean Blood Pressure	99.33 (6.88)	96.66 (95 - 105)	100.41 (6.84)	98.33 (95 - 103.33)
Respiratory Rate	25.27 (3.58)	24.5 (23.5 - 28)	26.22 (3.19)	25.5 (24.5 - 28)

Variables	20''		25''	
	Mean (SD)	Median (p.25-p.75)	Mean (SD)	Median (p.25-p.75)
Heart Rate	114.05 (17.83)	115 (98.5 - 124.5)	114.25 (19.02)	111.5 (99 - 129)
Oxygen saturation	96.35 (0.92)	96 (96 - 97)	96.22 (1.09)	96 (96 - 97)
Systolic Blood Pressure	135.75 (10.83)	130 (130 - 140)	135 (10.62)	130 (130 - 140)
Diastolic Blood Pressure	82.25 (5.76)	80 (80 - 85)	83.25 (6.55)	80 (80 - 80)
Mean Blood Pressure	100.08 (6.33)	96.66 (96.66 - 105)	100.5 (6.94)	96.66 (96.66 - 103.33)
Respiratory Rate	27.37 (2.87)	27 (26.5 - 28)	28.77 (3.56)	28 (26 - 30)

Variables	30''		Recovery	
	Mean (SD)	Median (p.25-p.75)	Mean (SD)	Median (p.25-p.75)
Heart Rate	114.67 (18.34)	115 (98 - 126)	73.42 (8.47)	70 (69 - 80)
Oxygen saturation	96.35 (1.12)	96 (96 - 97)	95.62 (1.19)	96 (95 - 97)
Systolic Blood Pressure	135.75 (10.09)	140 (130 - 140)	119.87 (8.95)	120 (110 - 120)
Diastolic Blood Pressure	83 (6.48)	80 (80 - 80)	79 (6.22)	80 (75 - 80)
Mean Blood Pressure	100.58 (6.70)	100 (96.66 - 103.33)	92.65 (6.82)	93.33 (88.33 - 94.66)
Respiratory Rate	28.4 (3.23)	28 (26.5 - 30)	21.82 (11.53)	20 (17 - 23)

SD: Standard Deviation; p25-p75: Percentiles 25 and 75.

Table 3: Linear regression analysis between moments (time in minutes) of the hemodynamic parameters of patients after stroke, submitted to aerobic training.

Variáveis	β (95% CI)	p	r ²	r ² -adjusted
Heart Rate				
Inicial	ref	-	0.494	0.483
5 minutes	30.47 (22.65; 38.29)	<0.001		
10 minutes	38.47 (30.65; 46.29)	<0.001		
15 minutes	40.02 (32.20; 47.84)	<0.001		
20 minutes	44.90 (37.07; 52.72)	<0.001		
25 minutes	45.10 (37.27; 52.92)	<0.001		
30 minutes	45.52 (37.70; 53.34)	<0.001		
Recovery	4.27 (-3.54; 12.09)	0.283		
Oxygen Saturation				
Inicial	ref	-	0.006	0.048
5 minutes	0.60 (0.07; 1.12)	0.024		
10 minutes	0.70 (0.17; 1.22)	0.009		
15 minutes	0.40 (-0.12; 0.92)	0.132		
20 minutes	0.92 (0.40; 1.44)	0.001		
25 minutes	0.80 (0.27; 1.32)	0.003		
30 minutes	0.92 (0.40; 1.44)	0.001		
Recovery	0.20 (-0.32; 0.72)	0.451		
Systolic Blood Pressure				
Inicial	ref	-	0.197	0.179
5 minutes	1.75 (-2.88; 6.38)	0.458		
10 minutes	5.00 (0.36; 9.63)	0.035		
15 minutes	6.75 (2.11; 11.38)	0.004		
20 minutes	8.25 (3.61; 12.88)	0.001		
25 minutes	7.50 (2.86; 12.13)	0.002		
30 minutes	8.25 (3.61; 12.88)	0.001		
Recovery	-7.62 (-12.26; -2.98)	0.001		
Diastolic Blood Pressure				
Inicial	ref	-	0.072	0.051
5 minutes	2.00 (-0.65; 4.65)	0.139		
10 minutes	3.50 (0.84; 6.15)	0.010		
15 minutes	4.25 (1.59; 6.90)	0.002		
20 minutes	3.00 (0.34; 5.65)	0.027		
25 minutes	4.00 (1.34; 6.65)	0.003		
30 minutes	3.75 (1.09; 6.40)	0.006		
Recovery	-0.25 (-2.90; 2.40)	0.853		
Mean Blood Pressure				
Inicial	ref	-	0.154	0.135
5 minutes	2.06 (-0.81; 4.94)	0.159		
10 minutes	4.06 (1.18; 6.94)	0.006		
15 minutes	5.15 (2.27; 8.02)	<0.001		
20 minutes	4.81 (1.93; 7.69)	0.001		
25 minutes	5.23 (2.35; 8.11)	<0.001		
30 minutes	5.31 (2.43; 8.19)	<0.001		
Recovery	-2.61 (-5.49; 0.26)	0.074		

Variáveis	β (95% CI)	p	r ²	r ² -adjusted
Respiratory Rate				
Inicial	ref	-	0.254	0.238
5 minutes	2.65 (0.37; 4.92)	0.022		
10 minutes	5.10 (2.82; 7.37)	<0.001		
15 minutes	6.05 (3.77; 8.32)	<0.001		
20 minutes	7.20 (4.92; 9.47)	<0.001		
25 minutes	8.60 (6.32; 10.87)	<0.001		
30 minutes	8.22 (5.95; 10.49)	<0.001		
Recovery	1.65 (-0.62; 3.92)	0.154		

95% CI: confidence interval of 95%; β: beta regression; r²: predictive capacity of the model; ref: reference value (initial).

Regarding the functional conditions and the hemodynamic parameters, whose data are described in table 4, we found a moderate inverse correlation ($r = -0.401$, $p = 0.01$) for the Berg Scale as a function of SAT; weak inverse correlation ($r = -0.036$, $p = 0.03$) for Berg Scale as a function of SBP; moderate inverse correlation ($r = -0.406$, $p = 0.009$) for MMSE as a function of DBP; weak inverse correlation ($r = -0.319$, $p = 0.044$) for LE-FM as a function of MBP; ($r = 0.317$, $p = 0.045$) for FM ROM as a function of RR and direct correlation ($r = 0.334$, $p = 0.034$) for Total FM as a function of RR.

Association between the clinical and anthropometric characteristics and the hemodynamic parameters are described in Table 5. We found statistical significance for moderate inverse correlation ($r = -0.435$, $p = 0.005$) between age and DBP for moderate inverse correlation ($r = -0.454$, $p = 0.003$) between injury time and RR. Relationships between the lesion side and the 20 minute phase of aerobic exercise were also observed ($p = 0.042$).

Table 4: Correlation between functional conditions and hemodynamic parameters at rest and at the time of 20 minutes of post-stroke patients submitted to aerobic training.

Variables	Rest		20 minutes	
	r	p	r	p
	Heart Rate			
MMSE	-0.113	0.484*	0.170	0.293**
EU-FM	-0.135	0.405*	0.045	0.782*
LE-FM	0.159	0.326*	0.060	0.708*
Balance-FM	-0.191	0.235*	0.047	0.772**
Sensory-FM	-0.259	0.106*	-0.196	0.225*
Joint range-FM	0.074	0.647*	0.059	0.714**
Pain-FM	-0.135	0.405*	-0.041	0.801**
Total-FM	-0.176	0.276*	0.053	0.744**
Orpington Prognostic Score	-0.024	0.880*	0.130	0.421*
Berg Balance Scale	0.210	0.192*	0.045	0.781**
	Oxygen Saturation			
MMSE	-0.091	0.575**	-0.047	0.772**
EU-FM	0.042	0.792*	-0.152	0.347*
LE-FM	-0.202	0.211*	0.121	0.453*
Balance-FM	0.135	0.405**	-0.134	0.409**
Sensory-FM	-0.006	0.970*	-0.040	0.805*
Joint range-FM	-0.088	0.587**	-0.278	0.081**
Pain-FM	-0.119	0.462**	0.085	0.601**
Total-FM	-0.006	0.967**	-0.091	0.575**
Orpington Prognostic Score	-0.195	0.227*	-0.084	0.604*
Berg Balance Scale	-0.401	0.010**	0.008	0.959**

Continuation - Table 5: Association between the anthropometric characteristics and clinical conditions and the hemodynamic parameters at rest and at the moment of 20 minutes of patients after Stroke submitted to aerobic training.

Variables				
	r	p**	r	p**
Age	0.090	0.579	0.056	0.728
BMI	0.059	0.717	-0.079	0.626
Time of Lesion	-0.170	0.293	-0.083	0.606
Diastolic Blood Pressure				
	Rest		20 minutes	
	Mean (95% CI)	p#	Mean (95% CI)	p#
Sex				
Male	79.2 (77.0; 81.4)	0.988	82.2 (80.2; 84.2)	0.965
Female	79.2 (75.3; 83.1)		82.3 (77.9; 86.6)	
Lesion Type				
Hemorrhagic	80 (77.7; 82.2)	0.437	82.6 (80.4; 84.8)	0.696
Ischemic	78.5 (75.5; 81.5)		81.9 (78.8; 84.9)	
Lesion Side				
Right	80 (75.7; 84.2)	0.616	81.8 (77.7; 85.8)	0.774
Left	78.9 (76.8; 81.0)		82.4 (80.2; 84.6)	
	r	p**	r	p**
Age	-0.435	0.005	-0.244	0.127
BMI	0.185	0.251	-0.128	0.428
Lesion time	-0.094	0.561	-0.014	0.931
Mean Blood Pressure				
	Rest		20 minutes	
	Mean (95% CI)	p#	Median (95% CI)	p##
Sex				
Male	95.7 (93.6; 97.7)	0.490	96.6 (96.6; 100.2)	0.869
Female	94.3 (90.3; 98.3)		100 (93.3; 105.3)	
Lesion Type				
Hemorrhagic	95.9 (93.1; 98.8)	0.467	96.6 (96.6; 104.3)	0.779
Ischemic	94.6 (92.1; 97.1)		96.6 (96.6; 101.8)	
Side Lesion				
Right	95.8 (91.57; 100.0)	0.710	96.6 (96.6; 106.6)	0.888
Left	95.0 (92.9; 97.1)		96.6 (96.6; 101.0)	
	r	p**	rho	p*
Age	-0.246	0.124	-0.079	0.626
BMI	0.145	0.372	-0.009	0.952
Lesion Time	-0.153	0.343	-0.080	0.622
Respiratory Rate				
	Rest		20 minutes	
	Mean (95% CI)	p#	Median (95% CI)	p##
Sex				
Male	20.2 (18.8; 21.6)	0.915	27 (27; 28)	0.647
Female	20 (17.0; 23.0)		28 (26.3; 28)	

Continuation - Table 5: Association between the anthropometric characteristics and clinical conditions and the hemodynamic parameters at rest and at the moment of 20 minutes of patients after Stroke submitted to aerobic training.

Variables	Rest		20 minutes	
	Mean (95% CI)	p#	Median (95% CI)	p##
Lesion Type				
Hemorrhagic	21 (19.1; 22.8)	0.216	27 (26.6; 28)	0.955
Ischemic	19.4 (17.6; 21.2)		27 (27; 28)	
Lesion Side				
Right	20.3 (17.0; 23.6)	0.856	26 (22; 28.2)	0.042
Left	20.1 (18.7; 21.4)		28 (27; 28)	
	r	p**	rho	p*
Age	0.064	0.692	0.083	0.606
BMI	-0.120	0.457	0.081	0.618
Lesion Time	-0.454	0.003	0.293	0.665

BMI: Body Mass Index; 95% CI: confidence interval of 95%. *Spearman test; **Pearson test. #t of student test; ##Mann-Whitney test.

DISCUSSION

It is well established that low levels of cardiorespiratory fitness are associated with a high risk of developing cardiovascular disease, mortality due to various causes, and even practicing exercise can prevent stroke itself.^{8,16}

There are several coherent and well-developed studies that prove that implement cardiorespiratory training is essential for this group¹⁷⁻²¹. However, it is also known that, after experiencing stroke, cardiovascular and cardiorespiratory deficits are commonly present in the health condition of these individuals⁵⁻⁸, added to this, Baert *et al.*⁹ carried out a study that indicates that individuals in chronic phase of stroke can be physically active, but not enough to increase or maintain their physical health. Considering this deficits that this individuals has in both motor and cardiorespiratory system, their inactivity and the lack of information about the influence that one capacity could be on each other, the researchers were instigated to investigate the correlation between prognosis, balance, motor, cognitive functions and the cardiorespiratory performance during and after aerobic exercise and the ability to perform aerobic exercise and return to their resting cardiorespiratory parameters in a proper time.

Primary aim of this study was to explore the correlations between the cited parameters and the functional conditions measures obtained through the applied scales and significant results were also found.

For balance ability, according to our data, a moderate inverse correlation was found, indicating that as lower is this capacity, the higher is the SAT percentage ($r = -0.401$, $p = 0.01$) and weak inverse correlation, also indicating that when the lower is the capacity of balance, the higher will be the SBP at 20 minutes of exercise ($r = -0.336$, $p = 0.03$), which could instigate the question if improvements in balance could also provide a decrease in blood pressure levels during the exercise. Acar *et al.*²² and Abate *et al.*²³ did not found relationship between hypertension and postural balance in elderly however they were not submitted to aerobic exercise and had no brain tissue damage.

In addition, moderate inverse correlation between cognition and DBP at 20 minutes of exercise was found, showing that as lower the cognitive ability of these individuals, as higher the DBP values at this stage of the training ($r = -0.406$, $p = 0.00$). Forte *et al.*²⁴, in their systematic review, identified that higher blood pressure is associated with a higher risk of cognitive decline, however the study was conducted in people without dementia or stroke. Likewise, a weak inverse correlation was also observed for LE-FM in relation to MBP, indicating higher values of this variable at 20 minutes of training for individuals who present lower muscle strength in these members, which could also indicate that muscle strengthening may be a protective factor for maintain blood pressure in adequate levels during aerobic exercise.

There were also direct weak correlations for range of motion and pain in relation to RR ($r = 0.317$, $p = 0.04$, $r = 0.334$, $p = 0.03$, respectively), demonstrating that the higher the ROM and motor impairment, the higher the RR values will be.

We observed a moderate inverse correlation for age, demonstrating that the higher this variable, the higher is the DBP ($r = -0.435$, $p = 0.005$), as already known. The longer is the time since the lesion, the lower is the RR ($r = 0.454$, $p = 0.003$).

Regarding the relation between variables, this is an unprecedented study and there are no studies that evaluated these outcomes associated with aerobic exercise prior to this article so we could compare results.

Second aim of this study was to analyze the acute effects of an aerobic exercise session on the hemodynamic response and breathing frequency of individuals with chronic stroke. Thus, the observed results within normal limits in the collected measures, besides the capacity to reach expected values for this exercise during the peak of the activity and to return to the initial parameters.

At the resting stage, the initial values of SBP presented by our sample are considered high, but not characterized as hypertension, according to the AHA blood pressure statements²⁵. At 25 minutes of exercise, BP is increased as expected to any subject undergoing exercise.

Our results showed a decrease in SBP found at the recovery period (initial SBP = 127, SD 9.26mmHg; final SBP = 119.87mmHg, SD 8.95), this event can be described as the post-exercise hypotension effect (PEH)²⁶⁻²⁹. Considering the benefits of PEH obtained by a regular training for the hypertensive population of this group, the result can be also beneficial.

It is possible to observe that, in the resting condition, the HR presented is 69bpm (SD 9.11), a normal value range of HR30. During exercise, this value increases to 114.25bpm (SD 19.02), which represents the ability of these individuals to achieve the submaximal HR proposed during the training. In the recovery phase, HR returns to 73.42bpm (SD 8.47), which may indicate good performance of vagal activation and sympathetic withdrawal during the following minutes after the event. The heart rate recovery (HRR), is frequently altered in populations with cardiovascular diseases or associated with risk factors³¹ and delays in this recovery are strongly linked to mortality³². Despite the cardiac comorbidities that frequently accompany this group, our sample had a good performance of this system before, during and after exercise.

Respiratory deficits may also be very common in individuals post-stroke, especially when the brainstem is compromised. Muscle weakness, decreased respiratory mechanisms and lung volumes, reduced chest wall mobility, physical inactivity, associated diseases and cardiovascular changes may further impair this ability of the subject and lead to less resistance to exercise, shortness of breath, sedentary lifestyle and, more importantly, recurrence of stroke³³. On this variable, the results presented by our sample are also positive: participants submitted to aerobic exercise at rest indicate RR within normal range presenting 20.17rpm (SD 3.97) during the peak of the exercise rate reached 28.77rpm (SD 3.56) and, at the recovery stage, 21.82rpm (SD 11.53).

A few authors studied cardiorespiratory responses of chronic individuals post-stroke for some different purposes and registered measurements that were also used in this study. Results of Billinger *et al.*⁵ showed a HR peak (127.4bpm, SD 28.8) and RR (33.0rpm, SD 8.5) larger than our group, as did Baert *et al.*⁹ whose results for this variable was also higher than ours (133.3bpm, SD 31.5), Olivier *et al.*³⁴ measured HR peak and, once more, there were found larger results compared to ours. In contradiction, Salbach *et al.*³⁵ founded a HR peak lower than our findings (98.3bpm, SD 17.1).

Comparing cardiorespiratory performance between individuals post-stroke and healthy individuals, the study by Tomczak *et al.*³⁶ found no differences between this

groups, except for the resting HR parameter, which was higher in the stroke group and a lower training HR than the control group was observed. The latest result differs from our findings, since the individuals were able to reach training HR, however the other analyzed parameters in the exercise and rest phases corroborate with those found in our study. Marsden *et al.*³⁷ submitted post stroke and healthy individuals to aerobic training; concluded that the stroke group has lower cardiorespiratory fitness than the healthy individuals group matched by age and sex.

Although the samples of these studies were similar to the assessed individuals in our research, these divergences were observed as well as a lack of cardiorespiratory and cardiovascular measurements information. It is important to emphasize that despite all of these studies contribute for our results analyze, none of them aimed or registered the recovery parameters after the submitted exercise.

Study Limitations

The sample size is recognized as a study limitation and it is justified by the choice to use a convenience sample.

CONCLUSION

Post-stroke individuals present moderate correlation between hemodynamic and respiratory responses during aerobic exercise and balance, muscle strength, injury time, age and side of lesion. They also have the capacity to return to their cardiorespiratory and cardiovascular resting state right after the activity besides their cardiorespiratory deficits.

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Conflict of interest

None declared.

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Resumo

Introdução: Indivíduos pós-AVC comumente apresentam déficits funcionais e cardiopulmonares, além de estilo de vida de inatividade física na fase crônica da doença. Diante disso, existe a hipótese de que as respostas hemodinâmicas possam ser afetadas por déficits motores, cognitivos e cardiopulmonares durante o exercício aeróbico. Para identificar as condições funcionais que podem influenciar o desempenho aeróbico desses indivíduos, foram estudadas as correlações entre as variáveis funcionais e as respostas hemodinâmicas durante e após o exercício aeróbico. Como objetivo secundário, a capacidade de retorno ao estado de repouso hemodinâmico também foi analisada.

Método: Neste estudo experimental, após serem avaliados quanto à função motora e cognitiva, equilíbrio e prognóstico, quarenta participantes foram submetidos a uma sessão de exercício aeróbico de 30 minutos em esteira. A frequência cardíaca, pressão arterial, saturação periférica de oxigênio, frequência cardíaca e frequência respiratória de treinamento foram medidas antes do início da sessão de exercício, a cada cinco minutos durante o exercício e cinco minutos após.

Resultados: Foram observados parâmetros cardiopulmonares dentro dos limites da normalidade em todas as fases do exercício e capacidade de retorno ao estado de repouso. Correlações inversas moderadas foram encontradas entre Escala de Berg e saturação do pulso de oxigênio ($r = -0,401$, $p = 0,01$), entre MEEM e pressão arterial diastólica ($r = -0,406$, $p = 0,009$), idade e pressão arterial diastólica ($r = -0,435$, $p = 0,005$) e entre o tempo de lesão e FR ($r = -0,454$, $p = 0,003$). Também foi observada relação entre o lado da lesão e a fase de 20 minutos do exercício aeróbico ($p = 0,042$).

Conclusão: Indivíduos pós-AVE apresentam correlação moderada entre as respostas hemodinâmicas e respiratórias durante o exercício aeróbico e equilíbrio, força muscular, tempo de lesão, idade e lado da lesão. Eles também têm a capacidade de retornar ao estado de repouso cardiopulmonar e cardiovascular logo após a atividade, apesar de seus déficits cardiopulmonares.

Palavras-chave: acidente vascular encefálico, exercício aeróbico, frequência cardíaca, pressão arterial, frequência respiratória.

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