EFFECTS OF AEROBIC EXERCISE TRAINING ON WALKING ENDURANCE AND SELECTED CARDIO-RESPIRATORY PARAMETERS IN STROKE SURVIVORS

Happiness Anulika Aweto[1] (Ph.D), Buhari Tafida Abdullahi[1] (M.Sc), Sunday Rufus Akinwunmi Akinbo[1] (Ph.D)

[1]Department of Physiotherapy, Faculty of Clinical Sciences, College of Medicine, University of Lagos, PMB 12003, Idi-Araba, Lagos, Nigeria.

Address for correspondence:

ABSTRACT

Background/Objective: Many stroke survivors continue to live with residual physical impairments which may promote a sedentary lifestyle and poor cardio-respiratory fitness. This study was aimed at determining the effects of aerobic exercise training on walking endurance and selected cardio-respiratory parameters in ambulatory stroke survivors.

Method: Thirty-seven stroke survivors (20 males and 17 females) completed this pre-post experimental study. They were recruited from the Physiotherapy clinics of Lagos University Teaching Hospital, and Lagos State University Teaching Hospital through a sample of convenience. Participants' walking endurance, selected cardio-respiratory parameters were measured before and after the intervention. They had 10 weeks of aerobic exercise training using bicycle ergometer. Exercise sessions were conducted two times per week at an intensity of 50-59% of heart rate reserve (HRR) for the first five weeks and later progressed to 60-69% of HRR for the remaining five weeks at a duration of 25 minutes for each exercise session. Data was analyzed using Paired t-test and Independent t-test the <0.05 level of statistical significance.

Results: The mean age, height and weight of the participants were 51.59±4.86 years, 1.7±0.9m and 69.8±5.1kg respectively. There were significant improvements in the walking endurance (p=0.001), all selected cardiovascular (p=0.001) and respiratory parameters (p=0.001) of the participants after 10 weeks of aerobic training. However, there were no gender differences in the effects of aereobic exercise training on selected cardio-respiratory parameters among the participants except in the forced expiratory volume in one second (FEV_1) (p= 0.037).

Conclusion: Aerobic exercise training is beneficial in improving walking endurance and cardio-respiratory parameters in stroke survivors.

Keywords: Aerobic exercise, walking endurance, cardio-respiratory response, stroke survivors.

Introduction

Stroke is one of the most common chronic conditions seen in older adults, with an incidence

approximately doubling each decade after the age of 55 years.[1] Most stroke survivors continue to live with residual physical impairments which may promote a sedentary lifestyle and resultant secondary complications.[2] One of the secondary complications commonly observed following stroke is poor cardio-respiratory fitness which contributes to the limitation of independent life and activities of daily living (ADL), increased energy cost of ambulation, and increased risk of stroke and cardiovascular disease.[3-6] Cardio-respiratory fitness is important for performing daily activities and mobility. Tang et al.[7] stated that some stroke survivors do not spontaneously recover their respiratory function after a maximal exercise test. The reduction in cardio-respiratory function might affect the recovery level of stroke survivors because they have a greater need for aerobic capacity and walking endurance.[8] Decreased aerobic capacity and muscle weakness impede participation in every day physical and social activities and impaired social communication further reduces quality of life.[9,10] It has been reported that VO_2 max values below 20 mL /kg−1/ min−1 is associated with limited physical function for instrumental activities of daily living.[11,12]

Walking for stroke survivors is often slower (e.g. from 0.16 to 0.88 m/s) compared with healthy persons aged 60 to 80 years, who normally walk at speeds greater than 1.23 m/s.[13] The slow speed of walking is not only unsafe for some activities of daily living such as crossing streets, particularly in metropolitan regions, but also requires considerable effort because of poor walking efficiency.[14,15] It is also a barrier to walking independently within the community, because a person needs to be able to walk relatively long distances. As such, persons who have recovered from a stroke often have poor walking skills and endurance, usually lacking ability to walk continuously for a few minutes.[16] Factors such as impaired neuromuscular control, decreased functional mobility, balance deficits, and reduced cardio-respiratory fitness make recovery from stroke difficult.[17,18]

Evidence suggests that exercise training in the post stroke population can facilitate improvements in the cardiovascular, respiratory, and neuromuscular systems.[19,20] However, many rehabilitation approaches for chronic stroke survivors rarely concern the assessment and improvement of cardio-respiratory capacity.[21] For a variety of reasons, aerobic exercise is not routinely prescribed for stroke survivors during stroke rehabilitation, which likely exacerbates their decline in cardio-respiratory fitness.[22] Research studies have confirmed that exercise intervention improves VO_2 max, physical function (e.g., Timed Up and Go), walking, and psychological wellbeing.[19,20,23-27] Yet, many clinicians do not use aerobic exercise interventions, perhaps because of the limited amount of research that has identified appropriate screening protocols and optimal dosing of aerobic exercise for this population.[28,29]

It is important to understand the cardiopulmonary response to exercise in both men and women so that the physiologic and hemodynamic responses obtained from an exercise can be used to appropriately guide exercise prescription.[18] Also strategies to reduce the underlying impairments post-stroke and thereby improve physical ability are needed if quality of living is to be enhanced in these patients. This study evaluated the effects of aerobic exercise training on walking endurance and selected cardio-respiratory parameters in ambulatory stroke survivors.

Materials and Methods

Prior to the commencement of the study, ethical approval was obtained from the Health Research and Ethics Committee of Lagos University Teaching

Hospital (LUTH) assigned Reference number: ADM/DCST/HREC//APP/1110. Introductory letters were obtained from the Department of Physiotherapy, Faculty of Clinical Sciences, College of Medicine, University of Lagos and taken to the Physiotherapy clinics of LUTH and Lagos State University Teaching Hospital (LASUTH) to obtain permission to carry out the study in their facilities. Fifty two (52) stroke survivors who were attending Physiotherapy clinics of LUTH and LASUTH were recruited for this pre-post experimental study. A continuous sample of convenience was used to recruit the participants into the study. They were screened for eligibility based on inclusion and exclusion criteria for the study. Inclusion criteria were adult stroke survivors who had a single episode of stroke at least 6 months prior to enrolment, who were independent in ambulation with or without an orthotic or assistive device, who had the ability to complete sit to stand transfer and who had no cognitive impairment by having a score of ≥ 24 from the Mini Mental Status Examination (MMSE).[30,31] Exclusion criteria were adult stroke survivors who had cardiac limitations such as uncontrolled hypertension and those that had major musculoskeletal problems such as amputation and severe incapacitating osteoarthritis. Two (2) volunteering participants were excluded. An explanation of the study purpose and the experimental method and processes were provided to the participants and written informed consent was sought and obtained from those who volunteered to participate in the study. This is because participation in the study was voluntary. Thirteen participants dropped out during aerobic exercise training and declined to come back for the follow-up assessment because of illnesses unrelated to exercise training or for personal reasons. Conseqently, 37 participants completed the study.

Procedure for data collection

The study was carried out at the in the gymnasia and physiotherapy demonstration rooms (PDR) of LUTH and LASUTH. Three research assistants were co-opted to help in the study. One of them was an intern physiotherapist at LUTH, the second was a physiotherapist doing her Master's degree in Physotherapy and the third was a final a year student of physiotherapy. The Socio-demographic and health profile characteristics such as age, gender, marital status, occupation, level of educational attainment, types of stroke were obtained from the participants as well as their case folders and recorded. The baseline assessments of all the outcome measures were taken prior to the aerobic exercise training. Participants were asked not to consume heavy meals or drinks (except water) and to avoid caffeinated products within two-three hours prior to the assessments. This is because they could affect the values of the outcome measures. All participants were familiarized with the Borg Rating of Perceived Exertion (RPE) scale.

On the day of assessment, participants were allowed to rest in sitting for at least 15 minutes prior to the assessment. The following were the outcome measures that were assessed as well as the procedures for assessment:

Cardiovascular parameters:

Blood pressure (BP): Each participant's BP was measured in sitting position using a mercury sphygmomanometer (Accoson, England) and a stethoscope (Littmann Classic II SE, UK). The systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured in mmHg.

Heart Rate (HR): To measure the HR of each of the participants in sitting position, the bell/diaphragm of the stethoscope was placed on the left 5th intercostals space on the lateral aspect of the mid clavicular line. With the aid of a stop clock, the heart beats were

counted for one minute and the HR recorded in beats per minute.

Rate pressure product (RPP): This is also known as Cardiovascular product or Double product and it is a measure of the stress put on the cardiac muscle based on the number of times it needs to contract per minute (HR) and the arterial blood pressure that it is pumping against (SBP).[32] It was calculated as the product of SBP and HR.

Mean arterial pressure (MAP): This is the average arterial pressure during a single cardiac cycle.[33] It was calculated as;

MAP = DBP + 1/3(SBP – DBP)

Respiratory parameters:

Baseline force vital capacity (FVC), force expiratory volume in one second (FEV_1) and peak expiratory flow rate (PEFR) were measured using digital hand-held spirometer (CONTEC SP-10, China):

Spirometry testing procedures: Each of the participants sat comfortably in a chair with back rest, had the feet firmly on the ground with all constricting clothing such as braziers and waist belts loosened to prevent alteration of test results from restricted thoracic expansion and abdominal mobility. The spirometer was cleaned with an alcohol wipe and disposable mouthpiece was used for each participant. The participants were instructed to breathe in as deeply as possible (full inspiration) and hold their breath just long enough to seal their lips around the mouthpiece and to clip the nose with a nose clip. They are then instructed to blow out through the mouth (exhale) into the mouthpiece forcibly, as hard, as fast and as long as possible (full expiration), until there is no air left to expel (at least for six seconds). The procedure was repeated three times at 15 minutes intervals and the FVC, FEV_1 and PEFR readings were obtained. For the FVC and FEV_1, the higher value between the two highest values which were within 0.150L of each other was the accepted value. The highest value of PEFR was the accepted value.[34,35]

VO_2 max calculation: VO_2 max (also known as maximum oxygen consumption, maximum oxygen uptake, peak oxygen uptake or maximum aerobic capacity) was calculated using Uth-Sorensen-Overgaard-Pedersen estimation of VO_2 max for humans which is based on the ratio of maximum heart rate (HRmax) to resting heart rate (HRmin). It was created by a group of researchers from Denmark.[36] The equation is stated as follows:

VO_2 max = 15.3 + HRmax/HRmin. It is measured in units of ml/kg/minute.

Six minutes walk test (6-MWT): The 6-MWT is a valid and reliable test of assessing physical performance for people with stroke.[37] It was performed on the same day on a corridor with minimal distractions. Prior to the commencement of the test, participants were informed that the objective of the test was to walk as far as possible for six minutes without to running or jogging. This was demonstrated to the participants by walking one lap (2x30m walk course). Standardized instructions and words of encouragement were given to the participants during the test as provided by the American Thoracic Society (ATS) guidelines for the 6-MWT.[38] The total distance covered by each participant in six minutes was calculated by multiplying the number of laps walked by 60 meters (one lap is to and fro the 30m walk course) plus the final partial lap in meters.[38] A stopclock was used to keep time. Participants were allowed to use their assistive device if needed during the test but were required to use the same assistive device for all testing sessions.

Intervention

Aerobic exercise training: The following exercise

prescription guidelines were used:

1. Aerobic exercise training of participants was done using the bicycle ergometer.
2. Exercise intensity was prescribed at 50-59% of heart rate reserve (HRR) (HRR = HRmax – HRmin) for 5 weeks and then increased to 60-69% of HRR for the remaining 5 weeks.[39]
3. Exercise frequency was two times per week for 10 weeks.
4. The main exercise duration for each session was 25 minutes. The warm-up and cool-down sessions were 5 minutes respectively.
5. Rate of perceived exertion (RPE) was kept between 12-16/20

Each exercise session was begun with pre-exercise vital signs assessment. Each session started with a 5 minute warm-up at a comfortable, self-selected pace. After 5 minutes, the exercise intensity was increased to the prescribed workload. The main aerobic exercise training would begin with exercise intensity for that session at the lower end-range of the targeted HRR (eg.50% of HRR for the first 5 weeks) for 15 minutes and the intensity would be increased to the upper end-range of the targeted HRR (i.e.59% of HRR for the first 5 weeks) for the remaining 10 minutes. The participants were monitored and encouraged to maintain the prescribed exercise intensity for the duration of the session. A 5-minute cool-down was employed after the main exercise session.[40] All exercise training was well tolerated as there were no adverse events during testing or training.

Post intervention assessment of parameters:

All the outcome variables assessed at baseline were re-assessed at the end of 10 weeks aerobic exercise training.

Data Analysis

Data was analysed using the Statistical Package for Social Sciences (SPSS) Version 21. Paired (Student) t-test was used to determine the difference in the walking endurance, selected respiratory and cardiovascular parameters pre- and post-10 weeks of aerobic exercise training of stroke survivors. Unpaired (Independent) t-test was used to determine if there were significant differences between the mean changes of selected respiratory and cardiovascular parameters in male and female participants post 10 weeks aerobic exercise training. The level of statistical significance was set at p less than 0.05.

Results

Socio demographic characteristics of participants

A total of 37 stroke survivors who were attending Physiotherapy clinic of Lagos University Teaching Hospital (LUTH) and Lagos State University Teaching Hospital (LASUTH) completed this study. Twenty (54.1%) of the participants were male and 17 (45.9%) were female. The mean age, mean height and mean weight of all the participants were 51.59 ± 4.86 years, 1.7 ± 0.9 m and 69.8 ± 5.1 kg respectively.

Effect of aerobic exercise training on walking endurance

Table 1 shows the effect of aerobic exercise training on walking endurance in the participants. There was a significant improvement in the walking endurance ($p = 0.001$) of stroke survivors after 10 weeks of aerobic exercise training of stroke survivors.

Table 2 shows the effect of aerobic exercise training on selected cardiovascular parameters in participants. There were significant improvements in the SBP ($p = 0.001$), DBP ($p = 0.001$), HR ($p = 0.001$), MAP ($p = 0.001$) and RPP ($p = 0.001$) after 10 weeks of aerobic exercise training of stroke survivors.

Table 3 shows the effect of aerobic exercise training on selected respiratory parameters in participants. There were significant improvements in the FVC (p= 0.001), FEV_1 (p= 0.001), PEFR (p= 0.001) and VO_2 max (p= 0.001) after 10 weeks aerobic exercise training of stroke survivors.

Table 4 shows the gender variation in the effect of aerobic exercise training on selected cardiovascular parameters. There was no significant difference in the effect of 10 weeks aerobic exercise training on selected cardiovascular parameters ($p > 0.05$) between male and female stroke survivors.

Table 5 shows the gender variation in the effect of aerobic exercise training on selected respiratory parameters. There was no significant difference in the effect of 10 weeks aerobic exercise training on selected respiratory parameters ($p > 0.05$) between male and female stroke survivors except in FEV_1 (p= 0.037).

Table 1: Effect of 10 weeks aerobic exercise training on walking endurance

Variable	Baseline	Post-intervention	t-value	p-value
	Mean ± SD	Mean ± SD		
6MWD (m)	90.7 ± 43.0	172.6 ± 59.0	14.2	0.001*

6MWD: six minutes walk distance; (Significance set at P< 0.05*); (m): meter

Table 2: Effect of aerobic exercise training on selected cardiovascular parameters in the participants

Cardiovascular Parameters	Baseline Mean ± SD	Post-intervention Mean ± SD	t-value	p-value
SBP (mmHg)	142.0 ± 14.3	121.7 ± 5.2	11.3	0.001*
DBP (mmHg)	94.5 ± 7.6	74.2 ± 7.5	15.7	0.001*
HR (bpm)	84.5 ± 12.5	70.3 ± 6.3	6.7	0.001*
MAP (mmHg)	110.9 ± 7.8	90.1 ± 6.1	18.5	0.001*
RPP (mmHgbpm)	12067.0±2111.1	8561.4±923.3	10.9	0.001*

(*Significance set at P< 0.05); SBP: systolic blood pressure; DBP: diastolic blood pressure

HR: heart rate; MAP: mean arterial pressure; RPP: rate pressure product; SD: standard deviation

Table 4: Gender variation in the effect of aerobic e xercises training on selected cardiovascular parameters

Variables	Male Mean ± SD	Female Mean ± SD	t-value	p-value
SBP (mmHg)	19.9 ± 12.5	23.0 ± 10.3	0.814	0.421
DBP (mmhg)	22.6 ± 5.9	17.8 ± 9.3	1.905	0.065
HR (bpm)	16.5 ± 5.2	11.4 ± 9.2	1.207	0.236
MAP (mmHg)	21.8 ± 6.0	19.6 ± 7.7	0.978	0.335
RPP (mmHgbpm)	3766.4±2386.5	3198.8 ± 1302.4	0.875	0.388

(Significance set at P< 0.05*); md: mean difference.; SBP: systolic blood pressure; DBP: diastolic blood pressure; HR: heart rate ; MAP: mean arterial pressure ; RPP: rate pressure product ; SD: standard deviation

Table 5: Gender variation in the effect of aerobic exercises training on s elected respiratory parameters

Variables	Male Mean ± SD	Female Mean ± SD	t-value	p-value
FVC (L)	1.1 ± 0.7	1.1 ± 0.6	0.178	0.860
FEV_1 (L)	0.9 ± 0.6	1.3 ± 0.4	2.166	0.037*
PEFR (L)	1.5 ± 0.5	1.4 ± 0.3	0.369	0.714
VO_2 max (mL/kg/min)	6.5 ± 6.7	14.9 ± 4.0	0.809	0.424

(*Significance set at P< 0.05) ; md: mean difference. ; FVC: force vital capacity, PEFR: peak expiratory flow rate, FEV_1: force expiratory volume in one second ; VO_2 max: maximum ; oxygen consumption; SD: standard deviation

Discussion

This study was aimed at determining the effects of aerobic exercise training on walking endurance and selected cardio-respiratory parameters in ambulatory stroke survivors. A ten (10) week aerobic exercise training brought about significant improvements in walking endurance and selected cardio-respiratory parameters of stroke survivors.

The finding that there was a significant improvement in the walking endurance of the stroke survivors following 10 weeks of aerobic exercise training may be explained by the fact that the weak respiratory muscles (diaphragm, intercostal and abdominal muscles on the affected side) common in patients with stroke may have been strengthened by the exercise training. This may have led to improved ventilation and oxygenation of the blood resulting in improved functional capacity. Weakness of the respiratory muscles in patients with stroke results in severe restrictive ventilatory impairment that may lead to hypoventilation and hypoxemia which implies a reduction in cardiopulmonary competence and could precipitate fatigue.[41,42] Post-stroke fatigue is known to be a common complication of stroke and also a contributing factor to the impairments and disabilities that negatively impairs functional performance.[43] This result is consistent with the report of the study by Tang et al.[20] that examined the benefit of structured aerobic exercise training on aerobic and functional capacity in stroke survivors and found a significant improvement in their walking endurance following a four weeks aerobic exercise training programme using treadmill. The finding is also consistent with another study that reported a significant increase in walking endurance of stroke survivors.[44]

The finding that there were significant improvements in all the selected cardiovascular parameters of the participants following 10 weeks aerobic exercise training implies that aerobic exercise improved the cardiovascular competence of stroke survivors. It has been suggested that as little as a 5mm Hg decrease in SBP could reduce mortality associated with stroke by 14%.[45] This study recorded a 20.3mmHg decrease in resting SBP and DBP respectively and a 14.2 bpm reduction in HR. Billinger et al.[30] reported a reduction of 11 mmHg and 1.4 mmHg in resting SBP and DBP respectively in ten stroke survivors who carried out exercise training for eight weeks using total body recumbent stepper. There were also significant reductions of 20.8 mmHg and 3505.6 beats/min/mmHg in MAP and RPP respectively.

The finding that there was no significant difference in the effect of 10 weeks aerobic exercise training on selected cardiovascular parameters between male and female stroke survivors implies that gender did not modify the effect of aerobic exercise training on the selected cardiovascular parameters in the stroke survivors. There was no available literature on gender variation in the effect of aerobic exercise training on selected cardiovascular parameters.

The finding that there were significant improvements in all the selected respiratory parameters following 10 weeks aerobic exercise training implies that aerobic exercise improved the respiratory competence of stroke survivors. The severe restrictive ventilatory impairment in stroke survivors resulting from the weakness of the respiratory muscles on the affected side may have been improved due to aerobic exercise training leading to improved ventilation and oxygen in the blood.[46] This corroborates previous studies that reported improved lung function parameters in stroke survivors after aerobic exercise.[21,47,48] Rimmer et al.[24] reported a significant improvement in VO_2

max after exercise intervention in stroke survivors. Duncan et al.[44] and Pang et al.[49] demonstrated a significant improvement in VO_2 max during a combination of aerobic and strengthening exercise intervention among stroke survivors.

The finding that there was no significant difference in the effect of 10 weeks aerobic exercise training on selected respiratory parameters (FVC, PEFR and VO_2 max) between male and female stroke survivors implies that gender did not have any influence on the effect of aerobic exercise training on these parameters in the stroke survivors. However, only FEV_1 showed significant difference between male and female gender. This is consistent with the finding of the study by Severinsen et al.[50] that reported a significant variation in FEV_1 ($p= 0.024$) between male and female participants who combined both aerobic and resistance exercise training.

Conclusion

Aerobic exercise training is beneficial in improving walking endurance and cardio-respiratory parameters in stroke survivors. There was no significant gender difference in the effect of aerobic exercise training on most of the selected cardio-respiratory parameters in stroke survivors.

Recommendation

Based on the findings of this study, it is hereby recommended that Physiotherapists who specialize in the management of patients with stroke should include aerobic exercise training using bicycle ergometer in the management of this group of patients to improve their walking endurance and cardiorespiratory fitness.

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Conflict of interest statement

The authors have no conflicts of interest.

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