RESEARCH PAPER

Impact of Aerobic Training on Cardio- Respiratory Fitness and Health Related Quality of Life in Stroke Survivors

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ABSTRACT

Background: The acute phase of ischemic stroke (AIS) is when the most severe complications have been observed, and the severity of AIS is directly correlated with the possibility of developing cardiac problems. Similarly, poorer neurologic prognosis and 90-day disability are more likely to occur in patients with reduced heart function following AIS. They greatly enhanced their walking capability and aerobic endurance with aerobic training programs that were similar in period and design to cardiac rehabilitation protocols.

Participants and Methods: This randomized controlled trial comprised forty post-stroke patients who were allocated from the outpatient clinic of the neurological department of El Kasr El-Aini hospital. They aged between 55 and 65 years and had a body mass index between 25 and 29.9 Kg/m^2. They were split into two equal groups: the Study Group (A): Twenty post-stroke patients who received an aerobic training program plus a selected physiotherapy program for stroke patients. Control Group (B): Twenty post-stroke patients who only received a selected physical therapy program for stroke patients. The outcome measures included Stroke Impact Scale, VO_2, CO_2, SpO_2, and HR, which were assessed before and after treatment.

Results: Within groups, a statistically significant change was detected ($p \leq 0.05$), while between-group results revealed statistically significant changes ($p < 0.05$), with the superiority of group A. Conclusion: In stroke survivors, aerobic training significantly improved all variables relating to cardiorespiratory fitness and quality of life.

Keywords: Stroke, Cardiorespiratory Fitness, Quality of Life, Aerobic training

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INTRODUCTION

In the United States, a stroke happens every 40 seconds, which means that a stroke fatality occurs in just three minutes and 14 seconds. Stroke was responsible for 1 in 6 deaths from cardiovascular disease (CVD) in 2021. About 610,000 of the more than 795,000 strokes that occur in Americans every year are first-time occurrences. A quarter of all strokes, or around 185,000 of them, occur across individuals who have already had a stroke. Ischemic strokes caused by disrupted blood supply to the brain, comprise about 87% of strokes. Stroke rates are declining, regarding the Framingham Heart Study. However, the cohort was primarily composed of white individuals **(1).**

According to **GBD Stroke Collaborators (2)**, worldwide, stroke ranks as the third most prevalent cause for disability and the second leading cause of fatality, after ischemic heart disease **(3).** Among the elderly, it is a common and often frequent disease. With an annual incidence of 76–119 per 100,000 people worldwide, stroke is a serious global health concern **(4).**

The majority of survivors of stroke frequently experience impairments linked to decreased capacity for physical activity and cardio-respiratory fitness (CRF) **(5,6).** These impairments have a variety of negative effects on the patients' health and increase their likelihood of developing additional CVD **(7).**

The primary effects of the concurrent presence of CVD and disabilities following a stroke include poorer CRF (median of 14 mL kg-1 min-1, varying from 8 to 23 mL kg-1 min-1) **(8)**, depression **(9),** limited mobility **(10),** low quality of life (QoL) perception **(11),** and limited social involvement **(Skolarus et al., 2014).**

According to **Crozier et al. (13)**, stroke survivors' CRF is less than half that of their non-stroke counterparts. Cardiorespiratory training possibilities are limited in stroke rehabilitation programs, particularly when it comes to high-intensity exercise. Research indicates that cardiorespiratory exercise helps stroke patients feel less disabled during or after standard stroke care. Exercise is recognized to help

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stroke patients, but the ideal cardiorespiratory training regimen is still up for debate **(14)**.

In stroke patients, physical activity may have an impact on a variety of activities and health conditions. Any skeletal muscle-produced motion that requires the use of energy, such as that which occurs during daily tasks at home, in the workplace, during recreational activities, or transportation, is considered physical activity. Exercise is a particular form of physical training that is done regularly in a planned and designed manner to preserve or increase fitness level **(9).**

Though moderate continuous aerobic exercise is part of standard cardiorespiratory training guidelines, high-intensity interval training (HIIT) has achieved considerable therapeutic interest following the American Heart Association's 2007 recommendation **(15).** HIIT is safe and beneficial for both healthy people and patients with chronic illnesses **(16).**

However, it appears that stroke survivors are not participating enough in therapeutic exercises that have a cardiovascular training impact, which may hinder their ability to restore their independent functioning **(17).** Post-stroke patients and their healthcare professionals will be able to prescribe suitable and effective exercise by having a greater awareness of the impacts of HIIT.

Regarding the systematic reviews of **Luo et al. (18) and Weiner et al. (19),** high-intensity exercise improves CRF in stroke patients and may be a safe new approach for cardiopulmonary rehabilitation following a stroke.

A structured exercise regimen called cardiac rehabilitation (CR) is intended to help stroke survivors break the pattern of inactivity, lower their chance of developing heart problems in the future, and feel more confident and have a better life **(20).**

Since it has been documented that aerobic training increases CRF in stroke patients, it may be essential to determine if aerobic exercise (AE) can help enhance physical fitness and reduce the time spent in low-energy expenditure tasks among this population **(14)** and that CRF is an essential indicator of physical activity following a stroke **(5).** Nevertheless, it's unclear how effective aerobic exercise is at influencing these variables (**9**).

The American Heart Institute suggests regular aerobic exercise as a preventative and therapeutic measure for stroke **(21).** AE is identified as "planned or organized repeated physical activity for long durations and at appropriate intensities to enhance fitness level." It is suggested that AE be practiced on the majority of weekly days for at least eight weeks at an intensity that progressively increases **(22).** When included in post-stroke rehabilitation programs, AE significantly enhances function and lowers the risk of consecutive strokes. It is recognized as a component of complete stroke recovery in clinical standards and best practices **(23).**

According **to Katz-Leurer et al. (24),** stroke patients' aerobic capacity and walking endurance are improved by moderate-intensity AE (between 64 and 76% of the age-predicted peak HR) for 20 to 25 minutes, trice weekly, for six weeks. Shorter exercise sessions (2 minutes, for instance) with brief stops at the beginning can be given to people who have limited exercise tolerance.

A key element of CR, aerobic training, can help stroke survivors improve their gait speed, endurance, and CRF **(25).** Exercise may partially counteract the reduction in HRQOL among stroke patients by (1) lowering secondary consequences like depression and pain and/or (2) increasing general fitness level, which raises functional ability levels (e.g., more confidence in carrying out routine activities) **(26).**

MATERIAL AND METHODS:

Ethical considerations:

The Research Ethics Committee of Cairo University's Faculty of Physical Therapy accepted this research (P.T.REC/012/003588). This research has also been conducted in accordance with the standards of the Declaration of Helsinki. The trial registry (NCT06539520) was accepted by ClinicalTrials.gov.

This randomized controlled trial was conducted from 2022 to 2024. Randomization was accomplished by generating random numbers in an Excel sheet. A thorough clarification of the study's goals and justification was provided to each participant, along with a statement regarding the questionnaire that was used to gather data, to gain their trust and cooperation. Participants received guarantees of data confidentiality and the freedom to discontinue the study at any moment. After that, every patient signed an informed consent form before taking part in the research.

Participants:

Forty post-stroke patients were allocated from the outpatient clinic of the neurological department of El Kasr El-Aini hospital. Consequently, they were randomly split into two equal groups: the study group (A) and the control group (B).

Study Group (A):

Twenty post-stroke patients received an aerobic training program plus a selected physiotherapy program for stroke patients.

Control Group (B):

Twenty post-stroke patients who only received a selected physical therapy program for stroke patients.

Inclusion criteria: Both genders, aged from 55 to 65 years, BMI from 25 to 29.9 kg/m², within one year post ischemic stroke, right- and left-sided strokes were included. Hemiparetic patients were included, medications (anti-spastic drugs, beta blockers, ACE inhibitors, and diuretics), a functional ambulatory category of ≥ 3, and hemodynamically stable before enrollment in the study. Controlled hypertension, controlled diabetes Did not participate in any research study within the last three months.

Exclusion criteria: Severe anemia, uncontrolled hypertension, uncontrolled diabetes mellitus, Recent cardiothoracic surgeries, cognitive problems (Mini-Mental State Exam < 24), auditory and visual problems, a modified Rankin score≥ 3, Seizure, musculoskeletal disorders, Stroke or severe head injury in the previous three months, vertebrobasilar stroke**.**

A thorough explanation and instructions about the assessment and treatment procedures were provided to each participant to gain their confidence and cooperation.

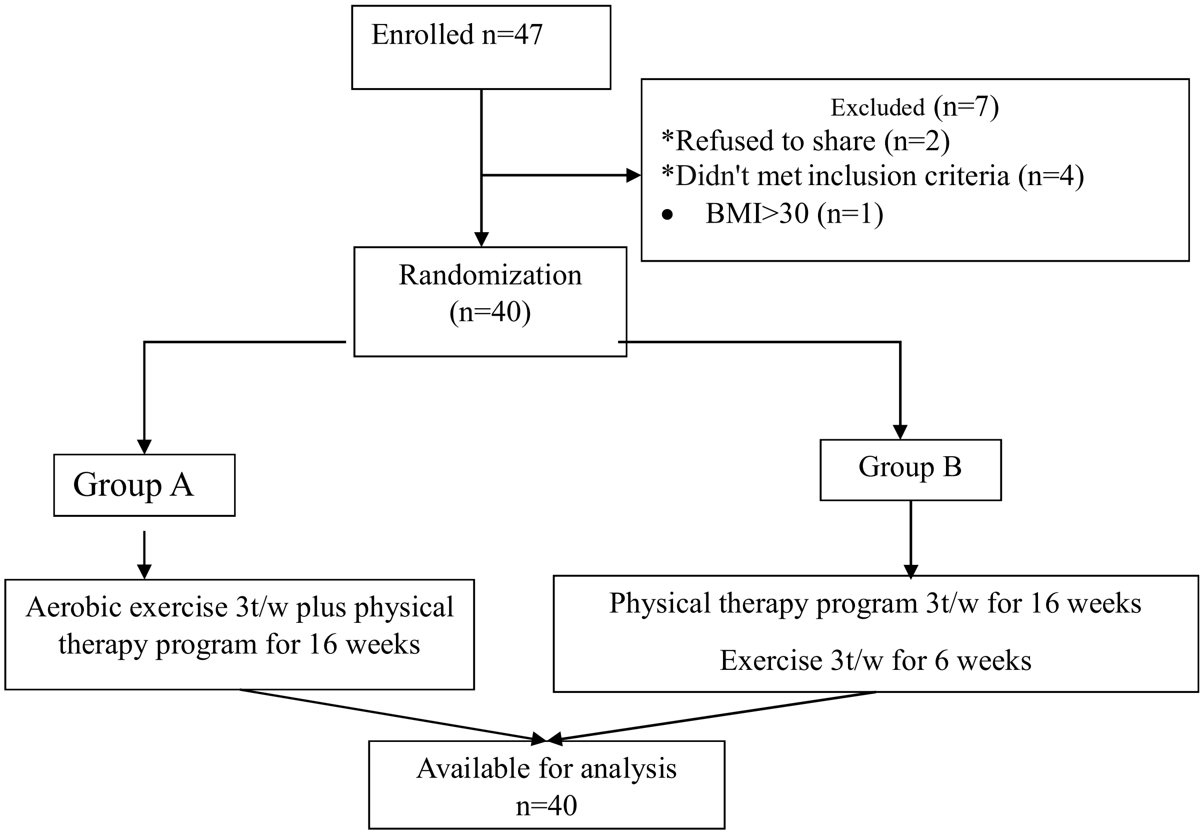

Fig. (1): Flow chart of the study

A- Evaluative instruments: cardiopulmonary exercise test

CPET involves mainly the analysis of respiratory gases including.

- Respiratory oxygen uptake (Vo2),
- Carbon dioxide production (Vco2),
- Ventilatory measures during a symptom-limited exercise test.
- Resting HR and SpO_2 were measured.
- SpO_2 and CO2 were monitored during the test

The test involves gradually increasing the intensity of exercise, usually on a treadmill, while breathing, heart rate, and blood pressure are monitored (Medgraphics).

B- Stroke Impact Scale (SIS version 3.0)

The SIS is a stroke-specific, self-report, health status measure. It was designed to assess multidimensional stroke outcomes, including strength, hand function Activities of Daily Living / Instrumental Activities of Daily Living (ADL/IADL), mobility, communication, emotion, memory and thinking, and participation. It can be used both in clinical and in research settings **(Zeltzer et al., 2018).**

1. Preparation:

Monitoring Devices: Electrocardiogram (ECG) electrodes were placed on chest to monitor heart's electrical activity. A mask or mouthpiece was fitted to measure patient's breathing and analyze the gases that exhaled. A clip may be placed on patient's finger to measure oxygen saturation (Medgraphics USA Ultima, SN218001449).

Lung Function Tests: Routine lung function tests were often performed before the CPET to assess baseline respiratory function.

2. The Exercise Protocol:

Warm-up: Patients started with 5-10 min warm up by walking on the treadmill then started at very slow speed

Gradual Increase: The intensity of exercise was gradually increased, typically every minute, by increasing the incline/speed of the treadmill.

Maximal Effort: Patients were encouraged to exercise to maximum tolerated level, which might involve feeling out of breath and experiencing muscle fatigue.

Cool-down: After exercise, patient had a cool-down period with walking to help the body recover.

3. Monitoring and Data Collection:

Throughout the test, the heart rate, blood pressure, oxygen saturation, and respiratory gas exchange were continuously monitored.

A doctor or respiratory scientist monitored the progress and the test was stopped if necessary.

4. Interpretation:

The data collected during the CPET was analyzed to assess heart and lung capacity, identify any limitations, and determine the cause of exercise intolerance.

The results can help doctors monitor the response to treatment and guide exercise prescriptions for pulmonary rehabilitation.

Treatment instruments:

- **Aerobic exercises (treadmill).**
- **Selected exercise P.T. program for stroke patients**

Evaluation procedures

1.Cardipulmonary exercises testing:

Cardiopulmonary exercise testing (CPET or CPEX), also referred to as a VO2 (oxygen consumption) test, is a specialized type of stress test or exercise test that measures your exercise ability. Information about the heart and lungs is collected to understand if the body's response to exercise is normal or abnormal.

You should receive instructions from your healthcare provider or the pulmonary laboratory where the test is being performed. These instructions may vary slightly between labs. Here are some common instructions:

Testing commenced with pulmonary function tests (PFTs), which include spirometry. You were then required to prepare yourself for the exercise test. Monitors were used to observe your cardiovascular and respiratory responses to exercise. Your chest was fitted with electrocardiogram (EKG) leads, which are wire electrodes attached to the skin by sticky patches.

The patient's blood pressure cuff was fitted around his/her upper arm. The patient wears a pulse oximeter sensor, which may be either in his/her fingers, ears, or forehead, to measure the degree of saturation of oxygen into the blood.

The patient breathes through a mouthpiece or mask fitted on the head with the help of a flow meter connected with tubes. The flow meter measures how deep and fast the person breathes.

- Before and during exercise, your doctor may request for arterial blood gas analysis. This is achieved through either the insertion of a needle into the artery of the wrist or catheterization (IV line) of the artery so that the blood can be collected during exercise without repeated needle insertion.
- If this was achieved, the blood pressure was obtained directly from the artery, and hence, you wouldn't have to wear the blood pressure cuff.
- You were given instructions concerning the exercise.
- During the first 2-3 minutes, data are gathered when you are in a resting position.
- Then a warm-up followed which entails walking on the treadmill or cycling freely on the stationary bike without any load on the pedals.
- After 2 to 3 minutes of warm-up, the exercising phase started.
- You may be running on the treadmill depending on the test protocol.
- You were observed briefly after exercising, and if you have an arterial catheter, this was withdrawn under pressure for several minutes before covering the area with a dressing.
- As you are being tested, the data about how your heart and lungs respond to exercising are recorded continually, but usually in 20-to-30-second increments.

2. **Stroke impact scale (SIS):**

▪ Patient was asked to fill in the questionnaire before and after training:

The SIS (version 3.0) has **8 domains**:

- Strength
- Hand function
- Mobility
- Activities of daily living (ADL/IADL)
- Memory
- Communication
- Emotion
- Participation

Each domain contains several questions.

▪ Each question is rated on a **5-point Likert scale**:

1 = Could not do at all
2 = Very difficult
3 = Somewhat difficult
4 = A little difficult
5 = Not difficult at all

▪ **Domain Score Calculation**

For each domain, use this formula:

$$\text{Domain Score} = \frac{(\text{Sum of item scores} - \text{number of items})}{(\text{number of items} \times 4)} \times 100$$

- Subtract the **minimum possible score** (which is number of items × 1)
- Divide by the **range** (number of items × 4)
- Multiply by 100 → gives a **0–100 scale**

- **Interpretation**
  - **0 = worst function**
  - **100 = best function**
  - Higher scores = better recovery / less impact of strok

Aerobic exercises (treadmill).

Treatment procedures

Aerobic training program (FITT) principle (treadmill).

Frequency: 3days/ week for 16 weeks (4 months)

Intensity: 50-80% of THR

Karvonen Formula

Target Heart Rate (THR) = [(max HR − resting HR) × %Intensity] + resting HR

Training HR zone was detected for each patient based on age.

Time: 30-40 min/session plus 5-10 min warming up and 5 min cooling down.

Type or Mode: Interval moderate aerobic exercise training treadmill walking (Xterra fitness TR150 USA based)

Progression: intensity of training was upgraded every month by 10% directed by rating of perceived exertion **(27).**

Instructions during training

The participants were instructed to hold the devices with both hands while standing on them. The walking shoes had flexible, non-slip soles, a well-cushioned heel, and strong arch support, and the patients wore comfortable, weather-appropriate layers of clothes. They were instructed to keep the head and chins up, gaze forward rather than down, and practice proper posture. The shoulders were kept relaxed, and the chest was held upright (shoulders down and back relaxed).

Ask them to contract buttocks and abdominal muscles, flatten back, and incline pelvis gently forward. And they were instructed to move in a straight direction while taking a few steps. And push off with toes, focus on rolling through the step, and land on the heel. To move the body forward, they used the calf muscles' intrinsic spring and ask them to breathe naturally. As walking requires deep rhythmic breathing to maximize oxygen delivery to the respiratory system.

They were instructed not to overstride or slouch shoulders or carry weights on hands or put them on ankles.

Selected exercise P.T. program for stroke patients: The program included exercises to strengthen the hip and promote standing and walking. The neural rehabilitation program was conducted for 1 hour each session, three sessions weekly, for four months. Neural rehabilitation was applied as follows **(Tanzman, 2019)**:

Weight transfer Side to Side : Weight was moved from the right hip to the left. Ask the patients to raise the hip off the ground, and the rib cage ought to shift side to side. Avoid leaning by bending at the waist. They were instructed to do these ten to fifteen times. When sitting, books were put beneath the hands to prevent the hands from rising off the seat and to allowed weight to be supported through the arms. this exercise was done ten to fifteen times.

Reaching Toward the Weak Side : Weight was transferred through the paralytic or weak arm and extend the unaffected arm toward the weaker side. The participants must have an assistant hold a weakened arm at the wrist and just above the elbow if it falls or the hand slides. They did this exercise ten to fifteen times.

Shoulder Flexion Overhead : Elbows were Maintain straight. Arms were lift as far above the head was comfortable. If shoulder was subluxed, meaning it has fallen out of its socket, raise the arms straight up but not overhead, placing them at a 90-degree angle with the body. For guidance regarding safe ROM exercises in the event of a shoulder subluxation, consult a physiotherapist or occupational therapist. Furthermore, don't elevate the arm any higher if it hurts. When the participants began to experience any shoulder pain, stop. Only move in a pain-free range. This exercise was done ten to fifteen times.

Shoulder External Rotation : The participant was instructed to put the hands behind the head and loosen the elbows to the side (maintain hands clasped) if the physical or occupational therapist allowed the patient and the patient could comfortably raise the arms overhead. This was a challenging activity for many stroke sufferers. If the patient felt pain or the therapist had instructed you not to perform the exercise, refrain from doing it. This exercise was done ten to fifteen times.

Overhead Press : Arms should be pushed above the head and down. This exercise was done ten to fifteen times.

Shoulder External Rotation with Theraband : The participants started by holding the Theraband in the hands with the elbows bent at 90 degrees and pressed against the body. Rotated arms back while extending the hands to the sides, maintaining a 90-degree elbow bend throughout the motion. This exercise was done ten to fifteen times.

Shoulder Internal Rotation with TheraBand : The participants were instructed to attach the TheraBand's one end to a doorknob. While maintaining a 90-degree elbow, they pulled the other end of the band to the abdomen. This exercise was done ten to fifteen times.

Heel Slides : With the knee bent, ask the participants to slide the affected foot up toward the buttocks while lying on the back. Then, slide the foot back down until the knee was extended. This exercise was done ten to fifteen times.

Bridging : While lying on the back with the feet resting on the plinth or mat and the knees flexed, ask the participants to raise the hips toward the ceiling and then lower them again. This exercise was done ten to fifteen times.

Lying Terminal Knee Extension : Place a bolster behind the knees while lying on the back by using multiple rolls of a towel. Ask them to raise the affected foot. This exercise was done ten to fifteen times. Then straighten the knee off the mat or bed, then drop the foot gently down. This exercise was done ten to fifteen times.

Toe and Heel Raises : The participants were instructed to elevate the toes and heels while seated in a chair; heel raised was not shown. This exercise was done ten to fifteen times.

Sensory Re-education Exercises: The participants were instructed to distinguish between different textures, including cotton, velvet, sandpaper, satin, rubber, and wool. This exercise was done ten to fifteen times.

Place items in a bowl of rice, dry beans, or sand, such as marbles, coins, etc. Try used the hand to locate things without using the eyes. The exercise was done ten to fifteen times. Someone touched the participant once when the eyes were open and once when they were closed. They tried to connect the location of the object's touch to the sensation felt on the skin. This exercise was done ten to fifteen times. Ask them to apply pressure to the skin while moving it around. And to observe and take note of how it felt. Ask them to distinguish between when the pressure is moving and when it is stationary by closing the eyes. This exercise was done ten to fifteen times. They were instructed to use a massager to deliver vibration to the skin while closing the eyes. Ask them to determine when the skin was subjected to vibration. The person was asked to move the vibration over the skin and show if he can identify when it was stationary and when it was moving. This exercise was done ten to fifteen times.

Body awareness therapy (BAT): Body awareness therapy (BAT) is a type of physical therapy that looks at a person's concentration and postural stability to help them develop a fresh perspective on their body. One of the primary goals of BAT was to increase a person's awareness of their motion. The center line of the body is identified by performing movements in different positions. BAT encompasses balance, coordination, free breathing, and postural control **(29).**

Data analysis and statistical design

Data were displayed as mean±SD. One-way MANOVA was employed for comparing between-subjects' characteristics of both groups, and chi-square for comparison of sex distribution between both groups. The Shapiro-Wilk test was applied to test the normality of data distribution. A repeated measures MANOVA was performed to compare within- and between-groups effects for the assessed variables (heart rate, PO2, VO2, and VCO2). SPSS (version 20 for Windows; SPSS Inc., Chicago, Illinois, USA) was employed for data analysis. A P value of ≤ 0.05 was indicated as significant.

Results:

The impact of treatment on Heart rate (HR):

There was no statistical significant difference in the mean values of HR pretreatment between both groups (p= 0.175). While there was statistical significant difference post treatment (p=0.017) in favor to group A **(Table 1).**

Table (1): Mean ±SD of HR pre and post treatment of both groups.

Heart rate (beat/min)	Group A Mean ±SD	Group B Mean ±SD	Mean difference (95% CI)	P-value[1]	η^2
Pre-treatment	113.3 ± 7.95	116.5 ± 6.61	2.13 (-7.88, 1.48)	0.175	0.048
Post-treatment	106.75 ± 8.24	112.55 ± 6.38	-5.8 (10.52, -1.1)	0.017*	0.140
MD (95% CI)	6.55 (5.63, 7.47)	3.95 (3.03,4.87)			
% of change	6%	3.5 %			
P-value	0.001*	0.001*			

*SD: standard deviation, CI: Confidence interval, p-value: level of significance within group, p-value1: level of significance between groups, *: significant, η2: partial eta squared*

Between groups comparison

There was no statistical significant difference in the mean values of SpO_2 pretreatment between both groups (p= 0.563), while there was statistical significant difference post treatment (p=0.008) in favor to group A **(Table 2).**

Table (2): Mean ±SD of SpO_2 pre and post treatment of both groups.

SpO_2 (ml/hg)	Group A Mean ±SD	Group B Mean ±SD	Mean difference (95% CI)	P-value[1]	η^2
Pre-treatment	95.75 ± 1.02	95.55 ± 1.14	0. 2 (-0.49, 0.89)	0.563	0.009
Post-treatment	98.25 ± 0.72	97.4 ± 1.14	0.85 (0.24, 1.46)	0.008*	0.173
MD (95% CI)	-2.5 (-2.79, -2.21)	-1.85 (-2.14, -1.56)			
% of change	2.6%	1.9%			
P-value	0.001*	0.001*			

SD: standard deviation, CI: Confidence interval, p-value: level of significance within group, p-value1: level

The impact of treatment on Oxygen Consumption:

There was no statistical significant difference in the mean values of VO_2 pretreatment between both groups (p= 0.746), while there was statistical significant difference post treatment (p=0.004) in favor to group A **(Table 3).**

Table (3): Mean ±SD of VO_2 pre and post treatment of both groups.

VO_2 (L/min)	**Group A Mean ±SD**	**Group B Mean ±SD**	**Mean difference (95% CI)**	**P-value[1]**	**η^2**
Pre-treatment	1.51 ± 0.17	1.49 ± 0.15	0.02 (-0.09, 0.12)	0.746	0.003
Post-treatment	1.86 ± 0.09	1.72 ± 0.17	0.14 (0.05, 0.23)	0.004*	0.202
MD (95% CI)	-0.35 (-0.42, -0.28)	-0.23 (-0.3, -0.15)			
% of change	23%	15.5%			
P-value	0.001*	0.001*			

*SD: standard deviation, CI: Confidence interval, p-value: level of significance within group, p-value1: level of significance between groups, *: significant, η2: partial eta squared*

The impact of treatment on Carbon Dioxide Production:

There was no statistical significant difference in the mean values of VCO_2 pretreatment between both groups (p= 0.453), while there was statistical significant difference post treatment (p=0.001) in favor to group A **(Table 4).**

Table (4): Mean ±SD of CO_2 pre and post treatment of both groups.

VCO_2 (L/min)	**Group A Mean ±SD**	**Group B Mean ±SD**	**Mean difference (95% CI)**	**P-value[1]**	**η^2**
Pre-treatment	0.88 ± 0.07	0.87 ± 0.08	0.01 (-0.03, 0.07)	0.453	0.015
Post-treatment	0.62 ± 0.08	0.71 ± 0.06	-0.09 (-0.13, 0.04)	0.001*	0.285
MD (95% CI)	0.26 (0.24, 0.3)	0.16 (0.13, 0.19)			
% of change	30%	18.5%			
P-value	0.001*	0.001*			

*SD: standard deviation, CI: Confidence interval, p-value: level of significance within group, p-value1: level of significance between groups, *: significant, η2: partial eta squared*

The impact of treatment on stroke impact scale:

There was no statistical significant difference in the mean values of stroke impact scale pretreatment between both groups (p= 0.950), while there was statistical significant difference post treatment (p=0.001) in favor to group A **(Table 5).**

Table (5): Mean ±SD of stroke impact scale pre and post treatment of both groups.

Stroke impact scale	**Group A Mean ±SD**	**Group B Mean ±SD**	**Mean difference (95% CI)**	**P-value[1]**	**η^2**
Pre-treatment	38.65 ± 5	38.75 ± 4.92	-0.1 (-3.28, 3.08)	0.950	0.001
Post-treatment	71.35 ± 11.67	59.15 ± 7.11	12.2(6.02, 18.39)	0.001*	0.296
MD (95% CI)	-32.7 (-37.15, -28.25)	-20.4 (-24.85, -15.95)			
% of change	85%	53%			
P-value	0.001*	0.001*			

*SD: standard deviation, CI: Confidence interval, p-value: level of significance within group, p-value1: level of significance between groups, *: significant, η2: partial eta squared*

DISCUSSION:

The cardiorespiratory fitness (CRF) of stroke survivors is less than half that of their normal peers. There are a few possibilities for cardiorespiratory training in stroke rehabilitation programs, particularly when it involves high-intensity exercise **(30).** Regarding **Saunders et al. (14)**, there is proof that cardiorespiratory training helps stroke patients feel less disabled through or following regular stroke care.

A non-pharmacological approach to treating stroke survivors involves exercise training. According to meta-analyses and review studies, exercise training improves cardiovascular variables and increases muscular strength and function in stroke survivors **(31).**

Kenneth originally brought up the theory of aerobic exercise in the 1970s, arguing that it is a kind of physical training that maintains and satisfies the need for oxygen during activities and results in positive alterations in the circulatory and pulmonary systems **(32).**

The American Heart Institute recommends regular aerobic exercise (AE) as a preventative and therapeutic measure for stroke **(33).** AE is described as "planned or organized frequent physical exercises over prolonged periods and at adequate intensities for enhancing fitness level." For at least eight weeks, it is suggested that AE be practiced on the majority of weekly days at an intensity that is progressively raised **(22).** When included in post-stroke rehabilitation programs, AE significantly enhances function and lowers the possibility of recurring strokes. It is referred to as a component of complete stroke recovery in clinical standards and best practices **(23).**

Our results were corroborated by those of **Luft et al. (34),** who indicated that frequent treadmill training increases cardiorespiratory capability and activates brainstem neural circuits. Additionally, brain activation implies possible neuroplastic mechanisms through which treadmill training can help patients with post-stroke hemiparesis regain their motor and functional abilities to walk.

According to **Nepveu et al. (35)**, motor retention capacity as determined by the Montreal Cognitive Assessment (MoCA) is improved by a session of high-intensity interval training (HIIT) conducted just after physical treatment. Despite this, no statistically significant variations were noted in the assessment of cortical excitability, which may be clarified in part by the sample's older age and the using of exercise dosages that were below what would be required to have this effect. According to that study, high-intensity exercise enhanced by physiotherapy prompting may be linked to neuroplasticity.

Our findings concurred with those of **Shaughnessy et al. (36),** who assessed the impact of six months of AE on functional recovery and independence. They demonstrated an improvement in both aerobic capacity and their capability to carry out routine activities. Notably, there were no objective measurements in this self-assessment study.

Intense AE twice a week for 12 weeks enhanced the physical performance and QoL of stroke patients in the subacute period, according to our findings with **Sandberg et al. (37).** Aerobic capacity, speed, equilibrium, functional mobility, QoL, and perception of functional recovery all improved.

HIIT has also been indicated to improve functioning in the context of cardiovascular conditions, and our study's results correspond with those of earlier systematic reviews on poststroke patients **(38; 39).** It is essential to recall that there is ongoing debate over the relative benefits of HIIT for the VO_2 peak in various populations.

The current results were corroborated by **Schroeder et al. (40),** who investigated training-induced modifications after aerobic and anaerobic (resistive training) exercise, and indicated that AE significantly improved CRF, while resistance training significantly increased muscle power.

Additionally, our results align with those of **Santos et al. (41),** who discovered that stroke has an impact on older patients' QoL, with limited roles caused by physical health problems and limited roles resulting from psychological concerns being the frequently impacted domains.

In addition, **Katz-Leurer et al. (42)** verified that stroke patients' aerobic fitness and walking endurance are enhanced by moderate-intensity AE (64–76% of their age-predicted peak HR) practiced for 20–25 minutes, trice weekly, for eight weeks. For people with low exercise tolerance, short exercise sessions (e.g., 2 minutes) with intermittent rest intervals can be provided.

Furthermore, our findings are aligned with **Gordon et al. (42),** who utilized the short form-36 to measure quality of life (SF-36) and compared a group that practiced AE plus classical physical therapy three days a week to a group that was given only traditional physiotherapy for 12 weeks. The patients reported feeling more energized and emotionally better after including AE into their routine, and the physical health domain indicated a notable improvement between before and after treatment assessments.

According to **Tyrell et al. (44),** increasing training duration was closely associated with an improvement in walking endurance. Less time could be accessible for the progression of AE durations in combined aerobic/strength training since the exercise program was not solely focused on AE. However, the fact that increased aerobic fitness might result in better performance in such a crucial functional task is encouraging.

Tyrell et al. (44) indicated a significant association between the increase in treadmill velocity and training duration and the degree of improvement in maximal walking speed. It's remarkable that following training, self-selected walking speed did not notably improve; only maximal walking speed increased. Walking speed was examined in the majority of chronic stroke trials when the participants had recovered their ability to walk independently.

According to **Lam et al. (45),** people with left-sided injury and those with recent strokes improved their walking endurance more. Given the treatment approach, subject traits, and outcome measure, it is expected that the response to AE is highly personalized.

Our research confirmed the findings of **Francica et al. (46),** who illustrated that AE can improve post-stroke people's cardiovascular and functional capacities. Additionally, **Pang et al. (25)** indicated that post-stroke patients who practiced AE had an improvement in their cardiorespiratory capacities.

In comparison to controls, post-stroke patients had less heart rate variability (HRV) **(47).** It has been shown that non-pharmacological approaches (exercise training) may raise HRV in other people and thereby lower the possibility for cardiovascular mortality, despite the fact that little research has attempted to examine the impact of exercise on autonomic cardiac control after stroke **(48).**

In contrast to our results, a 2019 study by Nave et al. looked only at people with serious motor consequences in the subacute stages following stroke and found that AE did not improve functional outcomes more than relaxation techniques.

CONCLUSION:

From the previous results and discussions, it could be concluded that aerobic training significantly was effective in improvement of all variables relating to cardiorespiratory fitness and quality of life in stroke survivors.

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