Effect Of Aerobic Physical Training On Stroke Survivors

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"The price of success is hard work, dedication to the job at hand, and the determination that whether we win or lose, we have applied the best of ourselves to the task at hand"
DEDICATION

I dedicate this thesis to my parents,
my loving husband
and
my siblings.
Acknowledgment

First and foremost I thank to ALMIGHTY ALLAH who gave me strength throughout my study period and for guiding me throughout my life.

I am very thankful to my Supervisor Britta Lindstrom for her constructive ideas, support, feedback, criticisms and positive corrections in writing this thesis.

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I am grateful to my parents; Mr. and Mrs. Naeem who gave me the opportunity to be educated, my in-laws, my siblings. Their love, encouragement and financial support made it possible for me to complete my studies in Umeå, thank you so much.

Lastly, I would like to thank to my husband Khuram chaudhry for his support, love, encouragement, during my studies. I love you so much.
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ABSTRACT
According to world health organization approximately 17 million deaths is attributable to heart disease and stroke a year that is the one third of all deaths globally. By 2020 the major cause of disability and death will be stroke and heart diseases. It is a major global health problem and the third largest killer problem of developed or industrialized countries after heart disease and cancer and half of the survivors are left with a permanent handicap but now it is also affecting developing countries. According to WHO each year 15 million people suffer from stroke out of which 5 million die and 5 million permanently disabled. Several studies have emphasized on the importance of physical activity and exercise training in stroke patients and show the importance of psychological, physiological, functional, strength, endurance, sensorimotor effect of various types of exercise.

PURPOSE
Main purpose of the study is to investigate the impact of physical training particularly the aerobic training in stroke patients.

METHODS
Literature review was conducted to investigate the impact of aerobic physical training in stroke survivors using different databases. Exercise, stroke, rehabilitation, aerobic training these terms was used. 15 articles fall on the inclusion criteria.

RESULTS & DISCUSSION
The literature provides that several different exercises can improve aerobic capacity, cardiovascular fitness, motor performance and mood after stroke. In different studies the mode of training varies including treadmill, cycle ergometer, elliptical machine, water or functional activities. Cycle ergometer exercise does not require much postural control compared to treadmill and better alternative for individual with poor balance. Water may serve as a good exercise medium because it provides resistance and water buoyancy and provide partial weight support. Early exercise training after stroke and continue it for long duration not only has potential benefits for improving cholesterol level and hypertension to lowering the risk of recurrent stroke but also improved health related quality of life.

CONCLUSION
This literature review has given an account of the reasons for the widespread use of aerobic training in stroke survivors. Aerobic exercise is an essential part of a stroke rehabilitation program. Stroke affects everyone differently, so each exercise program should be customized to fit the needs of the individual. Aerobic exercise with different program treadmill, cycling, water based and elliptical program improve the aerobic capacity, motor performance, cardiovascular fitness and depression in stroke survivors.

KEY WORDS
Exercise, stroke, rehabilitation, aerobic training

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### Abbreviations

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<th>Terms</th>
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<tr>
<td>WHO</td>
<td>World Health Organization</td>
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<tr>
<td>CVA</td>
<td>Cerebrovascular Accident</td>
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<td>BP</td>
<td>Blood Pressure</td>
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<td>ADL</td>
<td>Activities of Daily Living</td>
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<td>TIA</td>
<td>Transient Ischemic Attack</td>
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<tr>
<td>BWSTT</td>
<td>Body Weight Supported</td>
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<td>6MWT</td>
<td>Treadmill Training</td>
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<tr>
<td>HLBF</td>
<td>Hamstring/low Back Flexibility</td>
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<td>AEX</td>
<td>Aerobic Exercise</td>
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<td>EF</td>
<td>Executive Function</td>
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<td>CVD</td>
<td>Cardio Vascular Diseases</td>
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<td>BBS</td>
<td>Berg Balance Scale</td>
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<td>REG</td>
<td>Regular Rehabilitation</td>
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<tr>
<td>STAT</td>
<td>Supported Treadmill</td>
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<td>Systolic Blood Pressure</td>
<td>SBP</td>
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<td>BDNF</td>
<td>Brain-Derived Neurotrophic Factor</td>
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BACKGROUND

According to world health organization approximately 17 million deaths are attributable to heart disease and stroke a year that is the one third of all deaths globally (1). It is a major global health problem and the third largest killer problem of developed or industrialized countries after heart disease and cancer and now it is also affecting developing countries. In people over 60 years of age stroke is the major cause of physical disability (6). By 2020 the major cause of disability and death will be stroke and heart diseases (2). Half of the survivors are left with a permanent handicap and the cost of stroke has aroused little attention despite the huge burden of stroke on health care and social services. It is the no.3 cause of death in the U.S several studies of USA estimate the annual cost between US $6.5 and 11.2 billion. It is also causing an enormous economic burden in low and middle income countries. According to WHO each year 15 million people suffer from stroke out of which 5 million die and 5 million permanently disabled (7). Due to high blood pressure 12.7 million strokes occur worldwide. In Europe about 650,000 stroke deaths occur each year. In developed countries due to struggle to lower blood pressure and to reduced smoking the incidence of stroke is declining but as a whole the stroke rate remains high because of the aging of the population (7). 29th of October is a stroke day throughout the world (6). According to medicine stroke is known as cerebrovascular accident (CVA) it is the loss of functions of brain due to interruption in the blood supply to brain. It can be due to hemorrhage (leakage of blood), or ischemia (lack of blood flow) caused by (thrombosis, arterial embolism) due to this the affected area of the brain cannot function properly (8). It is sometimes difficult to recognize the stroke; this may be due to the lack of awareness. It can produced severe brain damage when the nearby people fail to recognize stroke symptoms. Now doctor says a nearby can recognize stroke by asking three questions: SMILE – ask the person to smile, TALK- ask the individual to speak a simple sentence(e.g. it is sunny out today), RAISE BOTH ARMS ask the person to raise both arms. If any trouble in one of these tasks you have to call medical help line immediately. Another signs of stroke are ask the individual to stick out their tongue if the tongue goes to on one side it is also an indication of stroke (3). If the person have stroke than the symptoms will be: Sudden weakness of the face, arm or leg mostly on one side of the body, sudden numbness of the face, arm or leg, sudden vision problem in one or both eyes, trouble in walking, dizziness, loss of balance or coordination, severe, sudden headache with unknown cause, difficulty in speaking or understanding speech (aphasia), seizures (rarely)(4). Stroke can be divided into two major types: Ischemic stroke and hemorrhagic stroke. Ischemic stroke is the most common type of stroke accounting for about
88% of all strokes (11). Ischemic stroke occur when blood supply to the brain is decreased resulting in a corresponding loss of neurologic function. There are four reasons of ischemic stroke: Embolism (obstruction due to an embolus), thrombosis (obstruction of blood vessel by blood clot), systemic hypo perfusion (decrease in blood supply e.g. in shock) and venous thrombosis. Hemorrhagic stroke which is less common than ischemic stroke and make up about 12% of all strokes (11). Intracranial hemorrhage is the accumulation of blood within the skull. There are two types of hemorrhage intra-axial hemorrhage (blood inside the brain) and extra-axial hemorrhage (blood inside the skull but outside the brain).Intra-axial hemorrhage is due to intra parenchymal or intra ventricular hemorrhage. Main types of extra-axial hemorrhage are subarachnoid hemorrhage (is the bleeding into the subarachnoid space, the space between the arachnoid membrane and the pia mater surrounding the brain), epidural hematoma (the blood occur between the durameter and skull) and subdural hematoma (between the durameter and the arachnoid mater) (5).

**Risk factor of stroke**

There are several risk factor related to stroke. We can categorize the risk factor of stroke into un modifiable and modifiable. The un modifiable risk factor of stroke include Age, this is an important risk factor for stroke after the age of 55 for each 10 years, the stroke rate more than double for both men and women. Heredity increases the chances of stroke, if your parents, grandparents, sisters and brothers have had stroke. Races have also an impact to suffer a stroke as seen in African Americans due to presence of high blood pressure, diabetes and obesity. It is also more common in men in younger age than women. It could be in younger women due to the use of birth control pills and pregnancy pose. Transient ischemic attack (TIA) or heart attack increases the risk of stroke as compare to a person who has not. TIAs produce stroke like symptoms but no lasting damage. It is the strong predictor of stroke, recognizing and treating TIAs can reduce the risk of major stroke (5). The modifiable risk factor include High blood pressure which is the major cause of stroke and the most important controllable risk factor for stroke. The effective treatment of high blood pressure is the important factor for the decline in the death rates for stroke. Cigarette smoking is also an important risk factor for stroke nicotine and carbon monoxide in cigarette smoke effect the cardiovascular system. The cigarette smoking combined with the use of oral contraceptive greatly increases the risk of stroke. Diabetes mellitus is an independent risk factor. Majority diabetes people also have high blood cholesterol and high blood pressure, this increase the risk of stroke more. Diabetes is treatable but the presences of the disease still increase the risk of stroke. High blood cholesterol increases the risk
of stroke. The people who have coronary heart disease or heart failure have higher risk of stroke than without heart disease. Dilated cardiomyopathy, some congenital heart defects and heart valve disease also increase the risk of stroke. Diet with rich fats and cholesterol can increase the blood pressure. Diet with rich sodium can also increase blood pressure. Diet with excess calories can cause obesity, so diet containing fruit and vegetables reduced the risk of stroke. Physical inactivity and obesity can increase the high blood cholesterol, high blood pressure, heart disease, diabetes and stroke. Start daily walking and do whatever you can to make your life more Active (9).

Treatment after stroke

Stroke recovery occur in phases acute (<14 days post stroke), sub acute (3-12 months post stroke) and chronic (12months post stroke) (12). Recovery usually happens in phases containing medical treatment, spontaneous recovery, rehabilitation and return to community it can vary from a few weeks to a few years. Medical treatment starts when the person first comes to the hospital than doctors identify the type of stroke and provide the appropriate treatment it may contain drugs to break up clots, thin the blood or surgery to broken or repair blood vessel. The aim of the treatment is to prevent another stroke and limiting the amount of brain damage (10). Spontaneous recovery occur naturally in most of the peoples, this is quick during the first few weeks and the abilities that have been lost starts to come back but sometimes continues for a long time (10). The rehabilitation is an important to keep abilities to make the persons more independent and gain back lost activities. It usually starts from acute care and in many patients it continues formal as rehabilitation program (10). In systematic research it has shown that rehabilitation after stroke increase the patient survival and reduce the length of inpatient stay (13-15). The main purposes of physiotherapy after stroke are to regain motor control in gait and related activities, to improve upper limb function and to cope with deficits in activities of daily living (ADL) and increase participation in general. For gait training assistive devices can be used and also use training i.e. treadmills and other electronic modalities for treatment. Moreover instructions and advices are given to patient and family members. In physiotherapy, evidence based medicine is recommended for clinical decision making (16-17). Muscle strength is usually reduced after stroke (18-19). The main purpose of rehabilitation after stroke is to improve muscle strength, walking ability and increase possibilities to manage the everyday activities (20-21). After stroke often the physical rehabilitation of stroke survivor ended within several months, as it was assumed that most of the recovery of motor function occurred during that period of time. Recent research studies shows that aggressive rehabilitation after that period
containing treadmill exercise without or with body weight support can enhance the aerobic capacity and sensorimotor function (22-23).

Several studies have emphasized on the importance of physical activity and exercise training in stroke patients and show the importance of psychological, physiological, functional, strength, endurance, sensorimotor effect of various types of exercise (24-26). In addition, several studies have shown the advantageous effect of regular physical activity on multiple CVD risks. It has also been shown that it reduces the risk of mortality from cardiovascular diseases and stroke (27-29). Stroke patients are usually deconditioned and inclined to sedentary life that restricts their activities of daily living. This raises the risk of falls and can cause recurrent stroke and cardiac diseases so they can reduced it by physical activity and exercise. Clinical studies show that acute and prolonged cycling and running exercises enhance the cognitive act. Stroke survivors with mobility impairment the body weight support treadmill training (BWSTT) allow secure and useful gait and cardiovascular training. Presently there are four hypotheses clearing how exercise affects executive control. The first hypothesis is this the exercise raise the cerebral blood volume (30)and angiogenesis(31),where the task performance is important. The second hypothesis recommend that the acute exercises elevate the neurotransmitters for instance nor-epinephrine and dopamine aid information process also called arousal hypothesis(34,35,32). The third hypotheses recommend that exercise upregulates neurotrophins for example BDNF and insulin (33). Lastly the fourth hypothesis recommend that exercise improve mood and lessen depression (32-33). Thus, the aim of this study is to investigate the impact of physical training particularly the aerobic training in stroke survivor after stroke.

METHODS

A literature review was performed to investigate the impact of aerobic physical training on stroke survivors. A systematically review of the literature was performed regarding the aerobic exercise training in stroke people. The specific questions were:

Does the aerobic exercise training in individuals recovering from stroke improve aerobic capacity?

What is the impact of different exercise modalities of the aerobic training on stroke survivors?

Data was collected from the different databases; Pub Med (www.ncbi.nlm.nih.gov/sites/entrez) and Cinahl. Other sources to find the relevant information were Google scholars, World Health Organization and American Heart Association. Terms used for searching were Exercise, stroke,
rehabilitation, aerobic training and wrote it together. 101 articles from Pubmed and 82 articles from cinahl were found showed in figure 1. After limiting search to full text, humans and English language I got 87 articles out of 101, in 87 articles there were 16 systematic reviews after excluding systematic review 71 articles left. From 71 articles 43 articles were excluded because it was not relevant to the topic only 28 articles included from pubmed. In cinahl after limiting my search to humans and English language I got 58 articles and there were 8 systematic review after excluding systematic review there were 50 articles. From 50 articles 30 were excluded because it was not related to my topic only 20 articles from cinahl included. Finally from 28 articles from pubmed and 20 articles from cinahl I handpicked 15 articles that was full text and fall into the inclusion criteria and some articles also selected listed in the reference of those articles that selected from these databases. 15 articles included based on the inclusion criteria: articles that used aerobic training as an intervention, articles written in English language, articles on humans and full text articles. Exclusion criteria were: reports published in books, systematic reviews, articles including aerobic training along with medication and electrical stimulation, reports published in conference proceedings and doctoral dissertations.
Figure 1: An overview of search strategy.
RESULTS

The literature provides evidence that several different exercises can improve aerobic capacity, cardiovascular fitness, motor performance and mood after stroke. I found 183 articles in which only 15 articles that have the positive effect on aerobic capacity and fall into the inclusion criteria.167 articles excluded because they did not fall on inclusion criteria. They used different kind of programs four of them used only treadmill (36, 37, 38,39) ,four cycling(23, 40, 41,42),one elliptical (43),one water (44) five used mixed program(45, 46, 47, 48,49). Characteristics of each selected study are described in Table1.

Treadmill training

Macko et al., (2005) (36) a randomized controlled study investigated the effect of aerobic exercise on 61 chronic stroke patients with hemiparetic gait. Patients were randomized to intervention and control group. The intervention group received a progressive treadmill training program consisting of 40 minute sessions three times per week for six months started with low intensity and increased progressively. The control group received supervised stretching lasting 35 minutes and 5 minutes for low intensity treadmill walking. Outcomes were measured at baseline, three months and six months. Significant improvement in peak $\text{VO}_2$ and 6 minute walk test in intervention group as compared to control group at three months. At six months significant differences were found between groups, peak $\text{VO}_2$ and six minute walk test was higher in intervention group as compared to control group. Yen et al., (37) investigated the effect of additional gait training on motor performance and corticomotor excitability changes in chronic stroke patients. Fourteen patients randomly assigned to control or experimental group. Both group participated in general physical therapy. Experimental group received additional body weight supported treadmill training for four weeks. Participants received baseline and post treatment assessment. Outcome measures included assessment of Berg Balance Scale (BBS) and gait parameters. After therapy patients showed improvement only in cadence and walking but there were no changes in corticomotor excitability. Additional gait training showed improvement in BBS score, step length and walking speed. Macko et al., (38) a non controlled study investigated the effect of aerobic exercise on 23 chronic stroke patients with hemiparetic gait. Patients did progressive treadmill training program for six months, three 40 minute sessions per week. Outcome were assessed baseline, three months and six months included aerobic capacity measured by peak workload and peak $\text{VO}_2$ during treadmill and walking economy $\text{VO}_2$ during sub-maximal effort treadmill walking. Patients showed significant gain in all outcomes after three months. At the six months assessment gain were maintained and
showed more improvement than three months. Filho et al., (39) compared motor recovery between regular rehabilitation and regular rehabilitation with supported treadmill ambulation training using the performance on a bicycle exercise test. 12 acute patients were randomly assigned to regular rehabilitation (REG) or supported treadmill ambulation training (STAT) for 2-3 weeks. STAT group received gait training utilizing partial body weight supported treadmill training. STAT group showed higher oxygen consumption, total work load and total time pedaling the bike as compared to REG group.

Cycle ergometry training

Potempa et al., (23) the first randomized exercise trial compared 10 weeks of adapted bicycle ergometry exercise with a control intervention consisting of passive range of motion exercise. Results showed significant differences in VO2peak over time, the exercise group (n=19) achieving 13% gains, compared with no change for controls (n=23). Quaney et al., (40) showed aerobic exercise (AEX) induced improvements in executive function (EF), mobility and motor learning after stroke. 38 chronic stroke survivors were randomized to AEX group (n=19, 10 men, 9 women) that performed progressive resistive stationary bicycle training and SE group (n=19, 12 women, 7 men) performed stretches at home that exercised three times per week. VO2 max significantly improved in AEX group also motor learning in the less affected hand it significantly improved information processing speed as compared to the SE group. Lennon et al., (41) a single blinded randomized controlled trial study evaluated the risk factor reduction and health related quality of life following a 10-week cardiac rehabilitation in non-acute ischaemic stroke patients. 48 stroke patients (1 non-ambulatory, 9 requiring assistance, 38 independently mobile) were randomly assigned to control and intervention group. It was 10-week program with measure taken at week 10 and 1. Participants in the both group received usual care excluding aerobic exercise in the intervention group. The intervention group attended sixteen cycle ergometry sessions and two stress-management classes. Significantly greater improvement was observed in intervention group as compared to the control group. Tang et al., (42) used matched control design to determine the feasibility of aerobic cycle training to conventional rehabilitation early after stroke. All participants performed graded maximal exercise test on semi-recumbent cycle, 6-minute walk test, spatiotemporal gait assessment and stroke impact scale. Until discharge, exercise group (n=23) added 30 minute aerobic cycle ergometry to inpatient conventional rehabilitation 3 days per week and the control group received only conventional rehabilitation. Both groups demonstrated improvement over time with greater benefits towards aerobic in exercise group as compared to control group and similar trend towards improved 6-minute walk test was observed.
Elliptical training

Jackson et al., (43) identified practical and cost effective methods to improve walking in individuals with stroke. Participants were 3 men with chronic stroke who could walk without an assistive device or cane with single point, trained 8 weeks 2-3 times per week using 20 minutes elliptical training. Outcome measures included 6-minute walk test, Berg Balance Scale, Timed up and go test measured before and after training. Participants showed improvement in balance, functional mobility, endurance.

Water exercise

Chu et al., (44) study concerning water-based exercise study lasted for 12 weeks. Subjects in the experimental group exercised 3 times per week for 1 hour. Patients progressed 30 minutes of water aerobic and remainder of time devoted to warm up, stretching, cooling down. Although the study had a very small sample size but the intervention produced the greatest relative gain in peak aerobic capacity (23%) and arguing for strong consideration of this form of intervention in stroke survivors.

Mixed program

Jorgensen et al., Duncan et al., Rimmer et al., Pang et al., and Lai et al., used combination of exercises. Rimmer et al., (47) involved primarily African-American stroke survivors a delayed entry controlled design was used to give training to all 35 participants. Patients were randomly assigned to an intervention group and a control group. The intervention group received a supervised training program for 12-weeks but the control group did not receive any intervention for the first 12 week and then received 12-week exercise training program. Outcome measures include peak vo2, flexibility, strength and body consumption. Training protocol consist of 3times per week muscle strength and endurance (20 minutes), cardiovascular endurance (30 minutes) and flexibility (10 minutes). Participants used one or more following machine for cardiovascular endurance training: up-right stepper, recumbent stepper ,stationary cycle, treadmill and elliptical cross trainer. They also completed one set on a variety of lower and upper body strength training machine at 70% of the 10 repetition maximum weight (10 RM) and increasing as they became stronger. Lastly a variety of lower and upper body stretching exercises performed at various time throughout each one hour session. Result showed vo2 peak, time to exhaustion and maximal work load. Duncan et al., (46) conducted the first home based randomized study. The program consisted of 90 minute duration of 36 sessions for 12-14 weeks. Usual care group had services prescribed by physicians and the exercise group was supervised
by occupational or physical therapist for all sessions. Components were flexibility, range of motion, strengthening, balance, endurance training (30 minutes riding on stationary bike) and upper extremity functional use. Both the usual and intervention group improved in upper and lower extremity motor control, gait velocity, strength and balance. Intervention group exceeded gain in balance, endurance, peak aerobic capacity and mobility than the usual group. Pang et al., (48) a randomized controlled study shows the effects of aerobic exercise on 63 chronic stroke patients. They were able to walk more than 10 meters with or without walking aids. Intervention group received the FAME program 3 times per week for one hour for 19 weeks which involved 30 minutes cardiorespiratory fitness exercise as well as mobility, balance and leg muscle strengthening exercises. Control group received seated upper extremity exercise with no aerobic exercise component. Outcomes measured at baseline and at 19 weeks, included measures for mobility (measured by 6 minute walk test), cardiorespiratory fitness (measured by peak VO2 during a test of maximum effort on a bicycle ergometer), strength of leg muscle (measured by hand held dynamometer), balance BBS. Significant improvement in intervention group for peak VO2, the 6-minute walking test, leg muscle strength on the paretic side only. Jorgensen et al., (45) a single group, pretest-posttest experimental study evaluated the impact of intensive physical training on gait performance and cardiovascular health parameters in chronic stroke patients. Fourteen subjects participated in a 12-week training 1.5 hour 5 times per week. Intervention was body weight supported treadmill training, high intensity, aerobic exercise and progressive resistance strength training. Outcome measures were gait performance (10-meter walk test, six minute walk test, and aerobic capacity) and cardiovascular health parameters (diastolic and systolic blood pressure, resting heart rate, body mass index). There were significant improvements in all parameter outcomes and gait speed increased during 6-Minute walk test and diastolic and systolic blood pressure decreased. Lai et al., (49) planned secondary analysis of data from 9-months controlled, randomized trial to analyze the effect of exercise on depressive symptoms. One hundred stroke patients who had completed acute rehabilitation. It was a progressive, structured, 3-months physical exercise program. 93 patients were assessed immediately after three months intervention six of the exercise group and sixteen of the usual care group had depressive symptoms. 80 were assessed nine months after intervention three of the exercise group and ten of the usual care group had depressive symptoms. Participants with and without depressive symptoms had equal treatment only participants with depressive symptoms had improved quality of life.
Table 1. Summary of the included articles and the aim of the study, methods or intervention, subjects and outcomes are shown. The studies are sorted after year from the oldest to youngest.

<table>
<thead>
<tr>
<th>Author</th>
<th>Aim of the study</th>
<th>Methods/Intervention</th>
<th>Subjects</th>
<th>Outcomes/Results</th>
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<tr>
<td>Potempa et al., 1995 (23)</td>
<td>(1)To describe the responses of hemiparetic stroke patients to intense Exercise. (2)To determine the effect of aerobic training on cardiovascular and Functional outcomes.</td>
<td>Treatment was given 3 times per week CYCLING TRAINING for 10 weeks from a workload 30% - 50% of maximal effort in exercise group and passive range of motion in control group.</td>
<td>42 subject randomly assigned to: (1) Exercise group. (2) Control group</td>
<td>Positive VO2. There was a positive aerobic capacity and submaximal exercise blood pressure and some sensorimotor improvement.</td>
</tr>
<tr>
<td>Rimmer et al., 2000(47)</td>
<td>To determine the effect of a 12 week exercise training program in a predominantly African American group of stroke survivors with multiple comorbidities.</td>
<td>Randomized controlled trial with pre-post lag control design. A lag control group design was employed to provide training to all participants. Participants trained 3 days per week for 60 min per day.</td>
<td>35 patients divided into intervention group(n=18) and a lag control group (n=17)</td>
<td>The exercise group showed significant gains in peak VO2, strength, HLBF.</td>
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<tr>
<td>Filho et al., 2001 (39)</td>
<td>To compare differences in motor recovery between regular rehabilitation(REG) and regular rehabilitation with supported treadmill ambulation training (STAT) using the performance on a bicycle exercise test and the locomotor scale of the functional independence measure (FIM-L).</td>
<td>The STAT group received daily gait training utilizing a treadmill with partial support of body weight and the regular group underwent regular rehabilitation care.</td>
<td>12 patients with acute stroke were randomly assigned to either REG or STAT for 2 – 3 weeks.</td>
<td>The STAT group had higher oxygen consumption, total work load and total time pedaling the bike compared to the REG group.</td>
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<tr>
<td>Authors</td>
<td>Study Description</td>
<td>Sample Size</td>
<td>Intervention</td>
<td>Conclusion</td>
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<td>Macko et al., 2001(38)</td>
<td>To investigate the hypothesis that treadmill training will improve peak fitness, while lowering the energy cost of hemiparetic gait in chronic stroke patients.</td>
<td>23 patients</td>
<td>Noncontrolled exercise intervention study with repeated measure analysis. Three 40 minutes sessions of treadmill exercise weekly for six months.</td>
<td>Treadmill training improves physiologic fitness by increasing VO2 peak while lowering the energy cost of hemiparetic gait and increases peak ambulatory workload capacity.</td>
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<td>Duncan et al., 2003(46)</td>
<td>To determine whether a structured, progressive, physiologically based exercise program for sub acute stroke produces gains greater than those attributable to spontaneous recovery and usual care.</td>
<td>100 patients</td>
<td>Randomized, controlled, single-blind clinical trail. Intervention was a structured, progressive, physiologically based, therapist-supervised, in home program 36 sessions of 90 minutes duration over 12-14 weeks. Usual care subjects had services as prescribed by their physicians and subjects received home visits by research staff.</td>
<td>Intervention group had higher balance, endurance, peak aerobic capacity and mobility as compared to the usual care group.</td>
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<td>Chu et al., 2004(44)</td>
<td>To evaluate the effect of an 8-week, water based exercise program (experimental group) with that of an upper extremity function program (control group) to increase the cardiovascular fitness.</td>
<td>12 community dwelling people with stroke with mild to moderate residual motor deficits. Randomized into two groups intervention group n=6 and control group n=6.</td>
<td>Single blind randomized controlled trial study subjects participated in exercise program for 1 hour, 3 times a week for 8 weeks. Experimental group exercised in chest deep water and the control group performed arm and hand exercises while sitting.</td>
<td>Experimental group showed significant improvement over the control group in cardiovascular fitness, maximum work load, gait speed and paretic lower extremity muscle strength.</td>
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<td>Macko et al., 2005(36)</td>
<td>Investigated whether T-AEX is more beneficial than conventional rehabilitation to better ambulatory function and cardiovascular fitness in patient with chronic stroke.</td>
<td>25 patients</td>
<td>Progressive T-AEX, 6 months (3 times per week) or R-CONTROL, a reference rehabilitation program of stretching and low intensity walking.</td>
<td>T-AEX improved cardiovascular fitness 17% vs. R-CONTROL 3%. In T-AEX group increasing training velocity predicted improved VO2 peak.</td>
</tr>
<tr>
<td>Pang et al., 2005(48)</td>
<td>Examine the effect of a community based group exercise program for older individual with chronic stroke.</td>
<td>Intervention group underwent fitness and mobility exercise program 1 hour session three sessions per week for 19 weeks and control group underwent a seated upper extremity program.</td>
<td>63 older individuals with chronic stroke randomized into intervention (n=32) and control (n=31) groups.</td>
<td>Intervention group had significantly more gain in mobility, cardiovascular fitness and paretic leg muscle strength than control.</td>
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<td>Lai et al., 2006(49)</td>
<td>To examine the effect of exercise on depressive symptoms on the benefits from exercise in stroke survivors Who have completed acute rehabilitation</td>
<td>A progressive 3 months physical exercise program and the setting was participants home 3 times a week for 36 sessions supervised by physical or occupational therapist</td>
<td>100 stroke survivors the participants were divided into : Exercise intervention and usual care.</td>
<td>Therapeutic physical exercise has a beneficial effect on depressive symptoms.</td>
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<td>Yen et al., 2007(37)</td>
<td>The study was to investigate the effect of additional gait training on motor performance and corticomotor excitability change in patient with chronic stroke.</td>
<td>Both experimental and control group participate in general physical therapy but the experimental group received additional body weight support training for 4 weeks.</td>
<td>14 participant randomly assigned to experimental and control group n=7 (experimental group) n=7(control group)</td>
<td>Additional BWSTT could improve motor performance and induced changes in corticomotor excitability.</td>
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<td>Lennon et al., 2008(41)</td>
<td>To evaluate risk factor reduction and health related quality of life following a 10-week cardiac rehabilitation program in non-acute ischemic stroke subjects</td>
<td>Randomized control trial consisted of 10 week schedule with measures taken at week 1 and 10.Both groups continued usual care (excluding aerobic exercise). Intervention group attended 16 cycle ergometry sessions of aerobic training</td>
<td>48 community dwelling ischemic stroke patients (38 independently mobile,1 non ambulatory ,9 requiring assistance) were randomly assigned to intervention or control group</td>
<td>Findings suggest non-acute ischemic stroke patients can improve their cardiovascular fitness and reduce their CRS with a cardiac Rehabilitation.</td>
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<td>Tang et al., 2008(42)</td>
<td>The aim of this study was to evaluate the feasibility of adding Aerobic cycle ergometer training to conventional rehabilitation early after stroke and to determine effects on aerobic capacity, walking ability, and health-related quality of life.</td>
<td>Prospective matched control designed.. The exercise group added 30 minute of aerobic cycle ergometry to conventional inpatient rehabilitation 3days / week and the control group received only conventional rehabilitation.</td>
<td>23 allocated into the exercise group and 22 into the control group.</td>
<td>Exercise group with 13% and 23% increase in VO2 and work rate respectively and 53% in 6MWT.</td>
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**DISCUSSION**

The aim of the study was to investigate the effect of physical training particularly, the aerobic exercises in stroke survivors through a literature review. In different studies the mode of training varies, including: treadmill, cycle ergometer, elliptical machine, water and functional activities. These different exercises can improve aerobic capacity, cardiovascular fitness, mood and motor performance after stroke. Surprisingly, I could not find any study that showed negative effect of physical training in stroke survivors in my search.
**Treadmill**

The treadmill training program was presented in four different articles. In Macko et al., 2001 (38) treadmill training increased the peak exercise capacity, while it decreased the energy cost of hemiparetic ambulation, thus improving physiologic fitness reserve in older stroke patients who had mild to moderate, chronic gait impairment and showed that treadmill training can improve the functional mobility in chronic hemiparetic survivors by improving the capacity and ambulatory work load as well as enable patients to perform ADLs at the lower percentage of peak VO₂. Limitation of the study is the small sample size and noncontrolled experimental study design. Macko et al., 2005 (36) first used a randomized trial and showed that treadmill aerobic training better ambulatory function and cardiovascular fitness in chronic stroke patients. This is more effective than conventional care. The small sample size and different design issues limit the interpretation of this study, which included patients who were medically eligible with moderate-mild gait deficits and do not represent the general stroke population. The first study by Yen et al., (37) demonstrated that the additional BWSTT induces changes in corticomotor excitability and improves the motor performance. Motor performance improvement may be related to changes in corticomotor excitability and additional BWSTT may be recommended for chronic stroke survivors with insufficient balance and abnormal gait pattern. In this study there was limited information regarding the amount of time spent on receiving therapy, the control group did not receive any placebo intervention and insufficient follow-up data. Filho et al., (39) demonstrated that regular rehabilitation with STAT resulted improved functional abilities and the utilization of STAT for early intervention in acute stroke rehabilitation showed that the procedure was well tolerated and safe and may result in more effective daily gait training. However, the participants involved in this study were individuals with moderate impairment, who could benefit from a gait intervention and they were not representative of the entire stroke population.

**Cycle ergometry**

The four studies showed the effect of cycle ergometry. In Potempa et al., (23) the results of the study showed that chronically, moderately disabled, hemiparetic stroke survivors can improve their aerobic capacity with adequate exercise training. Subjects undergoing aerobic exercise also improved functional workload and exercise time to a greater extent than expected for the increase in aerobic capacity. A small number of subjects in the aerobic exercise group also
showed significant reduction of exercise SBP with training and this can have important implications for reduction of cardiovascular risk in patients who have clinically significant elevations of blood pressure during exercise. This study showed that aerobic exercise using cycle ergometry is feasible and improves fitness in chronic hemiparetic stroke patients but gives no clear evidence that cycle exercise could improve neuromuscular function. In Quaney et al., (40) the lower extremity bicycle exercise in chronic stroke patients significantly improved motor learning that is required for daily function. The study gives initial evidence that AEX improve the motor learning, the speed of information processing and motor function in chronic stroke survivors. Study also showed that AEX improved mobility and selected cognitive domains related to motor learning that increase sensorimotor control after stroke. The study of Lennon et al., (41) suggested that non-acute ischemic stroke patients can improve the cardiovascular fitness with a cardiac rehabilitation program. This was a pilot study with relatively small numbers, which limited the power to demonstrate health status and of functional benefits. Another limitation in the methodology is that the control group did not receive comparable non-exercise related attention which was given to the intervention group. In Tang et al., (42) improvement was observed in aerobic capacity and gait symmetry in both the control and the intervention group. In contrast, neuromotor and cardiorespiratory benefit were only observed in the intervention group. Result from this study may be used to inform that conventional stroke rehabilitation with the routine implementation of aerobic exercise can improve functional ambulation. It is anticipated that early exercise training after stroke and continuation for long time not only has potential benefits for improving cholesterol level and hypertension for lowering the risk of recurrent stroke, but also improving health related quality of life. Limitation of the study was the lack of time of control therapy and aerobic exercise provided through conventional rehabilitation.

Elliptical machine training

Jackson et al., (43) study showed that using the elliptical machine was well tolerated and feasible by participants. The study showed improvement in functional walking capacity i.e. balance, endurance, functional mobility, however there was no improvement in gait speed. The results provide practical information for clinicians considering the use of elliptical training for gait training, endurance training in ambulatory persons with chronic stroke. The main limitation of this study was that two of the study participants were able to work in the community and the choice to use the 6MWT for measuring endurance may not have been
appropriate. Another limitation is the use of partial body weight support made it difficult to measure the possible effects of this support may have had on the training and outcomes.

**Water exercise**

Chu et al., (44) used water exercise and the participants exercised in a group program, which is a convenient and cost effective way to promote fitness in stroke survivors. The intervention group showed improvement in maximal workload, gait speed, cardiovascular fitness and paretic lower extremity muscle strength. Improvement in gait speed and strength suggest that water based exercise can improve functional mobility and lower extremity muscle function, and gains in muscle strength may have contributed in the improvement of gait speed. Due to the small sample size and high function of sample, caution is advised to generalize these results to stroke population.

**Mixed program**

Rimmer et al., (47) showed that time to exhaustion and maximal work load and in fact the gain in \( \text{vo}_{2} \) were not as much as those previously demonstrated by Potempa et al.,(23). This may happen due to multiple training modalities used. One important possible reason could be de-emphasis on the intensity of aerobic exercise needed for the gain in peak \( \text{vo}_{2} \). It was the first randomized study on stroke survivor to show significant differences between group effects for endurance and muscular strength. The study also showed improvement in body consumption in terms of body mass index, body weight and total skin folds. In Duncan et al., (46) intervention group exceeded gain in balance, endurance, peak aerobic capacity and mobility than the usual group. The study consisted of a progressive, structured program of therapeutic exercise in those stroke individuals who had completed acute rehabilitation services. The study showed gain in endurance, mobility, and balance afar those attributable to usual care and spontaneous recovery. It was an important study demonstrating the practical utility of home based interventions compared to frequently applied hospital based intervention programs for function and fitness after stroke. However, there was still a high level of supervision even if the study was home based. It was an efficacy study targeted at subacute stroke and may not be generalizable to all stroke population. The main limitation of this study is due to the fact that their main goal was
to determine whether a structured, comprehensive, progressive, intense intervention could achieve important goals. Unfortunately, it cannot be determined which program like progressive, structured or intensive contributed to the successful outcomes. The study measured outcomes immediately after the intervention, yet the benefits of duration after therapy require further study. Pang et al., (48) showed that the FAME program is beneficial and feasible for improving secondary complications resulting in older stroke adults from physical inactivity. This may provide a good model for community-based fitness programs for older chronic disabled people. The results are generalizable to a specific group of individuals with chronic stroke, but not for the entire stroke population. Jorgensen et al., (45) provided evidence that high intensity physical training for stroke survivors in the chronic stage increased walking speed, regardless of age, chronicity or level of functioning. Their findings showed that the stroke patients in the chronic stage can achieve improvement in gait performance and cardiovascular health parameters through high intensity physical training. The training is combination of PRST, BWSTT, AE and functional training. The main limitation of this study is the lack of a control group. Lai et al., (49) demonstrated that therapeutic physical exercise in the subacute recovery phase of stroke has a beneficial effect on depressive symptoms. Depressive symptoms do not limit the gain in functional limitation or impairments attributable to exercise. In persons with baseline depressive symptoms, exercise appears to benefit the quality of life. The limitation of this study is the use of GDS (the Geriatric Depression Scale) to characterize mood rather than a formal psychiatric interview because it is not known which patient had a psychiatric diagnosis of depression. Information on treatment adequacy and other forms of treatment like therapeutic counseling or active psychiatric care were not available.

All the modalities seem to be good and improving the aerobic capacity in stroke survivors. We could not conclude from this review that which one is beneficial because they used different methods and different outcomes and the aim of this review was to investigate the effect of physical training in stroke survivors not to look on specific outcomes. This review shows that aerobic physical training is beneficial for stroke survivors and is important during rehabilitation for improving the aerobic capacity.

**CONCLUSION**

This literature review has given an account of the reasons for the widespread use of aerobic training in stroke survivors. Aerobic exercise is an essential part of a stroke rehabilitation program. Stroke affects everyone differently, so each exercise program should be customized to
fit the needs of the individual. Aerobic exercises, such as, treadmill, cycling, water-based, and elliptical program improve the aerobic capacity, motor performance, cardiovascular fitness and depression in stroke survivors. Large randomized trials are needed to generate evidence based guidelines for the safe and effective exercise of stroke survivors across the spectrum of deficit profiles and recovery phase.

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