COMPARATIVE EFFECTS OF CYCLE ERGOMETER AND STAIR CLIMBING TRAINING ON ENERGY COST, WALKING SPEED AND MUSCULAR ENDURANCE OF STROKE PATIENTS AT AHMADU BELLO UNIVERSITY TEACHING HOSPITAL, ZARIA, NIGERIA.

BY

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES,
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DEPARTMENT OF PHYSICAL AND HEALTH EDUCATION, FACULTY OF EDUCATION, AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA

OCTOBER, 2014

DECLARATION

I hereby declare that this dissertation titled "COMPARATIVE EFFECFTS OF CYCLE EGOMETER AND STAIR CLIMBING TRAINING ON ENERGY COST, WALKING SPEED AND MUSCULAR ENDURANCE OF STROKE PATIENTS AT AHMADU BELLO UNIVERSITY TEACHING HOSPITAL, ZARIA, NIGERIA" has been written by me and that it is a record of my research work. It has not been presented either wholly or partially for the award of any degree or publication in any Institution.

All sources cited in the text have been acknowledged and listed in the references.

…….. ……

IGARA, EMMANUEL IKENNA **DATE**

CERTIFICATION

This dissertation titled "COMPARATIVE EFFECFTS OFCYCLE ERGOMETER AND STAIR CLIMBING TRAINING ON ENERGY COST, WALKING SPEED AND MUSCULAR ENDURANCE OF STROKE PATIENTS AT AHMADU BELLO UNIVERSITY TEACHING HOSPITAL, ZARIA, NIGERIA" by IGARA, Emmanuel Ikenna meets the regulations governing the award of Doctor of Philosophy (PhD) Degree in Exercise and Sport Science of the Ahmadu Bello University, Zaria, and was approved for its contribution to knowledge and literary presentation.

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DEDICATION

To my mother, Janet O. Igara, my wife Mrs. M.U. Igara and our children.

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Without God's help, this type of work would be very difficult to accomplish and the researcher thanks God for guidance.

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ABSTRACT

This study was on the comparative effects of cycle ergometer and stair climbing training on energy cost, walking speed and muscular endurance of stroke patients. To achieve this purpose, 24 volunteer stroke patients were randomly assigned to three groups of eight subjects each by balloting. Group A was cycle ergometer training group, Group B, stair climbing training group and Group C control group. Groups A and B were given training in cycle ergometer and stair climbing respectively whereas the control group C was not given any structured training. Cycle ergometer training consists of cycling a bicycle ergometer while stair climbing training consists of climbing up and down a staircase. The control group received usual physiotherapy which groups A and B also received. Training took place three times in a week for twelve weeks with intensity of 55% of maximum heart rate at the beginning of the training which was progressed to 70% of maximum heart rate towards the end of the training. Cycling and climbing stairs lasted for 30 minutes during a training session. All the subjects were tested for energy cost, walking speed and muscular endurance before starting the training, and 4, 8 and 12 weeks during the periods of training. The data thus collected were statistically analyzed using t-test statistics to compare the effects of the training in cycle ergometer and stair climbing. The results of the study showed that there were significant differences in energy cost and walking speed of stroke patients between cycle ergometer and stair climbing training groups. However, there was no significant difference in muscular endurance between cycle ergometer and stair climbing training groups. It was concluded that cycle ergometer training was better than stair climbing training although both of them provided good improvement in energy cost, walking speed and muscular endurance of stroke patients. The use of cycle ergometer and stair climbing to improve energy cost, walking speed and muscular endurance of stroke patients should be emphasized by exercise scientists.

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Operational Definitions of Terms

The technical terms used in this study are defined below in their operational sense.

1. Stroke patients–patients with weakness.
2. Walking gait-manner individuals like to walk.
3. Energy cost of walking-energy expended during walking.
4. Physiological cost index-method of calculating energy cost of walking.
5. Walking speed-distance walked divided by time taken.
6. Periods of training- training durations from pretest to posttest.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

A stroke, brain attack, or a cerebrovascular accident (CVA), is a sudden death of brain cells caused by lack of oxygen supply to the brain. Stroke is the first cause of acquired disability in the world (NeuroAids, 2011) and there are two main types of stroke; ischaemic strokes or cerebral infarcts, 80% of strokes, result from a blockage or reduction of blood flow in an artery that irrigates the brain. They are caused either by a blood (thrombus) which blocks the blood vessel or by building up of plaque (often due to cholesterol) within the arteries which narrows vessels, resulting in a loss of blood flow. The second type of stroke is called haemorrhagic strokes. They are due to the rupture of an artery within the brain triggering an intracerebral haemorrhage (15% of strokes) or to the rupture of an aneurysm (arteriovenous malformation) entailing subarachnoid haemorrhage (5% of strokes).

The effects of stroke vary depending on stroke location and severity. After a stroke, brain cells die in the affected areas resulting in damage or even loss of neurons. Recovery from a stroke is time consuming and sometimes very depressing. This is due to new limitations placed upon a person as a direct result of the nerve damage in the brain which leads to immobilization in other parts of the body. The continuum of neurological damage leading to muscle inactivity will cause after effects at paralyzed limbs. The stroke survivors are often left with persistent neurological deficits (Michael, Allien and Macko. 2005) that can affect functional abilities, of which impaired gait is a feature. Gait performance in person with stroke is typically characterized by the spatiotemporal asymmetry between both sides, decreased walking speed, and problems with trunk – limb, interlimb, and intralimb coordination (Danielsson and

Sunnerhatagen, 2004., Hsu, Jang and Jan. 2003., Zamparo, Francescato, De Luca, Lovati and di prampero, 1995.,Walters and Mulroy, 1999). These characteristics may eventually lead to a higher energy cost of walking in people with stroke. The lower walking speed with higher energy costs predisposes stroke survivors to sedentary life, which limits activities of daily living and impairs cardiovascular function (Ivey, Macko, Ryan and Macko, 2005).

Rhythmicity of walking after stroke is impaired and this contributes to an increase in energy cost of walking of stroke patients (Keenan, 2010). The energy cost to speed relationship during walking demonstrates a U-Shaped curve with a minimum energy cost, occurring at approximately 1.3m/s (Margaria, 1976., Minetti and Alexander, 1997). Stroke patients typically walk at low walking speed hence use greater energy during walking. A greater understanding of the energy cost to speed relationship in individuals walking with altered lower limbs mechanics may inform rehabilitation strategies for certain pathological gaits including stroke, as these individuals are often limited in their ability to walk safely at a range of speeds.

When individuals are immobilized by stroke, they walk at slower speeds. The loss of optimum gait is observed to be compensated for by circumduction and hip hiking to advance the immobilized leg. It was observed that limited hip and knee movement lead to a higher energy cost, and a change from the normal energy cost to speed relationships from a cubic to an inverse relationship.

It was hypothesized that the higher energy cost observed at all speeds may be in part due to the reported perceived increase in the weight of the paretic leg by the patients adding to the effort of raising the center of mass (Elsworth, Daves, Collett. Howells, Ramsbotton, Izadi and Sackley, 2006). The change from the normal U-Shape curve suggests that hip and knee immobilization disrupted the normal pendulum

mechanism. It is interesting that during limb immobilization a minimum energy cost was not observed by these researchers, rather the energy cost gradually reduced as walking speed increased.

Alterations in skeletal muscle are pronounced on the hemiparatic side after stroke and include gross muscular atrophy, increased intramuscular fat, and a shift to a fast myosin chain phenotype with reduced muscle oxidative capacity (Wade and Hewer, 1987). These molecular abnormalities after stroke have clear implications, since fast-twitch muscle fibers are more fatigable and have anaerobic metabolism (Landing, Hagenfeldt, Saltin and Wahren, 1977). Exercise training can shift muscle fibers to a slow myosin heavy chains phenotypes (Mckenzie, Yu, Macko, McLenithan and Hafer-Macko, 2008), and can improve the muscular endurance of stroke patients. The beneficial effects of aerobic exercises have been demonstrated in stroke (Macko, Smit, Dobrovolny, Sorkin Golderg and Silver, 2001 Ivey., Macko, Ryan and Macko, 2005).

1.2 Statement of the Problem

In exercise studies on stroke patients, the consistent findings have been that at least 60% of stroke cause neurological impairments affecting functional abilities. Stroke patients are characteristically known for low cardiorespiratory endurance which compounds the increased energy cost of hemiparesis. Stroke patients walk very slowly which adversely affects their walking economy. Exercise training that improves walking speed has been good in improving walking economy. Elevated energy cost of walking of stroke patients contributes to increased cardiovascular demands of walking. The most frequent complaints of reduced efficiency in walking among stroke patients are further augmented by reduction in cardio respiratory fitness and changes in neuromuscular control.

These problems underscore the need for appropriate training interventions that would improve the quality of walking and thus the lives of stroke patients.

1.3 Research Questions

This study was conducted to answer the following specific research questions:

1. Will the improvement from cycle ergometer and stair climbing training differ in energy cost of walking of stroke patients?
2. Will the improvement from cycle ergometer and stair climbing training differ on walking speed of stroke patients?
3. Will the improvement from cycle ergometer and stair climbing training differ on muscular endurance of stroke patients?

1.4 Objectives of the Study

The objectives of the study were to:

1. Determine the effects of cycle ergometer training on energy cost, walking speed and muscular endurance of stroke patients.
2. Determine the effects of stair climbing training on energy cost, walking speed and muscular endurance of stroke patients.
3. Compare the effects of cycle ergometer and stair climbing training on energy cost, walking speed and muscular endurance of stroke patients.

1.5 Basic Assumptions

On the basis of available research evidence, the following assumptions were made for the purpose of the study.

1. Energy cost, walking speed and muscular endurance are affected by stroke.

2. Energy cost, walking speed and muscular endurance of stroke patients can be improved by cycle ergometer and stair climbing training.
3. Abnormal walking gait affects the energy cost, walking speed and muscular endurance of stroke patients.
4. Effects of different therapeutic modalities, like cycle ergometer and stair climbing training on energy cost, walking speed and muscular endurance can be objectively measured.
5. Physiological energy expenditure measurements are reliable methods of quantitatively assessing the problems imposed by gait disability.

1.6 Hypotheses

On the basis of the research questions and the assumptions, the following hypotheses were formulated for the purpose of this study.

Major Hypothesis

1. There is no significant difference between cycle ergometer exercise and stair climbing training on energy cost, walking speed and muscular endurance of stroke patients.

Sub- hypotheses

I. There is no significant difference between cycle ergometer exercise and stair climbing training on energy cost of walking of stroke patients.

II. There is no significant difference between cycle ergometer and stair climbing training on walking speed of stroke patients.

III. There is no significant difference between cycle ergometer and stair climbing training on muscular endurance of stroke patients.

1.7 Significance of the Study

This study was justified on the following:

1. Cycle ergometer training is one of the most popular training modalities applied in different rehabilitation centers. Application of this training modality to produce positive effect on energy cost, walking speed and muscular endurance of stroke patients in Nigeria has not been done to the knowledge of the investigator. Therefore, it is not clear whether cycle ergometer training will produce positive effects on energy cost, walking speed and muscular endurance of stroke patients in Nigeria. The result of this study would indicate whether cycle ergometer training would be beneficial in this regard.
2. Stair climbing training has been applied in some rehabilitation centers to help in the restoration of functional capacity in stroke patients. The positive effects of this training modality on energy cost, walking speed and muscular endurance after stroke are not supported by sufficient research evidence in Nigeria. The results of this study would indicate whether stair climbing training would be beneficial in this regard to stroke patients in Nigeria.
3. The researcher has not come across any studies on the relative efficacy of 12-week cycle ergometer and stair climbing training in the improvement of energy cost, walking speed and muscular endurance of stroke patients in Nigeria. The result of this study would indicate the more efficient training methods between these two in improving the energy cost, walking speed and muscular endurance of stroke patients in Nigeria.
4. This study may bring to light issues relating to the improvement of walking gait of stroke patients for further research.

1.8 Delimitations

This study was delimited to the following:

1. Stroke surviving patients of not less than 36 years of age from Ahmadu Bello University Teaching Hospital, Zaria.
2. Comparison of the effects of cycle ergometer and stair climbing training on only energy cost, walking speed and muscular endurance of stroke patients.
3. Male and female stroke patients were recruited for the study.

1.9 Limitations

1. The effects of the time of onset of stroke were not controlled in this study. This could affect the results of the study since recovery of stroke patients depends on how long the stroke occurred.
2. The study did not take into account of whether the stroke patients started their rehabilitation during the acute or chronic stage of stroke. The time of commencement of therapy affects on recovery of stroke patients and this factor was not controlled.
3. Equal numbers of males and females subjects were not recruited in this study and this could affect the results.
4. The weights of the subjects were not matched and this variation could affect the result of the study.
5. The researcher did not measure the limb lengths of the subjects and limb length has effect on walking speed. This could affect the results of energy cost of walking and walking speed of the subjects.

CHAPTER TWO

2.0 REVIEW OF RELATED LITERATURE

2.1 Introduction

The purpose of this study is to compare the effects of 12-week cycle ergometer and stair climbing training on energy cost, walking speed and muscular endurance of stroke patients. Available related literature were reviewed and presented in this chapter under the following subtitles:

Causes of Abnormal Walking Gait after Stroke

Effects of Abnormal Walking Gait on Energy Cost of Walking after Stroke.

Effects of Reduced Walking Speed on Energy Cost of Walking after Stroke

Methods of Improving the Walking Gait after Stroke

Treadmill Training

Training with Orthosis Devices

Functional Electrical Stimulation

Effects of Cycle Ergometer Training on Walking Gait after Stroke

Effects of Cycle Ergometer Training on Energy Cost of Walking after Stroke

Effects of Cycle Ergometer Training on Walking Speed after Stroke

Effects of Stair Climbing Training on Walking Gait after Stroke

Effects of Stair Climbing Training on Energy Cost of Walking after Stroke.

Effects of Stair Climbing Training on Walking Speed after Stroke

Dysfunction in Muscle Biology, Aerobic Exercises and Muscular Endurance

Summary

2.2 Causes of Abnormal Walking Gait after Stroke

Timing characteristics of muscle activation are integral to coordinated movement and normal gait. Daly, Roenigk, Cheng and Ruff. (2011) identified the abnormal timing characteristics of muscle activation and deactivation for knee flexor and extensor muscles for patients following stroke and had persistent coordination and gait deficits in the swing phase of gait, and the association between muscle activation latency and coordination impairment and dysfunctional gait. In the swing phase of gait, complex and precisely coordinated muscle activation and deactivation timings are critical for safe, coordinated walking. In an attempt to study flexion and extension limb movements, one study utilized a cycle pedaling task to study muscle activation relationships during mechanically coupled movements of right and left lower limbs. This study showed delayed activation of the paretic vastusmedialis during cycling limb extension, and early activation and termination of hip and knee flexors (Kautz & Brown, 1998). There is controversy, however, with regard to how significantly these observations are related to functional gait; some have shown that functional gait gains occurred without any significant change in the abnormal electromyography (EMG) durations (Den Otter, Geurts, Mulder, and Duysens, 2007), whereas another study reported that neurological impairment was not necessary in creating some of these abnormal EMG patterns (Brunner & Romkes, 2008).

An alternative way to study impairment of the coordinated components of gait-swing phase is the study of the coordination of the timing of a simple, single joint movement that is required in gait –swing phase. During swing phase, there is demand for coordinated muscle latencies for knee flexion in order for the limb to clear the floor normally in the sagittal plane. After stroke, a “stiff-legged” pattern is characteristic, for which knee flexion coordination is abnormal, and movement excursion is significantly

less than normal throughout swing phase (De Quervain, Simon, Leurgans, Peace and McAllistern 1996., Kerrigan, Roth, and Riley, 1998). Not only does the stiff-legged gait pattern exhibit absence of timely execution of swing phase limb flexion, but also, there is highly variable limb flexion excursion (Daly, Kristen Kristen, Jennifer, Eric, Byron, Jean, and Robert, 2004) and inability to cease the performance of the knee extension pattern even when hip, knee and ankle flexor muscle strength is adequate (Hansen, Lucarelli, Torres, Roenigk, and Dally, 2003). A study was conducted to identify, in stroke survivors with persistent swing phase deficits, the timing characteristics of knee flexor and extensor muscles during a single joint knee flexion task, and to characterize the relationships among abnormal delay in muscle activation latency, joint movement coordination impairment, and dysfunctional gait (Daly et al; 2011). The results of the study showed that activation latencies of knee flexors and extensors were abnormally prolonged in subjects with hemiparetic stroke compared with control subjects. The findings in this current study are similar to those reported by others for upper limb muscles (Fagioli, Berardelli, Hallett, Accornero and Manfredi, 1988., Berardelli, Accornero, Hallett, Hallet, Innocenti, and Manfredi, 1985) and ankle muscles (Smith, Edgerton, Betts and Collatos, 1977). Some authors reported significant differences between normal activation latencies and stroke subjects for ankle muscle activation (Smith, Tarjan, Besio and Asfour, 1997).

2.3 Effects of Abnormal Walking Gait on Energy Cost of Walking after Stroke.

Although most stroke patients regain the ability to walk after stroke, several sagittal plane impairments (i.e. reduced paretic knee flexion, hip flexion, and ankle dorsiflexion) compromise toe clearance during swing. Compensatory frontal plane movements, including circumduction and hip hiking, may be employed to facilitate toe

clearance (Perry, 1992; Kerrigan, Frantes et al; 2000). Despite the recovery of walking, persistent gait disorders are linked to increased energy expenditure (Olney & Richards, 1996; Chen, Pattern, Kothari and Zajaa, 2005), which can negatively affect endurance and training. In addition, the frontal and sagittal plane deviations in gait kinematics suggest that abnormal multi-joint synergistic torque coupling previously observed in the lower limbs of stroke subjects may contribute to overgound gait behaviours (Cruz & Dhaler, 2008). Cruz and Dhaler carried out a study on the compensatory gait movements post stroke; the influence of synergies (Cruz & Dhaler, 2008). They suggested that given the relationships among abnormal cross joint coupling, single joint strength, and joint kinematics, task specific training may improve the quality of gait following stroke. The subsequent reduction of compensatory movements is anticipated to lessen energetic costs (Cruz & Dhaler, 2008) and improve training potentials. These findings also support the hypothesis that pelvic movement is a major compensatory strategy after stroke.

Under normal circumstances, limb advancement during swing phase is achieved through flexion of the hip, knee, and ankle joints in the sagittal plane (Winter, 1991). The normal swing phase limb-flexion pattern helps minimize the energy cost of walking (Soderberg, 1997; Kerrigan, Viramontes, Coreoran and Lararia, 1995). Despite conventional rehabilitation following stroke, persistent swing phase limb-flexion deficits that results to abnormal walking gait causes elevated energy cost of walking and compromised walking endurance (Kerrigan et al; 1995., Daly et al; 1993., Hesse et al; 1994).

Normal swing phase hip, knee, and ankle dorsiflexion is critical for gait safety and optimal expenditure of energy during walking (Soderberg, 1997., Kerrigan, et al; 1995., Perry, 1992., Walters, Campbell, Thomas, Hugaos and Davis, 1982), partially

because normal limb flexion contributes to the execution of a gait pattern that optimizes the center of mass (com) pathway. That is, normal swing phase minimizes the excursion of the center of mass (Soderberg, 1997), in turn minimizing the energy expenditure in walking. When a typical stroke, stiff-legged gait was simulated in normal individuals by immobilizing the knee, oxygen consumption during walking was significantly greater than normal compared to walking with normal swing phase knee flexion (2ml/kg/m versus 1.5 ml/kg/m) (Daly et al; 2004). In fact, gait deficits in hemiparetic individuals can elevate the energy cost of walking 1.5 to 2.0 of normal values (Gerston & Orr, 1971; Corcoran, Jebson, Brengelman, and Simons,1970). Thus it is important for patients following stroke to achieve normal knee flexion, as well as normal hip and ankle dorsiflexion. A normal individual has a preferred cadence or rhythm, which relates to leg length and usually represents the most energy-efficient rhythm for individual body structure (Keenan, 2010). Rhythmicity of walking after stroke is impaired and this contributes to an increase in energy cost of walking after stroke (Keenan, 2010).

2.4 Effects of Reduced Walking Speed on Energy Cost of Walking.

The energy cost to speed relationship during walking demonstrates a U-shaped curve with a minimum energy cost occurring at a speed of approximately 1.3 m/s (Margaria, 1976., Minetti & Alexander, 1997). This U-shaped curve can be explained by the mechanical work performed during walking. By raising the body's centre of mass the external work accounts for 60-75% of the total work done (Cavagna & Kaneko, 1977). The energy required to raise the center of mass is minimized by the stance leg working as an inverted pendulum, vertically deflecting the center of mass. When walking at an optimum speed, the speed associated with the lowest oxygen cost, around

65% of the energy acting on the centre of mass may be conserved by this mechanism (Cavagna, Thys, and Zamboni, 1976). At higher or lower speed less energy is conserved by the inverted pendulum mechanism and more energy is needed to control trunk movement and accelerate and decelerate the legs (producing internal work), thus giving rise to the U-shaped energy cost to walking speed curve (Cavagna & Margaria, 1996; Margaria, 1976).

Although the energy cost to walking speed relationship is well described in healthy individuals, little is known about how the energy cost to walking speed relationship is affected in individuals with pathologies affecting the lower limbs. When a limb is immobilized, individuals walk more slowly, with a general increase in the effort of walking (Hanada & Kerrigan, 2001, Mattsson, Brostrom, Borg, and Karlsson, 1990), and in individuals with conditions such as stroke (Witte & Carlsson, 1997). A change in the pendulum mechanism could result in disruption of the normal energy cost to speed relationship (Pohl, Mehrholz, Ritschel, and Ruckreim, 2002; Sullivan, Barbara, Knowlton and Dobkin, 2002). A greater understanding of the energy cost to speed relationship in individuals walking with altered lower limbs mechanics may inform rehabilitation strategies for certain pathological gaits, including stroke, as these individuals are often limited in their ability to walk safely at a range of speeds.

When individuals are immobilized they walk at slower speeds (Hanada & Kerrigan, 2001; Mattsson & Brostrom, 1990). The loss in optimum gait is observed to be compensated for by circumduction and hip hiking to advance the immobilized leg. Waters and Mulroy (1999) and Mattsson and Brostrom (1990) reported that walking with an immobilized knee caused an increase in energy cost of approximately 23%, similar to that calculated in the later study by Elsworth, Daves, Collett, Howells, Ramsbotton, Izadi and Sackley (2006). These researchers observed that limited hip and

knee movements lead to a higher energy cost, and a change from the normal energy cost to speed relationships from a cubic to an inverse relationship.

It was hypothesized that the higher energy cost observed at all speeds may be in part due to the reported perceived increase in the weight of the paretic leg by the patients adding to the effort of raising the center of mass, and greater vertical displacement of center of mass due to the limited stance phase and knee flexion (during both "stance" and "swing"), the additional effort required to control the trunk and the energy required to initiate and stop limb movement when optimal swing mechanics are altered (Elsworth et al; 2006).The change from the normal U-shaped curve suggests that hip and knee immobilization disrupted the normal pendulum mechanism. It is interesting that during limb immobilization a minimum energy cost was not observed by these researchers, rather the energy cost gradually reduced as walking speed increased. These findings support the current trend with neurological patients during rehabilitation which concentrates on increasing walking speed (Pohl et al., 2002; Sullivan et al; 2002). The results of the study by Elsworth indicated that when one limb is immobilized either experimentally or by diseases like stroke, the mechanics of walking are altered. These subjects are unable to walk optimally, that is, with minimum energy cost. Taking into consideration the positive effect of stretching at the hip on movement economy in hemiplegic stroke patients (Mattsson, & Brostrom, 1990) Elsworth recommended further investigation into stretching protocols and interventions like stair climbing and bicycle ergometer exercise training programmes that increase hip and knee mobility in individuals with a stiff-limbed gait, and for encouraging faster walking speeds during the rehabilitation process.

2.5 Methods of Improving the Walking Gait after Stroke.

There is little consensus in the literature on the best motor performance outcome measure or treatment intervention for patients with stroke (Murphy & Deborah, 2003). There is agreement that data should be collected and treatment outcomes evaluated. A review of some interventions to improve motor function after stroke and relevant guidelines are presented in this section. It is clear that one measure or treatment is not adequate and impairments, disability and quality of life should be addressed. Stroke severity and degree of deficits will greatly affect the utility and efficacy of outcome measures and interventions. Inconsistencies in research methods and heterogeneity of stroke severity make the selection of examinations and interventions challenging (Murphy & Deborah, 2003). Impairments, functional limitations, and disabilities vary often after stroke. Common treatment methods that were reviewed include 2.5.1 Treadmill training, 2.5.2 Training with Orthosis Devices, 2.5.3 Functional Electrical Stimulation,

2.5.1 Treadmill Training

Studies have examined the use of structured treadmill exercise in individuals with stroke more than six months in rehabilitation. These studies have indicated that this type of exercise can significantly improve performance of functional activity. Structured treadmill exercise, for example, increases gait efficiency, so less energy is used in walking, making the task of walking less stressful. In addition, the improvement in aerobic capacity with this type of exercise means that as individuals walk, they do so at a smaller percentage of their maximal capacities, further easing the physical burden. There are several appealing aspects of treadmill training. One is that treadmill training requires persons to perform a task required for everyday life, namely walking. The

second is that use of hand-rail support and "un-weighting" devices allow individuals to walk on a treadmill who would otherwise be unable to walk. These un-weighting devices are simple harnesses with cables threaded through pulleys and attached to weights. These weights serve to "lift" the person a bit, effectively decreasing their weight. In this way, individuals who have gait dysfunction may still be able to walk on a treadmill and receive benefits. Third, in persons with limited gait speed, exercise intensity can be increased by keeping the speed low but increasing treadmill grade. In addition to the functional benefits apparent with exercise after stroke, the cardiovascular and general health benefits of endurance training are important. Treadmill training improves physiological fitness reserve in chronic stoke patients by increasing VO_2 while lowering the energy cost of hemiplegic gait (Macko et al., 2001). These improvements may enhance functional mobility in chronic stroke patients by increasing peak ambulatory workload capacity (Macko, Desouza, Tretter, Silver, Smith, Anderson, Tomoyasu, Gorman and Dengel, 1997). Randomized study results also show that treadmill aerobic exercise training improves measured long-distance ambulatory capacity after stroke to a greater extent than an intervention that combines elements of conventional therapy (Mack, Ivery, Forrester, Hanley, Sorkin, Katzel, Silver and Goldberg, 2005). Treadmill aerobic exercise increased 6-Minute Walk distance by 30 percent, with most of the improvement occurring by 3 months (Ivey et al., 2008). Although short-distance ambulatory 30 – foot timed walks were improved with treadmill training, no significant differences were noted compared with control subjects (Macko, Ivey and Forrester, 2005).

The result of self-reported functional mobility which assessed the effects of exercise on self-reported walking distance, speed, and stair climbing suggest that training regimen significantly affects community based activity levels and preserves

fitness, function, and metabolic health after stroke (Ivey et al., 2008). Increases in treadmill training velocity over six months significantly correlated with increases in VO_2 but no change in 6-Minute Walk distances. A study carried out by Barbeau and Visintin (2003), on the optimal outcome obtained with body – weight support combined with treadmill training in stroke patients showed that an important transfer from treadmill speed to over- ground walking speed was observed in the body weight support group, with more benefits found in older subjects (65-85yrs) in the body weight support group. Faster treadmill walking facilitates a more normal walking pattern after stroke, without concomitant increases in common gait compensations, such as circumduction. The improvements in gait deviations were observed with small increases in walking speed (Christine et al; 2011).

2.5.2 Training with Orthosis Devices

Over-ground and treadmill walking studies have documented decreased hip range of motion in the impaired leg during gait as compared with the nonparetic limb for walking (Chen & Pattern, 2008; Chen et al., 2005). Despite the limited hip movement, people after stroke are especially reliant on hip control in the paretic limb to the extent that an orthosis is frequently placed at the ankle to limit its negative contribution to gait (Allison, et al; 2010). Given the relative importance of hip sensory afferents for the regulation of locomotion and the apparent deregulation of stretch related inputs following injury to the nervous system, it is plausible that abnormal bilateral reflex control of the hips could greatly affect the “normalcy” of gait after stroke (Allison, et al; 2010). Drop foot is a major cause of walking gait dysfunction after stroke. There are several treatment modalities to improve drop foot after a stroke. Incorporating appliances such as braces constructed from plastics can be used.

Stimulation of the peroneal nerve has recently been shown to improve the condition and its combination with a brace or ankle support as orthosis devices and physical therapy has shown great improvement. Shoes can also be fitted with a brace that is spring-loaded to decrease foot slapping and foot drag gait. This is a simple procedure that includes an ankle brace that is attached under the shoe lace which lifts the foot as the person walks.

Polypropylene Ankle Foot Orthosis (AFO) is a common choice for treating patients with impaired gait to prevent foot drop in swing phase. It not only facilitates toe clearance but also promotes heel strike in early stance (Leung & Moseley, 2003).

A number of studies have demonstrated the positive effect of using Ankle Foot Orthosis in the patients with stroke leading to hemiplegia gait, but some patients are still reluctant to use rigid Ankle Foot Orthesis because of limiting ankle joint movement during ambulation. Excessive planter flexion resistance will cause excessive knee flexion during stance phase (Lehmann, et al; 1987., Lehmann, et al. 1983). Carmick also pointed out that another disadvantage of rigid Ankle Foot Orthosis was its limitation of normal movement of the tibia forwards over the weight bearing foot resulting in decreased ankle dorsiflexion and early heel rise in stance (Carmick, 1995).

The hinged Ankle Foot Orthesis with planterflexion stop has been increasingly used to prevent foot drop. An articulated Ankle Foot Orthosis with planterflexion stop was found to significantly increase the roll-over shape arc length and arc radius, and also significantly moving the sagittal plane location of the first center of pressure point posterior to the ankle center (Fatone & Hansen, 2007). Walking with an effective roll-over may facilitate forward progression. Unlike the solid Ankle Foot Orthesis, the hinged Ankle Foot Orthosis allows the tibia to move forward over the weight bearing foot during stance resulting in more normal dorsiflexion motion. Yahamoto reported

that the most important function of Ankle Foot Orthosis for patients with hemiplegia is to provide the dorsiflexion assisting moment, which is normally provided by eccentric contraction of the pre-tibia muscles at the initial stance phase (Yahamoto, Ebina, Kubo, Kawai, Hayashi, Iwasaki, Kubota and Miyazaki, 1993). They proposed that the planterflexion resistive moment at the initial stance phase should be adjusted for the condition of each patient. Although Ankle Foot Orthosis have been demonstrated to be beneficial to stroke gait (Jaivin, Bishop, Braly and Tullos, 1992), some physiotherapists still have reservation to use the orthosis. They believed that orthosismight induce disuse effects during the period of orthotic intervention, which made the existing loss of strength getting worse and possibly delaying recovery (Appell, 1990). Evaluation study was performed by Tyson's group (Tyson & Thornton, 2001) who tried to assess the effect of hinged Ankle Foot Orthosis on functional mobility and gait impairments in people with severe hemiplegia and patients' view on the use of orthosis. The result showed significant improvements in functional mobility and in some gait parameters (Wong, Silbey, Hudnani and Roeland, 2010).

2.5.3 Functional Electrical Stimulation

Walking after a stroke is characterized by decreased walking speed, endurance, and symmetry. Over the years, a variety of approaches to gait retraining have been suggested. Recently, treadmill (with or without body weight support) has emerged as an intervention that improves walking performance in people who have had a stroke. Lamontagne and Fung (2004) found that patients with hemiparesis following stroke can safely walk up to 156% of the self selected speeds and that fast walking induces marked speed-related improvements in body and limb kinematics and muscle activation patterns. Functional electrical stimulation (FES) has long been used to improve walking

function in stroke survivors (Liberson, Helinquest, Scot and Dow, 1961) and may assist in increasing walking speed for those stroke survivors who cannot otherwise reach their maximally efficient walking speed.

The use of functional electrical stimulation in treadmill walking requires similar tasks as treadmill walking except that the patients walk on the treadmill at different speeds while receiving electrical stimulation to the muscles on the front of the leg and calf. Stimulation to the front of the leg will help to lift the toes during the swing phase of the paralyzed leg during walking. Stimulation to the calf muscle helps to push down on the treadmill belt during walking. The study carried on to investigate whether community-dwelling patients with chronic stroke who were regularly using an ankle foot orthosis (AFO) would benefit from changing to transcutaneous peroneal functional electrical stimulator (FES). The results showed that patients judged functional electrical stimulator superior to ankle foot orthosis, without a concomitant difference in walking speed or level of daily activities as measured by the number of steps per day (Van Swigchem, Vloothuis, de Boer, Weerdestergn and Geurts, 2010). Other outcome measures that focus on the stability and effort of walking may objectify the perceived benefits of functional electrical stimulation in community dwelling chronic stroke patients.

Functional electrical stimulation (FES) applied during fast walking (Fast FES) is an effective gait training strategy that can lead to improvements in gait performance, walking speed, endurance, balance, activity and participation poststroke (Hakansson, Keser, Reisman, Binder-Macleod and Higginson, 2011). These researchers carried out a study on the effects of 12 weeks of FES training on the improvements in those gait parameters and found that the average mechanical recovery increased from 34.5% before training to 40.0% after training which was statistically significant. The average

self-selected walking speed increased from 0.4mls to 0.7mls after the 12-week FES training. This result indicated that the subjects were better able to generate and utilize the external mechanical energy of walking after FES gait training. It was concluded that fast functional electrical stimulation (FES) has the capacity to increase the gait speed, improve the mechanical recovery, and reduce the mechanical energy expenditure of stroke survivors when they walk.

2.6 Effects of Cycle Ergometer Training on Walking Gait After Stroke

Motor recovery after stroke is complex and confusing (Langhorne, Coupar and Pollock, 2009). Many interventions have been developed to try to aid motor recovery (recovery of impairment and associated function), and many randomized controlled trials and systematic reviews have been done (Sandercock, Algra and Anderson, 2009). The systematic review conducted by Langhorne and colleagues (2009) showed that interventions that seemed promising for improving gait include fitness training (both cardiorespiratory training) (Pohl, Werner, and Holzgraefe, 2007., Cuviello- Palmaer, 1988., Katz-Leurer, Carmeli, and Shochina, 2003), a mixure of cardiorespiratory and strength training (Duncan, Studenski and Richards, 2003., Richards, Malovin, Wood-Dauphinee, Williams, Bouchard and Brunet 1993., Dean, Richards and Malovin, 2000., Yang, Wang, Lin, Chu and Chan, 2006., Richards, et al; 2004., James, 2002), high-intensity therapy (usually physiotherapy), Richards, 1993., Green, Forster, Bogle and Young, 2002., Wade, Collen, Robb and Warlow, 1992., Kwakkel, Wagennar, Twist, Langhorst and Koestier, 1999., Patridge, Mackenzie and Edwards. 2000) and repetitive task training (Salback, Mayo, Wood-Dauphinee, Hanley, Richards and Cote, 2004., Dean & Shepherd, 1997., Van Vliet, Lincoln and Foxall, 2005., Kwakkel, et al; 1999., French, Thomas and Leathley, 2007).

Different treatment methods exist for post stroke gait rehabilitation. Their availability, mode of application, and costs vary, yet outcomes are largely similar (Dickstein, 2008). Therefore, choosing an appropriate method may be guided by a pragmatic approach. Simple "low technology" and conventional exercise to date is at least as efficacious as more complex strategies such as treadmill and robotic-based interventions (Dickstein, 2008). In chronic spinal cord injury, contralateral leg sensory information appears to entrain ipsilateral activity (Kawashima, Nozaki, Abe, Aka and Nakazawa 2005). However, following stroke, contralateral leg activitiy has been shown to exacerbate motor impairements during pedaling (Kautz & Pattern, 2005; Kautz, Pattern and Neptune, 2006).

Clinically, motor impairments following stroke are often assessed and treated unilaterally, but it is plausible that altered sensorimotor interactions between the legs could contribute to reduced walking capacity. Using a pedaling paradigm (Ting, Kautz, Brown, and Zajac, 2000) have demonstrated in neurologically intact subjects that movement – related sensory input from the contralateral limb can affect the phasing and magnitude of ipsilateral muscle activity during pedaling. These studies provide evidence for an inhibitory effect of extensor activity of the contralateral leg onto the ipsilateral flexors and demonstrate the functional significance of locomotor – related neural coupling between the antagonist musculature of opposite legs in healthy humans.

2.7 Effects of Cycle Ergometer Training on Energy cost of Walking after Stroke

The literature suggests that in patient groups with chronic disease such as stroke where muscular metabolic activity is decreased, the result is a reduced demand for blood flow (Ivey, Gardner, Dobrovolny and Macko, 2004, De Groot, Bleeker, Van

Kuppervelt, Van der Woude, Hopman, 2006). Vascular remodeling (smaller diameter) may occur to maintain the flow-diameter relationship. When physical activity is added, this narrowing can hamper overall blood flow to the working muscle. This occurs because of the evidence that a peripheral "feedback mechanism" (Kamiya, Ando, Shibata and Mascular, 1988) exists directly within the arterial vessel wall that maintains a synergy between blood flow and diameter. Exercise is a potent stimulus that facilitates adaptive vascular responses to meet the metabolic demands of the working muscles (Thomas & Segal, 2004).

Stroke recovery should emphasize a balanced multisystem approach to restore function, but all too often, the cardiorespiratory system may not be sufficiently challenged because of the residual neuromotor deficits (Tang, Sibley, Scott, Bayley, 2009., Richardson, Mcllroy and Brooks, 2009). The lack of exercise early after stroke may contribute to the rapid decline in cardiorespiratory fitness (Gordon, Gulanick and Costa, 2004). However, recent work by Tang and colleagues (Tang, et al; 2009) demonstrated that aerobic exercise incorporated into the sub-acute phase of traditional rehabilitation may provide improvements not only in cardiorespiratory fitness but also functional ambulation. Furthermore, recent literature has suggested that vascular impairments may also result from physical inactivity in the chronic phases of stroke (Ivey, et al., 2004, Billinger & Kluding, 2009., Billinger, Gajewski, Guo and Kluding, 2009) and exercise may be beneficial for improving blood flow delivery to the hermiparetic leg (Billinger, et al; 2009). Research on the effects of aerobic exercise training on energy cost of walking is important as most individuals after stroke are deconditioned and have low levels of cardiorespiratory fitness. (Gordon, et al; 2004)

Although there is emerging evidence that rehabilitation can be effective in improving both intrinsic motor control and functional status, systematic trials

comparing the relative effectiveness of various motor control intervention types generally have been few in number and suboptimal in design (Gordon et al; 2004). Although about 14% of stroke survivors achieve a full recovery in physical function, between 25% and 50% require at least some assistance with activities of daily living, and half experience severe long-term effects such as partial paralysis. Consequently, activity intolerance is common among stroke survivors, especially in the elderly (Ivey, 2000; Gresham, Duncan, and Stason, 1995). Ambulatory persons with a history of stroke may be able to perform at about 50% of peak oxygen consumption and 70% of the peak power output that can be achieved by age-and gender-matched individuals without a history of stroke. The increased aerobic requirements of walking after stroke are major causes of activity intolerance. Energy cost of walking in hemiplegic stroke patients varies with the degree of weakness, spasticity, training, and bracing, but in general, the energy cost of walking is elevated in hemiplegic patients compared with that of the able-bodied subjects of comparable body weight (Waters & Yakura, 1989; Olney, Griffin and Monga, 1991). Indeed, in some cases, the debilitating motor effects of a stroke can markedly reduce mechanical efficiency and increase the energy cost of walking up to 2 times that of able-bodied persons (Roth & Harvey, 2000). Even common household tasks are associated with considerably greater energy requirements among post stroke patients (Bjuro, Fugl-Meyer and Grimby, 1975). Two major goals of cycle ergometer exercise training programmesto stroke survivors are improvement in measures of mobility (e.g. increasing gait speed) and motor functions (e.g. lowering the energy cost of a hemiplegic gait (Gordon et al; 2004).

2.8 Effects of Cycle Ergometer Training on Walking Speed After Stroke

Walking speed is a cardinal indicator of post stroke gait performance; however, no consensus exists regarding the optimal treatment method(s) for its enhancement. The most widely accepted criterion for establishing the contribution of treatment to walking speed is the gain in speed (Dickstein, 2008). The actual speed, however, at the end of training (final speed) may be more important for functional community ambulation. Final speed is assessed by the reported speed values and by inferring the capacity for functional community walking at the end of the intervention period. Dickstein concluded that different treatment methods exist for gait training after stroke and that, their availability, mode of application, and costs vary, yet outcomes are largely similar. Therefore, choosing an appropriate method may be guided by a pragmatic approach. Simple "low technology" and conventional exercise to date is at least as efficacious as more complex strategies such as treadmill and robot-based training (Dickstein, 2008). Tang evaluated the feasibility of adding aerobic cycle ergometry training to conventional rehabilitation after stroke and its effects on walking ability (Tang, 2009), and concluded that early aerobic training can be safely implemented without deleterious effects on stroke rehabilitation. He stated that a trend toward greater improvement in aerobic capacity and walking capacity suggests that such training may have an early beneficial effect and should be considered for inclusion in stroke exercise training programmes.

Neuromuscular dyscontrol during gait following stroke may be further `compromised by increased susceptibility to fatigue (Sibley, Tang, Brooks and Mcllroy, 2008). These authors examined the effects of extended effortful activity on spatio-temporal gait parameters after stroke. The influence of sub-maximal exercise was assessed among 26 stroke survivors who performed the Six-Minute Walk Test with

distance recorded every 2 minutes. Walking distances decreased 5.8 meters in the second 2-minute interval and another 2.3 meters in the final 2 minutes. Secondly, spatio-temporal gait parameters prior to and immediately following a standardized maximal exercise test on a cycle ergometer in 36 stroke patients were evaluated. In contrast to the expected reduction in walking speed, maximal exercise led to a 5.5 cm/s increase in preferred walking speed and a 4-5 steps / minute increase in cadence, but did not affect the gait symmetry. Subsequent division of participants by preferred pedaling cadence revealed that individuals with lower preferred cadence had the greatest increase in preferred speed, cadence and paretic leg step length. These unexpected results suggest that potential fatigue-induced effects on gait may have been masked by immediate positive influences of movement rate on walking speed; and such activity-specific effects may have clinical applications for stroke patients.

In spite of the challenges, engaging in exercise programmes very early after stroke may positively influence aerobic capacity and stroke-related outcomes, including walking ability (Tang, et al; 2009). These authors evaluated the feasibility of adding aerobic cycle ergometer training to conventional rehabilitation early after stroke and determined the effects on aerobic capacity, walking ability, and health-related quality of life. The result of their study showed that all exercise participants (n=23) completed the training without adverse effects. Aerobic benefits were demonstrated improvements over time with a trend toward greater aerobic benefit in exercise group with 13% and 23% increases in peak VO_2 and work rate respectively, compared to 8% and 16% in control group. A similar trend toward improved 6-Minute Walk Test distance (equivalent to increase walking speed), (exercise 53% versus controls 23%, P=.23) was observed. Katz-Leurer carried out a study on early cycling test as a predictor of walking performance in stroke patients. Multiple linear regression analysis demonstrated that

rhythm, constant cycling is the best predictor of walking speed ($r^2 = 0.4$), gait distance ($r^2 = 0.2$) and number of stairs climbed ($r^2 = 0.26$). Lower extremity motor strength and walking function had no additional separate contribution to the prediction of study outcomes. It was concluded that the inability to cycle at a constant rhythm for one minute, two weeks after stroke is a more significant predictor than lower extremity motor strength or walking function on walking performance at three months post-stroke.

2.9 Effects of Stair Climbing Training on Walking Gait after Stroke

Although most people take thousands of steps each day, walking is not a trival task and requires attention, balance, coordination, and proprioception. These elements come even more into play when performing the more difficult task of ascending and descending either one or multiple steps. Stair climbing is a modified form of level walking (Trew & Everett, 2005). Stair climbing, as compared to level walking, requires an increased joint range of motion, particularly at the hip and knee, and involves increased muscular activity to generate forces that vertically translate the body's centre of gravity (Trev & Everett, 2005). Stair climbing is potentially a more biomechanically and physiologically challenging task than level walking as the individual has to work against gravity to ascend to the next step. Greenman (1996) states that movement restriction in one of the major joints in the lower limb can increase the energy cost of normal walking up to 40% and up to 300% if two joints are restricted. As stair climbing requires greater muscular activity than level walking it is assumed that the energy cost of stair climbing with a lower limb dysfunction would be considerable.

Loss of functional movement is a common consequence of stroke for which a wide range of interventions has been developed. Stair climbing exercise programme has been a popular intervention in the restoration of normal walking gait after stroke (Igara,

2008; Igara & Venkateswarlu, 2010). The kinematic and kinetic patterns at the ankle are significantly different during stair ascent and level walking. Unlike level walking, during stair ascent, the foot always strikes the step with the forefoot rather than the heel. The individuals must bend their knee as they lift it, hence the ankle angle at foot strike is approximately 15^0 in dorsiflexion. During the first portion of stance, the ankle becomes more dorsiflexed as the foot accepts the weight when the opposite foot comes off the step, the foot begins to powerfully planterflex to raise the body's centre of mass and bring the opposite foot up. When the opposite foot hits the stair above it, the second double support phase begins. The centre of mass moves further forward, the foot again dorsiflexes slightly and some power is absorbed. During the latter portion of the stance, the foot pushes forcefully up off the step and the swing phase begins.

The requirements for descending stairs are significantly different than that of level walking and stair ascent. When descending stairs, the foot strikes the step in a more planterflexed position where the center of pressure is on the forefoot rather than the heel. During initial stance the foot begins to accept the weight of the body. As the body moves from a higher position, a significant amount of potential energy is absorbed. This energy causes the foot to dorsiflex passively as the weight is shifted from the ipsilateral leg. At the time of opposite foot contact, the foot is at its maximum dorsiflexion positon. At this time, the foot requires power to forcibly planterflex the foot and push off the step (Gates, 2002).

2.10 Effects of Stair Climbing Training on Energy Cost of Walking after Stroke

Cardiorespiratory fitness is markedly impaired within seven weeks after stroke (Kelly, Kilbreath, Davis, Zeman and Raymond, 2003). These authors evaluated the cardiorespiratory fitness of subacute stroke patients to determine whether reduced

fitness is associated with gait performance. They concluded that although muscle weakness and loss of coordination are the primary impairments that affect gait after a stroke, impaired cardiorespiratory fitness may secondarily affect gait performance by limiting walking endurance. This secondary impairment can be addressed by incorporating assessment of cardiorespiratory fitness status and aerobic exercise training for persons after stroke (Kelly et al., 2003).

A typical exercise for stroke patients is stair climbing, it takes a lot of coordination and balance (Livingstrong, 2001). Central nervous system impaired patients, for example, after stroke, consider the achievement of an independent, stable gait function and endurance in walking essential for independent mobility in daily life (Hussein, Schmidt, Volkmar, Kruger and Hesse, 2008). Hussein opined that modern concepts of rehabilitation favour a task specific repetitive training, and activities that facilitate natural motion and muscle activation patterns such as in stair climbing should be trained. Energy is expended in order to allow the ability to perform physical activity, and to reduce the energy cost on the individual, there is an evolutionary tendency to minimize the degree of energy expended during everyday tasks (Sparrow, 2000). Therefore, frequency conducted tasks; such as walking are associated with minimal energy cost. Further, the energy cost associated with a task could be minimized if the individual becomes more practiced or 'skilled' at the task (Sparrow & Newell, 1998). Sparrow (2002) showed that the level of muscular activation during movement is positively correlated with energy cost.

Greenman (1996) discussed how the musculoskeletal system is a major expender of total body energy. If the efficiency of the musculoskeletal system is compromised by dysfunction, particularly if normal gait is not preserved, a greater energetic cost occurs. This greater cost is incurred not only during physical activity, but for daily physical

activity as well. Stair climbing is a beneficial form of exercise that has been shown to improve cardiovascular fitness (Boreham, Wallace and Nevill, 2000; Fardy & llmarinen, 1975; Loy, Conley, Sacco, Vincent, Holland and Sletten, 1994), reduce cholesterol levels (Boreham, et al., 2000), reduce percentage body fat (Fardy & Ilmarinen, 1975), and has a positive association with bone mineral density (Coupland, et al., 1999). The results of the study by Teh and Aziz, (2002), have shown that stair climbing requires almost 10 times greater energy expenditure than at rest and therefore considered as moderate to vigorous exercise. In addition, stair climbing has been suggested as a beneficial form of exercise due to its presence at most places of residence or employment, and it does not incur any monetary cost (Teh & Aziz, 2002), and it is a more physiologically and biomechanically challenging task than normal walking (Eves, Webb and Mutrie, 2006; Protopapadaki, Drechster, Cramp, Coutts and Scott, 2007).

2.11 Effects of Stair Climbing Training on Walking Speed after Stroke.

Restoration of the ability to walk is considered the hallmark of poststroke rehabilitation, with gait speed regarded as a significant, sensitive, and reliable marker of deficit severity and functional community walking ability (Onley, Nymark, and Brouwer, 2006., Goldie, Matyas, and Evans, 1996; Schmid, Duncan and Studenski, 2007). Therefore, speed gains resulting from the application of physical treatment constitute a variable of major interest in gait studies. Accordingly, the effect of an intervention is often determined by the difference between the speed before and after a definitive treatment period (treatment gain), with statistical and sometimes also clinical significance of the acquired gain being reported. (Olney, et al., 2006; Schmid et al., 2006., Yagura et al; 2006., Sullivan, et al; 2002). However, from the patients' view point, the ultimate determinant of achievement at the end of the treatment period is likely to be the actual speed, rather than the treatment gains, because the final attained

walking speed is crucial for functional indoor and outdoor ambulation (Schmid et al; 2007.,

The most widely applied method for gait enhancement consists of exercises that were developed for neurological rehabilitation, with their boundaries loosely defined (Pollock, Baer, Pomeroy and Langhorne, 2003, Baer & Van Wijack, 2005). Lower extremity strengthening, (Pattern, Lexell and Brown. 2004) and task- oriented exercises, [Baer & Van Wijick, 2005, are additional modes of exercise therapy. The primary aim of this sectional review is to assess the contribution of stair climbing exercise training programme to gait speed of patients after stroke. Some researchers have proved that treatment choice in restoration of gait parameters, like walking speed, after stroke should be based on what is available within a particular treatment setting. Three studies of high quality compared the effects of patients walking on the ground with patients walking on a treatmill (Nilsson, Carlsson, Danielsson, Fugl-Meyer, Helltrom, Kristensen, Sjolund, Sunnerhagen and Grimby, 2001., Peurala, Tarkka, Pitkanen and Sivenius, 2005). In their studies, which were performed in both sub-acute and chronic phases, scores on walking tests improved but no differences were found between the two groups. Studies have shown that aerobic training with one training modality results in increased functional performance in other aspects of training. One study, for example, showed that training on a cycle-ergometer in sub-acute phase after stroke resulted in a trend toward functional improvement, and stair climbing improved statistically significantly (Katz-Leurer et al; 2003). Three systematic reviews were found that focused on the improvement of physical condition among stroke survivors. One review showed that aerobic exercise, like stair climbing, had statistically significant favourable effects on walking speed and walking endurance (Pang, Eng, Dawson and Gylfadottir, 2006a). The other two systematic reviews draw the same conclusion: functional

programmes on cardio-respiratory fitness improved walking performance (Saunders, Greig, Young and Mead, 2004). Four studies performed in the community used an exercise programme focusing on strength, balance and endurance. There was good evidence that exercising benefits fitness and walking capacity (Pang, Eng, Dawson, Mckay and Harris, 2005). Two systematic reviews of muscle strength training in stroke survivors concluded that such training has uncertain effectiveness on functional performance (Ada, Dorsch, and Cannang, 2006; Bohannon, 2007).

2.12 Dysfunction in Muscle Biology, Aerobic Exercises and Muscular Endurance

Skeletal muscle has recently been recognized as a site of secondary biological changes after stroke that may propagate the functional decline associated with stroke (Blaak, 2004; Ivey, Ryan and Hafer-Macko, 2006; Kernan & Inzucchi, 2004; Root,2004). A number of pathophysiological mechanisms underlie the biological changes in muscle in stroke survivors. Stroke alters the motor neuron activation of muscles on the paretic side. After stroke, individuals have a secondary lifestyle and altered gait pattern with reduced weight bearing, which also affect the skeletal muscle (Mckenzie et al., 2008). Alterations in skeletal muscle are pronounced on the hemiparetic side after stroke and include gross muscular atrophy, increased intramuscular fat, and a shift to a fast myosin chain phenotype with reduced muscle oxidative capacity (Gresham, Fetzpatrick, Wolf, McNamara, Kannel and Dawber, 1975; U.S.D.H.H.S, 1995; Wade & Hewer, 1987).These molecular abnormalities after stroke have clear implications, since fast-twitch muscle fibers are more fatigable and have anaerobic metabolism (Landin et al.,1977). The quadriceps muscle is traditionally examined in studying aging, diabetes, and exercise interventions (Ryan, Dobrovolny, Smith, Silver and Macko, 2002). Prior muscle biology studies have demonstrated

plasticity of muscle fiber composition and enzymatic activity that depend on the specific task requirements of individual muscles (Gregory, Vandenborne and Dudley, 2001); physical activity level (Mujika & Padilla,2001); and stimulus applied to the muscle, such as electrical stimulation Exercise can shift muscle fibers to a slow myosin heavy chains phenotype and improve insulin sensitivity (Mckenzie et al., 2008), and can improve the muscular endurance after stroke. The beneficial effects of aerobic exercise training have been demonstrated in stroke (Macko et al., 2005b; Ivey et al., 2005; Macko et al., 2005a).

2.13 Summary

The most commonly and widely recognized impairment caused by stroke is motor impairment, which can be regarded as a loss or limitation of function in muscle control or movement or a limitation in mobility (Wade, 1992). Motor impairment after stroke typically affects about 80% of patients (Longhorne et al; 2009) therefore much of the focus of rehabilitation is on the recovery of impaired movement and the associated functions. There seems to be a direct relation between motor impairment and function; for example, independence in walking (function) has been correlated with lower – limb strength (impairment) (Jorgensen, Nakayama, Raaschou and Olsen, 1995). Therefore, the ultimate goal of therapy for lower-limb impairment is to improve the function of walking and recovery of movement. Motor recovery after stroke is complex and confusing. Many interventions have been developed to try to aid motor recovery (recovery of impairment and associated function), and many randomized controlled trials and systematic reviews have been done (Sandercock, et al; 2009), yet none has come up with optimal treatment methods or on research.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Introduction

The purpose of the study was to compare the effects of 12- week cycle ergometer and stair climbing training on energy cost, walking speed and muscular endurance of stroke patients. To achieve this purpose, the research design, the population, sample and sampling technique, training protocols, experimental control and statistical techniques used in the study are described in this chapter.

3.2 Research Design

Experimental research design was adopted for this study. The subjects in Groups A, B and C were matched using similarities in their walking speed before the training. Walking speeds of the subjects were measured at the baseline. The twenty four subjects formed eight sub-groups with each sub-group having three subjects. The three subjects in each sub-group had similar walking speed at the baseline. There were therefore eight subjects in each of groups A, B, and C. Gender was not considered when forming these groups, rather it was only pretest walking speed that was considered in the grouping. Group A was cycle ergometer, Group B was stair climbing training and Group C was the Control group.

3.3 Population

The population of this study comprised all stroke patients attending physiotherapy clinics at Ahmadu Bello University Teaching Hospital, Zaria. These stroke patients were on out-patients basis after being discharged from hospitals. They were twenty eight patients, 16 males and 12 females and diagnosed for stroke by physicians.

3.4 Sample and Sampling Techniques

Stratified random sampling technique was used in this research. Twenty four subjects met the criteria to participate in this research. They were fourteen males and ten females. The subjects that could walk without manual support were selected. The letters A, B, and C were randomly assigned to two experimental groups and a control group. There were eight sub-groups of three subjects each. The three subjects in each sub-group had similar walking speed. This method ensured that the subject in groups A, B, and C had similar baseline characteristics.

The subjects from a sub-group picked one of the cards marked A, B, and C on the opposite side which could not be seen by the subjects. This, there were eight subject in a sub-group. This technique was applied to assign the letters A, B, or C on the opposite side which could not be seen by the subjects. This technique was applied to assign the letters A, B or C to cycle ergometer, stair climbing training and control groups respectively.

3.5 Training Protocols

A: Cycle Ergometer Training

Cycle ergometer training group performed cycling on a cycle ergometer for 30 minutes in a training session with intensity of 55% of their maximal heart rate during the first 4 weeks. Maximal heart rate was determined by 220 – age of the subject. The intensity of training was progressed to 62% of maximal heart during the second 4 weeks. It was further progressed to 70% of maximum heart rate during the third 4 weeks. As the stroke patients could not continue to train for 30 minutes, the exercise training session was divided into three parts of 10 minutes each. After every 10 minutes of cycling, the patient was given two minute rest after which he continued the training

for more 10 minutes, followed by two minute rest after which the final 10 minutes of training was performed. The two minute rest was given on the basis of the observation of the researcher that average stroke patient was almost exhausted after 10 minutes of continuous cycling. The two minute rest, during which the patient simply relaxed in a sitting position on stationary bicycle, was found to be adequate for the patient to recover so as to continue the training for more 10 minutes. This session of training for 30 minutes was repeated on three alternate days of a week for 12 weeks. All the stroke patients in this group participated in the training programme without any break. They were allowed to follow the usual physiotherapy treatment which included infrared radiation, massage, electrical stimulation, hand ergometry that the control group underwent.

B. Stair Climbing Training

Stair climbing training group performed climbing up and down a staircase for 30 minutes in a training session with intensity of 55% of their maximal heart rate during the first 4 weeks. Maximal heart rate was determined by 220 – age of the subject. The intensity of training was progressed to 62% of maximal heart during the second 4 weeks. It was further progressed to 70% of maximum heart rate during the third 4 weeks. As the stroke patients could not continue to train for 30 minutes, the training session was divided into three parts of 10 minutes each. After every 10 minutes of stair climbing, the patient was given two minute rest after which he continued the training for more 10 minutes, followed by two minute rest after which the final 10 minutes of training was performed. The two minute rest period was given on the basis of the observation of the researcher that average stroke patient was almost exhausted after 10 minutes of continuous stair climbing training. The two minute rest, during which the

patient relaxed in sitting position, was found to be adequate for the patient to recover so as to continue the training for more 10 minutes. This session of training for 30 minutes was repeated on three alternative days of a week for 12 weeks. All the stroke patients in this group participated in the training programme without any break. They were allowed to follow the usual physiotherapy treatment that the control group underwent.

3.6 TESTS

The tests conducted in this study to compare the energy cost, walking speed and muscular endurance of stroke patients are presented below:

A. Energy Cost of Walking

The test consists of a stroke patient walking for three minutes. The resting heart rate of each stroke patient was recorded in a relaxed sitting position before walking. The heart rate during walking was measured by a heart rate monitor. The heart rates thus obtained were used to calculate energy cost of walking using physiological cost index (Graham, Smith and White 2005). The formula used to calculate physiological cost index (MacGregor, 1981) was as follows:

Physiological cost index (beats / meter) = Walking heart rate (beats / minutes) -

Resting heart rate (beats / minute) divided by walking speed (meters / minute)

B. Walking Speed

This test consists of a stroke patient walking for 10 meters. The time to walk intermediate six meters was recorded to allow for acceleration and deceleration. The six meters was two meters from the starting line to eight meters before the finishing line. Timing started when the toes of leading foot crossed 2-meter mark and stopped when the leading foot crossed the 8-meter mark. The patients walked at their preferred walking speed. Three walking trials were performed and their average calculated. This

time, measured in seconds, was used to divide six meters to get the walking speed of the patient (Bohannon, 1997; Bohannon et al., 1996; Wolf and Catlin 1999).

C. Muscular Endurance

Prior to performing the repetition maximum testing sessions, all the stroke patients underwent two familiarization sessions to orientate themselves with the exercise technique. During these sessions the appropriate positioning and lifting techniques were instructed and each patient performed two sets of the exercise. This familiarization was completed one week before the pre-test assessment was conducted in all the groups. The repetition maximum testing protocol and body positioning on sitting for each patient both closely adhered to the recommendations of the National Strength and Conditioning Association (Baechle & Earle, 2008). For one repetition maximum testing, each patient warmed up with a low resistance which was performed 10 repetitions. Thereafter, resistance was increased in incremental loads until failure occurred despite verbal encouragement to continue (Hass et al., 2007). In order to be classified as a successful attempt, the patient had to lift the weight with full range of motion of the paretic knee in a controlled manner without compensatory movements (for example, shifting body position). The one repetition maximum was determined within five attempts for all the patients.

This test consists of a patient sitting on a high couch which did not allow his legs to touch the floor. Calibrated ankle weights were attached to the ankle of the affected leg to determine one repetition maximum (I-RM) during knee extension exercise as suggested by Baechle & Earle (2008), who reported that one repetition maximum is an accepted gold standard of maximal muscle testing. One repetition maximum is defined as the maximal weight that can be lifted once with correct lifting technique and is generally considered to have good to excellent (ICC > 0.95) reliability (ACSM, 2009;

Levinger, Goodman, Hare, Jerums, Toia and Selig, 2009). 70% of one repetition maximum was calculated as suggested by Levinger et al.,(2009), and was used to determine the maximum number of repetitions that the patient performed the lifting using this weight. The patients were tested before the training and repeated every 4 weeks of training when a new one repetition maximum (1RM) was determined, 70% of which was used to repeat the lifting exercises as many times as possible. The data thus collected were used to determine the change in muscular endurance as a result of 12 weeks of training.

3.7 Experimental control

In order to eliminate the influence of extraneous and intervening variables on the selected dependent variables, the following measures were taken:

1. In order to eliminate the bias of the testers for any particular group, they were rotated after every 4 weeks from group to group.
2. Any physical activity outside the training will influence the effects of the training on the dependent variables. This was controlled by informing the subjects not to involve in any structured physical training other than the training given in this study.
3. All the tests were conducted 30 minutes after arriving at the test station. This was to ensure that any walking or physical activity prior to tests did not affect the performance of the subjects.

3.8 Statistical techniques

Descriptive statistics of means, standard deviations and standard errors of energy cost of walking, walking speed and muscular endurance in cycle ergometer and stair climbing training and control groups were computed. The t-test statistics was used to

compare the effects of cycle ergometer and stair climbing training on energy cost, walking speed and muscular endurance of stroke patients. Rejection or acceptance of any of the hypotheses was carried out at 0.05 probability level of significance.

CHAPTERFOUR

4.0 RESULTS AND DISCUSION

4.1 Introduction

This study was conducted to compare the effects of cycle ergometer and stair climbing training on energy cost of walking, walking speed and muscular endurance of stroke patients. The training programmes lasted for 12 weeks and the data collected at baseline, immediately after 4^{th}, 8^{th} and 12^{th} week of cycle ergometer and stair climbing training were analyzed at the IyaAbubakar computer centre, Ahmadu Bello University, Zaria, using the Statistical Package of Social Sciences (SPSS) Version 20. Twenty four subjects were recruited for the training programmes and met the required attendance of cycle ergometry and stair climbing training sessions.

4.2 Results

The results of the analyses are presented and discussed according to the null hypotheses raised for this study. The alpha level of significance for accepting or rejecting the null hypotheses guiding this research was set at 0.05.

Table 4:2:1: Pre-training descriptive statistics of the physical characteristics of the subjects

		Male			Female		
Groups	Variables	Mean	S D.	S. E	Mean	S. D.	S. E
	Age(yrs)	41.00	5.148	2.302	43.00	3.464	2.000
Cycle	Height(m)	1.65	0.021	0.009	1.65	0.032	0.019
Ergometer	Weight(kg	63.20	4.494	2.010	67.00	7.000	4.041
	Age(yrs)	41.20	3.564	1.594	44.33	4.619	2.667
Stair	Height(m)	1.68	0.018	0.008	1.68	0.030	0.017
Climbing	Weight(kg	72.60	10.286	4.600	58.67	1.155	0.667
	Age(yrs)	40.50	4.203	2.102	42.75	4.425	2.213
Control	Height(m)	1.67	0.034	0.017	1.66	0.022	0.011
Group	Weight(kg	67.50	10.149	5.074	65.25	8.302	4.151

The result of Table 4.2.1 showed that the mean age of the male and female subjects used for this study in cycle ergometer, stair climbing and the control groups were 41.00± 5.148 and 43.00± 3.464 years, 41.20± 3.564 and 44.33± 4.619 years; 40.50± 4.203 and 42.75± 4.425 years respectively. The height of the male and female subjects in the cycle ergometer group was 1.65 ± 0.021m and 1.65± 0.032m respectively while the stair climbing group had height of 1.68+0.018m and 1.68± 0.030m. The control group had height of 1.67± 0.034 and 1.66± 0.022m respectively.

The weight of the male and female subjects in the cycle ergometer groups were 63.20± 4.494kg and 67.00± 4.041kg respectively while the stair climbing group had 72.60± 10.286kg and 58.67± 1.155kg the control group had 67.50± 10.149kg and 65.25± 8.302kg respectively.

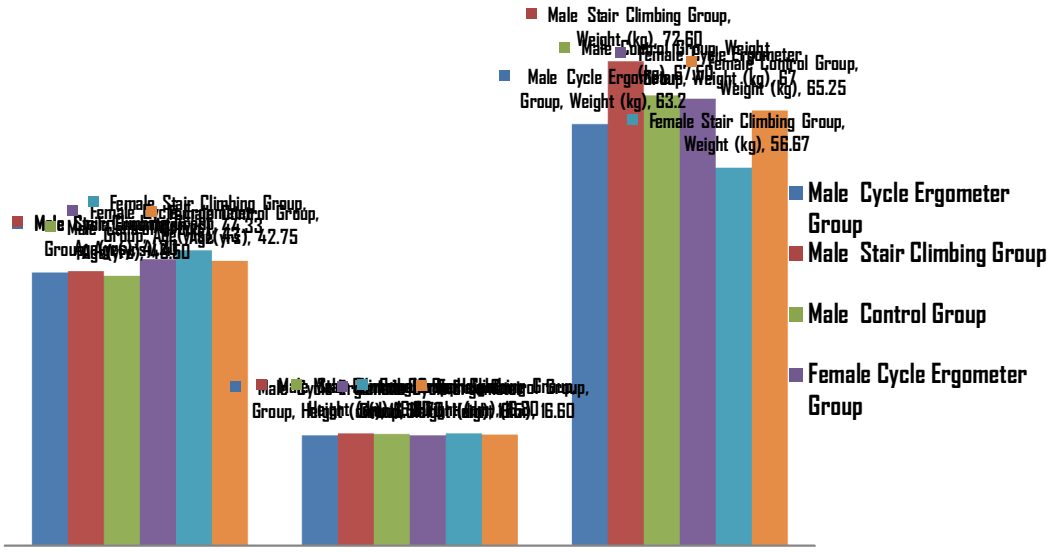


Figure 4.2.1:Histogram showing the physical characteristics of the subjects in Cycle Ergometer, Stair Climbing and Control Groups.

The histogram showed uniform distribution of age, height and weight of stroke patients in cycle ergometer, stair climbing training and control groups. The average age of the patients in cycle ergometer, stair climbing, training and control groups were 41.8 years, 42.4 years and 41.6 years respectively as shown above. The average height of subjects were 16.50dm, 16.80dm and 16.60dm for cycle ergometer,, stair climbing training and control groups respectively while the average weight were 64.6kg, 67.4kg and 66.4kg in that order.

Sub-hypothesis1: **There is no significant difference between the effects of cycle ergometer and stair climbing training on energy cost of walking of stroke patients.**

To test this hypothesis, the data collected at baseline, 4th, 8th and 12th week of cycle ergometer and stair climbing training on energy cost of walking of stroke patients are presented in Table 4:2:2a

Table 4:2:2a Descriptive statistics of means and standard deviations energy cost of walking of stroke patients for two methods of training.

Variable	Training methods	Period	Mean (b/m)	Std. Dev.	SEE
Energy cost.	Cycle Egometer	Pre-test	1.46	0.345	0.131
		4wks	1.18	0.239	0.091
		8wks	0.98	0.240	0.091
		12wks	0.78	0.136	0.051
	Stair Climbing	Pre-test	1.44	0.335	0.127
		4wks	1.30	0.270	0.102
		8wks	1.20	0.248	0.094
		12wks	1.15	0.248	0.094

Note: wks = weeks after the commencement of training b/m = beats per meter

Table 4:2:2a shows that the mean scores of cycle ergometer and stair climbing training on energy cost of walking of stroke patients used in this study. An observation of this Table revealed that the pre-training mean of energy cost of walking in the cycle ergometer group was 1.46± 0.345b/m while the 4th, 8th and 12th week means were 1.18± 0.239b/m; 0.98± 0.240b/m and 0.78± 0.136b/m.

The stair climbing group had 1.44± 0.335b/m; 1.30± 0.270b/m, 1.20± 0.248b/m and 1.15± 0.248b/m at the pre-test, 4th, 8th, and 12th week of training respectively. To find out whether the effects of the two training programmes were significantly different, t-test was used to analyze the data as shown in Table 4:2:2b.

This observation was displayed in a composite bar chart as shown in Figure 4.2.2;

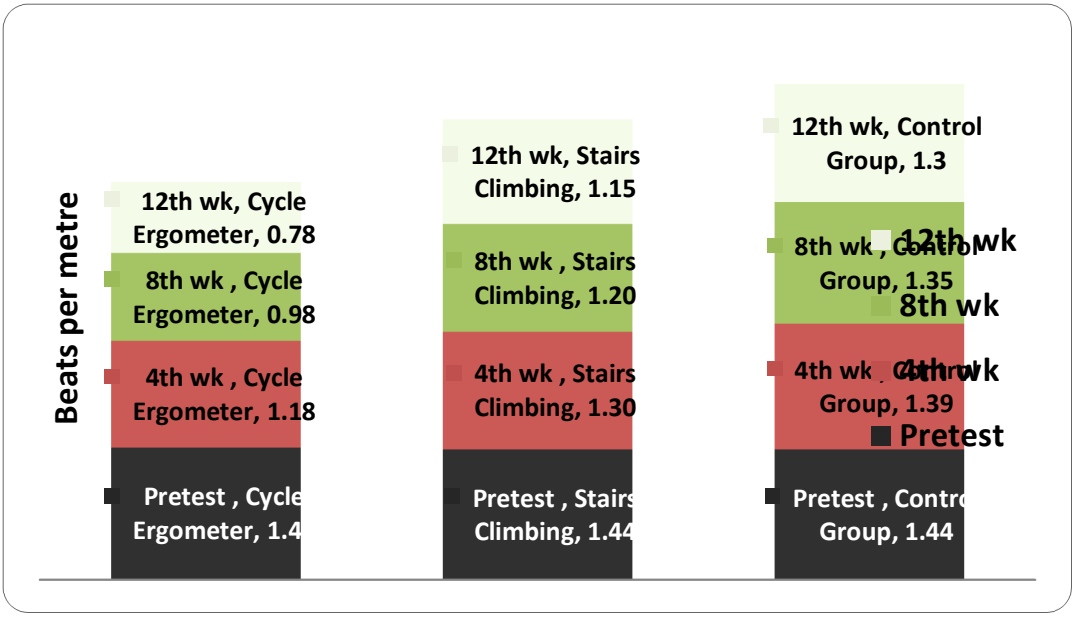


Figure 4:2:2: Composite bar chart showing differences in energy cost of walking of stroke patients in Cycle ergometer, stair climbing training and control groups.

Figure 4.2.2 shows that the pretest scores in energy cost of walking of stroke patients were similar in cycle ergometer, stair climbing training and control groups as the heights of the bars were almost equal at pretest level at the base of the bars. The height of the bars in cycle ergometer, stair climbing training and control groups became different in the 4^{th} week, 8^{th} week and 12^{th} week of training. The energy cost of walking was greatly reduced during the training in cycle ergometer than the mean scores in stair climbing training or the control group. Similarly, the height of the composite bar representing stair climbing training was shorter than the bar representing control group. This means that stair climbing training was better than physiotherapy alone in energy cost of stroke patients. Taken together, although stair climbing training was better than usual physiotherapy, cycle ergometer training was better than stair climbing in the improvement of energy cost of walking of stroke patients.

Table 4:2:2b Summary of t-test analysis on the effects of cycle ergometer and stair climbing training on energy cost of walking of the subjects.

Energy cost	Training method	N	Mean(b/m)	Std. dev	Std. error	df	t-value
Pre-test	Cycle Ergometer	8	1.46	0.345	0.122	14	0.103*
	Stair Climbing	8	1.44	0.335	0.118		
4th week	Cycle Egometer	8	1.18	0.240	0.085	14	0.941*
	Stair Climbing	8	1.30	0.298	0.095		
8th week	Cycle Ergometer	8	0.98	0.240	0.085	14	1,803*
	Stair Climbing	8	1.20	0.248	0.088		
12th week	Cycle Egometer	8	0.78	0.136	0.048	14	3.724**
	Stair Climbing	8	1.15	0.248	0.088		

t (14) = 2.15, P = 0.05 * Not significant, P > 0.05 ** Significant, P < 0.05

The result of the t-test analysis showed that the difference between the effects of cycle ergometer and stair climbing training on energy cost of walking of stroke patients became significant only after 12 weeks of training t (14) = 3.724, p <0.05

Sub-Hypothesis 11: There is no significant difference between the effects of cycle ergometer and stair climbing training on walking speed of stroke patients.

To test this sub-hypothesis, the data collected at baseline, 4th, 8th and 12th week of cycle ergometer and stair climbing training on walking speed of stroke patients are presented in Table 4:2:3a.

Table 4:2:3a Descriptive statistics of means and standard deviations of walking speed of stroke patients for cycle ergometer and stair climbing of training.

Variable	Training methods	Period	Mean (m/s)	Std. Dev.	SEE
Walking Speed	Cycle Egometer	Pre-test	0.40	0.088	0.033
		4wks	0.53	0.093	0.035
		8wks	0.72	0.087	0.031
		12wks	0.88	0.071	0.027
	Stair Climbing	Pre-test	0.42	0.148	0.052
		4wks	0.51	0.152	0.052
		8wks	0.61	0.148	0.052
		12wks	0.70	0.150	0.052

Note: wks = weeks after the commencement of training m/s = meter per second

The results in (Table 4:2:3a) shows that the mean scores of cycle ergometer and stair climbing training on walking speed of stroke patients used in this study. This Table revealed that the pre-training mean score of walking speed in the cycle ergometer group was 0.40± 0.088m/s. The group also recorded mean scores of 0.53± 0.093m/s; 0.72± 0.087m/s and 0.88± 0.071m/s respectively at the 4^{th}, 8^{th} and 12^{th} week of training.

The stair climbing group recorded 0.42 ± 0.148m/s; 0.51 ± 0.152m/s, 0.62± 0.148m/s and 0.70± 0.150m/s at the pre-test, 4^{th}, 8^{th}, and 12^{th} week of training respectively. To determine the significance the significance of the difference between the two groups in walking speed, t-test was used. The result as presented on Table 4:2:3b showed significant difference at the 12^{th} week only. Although the cycle ergometer group showed improvement in walking speed across the time period, the improvement was not statistically significant when compared with the stair group at the 4^{th} and 8^{th} week. This information was displayed in a composite bar chart in Figure 4.2.3 below.

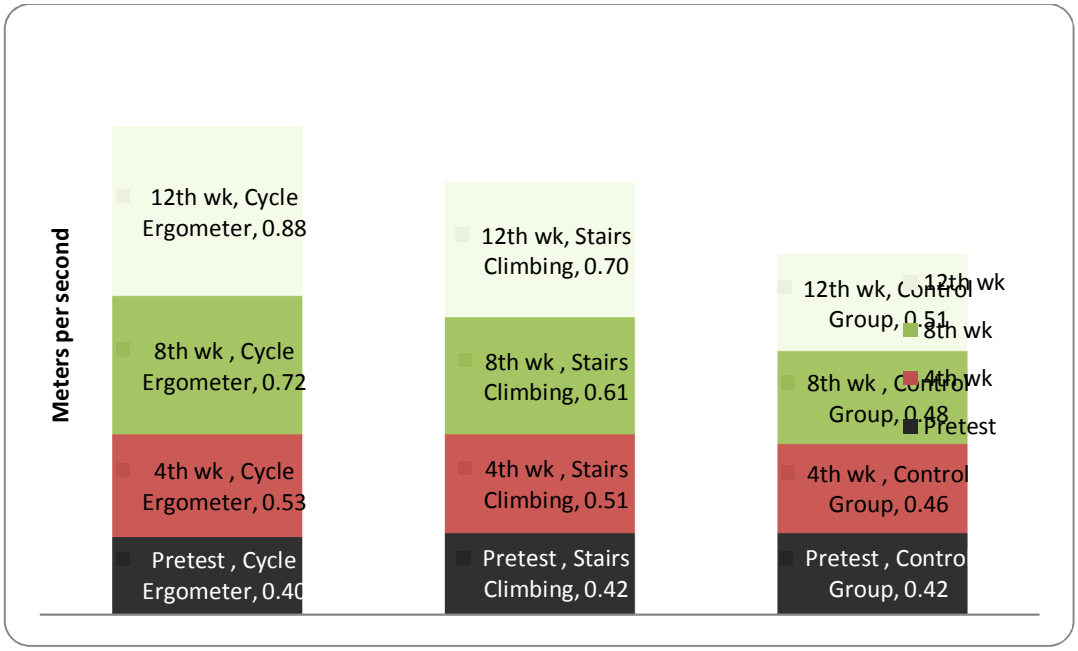


Figure 4:2:3: Composite bar chart showing differences in walking speed of stroke patients in cycle ergometer, stair climbing training and control groups.

The composite bar chart (Figure 4.2.3) showed that the scores of walking speed of stroke patients in cycle ergometer, stair climbing training and control groups were similar at pretest as shown by their heights in the base of the composite bar chart. However, the increase in walking speed became greater at the 4^{th}, 8^{th} and 12^{th} weeks in cycle ergometer training group compared to stair climbing training and control groups. Nevertheless, the height of the composite bar was shortest in control group compared to the two training groups as shown in Figure 4:2:3. It was shown therefore that cycle ergometer training produced greater increase in walking speed of stroke patients more than stair climbing training or control groups. The implication was than cycle ergometer training was the training of choice compared to stair climbing training and control groups in the restoration of greater walking speed in stroke patients.

Table 4:2:3b Summary of t-test analysis on the effects of cycle ergometer and stair climbing training on walking speed o f the subjects

Energy cost	Training method	N	Mean(m/s)	Std. dev	Std. error	df	t-value
Pre-test	Cycle Ergometer	8	0.40	0.086	0.031	14	0.328*
	Stair Climbing	8	0.42	0.148	0.052		
4^{th} week	Cycle Egometer	8	0.53	0.093	0.033	14	0.297*
	Stair Climbing	8	0.51	0.151	0.054		
8^{th} week	Cycle Ergometer	8	0.72	0.087	0.031	14	1.830*
	Stair Climbing	8	0.61	0.148	0.052		
12^{th} week	Cycle Egometer	8	0.88	0.071	0.025	14	2.979**
	Stair Climbing	8	0.70	0.150	0.053		

t (14) = 2.15, P = 0.05 * Not significant, P > 0.05 ** Significant, P < 0.05

The result of the t-test analysis showed that the difference between the effects of cycle ergometer and stair climbing training on walking speed of stroke patients were not significant at the, 4^{th} and 8^{th} week of the training ($p < 0.05$). The difference in walking speed of the two training method became significant after 12 weeks of training $t(14) = 2.979$, $p < 0.05$.

Sub-hypothesis1II: **There is no significant difference between the effects of cycle ergometer and stair climbing training on muscular endurance of stroke patients.**

To test this sub-hypothesis, the data collected at baseline, 4^{th}, 8th and 12^{th} week of cycle ergometer and stair climbing training on muscular endurance of stroke patients are presented in Table 4.2.4a.

Table 4:2:4a: Descriptive statistics of means and standard deviations of muscular endurance of stroke patients for cycle ergometer and stair climbing training.

Variable	Training methods	Period	Mean (reps)	Std. Dev.	SEE
Muscular Endurance	Cycle Egometer	Pre-test	4.00	1.309	0.463
		4wks	5.00	1.309	0.463
		8wks	5.75	1.165	0.412
		12wks	6.38	1.408	0.498
	Stair Climbing	Pre-test	4.13	0.845	0.295
		4wks	4.63	1.061	0.375
		8wks	5.63	1.061	0.375
		12wks	5.88	0.835	0.295

Note: wks = weeks after the commencement of training. reps = repetitions

The result on Table 4:2:4a shows the mean scores of the cycle ergometer and stair climbing training on muscular endurance of stroke patients. The analysis of the Table revealed that the pre-training mean of muscular endurance in the cycle ergometer group was 4.00+1.308reps while the 4^{th}, 8^{th} and 12^{th} week means were 5.00± 1.309reps; 5.75± 1.165reps and 6.38± 1.408reps respectively.

The stair climbing group had 4.13± 0.845reps; 4.63± 1.061reps, 5.63± 1.061reps and 5.88± 0.835reps at pre-test, 4^{th}, 8^{th}, and 12^{th} week of training respectively. To determine whether the effects of the two training programmes were significantly different, t-test was used to analyze the data as shown in Table 4:2:4b.

The information was displayed in a composite bar chart in Figure 4.2.4

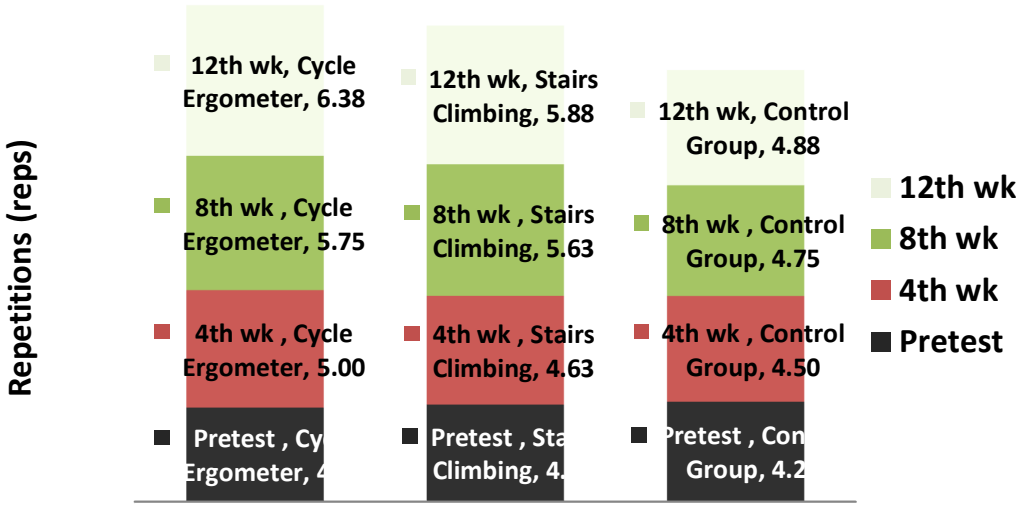


Figure 4:2:4: Composite bar chart showing differences in muscular endurance of stroke patients in cycle ergometer, stair climbing training and control groups.

The composite bar chart (Figure 4.2.4) showed that the heights of the three composite bars representing cycle ergometer training, stair climbing training and control groups were similar to each other especially those of cycle ergometer and stair climbing training groups. This similarity in mean scores of muscular endurance existed in all levels of pretest, 4th week, 8th week and 12th week of the training as shown in the heights of the composite bars.

Table 4.2.4b: Summary of t-test analysis on the effects of cycle ergometer and stair climbing training on muscular endurance of the subjects.

Energy cost	Training method	N	Mean(reps)	Std. dev	Std. error	df	t-value
Pre-test	Cycle Ergometer	8	4.00	1.310	0.463	14	0.218*
	Stair Climbing	8	4.12	0.836	0.295		
4^{th} week	Cycle Ergometer	8	5.00	1.309	0.463	14	0.629*
	Stair Climbing	8	4.63	1.061	0.375		
8^{th} week	Cycle Ergometer	8	5.75	1.65	0.412	14	0.224*
	Stair Climbing	8	5.63	1.061	0.375		
12^{th} week	Cycle Ergometer	8	6.38	1.408	0.498	14	0.864*
	Stair Climbing	8	5.88	0.835	0.295		

t (14) = 2.15, P = 0.05 * Not significant, P > 0.05

The result of t-test analysis showed that the difference between the effects of cycle ergometer and stair climbing training on muscular endurance of stroke patients was not significant even after 12 weeks of training t (14) = 0.864, P> 0.05.

Although this study was concerned with the comparative effects of cycle ergometer and stair climbing training on energy cost, walking speed and muscular endurance of stroke patients, the effect of each of the training in experimental and control groups on these dependent variables were also determined as were discussed in this section. The mean scores obtained at pretest, 4^{th} week, 8^{th} week and 12^{th} week were displayed in histograms to show changes in performance in energy cost, walking speed and muscular endurance in the three groups. These changes in performance scores were calculated as percentage changes by using the formular:

$$\text{搜ercentage Change } (\%\Delta) = \frac{Final\ Score - Initial\ Score}{Initial\ Score} \times \frac{100}{1}$$

Hence, the percentage changes were calculated from pre-test to 4^{th} week, 4^{th} week to 8^{th} week, 8^{th} week to 12^{th} week and from pretest to posttest. This was used as a horizontal axis as periods of training while values of the mean scores formed the

vertical axis. Changes in the heights of the bars were measures of changes in the mean scores of energy cost, walking speed and muscular endurance during pre-test, 4th week, 8th week and 12th week in the respective groups. The percentage changes were written in the middle of the bars between two training periods that were compared.

Histogram showing the effects of cycle ergometer training on energy cost of walking of stroke patients was shown in Figure 4.2.5

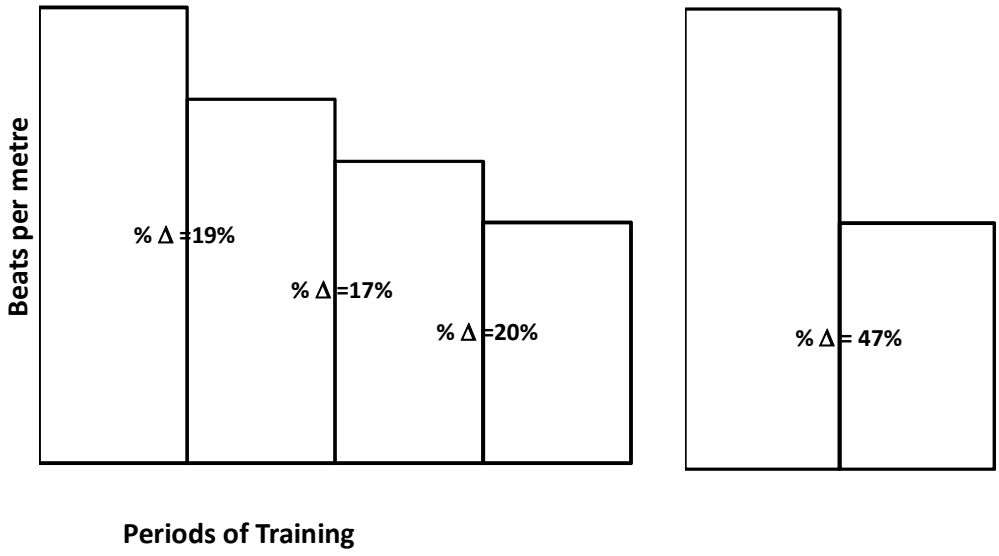


Figure 4:2:5: Histogram showing decrease in energy cost of walking of stroke patients in cycle ergometer training group.

The histogram showed a gradual decrease in energy cost of walking stroke patients in cycle ergometer training from pretest to 4th week and of 4th week to 8th week, 8th week to 12th week. There was however a marked percentage decrease of 47% from pretest to posttest scores. The percentage decrease from pretest to 4th week, 4th week to 8th week and 8th week to 12th week were 19%, 17% and 20% respectively. These percentage changes, although clinically relevant, the one that was of great interest was the percentage decrease of 20% from 8th week to 12th week of the training. This had an

important clinical implication on the need to continue the cycle ergometer training beyond 12 weeks.

The effects of stair climbing training on energy cost walking of stroke patients were discussed below with the aid of a histogram in Figure 4.2.6.

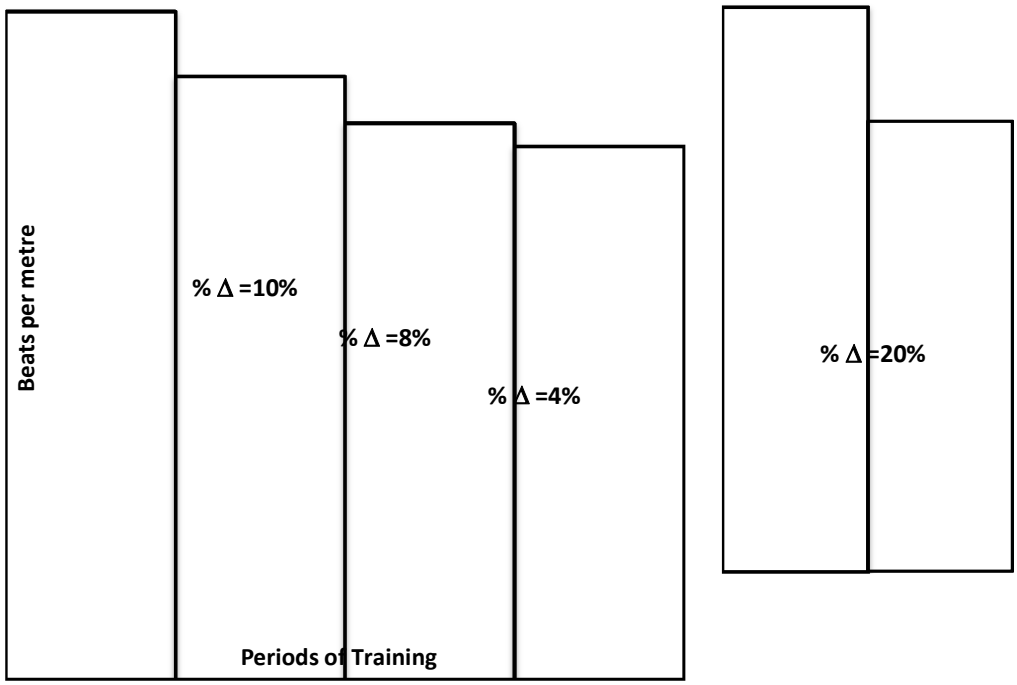


Figure 4:2:6: Histogram showing decrease in energy cost of walking of stroke patients in stair climbing group.

The histogram (Figure 4:2:6) showed a very slow decrease in energy cost of walking of stroke patients in stair climbing training from pretest to 4th week, 4th week to 8th week and from 8th week to 12th week of 10%, 8% and 4% respectively. These percentage changes were not comparable with the percentage changes obtained from cycle ergometer training that were previously discussed. The percentage change of 4% from the 8th week to the end of the 12th week training had clinical implications. This would suggest the need to terminate the stair climbing training at the 12th week since continuing the training would not be clinically relevant.

The effects of physiotherapy alone on energy cost of walking of stroke patients were discussed below with the aid of a histogram in Figure 4.2.7.

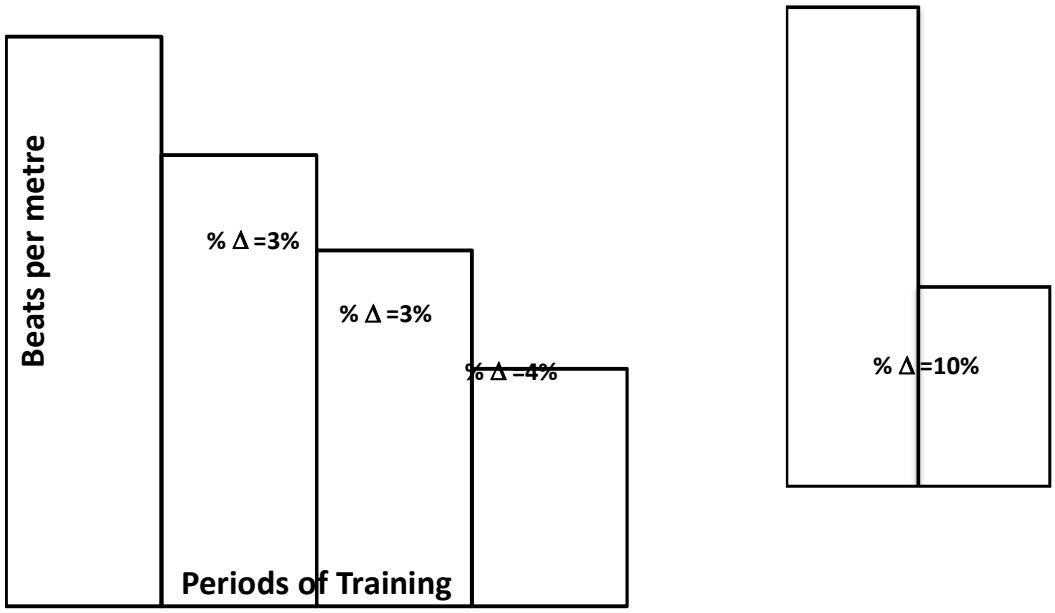


Figure 4:2:7: Histogram showing decrease in energy cost of walking of stroke patients in control group.

The histogram (Figure 4.2.7) showed very slow decline in the heights of the bars during the periods of training. The meaning of this was that there was slow reduction in energy cost of walking of stroke patients in the control group. The percentage changes were corresponding to the rate of recovery. The percentage changes from pretest to 4th week, 4th week to 8th week and 8th week to 12th week were 3%, 3% and 4% respectively. The percentage change from pretest to posttest was 10%. These results showed a gradual decrease in energy cost of walking that was similar in different test periods. The meaning of this result was that stroke patients could have some improvement in energy cost of walking if they received physiotherapy alone. An important implication was that

it would take much longer periods of training to achieve remarkable improvement in energy cost of walking if physiotherapy alone were to be applied.

The decrease in energy cost of walking of stroke patients in cycle ergometer training from pretest to 4th week (19%) was even greater than the pretest to posttest decrease in energy cost of walking of stroke patients in control group which was 10%. Similarly, the decrease in energy cost of walking of stroke patients in control group from pretest to the 12th week (10%) was the same percentage change of 10% in stair climbing training group within a short period of pretest to the 4th week. It was therefore suggested that either cycle ergometer or stair climbing training should be used with usual physiotherapy to achieve greater improvement in energy cost of waling of stroke patients.

The effect of cycle ergometer training on walking speed of stroke patients were discussed below with the aid of a histogram in Figure 4.2.8

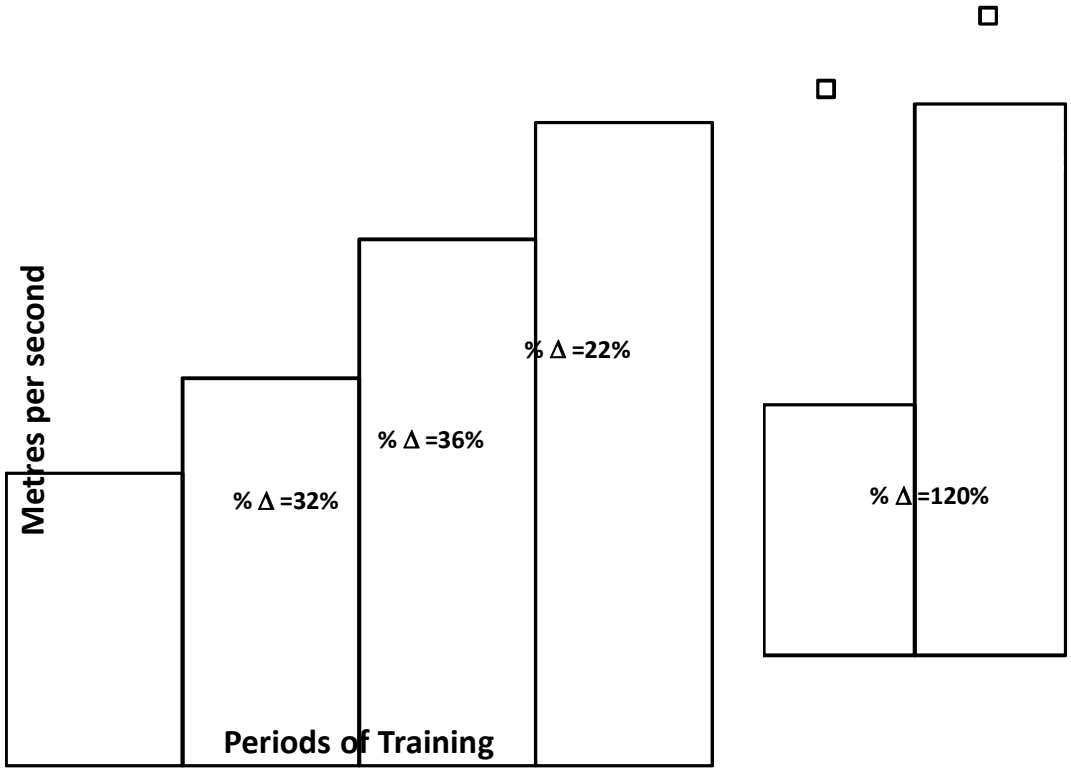


Figure 4:2:8: Histogram showing increase in walking speed of stroke patients in Cycle ergometer training group.

The histogram (Figure 4.2.8) showed marked increase in walking speed of stroke patients in cycle ergometer training group in each of the test periods. There was a percentage change of 32% from pretest (m = 0.40m/s) to the 4^{th} week (m = 0.53m/s). This implied that there was a clinically relevant increase in walking speed of stroke patients during the first four weeks of cycle ergometer training. This level of improvement was maintained from 4^{th} week (m = 0.53m/s) to 8^{th} week (m = 0.72m/s) of the training when the percentage change became 36%. Although a continued improvement was observed from the 8^{th} week (m = 0.72m/s) to the 12^{th} week (m = 0.88m/s) when the percentage change was 22%, the increase was smaller than the values calculated from pretest to 4^{th} week (32%) and from 4^{th} week to 8^{th} week of 36%. The implication was that the rate of improvement in walking speed of stroke patients who used cycle ergometer training was greater from the pretest to the 8^{th} week than other training periods.

The percentage change from pretest to posttest was 120% indicating the cumulative effects of the training. It was therefore suggested that cycle ergometer training for the improvement of walking speed of stroke patients should be extended beyond 12 weeks to achieve greater walking speed.

The effects of stair climbing training on walking speed of stroke patients were discussed below with the aid of a histogram in Figure 4.2.9.

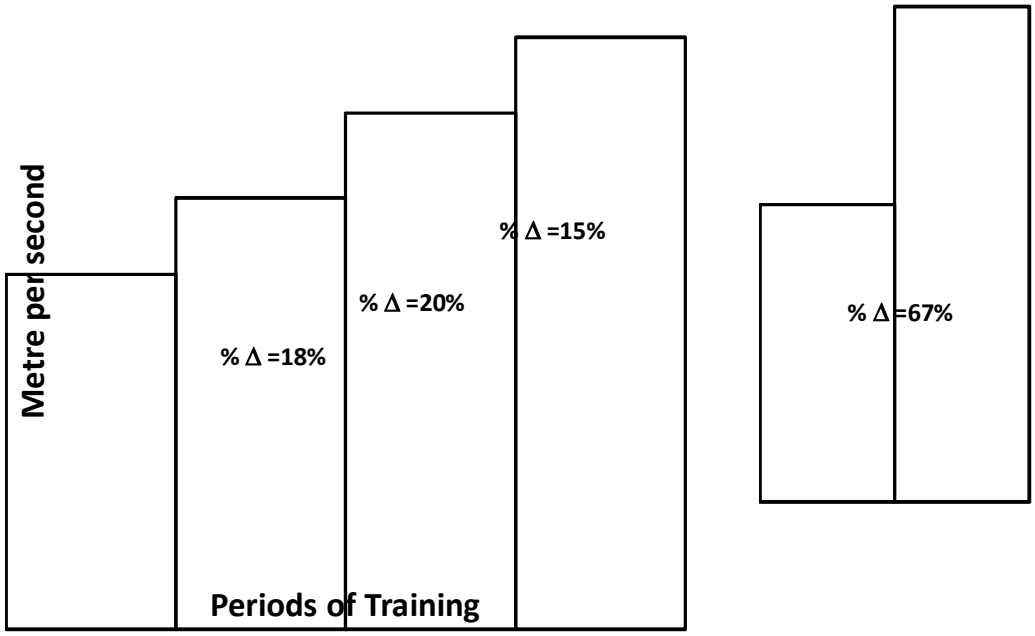


Figure 4:2:9: Histogram showing increase in walking speed of stroke patients in stair climbing group.

The histogram (Figure 4.2.9) showed continued increase walking speed of stroke patients in stair climbing group. The percentage changes from pretest (m = 0.42m/s) to 4th week (m = 0.51m/s), 4th week (m = 0.51m/s) to 8th week (m =0.61m/s) and 8th week (m = 0.61m/s) to 12th week (m = 0.70m/s) were 18th, 20% and 15% respectively. These results showed that greater improvement in walking speed occurred from pretest to 4th week and from 4th week to 8th week of the training. Although there was improvement in walking speed of stroke patients from the 8th week to 12 week, the percentage change of 15% was smaller than the percentage changes obtained from either pretest to 4th week of 18% or from 4th week to 8th th week when the percentage change was 20%. The percentage change from pretest (m = 0.42m/s) to posttest (m=0.70m/s) was 67%. The implication of these results was that the improvement in walking speed of stroke patients who used stair climbing training continued to improve even after 12 weeks of

training. It was therefore suggested that more than 12 weeks of stair climbing training should be prescribed to stroke patients to achieve greater increase in walking speed.

The effects of usual physiotherapy alone on walking speed of stroke patients were discussed below with the aid of a histogram in Figure 4.2.10;

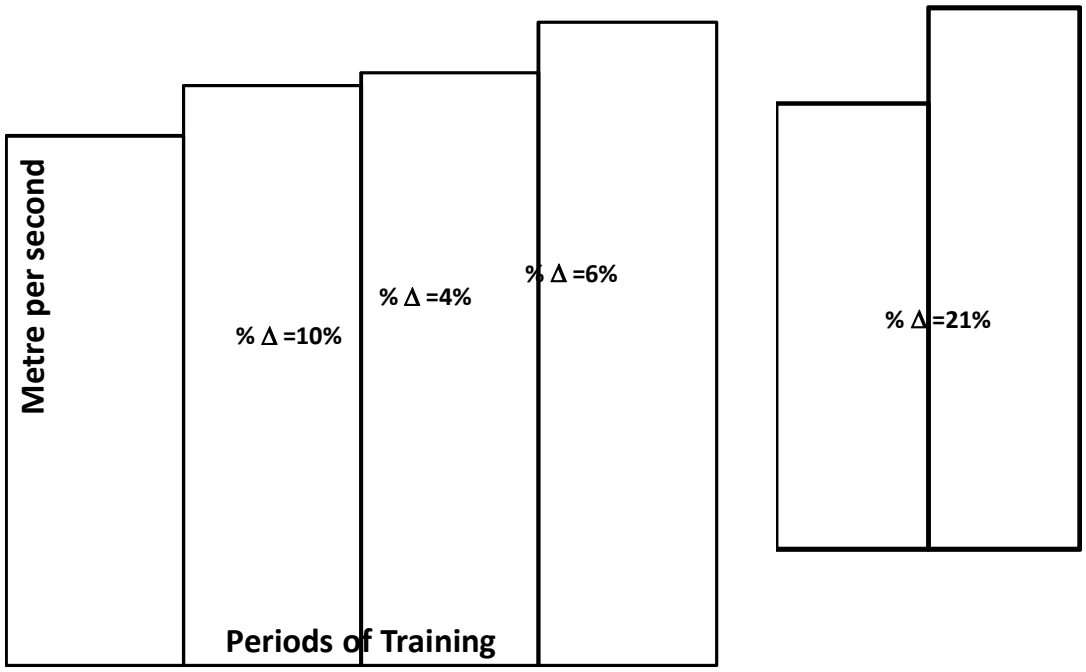


Figure 4:2:10: Histogram showing increase in walking speed of stroke patients in Control group.

An observation of the histogram (Figure 4.2.10) showed that there was gradual increase in walking speed from pretest (0.42m/s) to posttest (m = 0.51m/s) with a percentage change of 21%. The greatest improvement in walking speed occurred from pretest (m =0.42m/s) to the 4^{th} week (m = 0.46m/s) when the percentage change was 10%. Subsequently, the rate of increase in walking speed became small with the 4^{th} week to 8^{th} week percentage change of 4% and 8^{th} week to 12^{th} week percentage change of 6%. The implication of these results was that physiotherapy alone was not effective in the improvement of walking speed of stroke patients. It was therefore suggested that

either cycle ergometer or stair climbing training should be used by the stroke patients, in addition to physiotherapy to achieve greater increase in walking speed.

The effects of cycle ergometer training on muscular endurance of stroke patients were discussed with the aid of a histogram as shown in Figure 4.2.11.

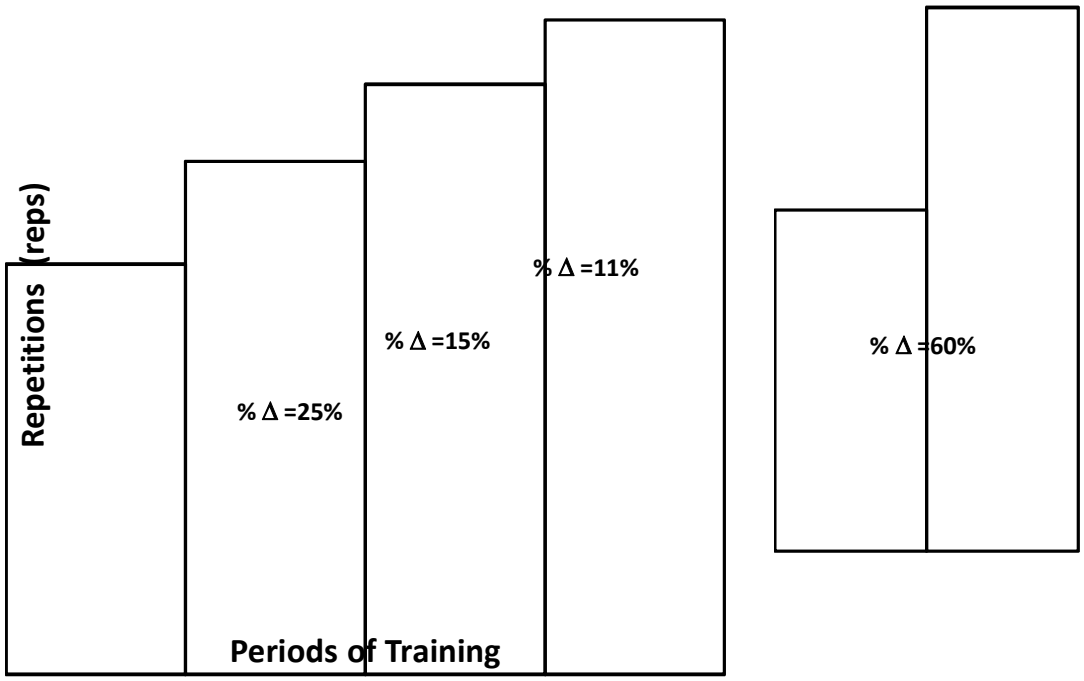


Figure 4:2:11: Histogram showing increase in muscular endurance of stroke patients in cycle ergometer training group.

The histogram (Figure 4.2.11) showed a gradual increase in muscular endurance of stroke patients in cycle ergometer training group from pretest (m = 4.00 reps) to the 4^{th} week (m = 5.00 reps) with a percentage increase of 25%. Similarly, there were increase in muscular endurance from 4^{th} week to 8^{th} week (m = 5.75 reps) and from 8^{th} week to 12^{th} week (m = 6.38reps) with percentage changes of 15% and 11% respectively. The percentage change from pretest to posttest was 60%. The meaning of these results was that the increase in muscular endurance could continue even after 12

weeks of cycle ergometer training. It was therefore suggested that the period of cycle ergometer training should be greater than 12 weeks for stroke patients to achieve greater improvement in muscular endurance. Nevertheless, the greatest improvement in test period was achieved from pretest to the 4th week when the percentage change was 25%.

The effects of stair climbing training on muscular endurance of stroke patients were discussed with the aid of a histogram in Figure 4:2:12.

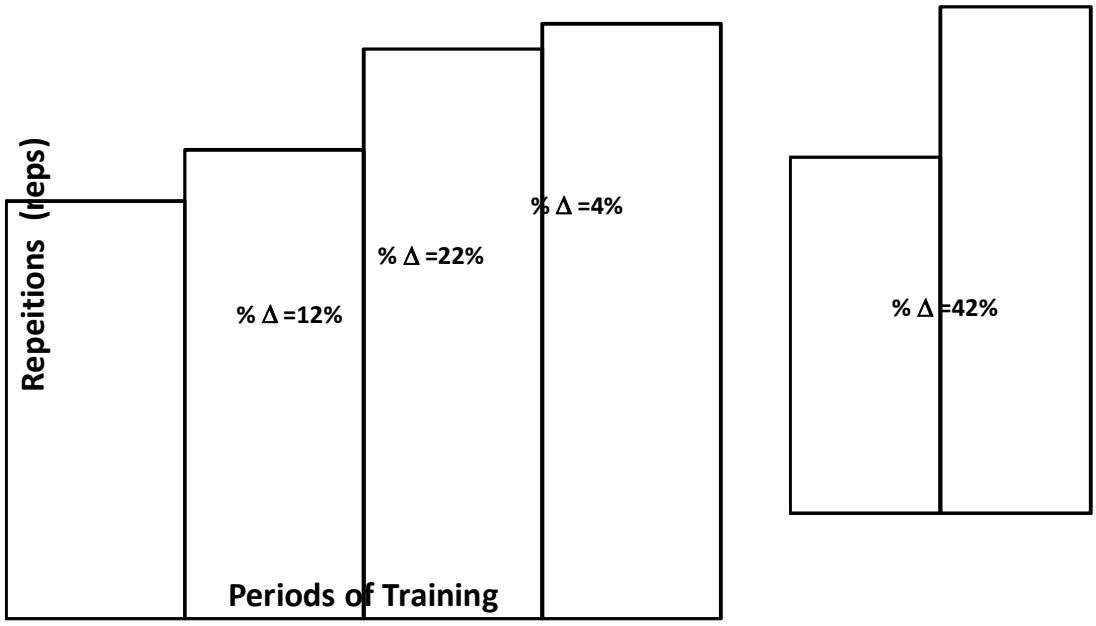


Figure 4:2:12: Histogram showing increase in muscular endurance of stroke patients in stair climbing training group

The histogram showed percentage changes of 12%, 22% and 4% from pretest (m = 4.13 reps) to 4th week (m = 4.63 reps), 4th week to 8th week (5.63 reps) and 8th week to 12th week (5.88 reps) respectively. The results showed that the greatest increase in muscular endurance of stroke patients occurred from the 4th week to 8th week. The increase in muscular endurance from 8th week to 12th week was very small with percentage change of only 4%.

The implication of this finding was that it would be clinically irrelevant for stroke patients to undergo stair climbing training longer than 8 weeks.

The effects usually physiotherapy on muscular endurance of stroke patients were discussed with the aid of a histogram in Figure 4:2:13.

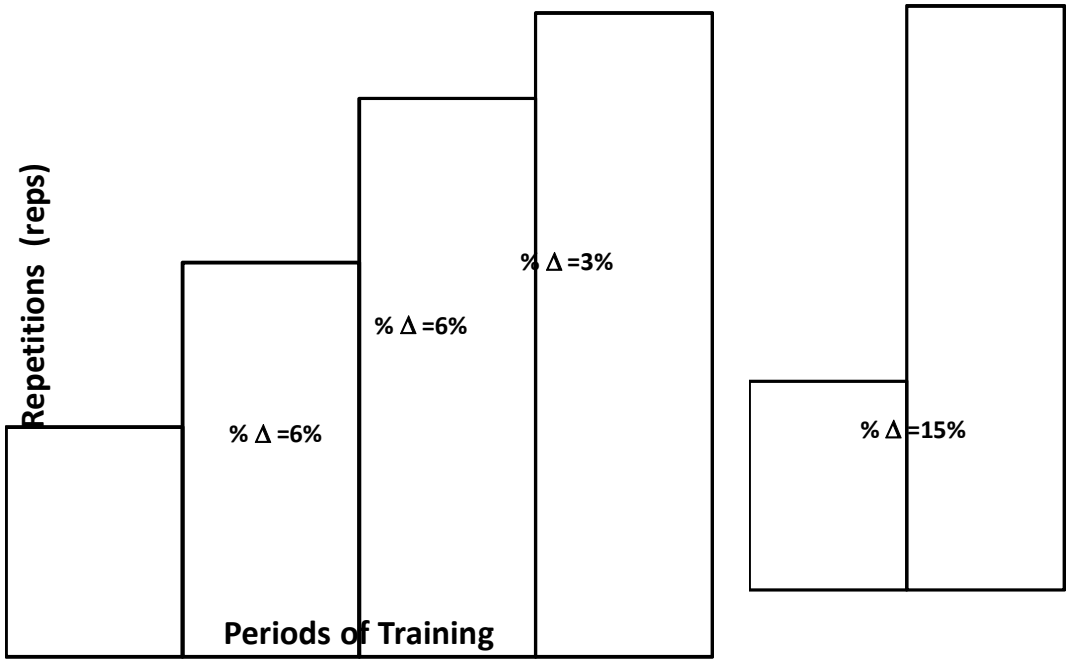


Figure 4:2:13: Histogram showing increase in muscular endurance of stroke patients in control group

The histogram showed very gradual increase in muscular endurance of stroke patients during the test periods. There was increase from pretest mean score (m = 4.25 reps) to 4th week mean score (m = 4.50 reps), 4th week to 8th week (m = 4.75 reps) and from 8th week to 12th week (m = 4.88 reps) with percentage changes of 6%, 6% and 3% respectively. The implication of these results was that physiotherapy alone was not effective in the improvement of muscular endurance of stroke patients. It was therefore suggested that either cycle ergometer training or stair climbing training should be used together with physiotherapy to achieve a greater increase in muscular endurance of stroke patients.

4.3 DISCUSSION

The purpose of this study was to compare the effects of cycle ergometer and stair climbing exercise training on energy cost of walking, walking speed and muscular endurance of stroke patients. This study was conducted on the assumption that there were several factors that were central to maximizing the locomotor capacity of stroke patients. First, the spinal cord has the ability to respond to appropriate afferent information to generate stepping during walking (Edgerton et al., 1997). Second, activity – dependent plasticity occurs in the neural circuitry responsible for locomotion at both spinal and sub-spinal levels (Edgerton, de Guzman, Gregor, Roy, Hadgson, and Lovely, 1991; Dobkin, 1993; Mur & Steven, 1977). Using these principles as the basis for locomotor training, it is assumed that the nervous system adapts to specific activity and that recovery requires relearning the tasks of walking by providing the spinal cord with appropriate sensory information (Edgerton et al., 1991). This study was based on the fact that conventional gait training is usually designed to emphasize facilitation of recovery by applying the principles of overload to strengthen the affected musculature. It was for this reason that the comparative effects of cycle ergometer and stair climbing training on energy cost of walking, walking speed and muscular endurance of stroke patients were investigated, the results of which were presented and discussed in this section.

The first sub-hypothesis stated that there was no significant difference between the effects of cycle ergometer and stair climbing training on energy cost of walking of stroke patients. The t-test statistics was used to test this hypothesis. The difference in energy cost of walking of stroke patients between cycle ergometer and stair climbing training groups was significant at the 12^{th} week with cycle ergometer training producing greater improvement. The differences in energy cost of walking of stroke patients

between cycle ergometer and stair climbing training were not significant at the 4th and 8th weeks of training. The null hypothesis was therefore rejected.

This means that both cycle ergometer and stair climbing training had similar effects in reducing the energy cost of walking of stroke patients in the 8th week. The difference between the two training methods became significant in the 12th week of the training. The implication of the results was that stroke patients who do their training in cycle ergometer could get similar decrease in energy they spend in walking if they did their training in stair climbing up to the 8th week of training. However, training in cycle ergometer produced greater improvement in energy cost of walking at the 12th week.

This result was similar to the research reported by Slijper et al., 2012. They conducted a research to find out if there would be a significant difference in energy cost of walking between two different orthosis devices applied for gait training of stroke patents for a period of six months. The result from their study showed no significant difference between the two orthosis devices. The physiological cost index of the two different orthosis devices were of 1.08 and 1.17 beat per meter were similar to the physiological cost index obtained after 8 weeks of cycle ergometer and stair climbing training respectively in this study. However, similar improvement in energy cost of walking with two different orthosis devices continued up to six months whereas in this study the difference in improvement in energy cost of walking between cycle ergometer and stair climbing training became significant during the 12th week.

The second sub-hypothesis stated that there was no significant difference between the effects cycle ergometer and stair climbing training on walking speed of stroke patients. The t-test statistics was used to test this hypothesis. The difference in walking speed of stroke patients between cycle ergometer and stair climbing training groups was significant at the 12th week when cycle ergometer training produced greater

improvement. There were no significant differences in walking speed of stroke patients during the 4th and 8th weeks of training between cycle ergometer and stair climbing training groups. This null hypothesis was therefore rejected.

These results mean that both cycle ergometer and stair climbing training had similar effects in increasing the walking speed of stroke patients up to the 8th week. The difference in the effects of these two training methods in walking speed of stroke patients became significant after 12 weeks of training. This implied that any of the two training methods could be applied to stroke patients if the periods of training should not be extended beyond 8 weeks. However, the results of this study showed that cycle ergometer training was more effective at the 12th week.

Walking speed is very important to stroke patients as it makes them more independent in walking. An increase in walking speed of 0.20m/s was considered clinically relevant (de Wit et al., 2004). In this study, walking speed increased by 0.48 m/s and 0.28m/s in cycle ergometer and stair climbing training respectively. In a previous study, Slijper et al. (2012) trained stroke patients on dynamic hinged ankle – foot orthosis and custom – made ankle – foot orthosis to find their comparative effects on gait speed of stroke patients. The differences between these two training protocols in their effects on gait speed of stroke patients were neither statistically significant nor clinically relevant. Significant improvement was found in this study for both cycle ergometer and stair climbing training with changes in walking speed of 0.48m/s and 0.28m/s respectively. The difference between these values (mean difference of 0.20m/s) was clinically relevant. This difference could be attributed to greater improvement in the efficiency of walking in cycle ergometer training group compared to stair climbing training group used in this study. These findings were in agreement with those of Perry (1992), which showed positive association between walking speed and gait efficiency.

Cycle ergometer training was a better training protocol than stair climbing training in improving walking speed of stroke patients as observed from the results of this study. In contrast, some researchers observed insignificant differences between the effects of different training methods on the improvement of walking speed of stroke patients. For example, Dickson (2008) reported that among the various training methods for gait training of stroke patients that their mode of application and cost varied, yet training outcomes were largely similar. They further reported that simple "low technology" and conventional exercises to date were at least as efficacious as more complex instrument such as treadmill and robot – based training equipment.

It was observed from the results of this study (Table 4.2.3a) that improvement in walking speed of the subjects continued to improve even after 12 weeks of cycle ergometer and stair climbing training. An important implication of this study was that a potential benefit from task – oriented aerobic training to a clinically relevant task of hemiparetic ambulation could occur. This finding was in contrast with previous studies that reported that improvement in walking speed plateaued before 12 weeks of training (Van de port et al., 2006; Kwakkel et al., 2006).

The third sub-hypothesis stated that there was no significant difference between the effects of cycle ergometer and stair climbing training on muscular endurance of stroke patients.

The t – test statistics was used to test this hypothesis. There were no significant differences in muscular endurance of stroke patients during the 4^{th}, 8^{th} and 12^{th} weeks between cycle ergometer and stair climbing training groups. The null hypothesis was therefore accepted.

The results mean that both cycle ergometer and stair climbing training had similar effects in increasing the muscular endurance of stroke patients. This implied that

any of these two training methods could be applied to stroke patients to achieve similar improvement in muscular endurance. Another implication of these results was that choosing cycle ergometer or stair climbing training would depend on the availability of cycle ergometers or staircase and on the preference of the patients since they provided similar gains in the restoration of muscular endurance of stroke patients.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

Comparative effects of cycle ergometer and stair climbing training on energy cost, walking speed and muscular endurance of stroke patients were presented in this chapter. The chapter contained the major findings, conclusion and recommendations.

5.1 Summary

This study was conducted to compare the effects of cycle ergometer and stair climbing training on energy cost of walking, walking speed and muscular endurance of stroke patients. To achieve the purpose of the study, 24 volunteer stroke patients attending physiotherapy clinics at Ahmadu Bello University Teaching Hospital, Zaria, were recruited randomly by balloting to three groups of 8 patients each. Group A was cycle ergometer training, Group B stair climbing training and Group C which was the Control group. Cycle ergometer training consists of cycling on stationary bicycle at intensity of 55% at the beginning of the training, progressed to 62% at the 8^{th} week and 70% of maximal heart rate at the 12^{th} week for 30 minutes (ACSM, 1998). This was repeated in three alternate days of a week for 12 weeks.

Stair climbing training consists of climbing a specially designed wooden staircase up and down at intensity of 55% to 70% of maximal heart rate for 30 minutes (ACSM, 1998), which was repeated in three alternate days of the week for 12 weeks. The intensity of this training was increased from 55% in the first week to 70% of maximal heart rate towards the 12^{th} week of training.

All the patients from the three groups were tested in energy cost of walking, walking speed and muscular endurance by established and reliable methods before

starting the training. These tests were repeated after every 4 weeks of training in all the groups. Descriptive statistics of means, standard deviations and standard errors of energy cost of walking, walking speed and muscular endurance in cycle ergometer, stair climbing training and control groups were computed. The t-test statistic was used to compare the effects of the training on the mean scores of energy cost, walking speed and muscular endurance of the experimental groups. Rejection or acceptance of any of the hypotheses was carried out at 0.05 probability level of significance.

The hypotheses were tested in line with the objectives of comparing the effects of cycle ergometer and stair climbing training on energy cost of walking, walking speed and muscular endurance of stroke patients. The major findings were stated below:

1. The difference in energy cost of walking of stroke patients between cycle ergometer and stair climbing training groups was significant at the 12^{th} week with cycle ergometer training producing greater improvement. Furthermore, energy cost of walking of stroke patients between cycle ergometer and stair climbing training were not significant at the 4^{th} and 8^{th} weeks of training.
2. The difference in walking speed of stroke patients between cycle ergometer and stair climbing training groups was significant at the 12^{th} week when cycle ergometer training produced greater improvement.
3. There were no significant differences in walking speed of stroke patients during the 4^{th} and 8^{th} weeks of training between cycle ergometer and stair climbing training groups.
4. There were no significant differences in muscular endurance of stroke patients during the 4^{th}, 8^{th} and 12^{th} weeks between cycle ergometer and stair climbing training groups.

5. The improvement in energy cost, walking speed and muscular endurance of stroke patients continued up to 12 weeks of cycle ergometer and stair climbing training.

5.2 Conclusion

1. Cycle ergometer and stair climbing training were effective methods used to improve energy cost, walking speed and muscular endurance of stroke patients.
2. Cycle ergometer training was more effective than stair climbing training in the improvement of energy cost, walking speed and muscular endurance of stroke patients.
3. Physiotherapy alone was not effective when compared with cycle ergometer and stair climbing training in the improvement of energy cost, walking speed and muscular endurance of stroke patients.
4. Improvement in energy cost, walking speed and muscular endurance of stroke patients continues to 12 weeks of training in cycle ergometer, stair climbing training and control groups.

5.3 Recommendations

The following recommendations were hereby made based on the findings of this study:

1. The use of cycle ergometer to improve energy cost, walking speed and muscular endurance of stroke patients should be emphasized by exercise scientists.
2. The use of stair climbing to improve energy cost, walking speed and muscular endurance of stroke patients should be emphasized by exercise scientists.

3. Physiotherapists should use any of the two methods as alternative exercise for improving mobility of stroke patients without resorting to more expensive exercise instruments.
4. Physiotherapy should be applied with either cycle ergometer or stair climbing to improve energy cost, walking speed and muscular endurance of stroke patients.

Areas of Further Research

1. Walking speed as a proxy measure of energy expenditure of walking should be investigated since this study showed strong relationship between the energy cost of walking and walking speed.
2. Further studies are recommended for patients with greater severity of stroke to determine the effects of exercise training on their gait efficiency.

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