Ergo bike-based locomotor training and leg ankle weights to enhance muscle strength and functional ambulation among patients with chronic hemiparetic stroke

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ABSTRACT

Stroke is the sudden loss of neurological function caused by an interruption of the blood flow to the brain. It is a leading cause of disability with residual neurological deficits that persistently impair function and leads to profound physical deconditioning. By limiting mobility, the hemiparetic gait that accompanies chronic stroke promotes a sedentary lifestyle which leads to disability through deconditioning and "learned non-use". Impaired motor function is one of the major factors contributing to a long-term disability in many patients with stroke and the restoration of these functions is a major goal in stroke rehabilitation. Muscle weakness has been implicated as a factor underlying deficits in gait performance in subjects with stroke. In this study the effectiveness of ergo bike-based locomotor training and open chain exercise with leg ankle weights to enhance muscle strength and functional ambulation among patients with chronic hemiparetic stroke was assessed using the manual muscle testing, upright motor control, type of ambulation and level of assistance. Experimental design was utilized in this study to compare which treatment approach was more effective in improving muscle strength and functional ambulation as to level surface, type of ambulation and level of assistance. Eighteen patients with chronic hemiparetic stroke were included in the study with the following inclusion criteria: 50-70 years old, mesomorph, type B personality and suffered second episodes of stroke. Patients were then grouped into two: nine for the controlled group and another nine for the treatment group. Controlled group were those who underwent leg ankle weights upon doing open chain exercises for one month and the treatment group were those who were treated using ergo-bike with resistance. Prior to the study, each patient underwent a standardized physical therapy assessment in which muscle strengths of both lower extremities and functional ambulation as to level surface, type of ambulation that were used and the level of assistance were assessed. Pre- assessment was done on both groups during the first week and on the fourth week post- assessment with the same criteria was conducted. Outcomes revealed that there was no significant difference between the two methods in terms of muscle strength, and functional ambulation as to the level surface. There was significant difference between the two methods in terms of type of ambulation and level of assistance, it was therefore concluded that the ergo bike-based locomotor training was more effective than open chain exercise with leg ankle weights.

Keywords: Ergo-bike, locomotor training, leg-ankle weights, muscle strength, functional ambulation, hemiparetic stroke

INTRODUCTION

Stroke is the sudden loss of neurological function caused by an interruption of the blood flow to the brain. Its major contributing factor is atherosclerosis characterized by plaque formation with an accumulation of lipids, fibrin, complex carbohydrates and calcium deposits on arterial walls that leads to progressive narrowing of blood vessels. It is a leading cause of disability [1–4], with residual neurological deficits that persistently impair function and lead to profound physical deconditioning [5–6]. It is a common disease that is associated with aging, with 72% of people who suffer a stroke in any year aged 65 and older [7]. Typically it is a disease of the older adult and the risk of stroke doubles for each decade after the age of 55[8]. Hemiparesis is the most common chronic disabling sequelae after stroke [9–11]. By limiting mobility, the hemiparetic gait that accompanies chronic stroke promotes a sedentary lifestyle which leads to disability through deconditioning and "learned non-use" [12–13].

Stroke-related impairments may lead to reduce mobility and foster a sedentary lifestyle that has been associated with further functional decline [14–15], social isolation, and depression [16–17]. Whereas the major physical impairments as a consequence of stroke are weakness and loss of coordination [18], and many everyday activities are unachievable or are accomplished with great effort and difficulty. In particular, weakness has been shown to contribute to the functional deficits observed after stroke [19–21]. Impaired motor function is one of the major factors contributing to a long-term disability in many patients with stroke and the restoration of these functions is a major goal in stroke rehabilitation [22]. Impaired mobility following cerebrovascular accident (CVA) or stroke is a common reason for referral to physical therapy. Although mobility problems occur, 57-85% of patients with hemiparesis are able to achieve independence with ambulation 6 months after stroke [23]. Acute neurological impairments often resolve spontaneously but persisting disabilities lead to partial or total dependence in activities of daily living in 25–50% of the survivors of the insult [24]. However, many patients with hemiparesis, who recover the ability to ambulate independently, continue to persist with slow gait speed and asymmetrical movement patterns [25]. Although approximately, 70% to 80% of adults who have survived a stroke will recover the ability' to walk short distances on flat surfaces, only 50% achieve even limited community ambulation' and fewer than 20% have difficulty in community ambulation. An essential part is the restoration of mobility in an attempt to regain independent living and walking.

Increasing intensity of rehabilitation and gait training is often beneficial, since many patients with chronic stroke have difficulty to improve their ambulation [26]. There is evidence that certain rehabilitation interventions are efficacious for assisting recovery in a person post stroke[27].The restoration of mobility is central to regaining independent living and gait training forms an essential part of the rehabilitation process. Intensive rehabilitation programme is often of great benefit, since many patients with CNS lesions show a marked improvement in their mobility [28].

Muscle weakness has been implicated as a factor underlying deficits in gait performance in subjects with stroke [29]. The relationship between lower extremity strength and gait speed is supported by previous studies that examined this relationship with the strength and power of individual muscle groups. In these studies, strength or power of the paretic knee extensors, hip flexors and plantar flexors, and the nonparetic knee extensors were found to predict gait speed in people with stroke. The different muscles identified in each of these studies may be partially explained by the strong relationship in weakness among muscle groups in an individual participant. It is well known that strength training of muscles within one extremity leads to a modest increase in strength in the contralateral homologous muscles [30]. It is now recognized that weakness is an important factor limiting the recovery of motor performance following brain damage [31, 32].

Patients with stroke have elevated hemiparetic gait costs secondary to low activity levels and are often severely deconditioned [33]. Impaired walking ability is a hallmark residual deficit following stroke. The impairment of gait is frequently responsible for long-term disability and handicap. In the early period following a stroke, lower-extremity (LE) paresis from impaired muscle activation limits the ability' to advance the limb for swing and to support body weight during stance. Patients with stroke have a specific walking pattern characterized by a longer stance phase of the non-affected leg than of the affected leg [34, 37]. Consequently the step time is longer on the affected side than on the non-affected side. The time and number of steps required to walk 10m is the most popular way to assess gait in stroke patients [38]. Abnormal swing phase after stroke can be characterized by reduced peak flexion values at all or any one of the lower-limb joints; a delay in the flexion at the hip, knee, or ankle; and/or lack of progression of flexion throughout the swing phase at the hip, knee, or ankle [39] . In the presence of these motor impairments, compensatory strategies can result in a number of characteristic gait patterns, including a “stiff-legged” swing phase in which the involved limb is dragged behind the torso [40], circumduction of the involved limb at the hip, hiking or elevating the involved side of the pelvis, vaulting onto the toes during stance on the uninvolved limb, or lateral leaning to the uninvolved side during swing on the involved side [41–42]. The slow velocity of gait is not only unsafe for some activities of daily living such as crossing streets, particularly in metropolitan regions[43] but also requires considerable effort because of poor walking efficiency[44] . It is also a barrier to walking independently within the community because a person needs to be able to walk relatively for long distances [45, 46]. As such, persons who have recovered from a stroke often have poor walking skills and endurance, usually being unable to walk continuously for 6 minutes [47]. Strategies to reduce the underlying impairments after stroke and thereby improve physical ability are needed if quality of living is to be enhanced in these older adults. Intervention techniques for retraining gait can be aimed at activities and or specific impairments (World Health Organization, 2001). Activity training reflects the assumption that functional activity-oriented practice leads to improved motor performance and skill acquisition [48]. Incomplete recovery and development of secondary impairments, however, may contribute to continued gait dysfunction.

Muscle strength and associated declines in functional performance related to normal aging can be ameliorated through strengthening programs and also may prove useful in promoting long-term independence for both stroke subjects and the elderly population [49]. Impairment in muscle strength is thought to be an important limiting factor in determining walking speed after stroke. There is a positive correlation between muscle strength and maximum gait speed. In light of the documented deficits in persons with hemiparesis, improving functional movement and strength without compromising motor performance should be a goal of the physical therapist. And studies suggest that effortful isokinetic exercise is beneficial for persons with hemiparesis [50-53]. An ideal exercise would specifically target weaker muscles without exacerbating abnormal muscle activity and would involve multi-segmental, complex movements that can be applied within a functional context.

Ergometer pedaling is an ideal functional exercise. The movement is significantly complex to provide a functionally relevant test for motor performance. Pedaling demands multi-segmental coordination of bilateral, reciprocal, symmetrical lower extremity movements in which the muscles go through periods of activity and subsequent passive lengthening. Because pedaling is functional, safe, and accessible to patients with a wide range of ambulatory function, the bicycle ergometer has been used to study bilateral movement patterns in several patient populations including stroke [54-61] and is commonly used in rehabilitation. Studies in stroke rehabilitation suggest that significant improvement in lower extremity function might result from using cycling as a training medium [54-56, 62]. Mechanical measures of pedaling performance can characterize impairment in persons with hemiparesis [60, 61]. To pedal at a given cadence and workload, the combined mechanical work done by the two limbs must be sufficient to overcome the resistive load. The net mechanical work done by the paretic leg represents the net contribution of the paretic limb and can be positive (the limb assists crank propulsion), negative (the limb resists crank propulsion), or zero. Since the total work provides a net measure for a cyclic movement, and pedaling typically includes periods of assistance and resistance [63], it is useful to independently assess the assistance and resistance provided by the leg. Cycling and walking share a similar locomotor pattern of reciprocal flexion and extension movements and have alternating muscle activation of antagonists [64, 65]. Cycling leg exercise, while sitting incorporates bilateral assisted active training; the paretic leg cycles with the help of the non-paretic limb. Thus, while strengthening the lower limb muscle, cycling activity acts as a pseudo walking task-oriented exercise and improve walking capacity. Beyond muscle strength, cycling exercise also encourages muscle control of the lower limbs which may enable patients to take more weight through the affected leg while standing [66]. Patients who participate in a short cycling exercise program continue to improve after the end of the program more than those who do not. Cycle ergometry may be the preferred mode of aerobic exercise for persons after stroke, because previous studies have shown that stroke patients do not have the capacity to walk at a sufficient pace to provide adequate stimulus to the cardiovascular system [67] .The ergo-bike based locomotor training with resistance is necessary to improve muscle strength and type of ambulation because it is a multisegmental movement same with the ambulation [68].

Exercise may have many beneficial effects at the level of skeletal muscle after stroke. It may prevent changes associated with physical inactivity [69, 70] .The World Health Organization (WHO) and the U.S. Centers for Disease Control and Prevention, citing strong scientific evidence regarding the benefits of exercise in reducing the risks of chronic disease, have urged that physical activity programs be considered integral to the prevention and management of chronic disease [71,72] .There is preliminary evidence that progressive resistance strength training programs reduce musculoskeletal impairment after stroke [73]. Patients who were involved in progressive resistance exercises were more independent at one month compared with patients who received functional training or active exercise [74]. Programs that combined muscle strength training with stretching, and conditioning have demonstrated significant improvements in walking function.

METHODS

Eighteen patients with unilateral impairment of the lower limb after chronic hemiparetic stroke who met the study inclusion in physical therapy rehabilitation department at Jose R. Reyes Memorial Medical Center. Inclusion criteria were the following: age 50–70 years, at least one year post stroke and suffered second episodes of stroke, mesomorph, type B personality, and motivated to participate in an intensive exercise programmed were included in the study. Exclusion criteria were the following: serious heart or lung disease or other medical conditions that made it difficult or risky to participate in intensive training, presence of other neurological diseases aside from stroke like brainstem lesions or bilateral signs, unconscious or totally incontinent after the event, severe pain or degenerative diseases to the musculoskeletal system, problems in terms of following the instructions; and close to normal sensori-motor function on the affected leg. Patients were grouped into a controlled group who were treated with leg ankle weights upon doing open chain exercises for one month and treatment group who were treated using ergo-bike with resistance. On the first week, pre assessment was done on both groups to evaluate the strength of the lower extremity muscles, functional ambulation as to level surface, type of ambulatory aid and level of assistance. On the fourth week, post assessment was conducted on both groups. Outcomes for one month assessment were collected, tabulated, computed and analyzed.

Design

The study aimed to compare the effectiveness of ergo-bike with resistance and open kinematic chain exercise with leg ankle weights among patients with hemiparetic stroke. Experimental design was utilized in this study to compare which treatment approach was more efficient in improving muscle strength and functional ambulation as to level surface, type of ambulatory aid and level of assistance.

Subjects

Eighteen patients with unilateral impairment of the lower limb after chronic hemiparetic stroke who met the study inclusion in physical therapy rehabilitation department at Jose R. Reyes Memorial Medical Center were recruited for the study and were asked to participate from February 2010 to March 2010. Inclusion criteria were the following: age 50–70 years, at least one year post stroke and suffered second episodes of stroke, mesomorph, type B personality, and motivated to participate in an intensive exercise programmed were included in the study. Exclusion criteria were the following: serious heart or lung disease or other medical conditions that made it difficult or risky to participate in intensive training, presence of other neurological diseases aside from stroke like brainstem lesions or bilateral signs, unconscious or totally incontinent after the event, severe pain or degenerative diseases to the musculoskeletal system, problems in terms of following the instructions; and close to normal sensori-motor function on the affected leg. Informed consent was given for each of the patient as to the purpose and benefits of the study. Subjects who qualified and agreed to participate in the study signed the written consent form approved by the Research Coordinating Council of Jose R. Reyes Memorial Medical Center. Subjects were then grouped into two: treatment group and controlled group.

Instrument

The researcher used the standard measurement for muscle strength and ambulation particularly manual muscle testing (MMT) and upright motor control. The evaluation was composed of pre and post assessment.

Procedure

Subjects signed an informed consent

MMT and Functional Ambulation were assessed

Grouped

Treatment group Controlled group

Ergo-bike with resistance Open chain exercise with leg ankle weights

Collect 2 outcomes:
MMT and Functional Ambulation (week 1)

Collect 2 outcomes:
MMT and Functional Ambulation (week 4)

Figure 1:

Explains that the study was conducted first by giving informed consent to the selected subjects, the diagram shows the comparison between muscle strength and functional ambulation which was divided into two programs the controlled group and the treatment group. The results were collected on the first week as a pre assessment and on the fourth week as a post assessment on both treatment group and controlled group. Both groups were expected to collect two outcomes the muscle strength and functional ambulation on level surface and were compared accordingly.

Data Analysis

Weighted mean, frequency distribution and Independent Sample t-test were used in the study to further analyze the results. The two variables were treated based on how effective the two procedures to the patient consisting of the pre and post assessment, the results were statistically computed as to the responses to the procedures using SPSS software version 17.

RESULTS AND DISCUSSION

Table 1
Muscle Testing Assessment for Muscle Strength using Ergo-Bike-Based Locomotor Training

Motion	Pre (Grade)	Interpretation	Post (Grade)	Interpretation
hip flexion	3.61 (3+)	Fair (+)	4	Good
hip extension	3.61 (3+)	Fair (+)	4	Good
knee flexion	3.72 (3+)	Fair (+)	4	Good
knee extension	3.72 (3+)	Fair (+)	4	Good
ankle dorsiflexion	3.72 (3+)	Fair (+)	4	Good
ankle plantarflexion	3.72 (3+)	Fair (+)	4	Good

Table 1 shows that there is significant increase of muscle strength during the post assessment of treatment group.

Table 2
Upright Motor Control for Ambulation Using Ergo-Bike-Based Locomotor Training

Motion	Pre	Interpretation	Post	Interpretation
hip flexion	2	Moderate	2	Moderate
hip extension	2	Moderate	2	Moderate
knee flexion	2	Moderate	2	Moderate
knee extension	2	Moderate	2	Moderate
ankle dorsiflexion	1	Weak	1	Weak
ankle plantarflexion	2	Moderate	2	Moderate

Table 2 shows that there are no changes upon ambulation using upright motor control assessment on both pre and post assessment of treatment group.

Table 3
Ergo-Bike-Based Locomotor Training

Type of Ambulation	Pre	Post
Non-Ambulatory (Wheel Chair)	6	-
Ambulatory (Quad Cane and Single Tip Cane)	3	9
Level of Assistance		
Plus one moderate assist	7	-
Plus one minimal assist	2	9

Table 3 shows that there are significant changes on the type of ambulation and level of assistance during post assessment.

Table 4
Muscle Testing Assessment for Muscle Strength using Open Chain Exercise with Leg Ankle Weights

Motion	Pre (Grade)	Interpretation	Post (Grade)	Interpretation
hip flexion	3.67 (3+)	Fair (+)	4	Good
hip extension	3.61 (3+)	Fair (+)	4	Good
knee flexion	3.67 (3+)	Fair (+)	4	Good
knee extension	3.67 (3+)	Fair (+)	4	Good
ankle dorsiflexion	3.67 (3+)	Fair (+)	4	Good
ankle plantarflexion	3.67 (3+)	Fair (+)	4	Good

Table 4 shows that there is a significant increase of muscle strength during the post assessment of controlled group.

Table 5
Upright Motor Control for Ambulation Using Open Chain Exercise with Leg Ankle Weights

Motion	Pre	Interpretation	Post	Interpretation
hip flexion	2	Moderate	2	Moderate
hip extension	2	Moderate	2	Moderate
knee flexion	2	Moderate	2	Moderate
knee extension	2	Moderate	2	Moderate
ankle dorsiflexion	1	Weak	1	Weak
ankle plantarflexion	2	Moderate	2	Moderate

Table 5 shows that there are no changes upon ambulation using upright motor control on post assessment of controlled group.

Table 6
Chain Exercise with Leg Ankle Weights

Type of Ambulation	Pre	Post
Non- Ambulatory (Wheel Chair)	6	3
Ambulatory (Quad Cane and Single Tip Cane)	3	6
Level of Assistance		
Plus one moderate assist	6	6
Plus one minimal assist	3	3

Table 6 shows that there are significant changes during post assessment based on the type of ambulation. There are no changes observed as to level of assistance.

Table 7.1
Comparison on the Effectiveness of Ergo Bike-Based Locomotor Training
α = 0.05; t_{table} = 2.306; df = 8

Motion	$t_{computed}$	Sig.Value	Interpretation
Pre – post of hip flexion	4.000	.004	Highly Significant
Pre – post of hip extension	5.292	.001	Highly Significant
Pre – post of knee flexion	4.000	.004	Highly Significant
Pre – post of knee extension	4.000	.004	Highly Significant
Pre – post of ankle dorsiflexion	4.000	.004	Highly Significant
Pre – post of ankle plantarflexion	4.000	.004	Highly Significant

Table 7.1 shows the difference on the effectiveness of ergo biked-based locomotor training during the pre and post assessment. It can be gleaned that all computed t values were greater than the critical value of 2.306 with 0.05 level of significance. This means that there was significant difference on muscle strength during the post assessment.

Table 7.2
Comparison on the Effectiveness of Open Chain Exercise with Leg Ankle Weights
$\alpha = 0.05$; $t_{table} = 2.306$; df = 8

Motion	$t_{computed}$	Sig.Value	Interpretation
Pre – post of hip flexion	5.292	.001	Highly Significant
Pre – post of hip extension	5.292	.001	Highly Significant
Pre – post of knee flexion	3.162	.013	Significant
Pre – post of knee extension	3.162	.013	Significant
Pre – post of ankle dorsiflexion	3.162	.013	Significant
Pre – post of ankle plantarflexion	3.162	.013	Significant

Table 7.2 shows the difference on the effectiveness of open chain exercise with leg ankle weights during the pre and post assessment. It can be gleaned that all computed t values were greater than the critical value of 2.306 with 0.05 level of significance. This means that there was significant difference on muscle strength during the post assessment.

Table 7.3
Comparison on the Effectiveness of Ergo Bike-Based Locomotor Training and Open Chain Exercise with Leg Weights on both Pre and Post Assessment of Muscle Strength
$\alpha = 0.05$; $t_{table} = 2.120$; df = 16

Motion	$t_{computed}$	Sig.Value	Interpretation
hip flexion	0.5000	0.624	Not Significant
hip extension	0.000	1.000	Not Significant
knee flexion	0.459	0.653	Not Significant
knee extension	0.459	0.653	Not Significant
ankle dorsiflexion	0.459	0.653	Not Significant
ankle plantarflexion	0.459	0.653	Not Significant

Table 7.3 shows the comparison of the effectiveness of ergo bike-based locomotor training and open chain exercise with leg ankle weights on both pre and post assessment. It can be noted that the computed t values were all less than the tabular value of 2.120 with degrees of freedom of 16 at 0.05 level of significance. There was no significant changes between the two methods which only indicated that either method can be used to strengthen the muscle.

Note: Upright motor control for ambulation using ergo bike and open chain exercise with leg ankle weights on both pre and post assessment (constant)

Table 7.4
Comparison on the Effectiveness of Type of Ambulation during Pre and Post Test
$\alpha = 0.05$; $t_{table} = 2.306$; df = 8

	$t_{computed}$	Sig.Value	Interpretation
Open chain exercise with leg ankle weights			
Pre – Post experiment	2.000	0.081	Not Significant
Ergo bike based locomotor training			
Pre – Post experiment	4.000	0.004	Highly Significant

Table 7.4 revealed that ergo bike-based locomotor training shows variation during pre and post test assessment since the resulted t value was greater than the tabular value of 2.306. This only means that there were improvements on the patients' conditions using this training method. In terms of open chain exercise with leg ankle weights, it was found out that the trainings that were given during the pre and post test were not significant.

Table 7.5
Comparison on the Effectiveness of Level of Assistance during Pre and Post Test
$\alpha = 0.05$; $t_{table} = 2.306$; df = 8

	$t_{computed}$	Sig.Value	Interpretation
Ergo Bike-Based Locomotor Training			
Pre – Post experiment	5.292	0.001	Highly Significant

Note: Open Chain Exercise with Leg Ankle Weights (constant)

Table 7.5 shows that there is significant difference on the pre and post test given using the ergo bike-based locomotor training. The resulted value of 5.292 was greater than the tabular value of 2.306 at 0.05 level of significance. It only implied that there was a big improvement among the patients' with chronic hemiparetic stroke.

CONCLUSION

There was no significant difference between the two methods in terms of muscle strength, and functional ambulation as to the level surface since there was significant difference between the two methods in terms of level of assistance and type of ambulation, it can be concluded that the ergo bike-based locomotor training was more effective than open chain exercise with leg ankle weights.

RECOMMENDATIONS

Based on the findings the following recommendations are given:

1. If the target outcome among chronic hemiparetic stroke is to improve the type of ambulation and enhance the level of assistance, the ergo bike-based locomotor training should be utilized rather than open chain exercise with leg ankle weights..
2. That this study shall be conducted on a larger population with the same parameters to determine the accuracy of effectiveness of one method over the other.

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