



Full Length Research Paper

Task-oriented circuit training improves ambulatory functions in acute stroke: a randomized controlled trial

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ABSTRACT

Stroke survivors have reduced ambulatory capacity which impairs their activities of daily living. Exercise training modalities can be used to improve ambulatory functions of stroke survivors. To investigate the effects of task-oriented circuit training in improving ambulatory functions of stroke survivors in the acute stage of stroke rehabilitation. Twenty (20) stroke survivors were randomized into circuit training group (CTG) and control group (CG), with 10 subjects in each group. The subjects in the CTG, in addition to conventional therapy, underwent 8 weeks of task-oriented circuit training; subjects in the CG received conventional physiotherapy treatment only. Assessments were done at weeks 4 and 8 with ten-metre walk test (10MWT), six-minute walk test (6MWT) and functional ambulatory category (FAC) as outcome measures. There were significant differences in the 10MWT, 6MWT and FAC between the CTG and the CG at week 8 ($P < 0.05$). There were significant differences in 10MWT and 6MWT within both CTG and CG at weeks 4 and 8 ($P < 0.05$). Mean differences in FAC within the CTG was significant ($P < 0.011$); but was not significant within the CG ($P > 0.591$) at weeks 4 and 8. Task-oriented circuit training improved ambulatory functions of stroke survivors in the acute stage.

Keywords: Stroke, Circuit Training, Stroke Rehabilitation, Ambulatory Function.

INTRODUCTION

Ambulatory or walking function is one type of activities of daily living (ADL) that becomes severely impaired following stroke. The ability to walk is impaired in more than 80% of stroke survivors (Verma et al., 2011). These observations are as a result of residual motor weakness, poor motor control and spasticity resulting in an altered gait pattern, poor balance and risk of falls during walking (Da Cunha et al., 2001). The increased energy cost of walking or gait fosters less willingness to move, favouring further decline in cardiovascular fitness, disuse atrophy and weakness (Lexell and Dutta, 1997; Macko et al., 1997). The physical deconditioning along with age-associated declines in fitness and muscle mass can

further contribute to activity intolerance, compromising patients' capacity to meet the high energy demands of hemiparetic gait (Lexell and Dutta, 1997). These show that stroke survivors, like most neurologically impaired individuals, have walking dysfunction arising not only from the impairments associated with the lesion but also from secondary cardiovascular and musculoskeletal consequences of the disease and physical inactivity (Carr and Shepherd, 2003). These make ambulatory retraining of stroke survivors an integral component of their rehabilitation (Yang et al., 2007; Olawale et al., 2011).

Several studies have explored ways of improving ambulatory functions of stroke survivors (Yocheved et al.,

2001; Pohl et al., 2002; Marigold et al., 2005; Al-Jarrah et al., 2014; Wu et al., 2014). In most of these studies, treadmill training has been the most commonly used method of improving ambulatory functions of stroke survivors. Many studies have been carried out on gait training of stroke survivors with the use of body weight support during training on a motorized treadmill (Hesse et al., 1995; Barbeau and Visintin, 2003; Ada et al., 2003). This method has been found to reduce body weight and some biomechanical factors to facilitate walking. Norman et al. (1995) found that a treadmill apparatus with harness support was useful for evaluation and rehabilitation of gait of stroke survivors. Furthermore, Hesse et al. (1995) reported that, treadmill training with partial body weight support improved ambulation of stroke survivors compared with conventional physiotherapy in non-ambulatory hemiparetic patients.

Ambulatory training after stroke should go beyond walking either on treadmill or overground. Thus, ambulatory restoration after stroke needs a more intensive and rigorous training that will holistically improve gait, balance, postural control and coordination as well as reducing energy cost of ambulation and risk of falls. Circuit training is one of such exercise training techniques that can be employed to improve ambulation of stroke survivors. Circuit training is a technique in which exercises are performed in successive stations with either a predetermined number of repetitions or for a set duration. It is an approach for training aerobic capacity in sports (Duncan and Sean, 2003). Previous studies have showed that organizing training into a circuit with series of workstations is safe and can result in improvements in muscle strength, gait speed, walking distance, stair climbing, and transfers (Dean et al., 2000; Wevers et al., 2009; English and Hillier, 2010; Dean et al., 2010, Van der Port et al., 2012). A controlled pilot trial revealed that, a task-related circuit training for the locomotor apparatus improved performance of task in patients with chronic stroke (Dean et al., 2000). Moreover, Van der Port and colleagues (2012) reported that, task oriented circuit training can safely replace usual physiotherapy for patients with stroke who are discharged from inpatient rehabilitation to the community and need further training in gait and gait related activities.

Ambulatory retraining after stroke involving circuit training is under-searched area. Moreover, there is paucity of data regarding the use of circuit training as treatment intervention for restoring ambulatory functions in the early stages of rehabilitation of stroke survivors. Thus, the purpose of this study was to investigate the effect of task-oriented circuit training on ambulatory functions of stroke survivors in early stages of rehabilitation. Outcome measures were ten-metre walk test (10MWT), six-minute walk test (6MWT) and functional ambulatory category (FAC). It was hypothesised that task-oriented circuit training would improve ambulatory functions in acute stroke that conventional physiotherapy.

METHODS

Subjects

This study was conducted at the Physiotherapy Department of Korle-Bu Teaching Hospital, Accra, Ghana. The study involved hemiparetic stroke survivors referred for physiotherapy. Twenty (20) hemiparetic stroke survivors were recruited into the study. Thirteen (13) were males and seven (7) females. Inclusion criteria were first-episode single stroke, stroke duration of <3 months, ability to walk 10 metres independently with or without walking aid and functional ambulatory category (FAC) score of 3 or more. Patients were excluded from the study if they had aphasia, cardiac arrhythmias or any such conditions which make exercises contraindicated. The study was approved by the Ethical and Protocol Review Committee of University of Ghana School of Allied Health Sciences. All subjects who met the inclusion criteria gave written informed consent after having understood explanations of the study protocol and any potential risk that could be encountered.

Procedure

Subjects were randomized into two groups: Group 1: circuit training group (CTG) and Group 2: Control group (CG). Each group consisted of ten subjects. Both groups received treatment thrice a week for 8 weeks.

Group 1 (Circuit Training Group)

Treatment for CTG began with two sessions of pre-test. The pre-test was to familiarize subjects to the exercise stations in the circuit. It involved testing the six exercises used in the circuit training to estimate the level of capacities of the subjects in terms of sets, repetitions and times for the exercises and what they were supposed to do in the course of the training. The exercises were treadmill walking, push-ups, squatting, straight leg raise (SLR), stairs walking and cycling exercises. The circuit comprised six (6) exercise stations:

- (1) **Station 1 - Treadmill walking**3 minutes with speed of 0.9 km/h
- (2) **Station 2 - Push-Ups**1 set of 10 repetitions in a minute
- (3) **Station 3 - Squatting exercise**1 set of 15 repetitions in a minute
- (4) **Station 4 - Straight Leg Raise exercise**1 set of 10 repetitions in a minute
- (5) **Station 5 - Stairs walking**3 minutes
- (6) **Station 6 - Cycling**3 minutes

The frequency of the circuit training was three times per week, for eight weeks. The circuit was performed twice per session. The intensity of the circuit training was targeted between 10 (light) and 15 (hard or heavy) of the

Borg's scale of rating of perceived exertion (RPE) (Borg, 1982). Thus, subjects performed circuit training at light intensity at the beginning and hard intensity towards the end of the session. The speed of the treadmill was between 0.9 km/h and 3.0 km/h; also the speed of cycling and resistance as well as squatting, straight leg raise and stairs walking were adjusted to the training intensity. The duration per training session was 35 minutes including: warm-up (5 minutes), first circuit training (12 minutes), rest interval (5 minutes) and the second or repeat circuit training (12 minutes). Thus, subjects performed 105 minutes of circuit training per week for 8 weeks. The type and nature of exercise stations was to achieve a total lower limb as well as total body work-out. The same circuit was used throughout the study period. The resting heart rate and blood pressure were monitored before and after each session. In addition to the circuit training, the CTG received the usual conventional therapy as the CG.

Group 2 (Control Group)

The control group received only the usual conventional therapy of passive and active exercises. Subjects also performed upper limb strengthening exercises, walking re-education, as well as standing and balance retraining carried out between parallel bars. Subjects performed walking re-education by starting between parallel bars and progressing to free overground walking with aids (cane).

Assessment on Outcome Measures

Both CTG and CG were evaluated at baseline and the 4th and 8th week using the 10-metre walk test (10-MWT), 6-minute walk test (6-MWT) and the functional ambulatory category scores (FACS). The test were performed on the same day between 8:00 am to 12:00 noon. The 10-MWT was performed first followed by the 6-MWT. Subjects who were on any medications were told to take them as prescribed. No special medication was involved in these tests. However, subjects were at liberty to request for water during these tests.

The 10-metre walk test (10MWT)

This test was done to assess the time taken by subjects to complete a ten-metre walkway. A 14-metre walkway was marked on the floor of the gymnasium. Subjects were told before the test that they could walk with or without walking aid and they were required to walk at their self-selected walking speeds (Dean et al, 2000). A stop clock was used to record the time taken by the subjects to cover ten-metre distance from the 2-metre mark to the 12-metre mark on the walkway. The stop clock was started simultaneously with the initiation of movements by the subjects. The time used to cover the 10-metre walkway was then recorded in seconds. Three

recordings were made and the average time calculated. This test was performed on a separate after the

The 6-minute walk test (6-MWT)

The 6-minute walk test was done to assess the walking endurance of the subjects. Subjects walked over a 40-metre walkway of the remedial therapeutic gymnasium for six minutes. The total distance covered during the 6 minutes was measured. Prior to the test, subjects were told that they could rest but that was allowed only at their request and it could be either sitting or standing and they were again told they could walk with or without their walking aids (Lord and Rochester, 2005).

The functional ambulatory category scores (FACS)

The functional ambulatory category scores were assessed while subjects were walking to evaluate the level of dependency of subjects in performing functional activities. FAC is a six-point hierarchical rating scale that reflects the amount of assistance a person requires to walk. This scale allows easy classification of patients in respect of their walking ability, with maximum score identifying a person able to ambulate independently on non-level surfaces (Holden et al, 1984). The points were scored according to the following: Score 0 - a subject is non-functionally ambulatory (cannot walk), Score 1- a subject requires continuous manual contact, Score 2- a subject requires intermittent manual contact, Score 3- a subject requires verbal supervision/guarding, Score 4- a subject is an independent ambulatory who can walk freely on level surface only, and Score 5- a subject is an independent ambulatory who can walk freely on any surface (Holden et al, 1984).

Data Analysis

The data were analyzed using the Epi-Info Software, 2000; version 3.32 of the Centre for Disease Control (CDC). All data were presented as mean plus or minus standard deviation (mean \pm SD). The paired and unpaired *t*- tests were used to find significant differences in the means of the outcome measure (10MWT, 6MWT and the FAC) within and between the groups respectively. A p-value of less than 0.05 ($p < 0.05$) was considered significant.

RESULTS

Twenty (20) subjects comprising thirteen (13) males and seven (7) females took part in this study. There were 10 subjects in each of the two groups.

The demographic profile of the subjects is presented in Table 1.

Table 1. Demographic characteristics of the subjects

Group	Gender	Age (yrs) (mean±SD)	Duration of stroke (months) (mean±SD)	Type of stroke		Affected side	
				Ischaemic	Haemorrhagic	Left	Right
CTG	M=7 (35%)	57.6 ± .3	2.2 ± 0.8	4 (44.4%)	2 (22.2%)	6 (30%)	4 (20%)
	F=3 (15%)						
CG	M=6 (30%)	55.8 ± 6.7	2.4 ± 0.9	2 (22.2%)	1 (11.1%)	7 (35%)	3 (15%)
	F=4 (20%)						

CTG – Circuit Training Group; CG – Control Group

Table 2. Comparing outcome measures in the CTG at baseline, week 4 and 8

	Baseline	Week 4	Week 8	P- value
6-MWT (m)	249.5 ± 10.7	251.6 ± 18.9	262.3 ± 17.9	0.064
10-MWT (s)	44.4 ± 4.7	46.3 ± 2.7	34.5 ± 3.1	0.068
FAC Score	3.3 ± 0.5	3.3 ± 0.5	3.4 ± 0.5	0.625

6-MWT – Six-Minute Walk Test, 10-MWT – Ten-Metre Walk Test, FAC – Functional Ambulatory Category.
*Significant.

Table 3. Comparing outcome measures in the CG at baseline, week 4 and 8

	Baseline	Week 4	Week 8	P- value
6-MWT (m)	253.0 ± 12.5	278.7 ± 20.4	360.2 ± 26.0	0.043*
10-MWT (s)	43.0 ± 3.7	40.2 ± 2.9	19.5 ± 1.5	0.033*
FAC Score	3.4 ± 0.5	3.8 ± 0.5	4.6 ± 0.5	0.043*

6-MWT – Six-Minute Walk Test, 10-MWT – Ten-Metre Walk Test, FAC – Functional Ambulatory Category.

Table 4. Comparing outcome measures at baseline between CTG and CG

	CTG	CG	P- value
6-MWT (m)	253.0 ± 12.5	249.5 ± 10.7	0.514
10-MWT (s)	43.0 ± 3.7	44.4 ± 4.7	0.473
FAC Score	3.4 ± 0.5	3.3 ± 0.5	0.662

6-MWT – Six-Minute Walk Test, 10-MWT – Ten-Metre Walk Test, FAC – Functional Ambulatory Category. No significant differences in outcome measures between groups ($p > 0.05$).

Table 5. Comparing Outcome Measures at week 4 between CTG and CG.

Outcome Measures	CTG (Mean ± SD)	CG (Mean ± SD)	P-value
6-MWT (m)	278.7 ± 20.4	251.6 ± 18.9	0.007*
10-MWT (s)	40.2 ± 2.9	46.3 ± 2.7	0.001*
FAC Score	3.8 ± 0.5	3.3 ± 0.5	0.024*

6-MWT – Six-Minute Walk Test, 10-MWT – Ten-Metre Walk Test, FAC – Functional Ambulatory Category.
*Significant

Table 6. Comparing Outcome Measures at week 8 between CTG and CG.

Outcome Measures	CTG (Mean \pm SD)	CG (Mean \pm SD)	P-value
6-MWT (m)	360.2 \pm 26.0	262.3 \pm 17.9	0.001*
10-MWT (s)	19.5 \pm 1.5	34.5 \pm 3.1	0.001*
FAC Score	4.6 \pm 0.5	3.4 \pm 0.5	0.002*

6-MWT – Six-Minute Walk Test, 10-MWT – Ten-Metre Walk Test, FAC – Functional Ambulatory Category.
*Significant

DISCUSSION

In this study, we investigated the effects of task-oriented circuit training on ambulatory functions of stroke survivors in the acute stages. The results showed that improvements in ambulatory functions were greater in the circuit training group than in the control group, as demonstrated by changes in 10-MWT, 6-MWT and FAC. All subjects were drawn from the same population of stroke survivors and no statistically significant differences (in 10MWT, 6MWT and FAC) were found among the two groups at baseline.

The results support earlier findings of studies on exercise training designed to improve walking functions of stroke survivors when compared with conventional therapy (Hesse et al., 1995; Norman et al., 1995; Olney and Richards, 1996; Richards and Olney, 1996; Yocheved et al., 2001; Pohl et al., 2002; Marigold et al., 2005; Olawale et al., 2011; Al-Jarrah et al., 2014). The improvements in walking abilities of the subjects in the circuit training group can be due to improvements in muscle strength and endurance of lower limb muscles, improved cardiorespiratory functions, speed, balance, neuromuscular control and coordination. Previous studies have reported that task-oriented circuit class training may be effective in terms of gait speed, walking distance and balance control (Dean et al., 2000; Mudge et al., 2009; Wevers et al., 2009; English and Hillier, 2010; Rose et al., 2011; Dean et al., 2010; Van der Port et al., 2012).

It has been reported that the effects of increasing therapy is enhanced if it involves the practice of higher levels of functional activities such as standing and walking (Van Peppen et al., 2004). Although physical activity is key to ambulatory functional recovery in stroke survivors, its effect becomes significant if it involves more weight-bearing exercise of the lower limbs (Van Peppen et al., 2004). Thus, the circuit stations utilized in this study mainly involved weight-bearing exercises which maximally tasked the locomotor apparatus for balance and postural maintenance while performing a particular motor task.

The subjects in the circuit training group recorded greater increases in 6-minute walk distance test than those in the control group. This connotes improvement in endurance and walking capacity at the end of the study period. The six-minute walk test is a measure of walking

endurance and it reflects the physical capacity and walking function at a submaximal level (Lord and Rochester, 2005). This outcome measure has been used in several studies in stroke survivors to measure walking endurance (Dean et al., 2000; Lord and Rochester, 2005; Straudi et al., 2009; Dean et al., 2010; Simpson et al., 2011). The total distance walked increased significantly from the 4th to 8th week, and it was about 52.1% to 65.5% respectively, of the predicted values of healthy subjects, as given by Enright and Sherrill (1998) equation. Pohl et al. (2002) evaluated the walking performance in stroke survivors and found that stroke-related neuromuscular impairments contribute to diminished performance in the 6-minute walk test. This means that even after the intensive exercise training, stroke survivors may still have walking limitations which calls for serious exercise programmes to restore to a near total or pre-stroke ambulatory functional state. This makes restoration and improvement of walking ability in these subjects a major treatment goal especially (Wade et al., 1987; Yocheved et al., 2001). Hence, a more rigorous and intensive exercise protocol can be of great advantage.

The time taken to walk ten metres improved better in the circuit training group over the study period. This means their walking speed increased and so covered the 10-metre walkway within a shorter time compared with their counterparts in the control group. Similar results were reported in other studies (Dean et al., 2000; Dean et al., 2001; Ada et al., 2003; Ada et al., 2010). Dean et al (2000) reported that stroke patients had low walking speed and this resulted in increased total energy cost of ambulation. Thus, a low walking speed together with poor muscle function and low aerobic capacity may result in a two-fold increase in energy cost of walking (Waters and Mulroy, 1999; Platts et al., 2006).

Furthermore, the FAC score improved significantly in the circuit training group when compared with the control group. The FAC is a six-point (from 0-5) hierarchical rating scale that reflects the amount of assistance a person requires to walk (Holden et al., 1984). This scale allows easy classification of subjects in respect of their walking ability, with maximum score identifying a person able to ambulate independently and without physical assistance (Holden et al., 1984; Kollen et al., 2006). All subjects who underwent the circuit training did not offer to use any assistive device during the test and about 75% of

them could walk on all surfaces at the end of the study period without any physical assistance. The FAC score gives a good indication of postural control and balance of patients when walking.

The results of this study indicate that improving ambulatory function with circuit training is feasible. This technique is usually viewed by some rehabilitation professionals as too vigorous for neurologically impaired individuals and hence, certainly not a choice or treatment preference. Meanwhile, circuit training is beneficial because, the technique harnesses effects of individual exercise in a unique fashion. Previous studies have reported the usefulness and effectiveness of treadmill alone with partial body-weight support and without body-weight support in gait training of stroke survivors (Yocheved et al., 2001; Barbeau and Visintin, 2003; Ada et al., 2003; Ada et al., 2010; Dean et al., 2010). However, findings of this study promise more advantages and better training effects by combining several exercises into circuits than using the individual exercises alone. Practically, it is easy to design circuit training from simple exercises and non-expensive exercise equipment. Circuit training stimulates the feeling of fun and saves time and gives opportunity for patients to individually challenge themselves. Moreover, patients find it enjoyable as it stimulates friendship and sharing of experience.

CONCLUSION

The circuit training utilized in this study resulted in increased walking speed, walking endurance and functional ambulatory category scores of the stroke survivors. Therefore, the study shows that circuit training can be used to improve ambulatory functions of stroke survivors in the acute stage. However, the outcome of the study warrants further investigation because of the relatively small sample size and short duration of the study.

Limitations of the study

The limitations of this study include small sample size and short period of study. Perhaps more robust results would have been obtained with a larger number of patients, longer duration and if the study had utilized a multi-centre design. Another limitation was that the subjects might not have received the best known current treatment in stroke rehabilitation. However, they received the ideal treatment available at the study centre at the time of the study.

ACKNOWLEDGEMENTS

The authors are grateful to the staff of Department of

Korle-Bu Teaching Hospital and all patients who participated in this study.

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How to cite this article: Frimpong E., Olawale O.A, Antwi D.A., Antwi-Boasiako C., Dzudzor B. (2014). Task-oriented circuit training improves ambulatory functions in acute stroke: a randomized controlled trial. *J. Med. Med. Sci*. 5(8):169-175