The effects of comprehensive core body resistance exercise on lower extremity motor function among stroke survivors

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Abstract. This study investigated the effects of comprehensive core body resistance exercise on lower extremity motor function in stroke survivors. This resistance exercise was developed to aid stroke patients with various severity to perform this exercise, aimed to improve their core strength, stability, and control. Thirty-four stroke patients aged 47.7±13.16 years old were selected from the Rehabilitation Department, Queen Elizabeth I Hospital in Sabah, Malaysia. All patients underwent supervised training either assistive, active or active resistance exercise, biweekly for 12 weeks. Motor function was evaluated using Fugl-Meyer Assessment Lower Extremity (FMA-LE). The data were collected at baseline and at four weeks training interval. Repeated measures ANOVA and paired $t$ test were employed to analyse the effects of the resistance exercise on lower extremity motor function. The twelve-week resistance exercise showed statistically significant effects on lower extremity motor function, lower extremity, coordination/speed, passive joint motion, and joint pain. However, sensation was found insignificant. Paired $t$ test showed statistically significant improvement in lower extremity motor function, lower extremity, coordination/speed, passive joint motion, joint pain, and sensation. This study suggested that the obtained results indicate that the core body resistance exercise was applicable without any induced negative effect such as spasticity or joint pain.
1. Introduction
Motor deficits are the most obvious impairments after stroke that define as “a loss or limitation of function in muscle control or movement or limitation of movement” [1, 2]. Hemiparesis or paresis on one side of the body and on the contra-lateral side to cerebral lesion [3] is the most common motor deficit after stroke. Hemiparesis will cause poor motor control, loss coordination, and reduced muscle strength on one side of the body.

Motor function impairments especially on the lower extremity affect patients’ gross motor skills and mobility as well as limit their abilities in activities of daily living (ADL), such as standing, transfers, walking, and stepping up and down stairs [4]. Their participation in society and their chances of returning to employment were also restricted. In stroke rehabilitation, motor recovery refers to the ability of an individual to carry out movement under voluntary control in the same manner as before the stroke [5].

A few studies have recognized that muscle weakness as the limiting factor in motor function recovery after stroke [6, 7]. Strengthening exercises are believed would be beneficial to lessen the effects of muscle atrophy [8] by increasing the muscle strength, which may result from an adaptation of the nerve tissues [9].

Resistance exercise refers to any exercise that causes the muscles to contract against an external resistance with the expectation of an increase in muscle strength, tone, mass, and/or endurance. This external resistance could be the own body weight, resistance band, weight, dumbbells, or any other object that can cause the muscle to contract [10]. A study by Wist et al. (2016) showed that progressive resistance training seemed to be the most effective treatment to improve strength on lower limbs, which improved balance and walking abilities in patients with chronic stroke significantly.

Previous research on resistance exercises typically focus on upper or lower limbs. The core of the body is often neglected. As a central key point of the body, the core muscles play an important role in providing optimal support for our body in antigravity posture and stabilization of proximal body parts during voluntary limbs movement [12].

In stroke rehabilitation, the core body muscle performance is an essential aspect in predicting the functional outcome after stroke [13]. Good core stability plays an important role in balance and extremity used during daily functional activities [14]. There was a study also showed that facilitating synchronization between global and local muscular activities help to improve balance and walking ability [15]. Achieving better core body control will improve better distal limb control that might be anticipated during balance and functional mobility [16].

Hence, this study was conducted to examine the effects of comprehensive core body resistance exercise on lower extremity motor function in stroke survivors. We believe, increase in core muscle strength, stability, and control could be transferred to improve lower extremity motor function.

2. Methods

2.1 Study design
A quasi-experimental, multiple post-test design without a control group was used in this study. The study intervention took place in the Physical Fitness Rehab Centre, Faculty of Psychology and Education, Universiti Malaysia Sabah, Malaysia. The study protocol was approved by the Medical Research and Ethics Committee, Ministry of Health Malaysia, NMRR-16-38-28777 (IIR). Ethical approval from the Director of Queen Elizabeth I Hospital was also obtained for approaching the stroke patients and accessing their case note.

2.2 Subject
The inclusion criteria used in this study were patients with the (1) age of 15 to 75 years old, (2) at least 3 months post-stroke, (3) unilateral hemiplegia or hemiparesis, (4) a minimum score of 24 out of 30 in Mini-Mental State Examination (MMSE), which indicated a normal cognition (i.e. able to understand simple verbal and visual instructions), (5) able to come twice per week to the research centre.
We excluded patients who were: (1) less than 3 months post-stroke to exclude spontaneous recovery, (2) bilateral hemiparesis, (3) unstable medical conditions such as severe respiratory and cardiac diseases, uncontrolled hypertension and diabetes, and mental illness, according to physicians’ examination, and (4) scoring less than 24 out of 30 on Mini-Mental State Examination (MMSE). Stroke conditions were confirmed based on patients’ medical report.

Based on the inclusion criteria, 260 patients were approached from the outpatient clinic, Department of Rehabilitation Medicine, Queen Elizabeth I Hospital, Sabah, Malaysia, but only 80 were willing to participate in the program. However, 50 patients were selected and consented but only 34 patients completed the 12-week intervention.

2.3 Intervention

In this study, the core of the body was broadly considered as the torso consisted of different muscle groups that resided in the area from the shoulder region, trunk and abdominal, pelvic and hips complex. Therefore, the prescribed comprehensive core body exercise program was employing supine, sitting, weight training, and functional movement training in which emphasised on targeting all core muscle groups including the local or global muscles using resistance exercises. The intervention was carried out for 12 weeks with two times sessions per week. Every patient was prescribed with 5 to 10 exercises that were targeting major core muscles group with 1-2 sets of 10-15 repetitions for each exercise session. The intensity of exercise increased progressively every 2 weeks and/or after the patients successfully achieved the given sets with proper technique.

This exercise program consisted of four stages starting from supine exercise, progressed to sitting exercise, weight machine, and the final stage of functional movement. All of the exercise guidelines protocols were summarized in Table 1. Mode of exercise and type of exercise prescribed were tailored according to the patient’s abilities based on the pre-requisition criteria for each stage to ensure the application of overload training principle as well as for safety purposes. Every patient underwent supervised core body resistance exercise either assistive, active or active resistance exercise training with specified exercise program prescription throughout this study. For the supine exercise stage, there were no pre-requisition criteria. A patient who presented with static posture control, sitting balance and stability was prescribed with the sitting exercise activities. Weight machine stage was only prescribed for a patient who showed dynamic posture control, stability and mobility, whereas functional movement exercise was only be initiated when the patient demonstrated joint stability, dynamic balance and mobility when performing selective activities.

All sessions were supervised to ensure patients performed a correct technique and to monitor the appropriate amount of exercise and rest intervals. If any movement was insufficient, the exercise trainer provided additional verbal instructions, manipulative inductions, or assistance. The blood pressure and heart rate measurement were taken before and after the intervention. Each exercise session began with static stretching and ended with cooling down in a sitting position, conducted by the trainer.
Table 1. Comprehensive core body resistance exercise protocol.

| Mode of exercise | Activity | Pre-requisite | Intensity/Duration | Frequency/ |
|------------------|----------|---------------|--------------------|------------|
| **Supine exercise** | | | | |
| Body weight | Glute bridge | None. | 1-2 sets of 10-15 repetitions. | |
| With or without assistance | Drawing in (TVA contractions) | | | |
| | Holding knee to chest | | | |
| | Knee marches | | | |
| | Hip abduction-adduction with knees bent or straight legs | | | |
| | Hip rotation with knees bent | | | |
| | Hip-knee flexion-extension | | | |
| | Abdominal crunch (with shoulder off the floor) | | | |
| | Double straight leg raise | | | |
| | Lateral side leg raise | | | |
| | Leg cross | | | |
| | Lateral trunk rotation. | | | |
| | Shoulder flexion (Bilateral arms movement) | | | |
| | IYT (Bilateral arms movement) | | | |
| **Sitting exercise** | | | | |
| With or without Resistance (thera band or resistance tube band) | Shoulder extension with back hyperextension | Static posture, sitting balance and stability. | | |
| | Arm row | | | |
| | Chest press | | | |
| | Trunk forward side bent | | | |
| | Lateral trunk flexion | | | |
| | Trunk Forward reach | | | |
| | Hip rotation | | | |
| | Hip abduction-adduction | | | |
| **Weight machine** | | | | |
| Load (10-15 RM) | Back extension | | | |
| | Leg press | | | |
| | Chest press | | | |
| | Ab crunch | | | |
| | Lat pull down or Low row | | | |
| | Hip rotator. | | | |
| **Functional Movement** | | | | |
| With or without support | Level 1: Squat | Joint stability, dynamic balance and mobility | | |
| | Level 2: Overhead squat | | | |
| | Level 1: Standing chest press (feet shoulder apart) | | | |
| | Level 2: Dumbbell overhead press | | | |
| | Level 1: Standing row | | | |
| | Level 2: Staggered stance standing one arm row | | | |
| | Level 1: Standing leg balance (horizontal abduction, frontal reach, diagonal reach) | | | |
| | Level 2: Half kneeling lunges rise. | | | |
| | Level 1: Thoracic rotation. | | | |
| | Level 2: Body swing | | | |
| | Static posture, sitting balance and stability. | | | |
2.4 Measurement
The Fugl-Meyer Lower Extremity (FMA-LE) consisted of 4 domains that comprised of Lower extremity motor function (LEMF), Sensation (S), Passive joint motion (PJM), and Joint pain (JP) (retrieved from Rehabilitation Medicine, University of Gothenburg, 2010) was used to evaluate lower extremity motor functions. Data were collected at baseline and four weeks training interval (wk0, wk5, wk9 and wk13).

2.5 Data analysis
To measure the effects of core body resistance exercise program employed in this study on lower extremity motor function, changes in lower extremity motor function, sensation, passive joint of motion, and joint pain were analysed using repeated measure ANOVA and paired sample \( t \) test using Statistical Package for Social Science (SPSS) version 20.0. The level of significance was set at \( p<0.05 \).

3. Results
As presented in table 2, the mean age of the study sample was 47.7±13.16 years, 58.8% was male, and time since onset was 17±15.35 months with 67.6% of patients sustained a haemorrhagic stroke and 55.9% of the stroke occurred on the right side.

| Table 2. The characteristic of participants. |
|--------------------------------------------|
| Gender n(%)                                |
| Male                                       | 20 (58.8%) |
| Female                                     | 14 (41.2%) |
| Paretic Side n(%)                          |
| Right                                      | 19 (55.9%) |
| Left                                       | 15 (44.1%) |
| Stroke type n(%)                           |
| Ischemic                                   | 11 (32.2%) |
| Haemorrhagic                               | 23 (67.6%) |
| Age (years – mean±SD)                      | 47.7±13.16 |
| Time since onset (months – mean±SD)        | 17±13.35   |

Repeated measures ANOVA analysis (Table 3) revealed that lower extremity motor function \( [F(33.99)=33.54, \ p<0.001] \), lower extremity \( [F(3.99)=33.16, \ p<0.001] \), coordination/speed \( [F(2.474,81.632)=9.13, \ p<0.001] \), passive joint motion \( [F(2.108, 69.557) =42.58, \ p<0.001] \), and joint pain \( [F(1.663,54.876)=9.06, \ p=0.001] \) were statistically significant except for the sensation \( [F(2.301,75.937)=2.54, \ p=0.78] \). The mean±SD values were however, progressively changed across time.
Table 3. Repeated Measure ANOVA data on the lower extremity (LE), coordination/speed (CS), lower extremity motor function (LEMF), passive joint motion (PJM), Joint pain (JP) and sensation (S).

|                | WK0       | WK5       | WK9       | WK13      | Repeated Measures ANOVA |
|----------------|-----------|-----------|-----------|-----------|-------------------------|
|                | mean±SD   | mean±SD   | mean±SD   | mean±SD   | df     | F       | p        |
| LE (mean±SD)   | 9.32±4.86 | 13.35±5.83| 12.62±6.10| 15.18±5.28| 3      | 33.16   | 0.000    |
| CS (mean±SD)   | 1.91±1.78 | 2.74±2.17 | 2.53±2.14 | 3.15±1.96 | 2.47   | 9.13    | 0.000    |
| LEMF (mean±SD) | 11.24±6.12| 16.09±7.67| 15.15±7.78| 18.32±6.75| 33     | 33.54   | 0.000    |
| PJM (mean±SD)  | 10.71±5.46| 17.03±3.60| 17.15±2.96| 17.53±2.84| 2.11   | 42.58   | 0.000    |
| JP (mean±SD)   | 15.76±5.66| 18.09±2.66| 18.06±2.35| 19.00±1.72| 1.66   | 9.06    | 0.001    |
| S (mean±SD)    | 7.97±4.24 | 8.79±3.94 | 8.59±4.02 | 9.24±3.65 | 2.30   | 2.54    | 0.78     |

As shown in Figure 3, the LEMF score increased significantly in test-2 before the slight decrease in test-3 due to some patients presented with health issues such as diarrhoea, flu, and one with low sodium (hyponatremia), during the assessment time. However, the LEMF means score showed an increase trend towards the last test. The improvement of LEMF was due to an increase in reflex activity, lower extremity volitional movement, and coordination/speed as shown in Figure 1 and Figure 2.

Figure 1. The changes in means score of lower extremity (LE) with comprehensive core body resistance training across time.
Figure 4 shows a sharp increase in PJM in test-2 before it slightly rose towards the last test. This indicated that an average passive joint motion in lower extremity compared to the unaffected side, showed the best improvement in test-2 due to the largest improvement in hip and knee PJM. The improvement was a slowdown in test-3 and test-4 because there were only slight changes in PJM in ankle and foot. A few patients who had contracture in the ankle also contributed to this trend. JP pain was improved significantly over the four test with a slight decrease in test-3 (Figure 5). Figure 6 shows some fluctuation in LES means score. There was a substantial increase in the test-2 before declining in test-3 and rose rapidly again in test-4. The decline in test-3 was most probably due to one patient who had a seizure episode just 2 weeks before assessment week and most likely such incident had affected the loss of sensation in the lower body.

Figure 2. The changes in means score of coordination/speed (CS) with comprehensive core body resistance training across time.

Figure 3. The changes in means score of lower extremity motor function (LEMF) with comprehensive core body resistance training across time.
Figure 4. The changes in means score of Passive Joint Motion (PJM) with comprehensive core body resistance training across time.

Figure 5. The changes in means score of Joint Pain (JP) with comprehensive core body resistance training across time.
Paired *t* test analysis (Table 4) shows that lower extremity motor function [mean diff=7.088, *p*<0.001], lower extremity [mean diff=5.853, *p*<0.001], coordination/speed [mean diff=1.235, *p*=0.001], passive joint motion [mean diff=6.824, *p*=0.001], joint pain [mean diff=3.235, *p*=0.001] and also sensation [mean diff=1.265, *p*=0.034] were improved significantly following the twelve-week intervention.

**Table 4.** Lower extremity, coordination/speed, lower extremity function, passive joint motion, joint pain and sensation before and after treatment.

|       | Pre (WK0) Mean±SD | Post (WK13) Mean±SD | Pre-Post Mean Diff±SE | *t*   | df | Sig (2-tailed) |
|-------|-------------------|---------------------|-----------------------|-------|----|----------------|
| LE    | 9.32±4.86         | 15.18±5.28          | 5.85±0.54             | 10.85 | 33 | 0.000          |
| CS    | 1.91±1.78         | 3.15±1.96           | 1.24±0.27             | 4.62  | 33 | 0.000          |
| LEMF  | 11.24±6.12        | 18.32±6.75          | 7.09±0.64             | 10.99 | 33 | 0.000          |
| PJM   | 10.71±5.46        | 17.53±2.84          | 6.82±0.80             | 8.50  | 33 | 0.000          |
| JP    | 15.76±5.66        | 19.00±1.72          | 3.24±0.88             | 3.67  | 33 | 0.001          |
| S     | 7.97±4.24         | 9.24±3.65           | 1.27±0.57             | 2.22  | 33 | 0.034          |

**Figure 6.** The changes in means score of sensation (S) with comprehensive core body resistance training across time.
4. Discussions
This study investigated the effects of core body resistance exercise on lower extremity motor function in stroke survivors. The motor function recovery in this study referred to the ability of the paretic lower extremity to carry out movement under voluntary control in the same manner as the normal side. At the end of 12 weeks, all patients demonstrated significant improvement in the LEMF domain. The improvement was as a result of enhancement in LE voluntary function and CS sub-domain score of the paretic lower extremity that evaluated in FMA-LE scale. Improvement in lower extremity voluntary function in this study was largely due to improvement in sub-test volitional movement within synergies and mixing synergies score. The increase in coordination/speed score was also observed in this study as a result of reducing in paretic leg tremor, less dysmetria, and improved in paretic leg speed during the assessment. These findings suggested that an increase in LE volitional movement and CS were occurred due to physiological responses to resistance exercise.

Core strength referred to the ability of the core muscle to generate force and power [17]. With stronger core muscles, together with neuromuscular facilitation, hence increase the core stability. Thus, increasing the core muscle strength in this study would help to improve lower extremity stability. This was because of forces generated at the core were transferred to the limbs for the limb movement to be efficient [18]. Regardless of the direction of extremity movement, trunk muscle activity happened before the activity of the prime mover of the extremity [19, 20]. Therefore, adequate core stability allowed the peripheral muscles to produce the same given amount of power with less forceful contractions [18], permitted an efficient transfer of power to the extremities [21]. Core stability also played an essential role to preserve the integrity of the spine, provided the resistance to perturbations, and supplied a stable base for movement the limbs [22].

Although exercise intervention used in this study focused on major core muscles, both limbs including the paretic limb were also forced to be used during exercises either assisted or passive movement. Whereby, most of the exercises prescribed in this study involved bilateral movement. Thus, adaptation with resistance training was not only occurred in core body muscles but also within the limbs. The central and peripheral adaptation of resistance training increased the motor unit recruitment and cortical reorganization [23] and therefore reduced atrophy [24] that led to the improvement in LEMF.

As demonstrated in this study, the core body resistance exercise led to a significant increase in lower extremity PJM and a reduce in JP during passive movement. These implied that resistance training had the potential to alter the passive viscoelastic properties of muscle and tendon [25], which could influence hypertonia. This finding was also in line with other recent studies [26, 27, 28], revealed that resistance exercise did not bring any harmful effects to stroke patients such as pain or exacerbation of spasticity.

Despite resistance exercise was rarely used in the past for stroke patient rehabilitation due to a fear of an increase in muscle spasticity, this study further confirmed the positive evidence that neither activities requiring effort nor strength training increase spasticity among stroke patients [11, 29, 30, 4]. Consequently, resistance or strength training should be reintroduced in a stroke rehabilitation program.

5. Conclusions
This study proposed the core body resistance exercise should be implemented as a part of rehabilitation training in patients with sub-acute and chronic stroke that sustained hemiplegia or hemiparesis. It would provide patients with an effective rehab program. Since core body resistance exercise was beneficial in improving lower limb motor function. Patient’s quality of life would improve accordingly as well. Specific training for sensation should be designed and adopted in stroke rehabilitation intervention for better improvement.
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