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Effectiveness of close kinematic chain exercise on lower limb functions in stroke survivors

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Abstract
Background: Stroke is defined as rapidly developed clinical signs of focal disturbance of cerebral function, lasting more than 24 hours or leads to death with no apparent cause other than of vascular origin. It is currently the most leading cause of death worldwide. Motor deficits are characterized by paralysis (hemiplegia) or weakness (hemiparesis) of limb/s. In maximum cases balance and gait impairments are persistent. Close kinematic chain exercises (CKC) emphasises the sequential movement of joints and require coordinated and sequential muscle activation patterns to control proper joint movement. CKC exercises have proven to be effective in improving balance.
Purpose: To assess the effectiveness of Close Kinematic Chain exercises on lower limb functions using Lower Extremity Functional Scale.
Methods: In this study, patients were randomly divided into two groups. Experimental group was given close kinematic chain (CKC) exercise and conventional group was given conventional exercises. 5 weeks of protocol was given to the patients in both the groups. Pre and post scores of Lower Extremity Functional Scale (LEFS) were recorded. Comparison was done between and within the groups.
Result: Experimental group showed significant improvement in lower limb functions compared to conventional group.
Conclusion: Close kinematic chain exercises are more effective in improving lower limb functions.

Keywords: TIA, stroke, CKC, balance, lower limb functions

1. Introduction

The World Health Organization (WHO) defined Stroke as rapidly developed clinical signs of focal disturbance of cerebral function, lasting more than 24 hours or leads to death with no apparent cause other than of vascular origin [1]. The latest estimate from the Global Burden of Disease injuries and risk factor study (GBD 2015) revealed that stroke is currently the most leading cause of death in worldwide. Ischemic heart disease and stroke together accounted for 15.2 million deaths (15-15.6 M) in 2015 [4]. The literature till date revealed that the burden of stroke in people less than 65 years has increased over the last few decades. So, the incidence has increased by 25% among adults aged 20 to 64 years worldwide. Some studies showed that about 12% of strokes occur among the population younger than 40 years [5].

Cerebrovascular accident [CVA] is the sudden loss of neurological function caused by an interruption of the blood flow to the brain. Strokes can be classified according to etiological categories (thrombosis, embolus and haemorrhage), specific vascular territory (anterior cerebral artery syndrome, middle cerebral artery syndrome and posterior cerebral artery syndrome) and management categories (transient ischemic attack, minor stroke, major stroke, deteriorating stroke and young stroke). But there are majorly two types of strokes, ischemic stroke and haemorrhagic stroke, which are commonly studied. Ischemic stroke is the most common type, affecting about 80% of individuals. It results when a clot blocks or impairs blood flow and reduces essential oxygen and nutrients to brain. Haemorrhagic stroke occurs when blood vessels rupture, causing leakage of blood in or around the brain. It affects the remaining 20%. Clinically, a variety of focal deficits are possible, including changes in the level of consciousness and impairments of sensory, motor, cognitive, perceptual, and language functions. To be classified as stroke, neurological deficits must persist for at least 24 hours.

Motor deficits are characterized by paralysis (hemiplegia) or weakness (hemiparesis), typically on the side of the body opposite to the side of the lesion. The term hemiplegia is often used to refer to variety of motor problems that results from stroke. The severity of neurological deficits in an individual depends on the location and the extent of brain injury, the amount of collateral blood flow and early acute care management received. Impairments of stroke may resolve spontaneously within 3 weeks as brain swelling subsides (reversible ischemic neurological deficit). The residual neurological impairments are those that persist longer than 3 weeks and may lead to lasting disability [6].

The basic principle in the approach to the medical management of stroke includes an attempt to achieve improvement in cerebral perfusion by re-establishing blood flow, decreasing neuronal damage at the site of ischemia by modifying the pathophysiological process and decreasing oedema in the area of damaged tissue. Many pharmacologic and surgical treatments have been targeted toward at least one of these areas. The pharmacologic therapies are divided broadly into antithrombotic, thrombolytic, neuroprotective and angioedema therapies. Surgical therapies include endarterectomy, extra cranial– intracranial bypass and balloon angioplasty [8].

Physical inactivity after stroke increases the risk of cardiovascular disorders and is associated with decreased mobility and functional independence [9]. Therefore, early physical activity after a stroke as part of secondary prevention is emphasised in several clinical guidelines[10]. Thigh muscles (quadriceps and hamstrings) strength is important for the ability to stand up from sitting, walking and stair climbing. In addition, muscle fitness is important for glucose metabolism and cardio-respiratory vigour [11]. Stroke survivors usually display continuous cardiovascular risk, including low physical activity and time spent in sedentary behaviours [12]. It has been observed that attempts to increase physical activity after stroke are not always successful [13]. This could partly be due to a lack of models for supervised training adapted for individuals post stroke [14, 15]. Thus, it is vital to find user-friendly rehabilitation alternatives in order to increase physical activity [16]. Current Swedish guidelines promote early non-pharmacological treatments after all types of cerebrovascular events but there is lack of reasoning for the effectiveness of these treatments [17]. Evidence till the date reports physiotherapy interventions like stretching, PNF techniques, and strengthening exercise improves balance and lower limb activities [18].

Closed Kinetic Chain Exercises (CKCE) emphasise the sequential movement of joints and require coordinated and sequential muscle activation patterns to control proper joint movement. In these exercises, the distal part of the joint remains fixed and proximal one is moved. However, in clinical practice the definition of a closed kinetic chain is when distal aspect of the extremity remains fixed during the activities. It has been seen that the CKC exercise has effect on the activation of the muscles in paralytic patients. CKCE is important in the management of stroke survivals, however, there is hardly any evidence proving the same [19].

The Lower Extremity Functional Scale (LEFS) is a valid patient-rated outcome measure (PROM) for the measurement of lower extremity functions. It was first developed by Binkley *et al*. (1999) in a group of patients with various musculoskeletal conditions [20]. The objective of the Lower Extremity Functional Scale (LEFS) is to measure “patients' initial function, ongoing progress and outcome” for a wide range of lower-extremity conditions [21, 22].

Hence, this study attempts to see the effectiveness of closed kinematic chain exercises on stroke survivals in relation to lower limb functions using lower extremity functional scale.

2. Materials and methodology

A total of 37 patients from Neurosciences OPD of Maharashtra Institute of Physiotherapy, Latur had participated in this study. Inclusion criterions for this study were 1. History of stroke more than 3 months; 2. Age between 40-60 years; 3. Both genders; 4. Mini-Mental Scale Score >24; 5. Patient should be able to communicate properly; 6. Patients can ambulate independently; 7. Full range of motion of hip, knee and ankle. Exclusion criterions were 1. Any hip, knee or ankle injury or disease; 2. Psychological instability; 3. Patients on anti-depressants drug therapy; 4. Patients unwilling to participate. This study was approved by Maharashtra Institute of Physiotherapy, Latur ethics committee. Participants were screened and were selected in accordance to inclusion and exclusion criteria. An informed consent was taken from each participant and an explanation of the study was given.

The Lower Extremity Functional Scale Score was taken of all the participants and recorded as pre-treatment data. Participants were allocated into two groups based on simple randomly sampling design using lottery method. Group A or Experimental group was given 5 weeks of Closed Kinematic Chain (CKC) were given and Group B or Conventional group were given 5 weeks of conventional therapy.

I. Closed Kinematic Chain Exercises [23, 24, 25, 26, 27]

- Single one – third knee bend
- Stationary bicycling
- Step - up and step - down exercise

To perform single one – third knee bend exercise, participants were instructed to hold a stable support if they needed and to stand tall maintaining erect position. Then transfer your weight to affected leg by swinging the other leg out behind and keep on the floor. And asked to hold this position for 10 seconds with stopwatch [24].

To perform stationary bicycling, participants were asked to wear shoe and asked to sit on a cycle comfortably. They were instructed to grasp the handle with both hands firmly. Keeping both soles of foot on each pedal, sit as much straight as you can. Now the participants had to imagine a clock and start pedaling from 12 O’ clock position to 12 O’ clock position. Then after imagination of clock, participants were asked to move the pedal with lower limb strength for 10 times [25-26].

5 cm tall stair height was used for this exercise. Demonstration to participants by therapist with instructions was given to the participants. Participants were then instructed to stand in front of stairs and hold the stair railing. Participants then did the step up and down for 10 times [27].

Each exercise was repeated 10 times with 3 seconds of rest between each repetition. 3 sets of each were given with a rest period of 1 minute between each set. Exercises were given for 30 – 45 minutes, thrice a week for 5 weeks [28].

II. Conventional Exercises [29]

- Kneeling
- Half – kneeling

- Standing with support
- Standing without support
- Balance and gait training

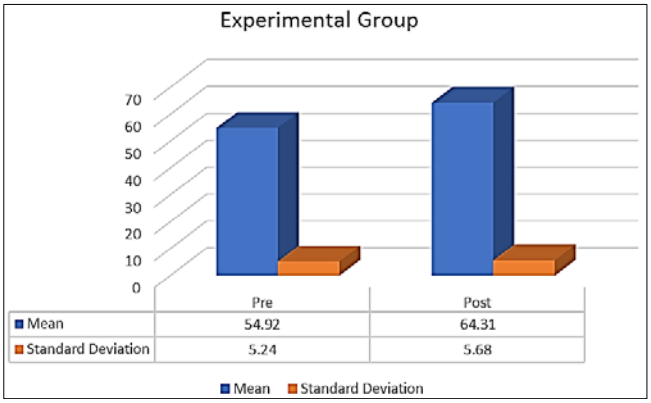
Each exercise was repeated 10 times with 3 seconds of rest between each repetition. 3 sets of each were given with a rest period of 1 minute between each set. Exercises were given for 30 – 45 minutes, thrice a week for 5 weeks[28].
The Lower Extremity Functional Scale Score was taken of all the participants at the end of 5 weeks and was recorded as post-treatment data. Pre- and post-treatment data were compared within and between the groups to obtain the results.

3. Statistical analysis

24 of the 30 participants attended the 5 - week intervention program. Two (one from each treatment group) of these 30 participants left the treatment in between because of another attack of stroke during the study period. Four participants (two from each group) did not attend the last follow up session due to unknown reasons. Therefore, the results of these patients were not used in the statistical analysis of the study.
Descriptive statistical data was presented in the form of mean and standard deviation. Paired and unpaired T test was used to calculate the statistical difference within the group and between the groups, respectively. For all the statistical analysis, $p<0.05$ was considered as statistically significant.

Table 1: Shows pre and post values of mean and SD of Experimental Group

Experimental Group	Pre	Post	p value
Mean	54.92	64.31	0.0001
Standard deviation	5.24	5.68	significant

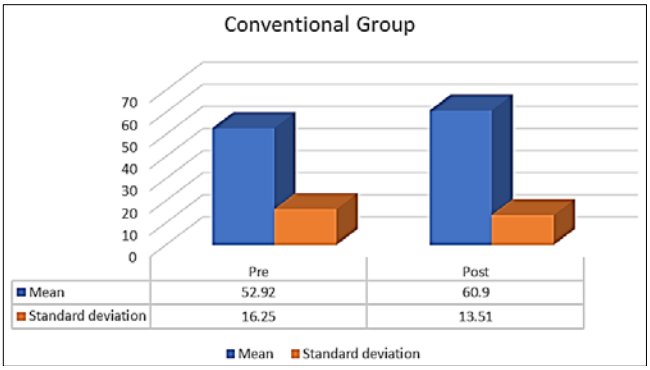


Graph 1: Graphical representation of pre and post values of mean and SD of Experimental Group

Interpretation: Pre and post mean values of experimental group were 54.92 and 64.31, respectively. Pre and post standard deviation values were 5.24 and 5.68, respectively. Paired t test was used for statistical analysis. p value was calculated as 0.0001.

Table 2: Shows pre and post values of mean and SD of Conventional Group

Conventional Group	Pre	Post	p value
Mean	52.92	60.90	0.0035
Standard deviation	16.25	13.51	significant

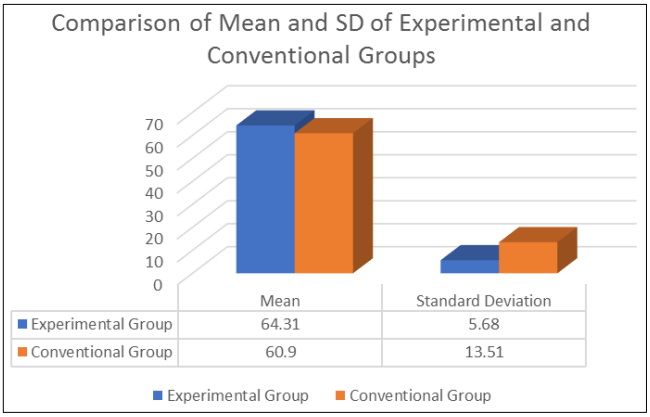


Graph 2: Graphical representation of pre and post values of mean and SD of Conventional Group

Interpretation: Pre and post mean values of conventional group were 52.92 and 60.90, respectively. Pre and post standard deviation values were 16.25 and 13.51, respectively. Paired t test was used for statistical analysis. p value was calculated as 0.0035.

Table 3: Shows post mean and SD values of Experimental and Conventional Groups

Group	Mean	Standard Deviation	p value
Experimental Group	64.31	5.68	0.0415
Conventional Group	60.90	13.51	significant



Graph 3: Shows post mean and SD values of Experimental and Conventional Groups

Interpretation: Post mean and standard deviation values of experimental group were 64.31 and 5.68, respectively. Post mean and standard deviation values of conventional group were 60.90 and 13.51, respectively. Unpaired t test was used for statistical analysis. p value was calculated as 0.0415.

4. Results

There was a significant improvement in lower limb functions in both the groups.
But statistically, experimental group shows more improvement than conventional group.

5. Discussion

The purpose of present study was to determine the effect of close kinematic chain exercise on lower limb function in stroke survivors. Studies show that all interventions in the form of physiotherapy are effective for lower limb function in stroke survivors. In the current study, the exercise programs were divided into the closed kinematic chain (CKC) and conventional (CON) exercise groups. In many

research papers CKC and CON exercise groups, individually, have had shown significant improvement in the lower limb function.

Stroke leads to opposite side paralysis or paraparesis, that is, weakness of upper and lower extremity. Other manifestations of stroke include altered consciousness, visual impairments, speech difficulties, bowel and bladder incontinence, intellectual deficits, behavioural problems, balance impairment, gait impairments and many more. Balance and gait impairments are proven to be the major issue after stroke in patients. This study focuses on improving lower limb functions [6].

Treatment of lower limb functions post stroke can be done in many ways depending on the impairment. They include sensory integration, tone normalisation, muscle strengthening, coordination training, balance improving, gait training, bowel and bladder training, etc. Strengthening training of the paretic lower limb post stroke is reported as one of the most important treatments to enhance functional ability in patients [6, 7, 8].

CKC exercises are universal intervention methods to strengthen paretic muscles in stroke rehabilitation [30]. They stimulate mechanoreceptors in the joint and increased muscle fibres. The number of motor unit's increases during these resistance exercises which leads to increase in strength in muscle[31]. They also increases the intra-articular pressure and enhance the joint position sense by stimulating Ruffini nerve endings (nerve endings sensitive to the changes in intra capsular fluid volume). These factors help improve weight transfer, decrease postural sway and improve balance in patients with stroke [35].

Step-up training in patients with stroke requires strong propulsion on the paraplegic side and strong support on the non-paraplegic side. Therefore, it was reported that the step - up training is advantageous for increasing the strength of the knee extensor muscles stated by author Kim [31]. It help strengthen the quadriceps and hamstrings simultaneously using the hip and ankle joints. This would, therefore, provide positive feedback from the entire lower extremity. Hence, the increase in the stimulation of mechanoreceptors around the joint attributes to improve the strength of quadriceps and hamstrings [31, 32].

Insufficient activation of the gastrocnemius and tibialis anterior are often observed in the gait cycle of stroke patient which leads to an insufficient push off and toe clearance. But, CKC exercises induces a calf muscle stretch, increasing the afferent information arising from the muscle spindle and golgi tendon organs of the calf muscles [33]. They also produce a more eccentric knee extensor strength to control the movement, thus recruiting more motor units and activating more muscle spindles. Thus, the tibialis anterior activation work more effectively together with higher force generation after calf muscle stretching that CKC exercise provide for stroke patients [34].

CKC exercise work in spiral or diagonal movement patterns. It stimulates proprioception, increase joint stability, increases co-activation of muscles, allow better utilization of the SAID (specific adaptations to imposed demand) principle and permit more functional patterns of movement particularly in lower extremity. This happens because CKCE they closely stimulate the actual movement patterns encountered in daily activities [29, 37].

In support with the present result, Brown DA [26], in his study has stated that CKC exercises are used to restrain joints and muscle proprioceptors to respond sensory input and provides greater joint compressive forces. As in CKC exercises multiple joints are exercised, through weight bearing and muscular contraction, velocity and torque are comparatively more controlled, shear forces are reduced, joint congruity is enhanced, proprioceptors are re-educated, postural and dynamic stabilization mechanics are facilitated [36].

Similarly, Blundell SW [27] concluded in their study that the improvement in gait pattern by CKC exercises was better. They stated that CKCE reduce the problem of foot drop in stroke patients by controlling eccentric contraction of calf muscle. Closed chain pronation not only lowers the arch but also lowers the pelvis by creating a functional decrease in leg length [38].

Arthur J Nelson [28] and Sauvage LR Jr [29] found that CKC exercises like squatting, step-up and down, bicycling concentrates on co-contraction of the quadriceps, hamstrings, hip flexors, and soleus and gastrocnemius muscles [39]. As CKC exercises involves multi-joint movements, it focuses on the ankle, knee, hip and ultimately strengthening of major muscles of lower limb takes place [32, 40].

Also, Kim MK [31], suggested that muscle activation of the gastrocnemius and tibialis anterior increased significantly only in the CKC exercise group. This indicates that the CKC exercise can improve lower-limb muscle strength in chronic stroke patients [33, 40].

Thus, results of this study provide rehabilitation clinicians with clinical evidence regarding the effectiveness of CKC exercises in improving the functional ability of lower limb in stroke patients.

We are interested in knowing whether you are having any difficulty at all with the activities listed below **because of your lower limb problem** for which you are currently seeking attention. Please provide an answer for **each** activity.

Today, *do you* or *would you* have any difficulty at all with:

	Activities	Extreme Difficulty or Unable to Perform Activity	Quite a Bit of Difficulty	Moderate Difficulty	A Little Bit of Difficulty	No Difficulty
1	Any of your usual work, housework, or school activities.	0	1	2	3	4
2	Your usual hobbies, re creational or sporting activities.	0	1	2	3	4
3	Getting into or out of the bath.	0	1	2	3	4
4	Walking between rooms.	0	1	2	3	4
5	Putting on your shoes or socks.	0	1	2	3	4
6	Squatting.	0	1	2	3	4
7	Lifting an object, like a bag of groceries from the floor.	0	1	2	3	4
8	Performing light activities around your home.	0	1	2	3	4
9	Performing heavy activities around your home.	0	1	2	3	4
10	Getting into or out of a car.	0	1	2	3	4
11	Walking 2 blocks.	0	1	2	3	4
12	Walking a mile.	0	1	2	3	4
13	Going up or down 10 stairs (about 1 flight of stairs).	0	1	2	3	4
14	Standing for 1 hour.	0	1	2	3	4
15	Sitting for 1 hour.	0	1	2	3	4
16	Running on even ground.	0	1	2	3	4
17	Running on uneven ground.	0	1	2	3	4
18	Making sharp turns while running fast.	0	1	2	3	4
19	Hopping.	0	1	2	3	4
20	Rolling over in bed.	0	1	2	3	4
	Column Totals:		0	0	0	0

Minimum Level of Detectable Change (90% Confidence): 9 points **SCORE: 0 / 80 (fill in the blank with the sum of your responses)**

Source: Binkley et al (1999): The Lower Extremity Functional Scale (LEFS): Scale development, measurement properties, and clinical application. Physical Therapy. 79:371-383.

Fig 1: The lower extremity functional scale

6. Conclusion

This study concluded that Closed Kinematic Chain (CKC) exercises for 5 weeks are more effective in improving lower limb functions than conventional exercise for 5 weeks using Lower Limb Functional Scale (LEFS).

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