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RESEARCH ARTICLE

The Effect of Knee Strengthening Exercises on Improving Lower Limb Dynamic Balance in Stroke Patients

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Abstract: ***Background***: Stroke often results in weakness or paralysis (hemiparesis) on one side of the body, especially in the lower limb. This weakness affects the muscles involved in postural control and coordinated movement, reducing dynamic balance. ***AIM***: The aim of this study is to evaluate the effectiveness of knee strengthening exercises in improving dynamic balance and reducing the fall risk among stroke patients. ***Methods***: Thirty subjects with stroke were allocated randomly into 2 groups as experimental or control group. Group A (Experimental group) Each patient in experimental group received Knee strengthening exercises for 8 weeks, 5DAYs a week, twice a DAY for 10 repetitions. Group B (control group) Each patient in control group received the conventional physiotherapy program as Core strengthening exercises for abdominal core musculature for 8 weeks, 5 DAYs a week, twice a DAY for 10 repetitions. Outcome measures as dynamic balance and fall risk were assessed at baseline and end of 8 weeks. ***Results***: Dynamic balance and fall risk scores significantly improved in both the groups (P<.05). The improvements in dynamic balance and fall risk scores were greater in the experimental group compared with the control group. ***Conclusion***: Knee strengthening exercises could be used effectively in improving dynamic balance and reduce the risk of fall in stroke individuals with balance deficits.

Keywords: Stroke, dynamic balance, knee strengthening exercises, core strengthening exercises, fall risk.

INTRODUCTION

Stroke is a prevalent and severe health issue that affects people all over the world. Many stroke victims experience significant disability and restrictions in their potential to do activities of daily living (ADL).[1] Following stroke, balance issues are believed to be prevalent. According to research, during the acute period of stroke, over 80% of patients experience balance impairment.[2] Cerebral vascular accidents, commonly referred to as strokes, are neurological conditions that pose a serious threat to world health. Major risk factors for stroke such as Diabetes mellitus (DM), hypertension, high cholesterol, cardiovascular disease, cigarette smoking, drinking, obesity, sedentary lifestyle, stress, and few other factors.[3] When blood clot in an artery blocks blood flow, it damages the central nervous system (CNS), impairing speech, balance, sensory and motor abilities, and cognitive function. Over 80% of those with stroke who have experienced its initial onset typically have a balance impairment. [4] Following stroke, falls were seen in 26–35% of patients due to their compromised balance. Thus, core trunk stability is required in increasing gait, flexibility, and balance.[5]

The ability to remain stable and in control when moving or engaging in dynamic activities that require synchronisation of the neurological system, musculoskeletal system, and sensory systems (such as proprioception and vestibular function) is known as dynamic balance.[6] Recent studies concluded that strengthening muscles in various lower limb joints improves balance by enhancing lower limb motor coordination. Strengthening training that involved in many lower limb joints lead to notable enhancements in dynamic balance among patients with stroke who have fear of falls.[7]

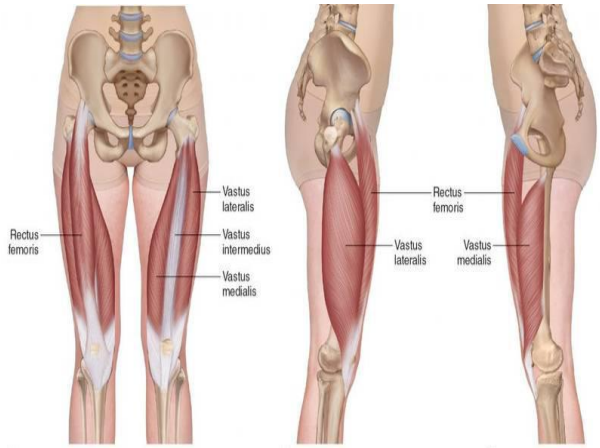


Fig: 1

Training various muscles in lower limbs but the program has most frequently included the knee extensors and flexors. Numerous research has examined the relationship between walking ability and knee muscle function.[8] The knee flexor and extensor of paretic limb have more correlation in strength and gait performance. [9] It was shown that older participants utilised their hamstrings more than younger ones, most likely because the elderly patients need hip equilibrium. Consequently, it was discovered that enhanced leg weight-bearing capacity and knee flexor strength may help stroke patients in improving balance following water therapy.[10]

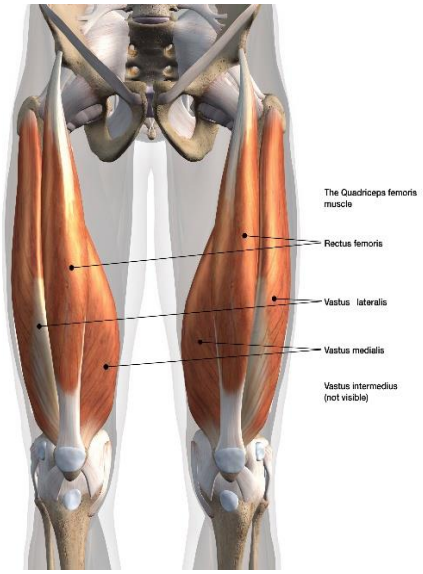


Fig:2 Posterior knee muscles

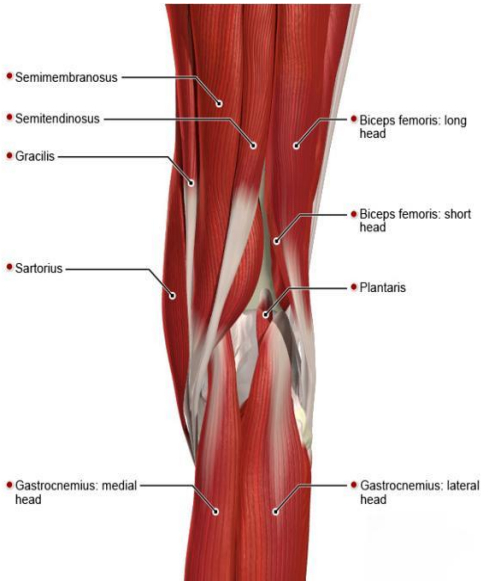


Fig:3 Anterior knee muscles

When getting up from a seated posture, the quadriceps muscles contract in a concentric motion. The improvement in this function following eccentric training suggests that the eccentric training had an impact on both the eccentric function that was trained and the strength that could be used in concentric motions to enhance dynamic balance and gait.[11]

Studies concluded that fall risk is directly influenced by the relationship between postural balance and lower body strength.[12] The core is like the box in structure which is made of the diaphragm on top, pelvic floor muscles and hip girdle muscles on the bottom, the abdominal muscles at the front, and the gluteal and paraspinal muscles at the back. It serves as a muscle corset that stabilises the spine and body both with and without limb movement.[13] Thus, the aim of the study was to evaluate the effects of strengthening exercises for muscles across knee on improving dynamic balance among stroke patients.

Chul Woong Hyun, et al. (2015) [25] in the study has the need to investigate the underlying neuromuscular mechanisms that link knee extensor strength and balance function. This study is done to determine the efficacy between knee strengthening exercises and core strengthening exercises for stroke patients to improve dynamic balance. There are only few studies that focus on stroke patients with balance deficits, while most of them concentrate on weakness or other deficits. Additionally, relatively few studies have evaluated the impact of strengthening exercises which are tailored to specific needs of the population.

METHODOLOGY:

- STUDY DESIGN: Experimental study design (pre and post)
- STUDY TYPE: Comparative type
- STUDY SETTINGS: Rehabilitation centre (Head to heel physiotherapy clinic), Porur – Chennai and Hospital setting (MMS hospital), Iyyappanthangal – Chennai.
- STUDY DURATION: 8 weeks
- SAMPLE SIZE: 30
- SAMPLE METHOD: Convenient sampling method
- GROUP A: Knee strengthening exercises
- GROUP B: Core strengthening exercises
- TREATMENT DURATION: 1hr (5times per week)

INCLUSION CRITERIA:

- Both males and females.
- Age >40 years old.
- Stroke occurring at least 6 months before the start of the study
- Unilateral localisation of stroke
- Sufficient comprehension for participating in the study
- Good static sitting balance (as per Berg Balance Score 20-45)
- Full passive range of motion of affected lower limb.

EXCLUSION CRITERIA:

- History of Vertigo and vestibular dysfunction.
- Unstable vitals.
- Uncomprehensive patients.
- Recent lower limb fractures or major orthopaedic problems (amputation).
- Observable lower limb structural deformities.
- Reduced sitting balance score (according to BBS score <20)
- Joint pain and limited joint motion (ROM) of hip and ankle
- Other neurological disorders (Parkinson's disease)

OUTCOME MEASURES AND TOOLS USED:

- Dynamic balance – Berg balance scale (BBS)
- Fall risk – Fall efficacy score (FES)

PROCEDURE:

- 30 samples were selected according to the inclusion and exclusion criteria and the samples were allotted into 2 groups – group A and group B.
- Informed consent was acquired from all the participants before the study was conducted.

EXPERIMENTAL GROUP (GROUP A):

- For Group-A, knee strengthening exercise program were given to the subjects for 8weeks (5DAYs per week).
- The knee strengthening exercise program consists of Progressive strengthening of muscles around the knee in improving balance and increasing functional mobility to the targeted muscles like quadriceps, hamstrings, gluteus, calf muscles.
- Basically, this protocol consists of knee strengthening exercises for the quadriceps and hamstring muscle in which the subject is positioned in supine lying, standing, sitting which helps in proper weight bearing and focus on the targeted muscles.
- The exercise starts with mild warm up for 15mins in the initial start of the exercises.
- This protocol helps in targeting the knee flexors and extensors and provides dynamic stability to the knee.
- Group A deals with exercises like Seated Knee extension, Seated Heel Slides, prone knee curls, Standing Balance Exercises.

Straight Leg Raise (SLR) [26]

- **Patient Position:** Supine with one leg bent (knee at 90°) and the other leg straight.
- **Therapist Position:** Side standing for observation or stabilization.
- **Procedure:** The subject is instructed to lift the leg straight to the height of the bent knee by tightening the thigh muscles. Subject is instructed to hold 2–3 seconds, then lower slowly and repeat 10–15 reps.

Seated Knee Extension (Quad Sets) [27]

- **Patient Position:** Sitting upright in a chair with thighs fully supported, knees flexed at 90°.
- **Therapist Position:** Beside or in front of the subject for supervision or assistance.
- **Procedure:** The subject is instructed to straighten the knee by lifting the foot forward until the leg is fully extended. Subject is instructed to hold 2–3 seconds, then lower slowly and repeat 10–15 reps.

Leg Press [27]

- **Patient Position:** Supine or seated with feet on leg press platform or resistance band.
- **Therapist Position:** Beside machine or in front if supervising with band.
- **Procedure:** The subject is instructed to push the heels to extend the knees and slowly return to start position with control without locking the knees and repeat 10–15 reps.

Prone Hamstring Curls [27]

- **Patient Position:** Lying face down (prone lying).
- **Therapist Position:** Side standing to assist or add resistance.
- **Procedure:** The subject is instructed to bend the knee by bringing the heel toward the buttocks then to lower the leg slowly and repeat 10–15 reps.

Seated Heel Slides [27]

- **Patient Position:** Sitting on a chair or lying supine with legs extended.
- **Therapist Position:** Beside the subject if assistance is needed.
- **Procedure:** The subject is instructed to slide the heel backward along the floor to flex the knee as far as comfortably possible and then slowly returns to starting position. Use a towel under the foot for easier sliding and repeat 10–15 reps.

CONTROL GROUP (GROUP B):

- For Group-B, exercises were given for 30-40min, exercise program consists of strengthening exercise for core muscles such as transversus abdominis, rectus abdominis, obliques, multifidus, erector spinae, and pelvic floor muscles were targeted in this protocol which helps in maintaining spinal and pelvic stability.
- Group B undergone with pelvic tilts, pelvic bridges, knee rolling, trunk rotation and modified planks (with support) in lying, side lying and standing.

Pelvic Tilts [26]

- **Patient Position:** Supine lying (lying on back) with knees bent, feet resting flat on the floor, arms by the sides.
- **Therapist Position:** Beside the subject to monitor pelvis and lower back movement.
- **Procedure:** The subject is instructed to flatten their lower back against the floor by tilting the pelvis backward (posterior tilt) gently. Subject is instructed to hold it for 5–10 seconds at the top, then lower it down slowly and repeat 10–15 times.

Pelvic Bridges (Glute Bridges) [26]

- **Patient Position:** Supine with knees bent, feet rested flat, arms are relaxed at sides.
- **Therapist Position:** Beside the subject for observing hip lift and spinal alignment.
- **Procedure:** The subject is instructed to raise the hips above the floor by squeezing buttock and engaging the core by making a straight line from the shoulders to knees. Subject is instructed to hold it for 5–10 seconds at the raised position, then lower it down slowly and repeat 10–15 times.

Knee Rolling (Lower Trunk Rotations) [26]

- **Patient Position:** Supine, knees bent, feet flat, arms outstretched to the sides.
- **Therapist Position:** Side standing to monitor spinal movement and provide guidance.
- **Procedure:** The subject is instructed to gently rock both knees to one side while keeping shoulders flat and then return to centre, then roll to the opposite side and repeat it 10–15 times on each side.

Trunk Rotations (Seated or Supine) [26]

- **Patient Position:** Supine, knees bent, feet flat, arms across the chest or out to the sides.
- **Therapist Position:** Beside the subject for observing upper trunk and lower back motion.
- **Procedure:** The subject is instructed to rotate upper trunk or lower body in a twisting motion while keeping the opposite segment stable and return to neutral. Subject is instructed to repeat it for alternate sides for 10–15 repetitions each side.

After the 8-week of rehabilitation period, the base line values were checked again and compared with the initial values.

RESULTS:

Table-1: Comparison Of Berg Balance Scale Between Group – A And Group – B In Day 1 & Day 40

BBS	GROUP - A		GROUP - B		t - TEST	df	LEVEL OF SIGNIFICANCE
	MEAN	S.D	MEAN	S.D			
DAY 1	33.13	2.59	32.33	2.05	-0.94	14	0.354
DAY 40	39.3	3.03	36.6	2.29	-2.78	14	0.009

The Berg Balance Scale scores for both Group A and Group B improved from DAY 1 and DAY 40, indicating a general improvement in balance. While DAY 1 scores did not differ significantly ($p = 0.354$), DAY 40 scores showed a statistically significant improvement in Group A compared to Group B ($p = 0.009$) thus suggests that the intervention used in Group A was more effective in enhancing balance performance. This table shows that there is no statistical significance in DAY 1 values between Group A & Group B ($P > 0.05$) and also statistically high significance difference in DAY 40 values between Group A & Group B ($P \leq 0.001$).

Table-2: Comparison Of Berg Balance Scale Within Group– A And Group – B In Day 1 & Day 40

BBS	DAY 1		DAY 40		t - TEST	LEVEL OF SIGNIFICANCE
	MEAN	S.D	MEAN	S.D		
GROUP- A	33.13	2.59	39.33	3.03	35.5	0.0001
GROUP- B	32.33	2.05	36.6	2.29	39.35	0.0001

Both groups show very highly statistically significant differences between DAY 1 and DAY 40 scores at common significance level. Group A p-value < 0.0001 (very highly significant) and Group B p-value < 0.0001 (very highly significant). It shows the significant results on group A with the p value of <0.05.

FES	GROUP - A		GROUP - B		t - TEST	df	LEVEL OF SIGNIFICANCE
	MEAN	S.D	MEAN	S.D			
DAY 1	22.33	1.48	22.00	1.51	6.45	14	<0.0001
DAY 40	26.07	1.69	25.33	2.00	5.14	14	<0.0001

Table-3: Comparison Of Fes Between Group – A And Group - B In Day 1 And Day 40

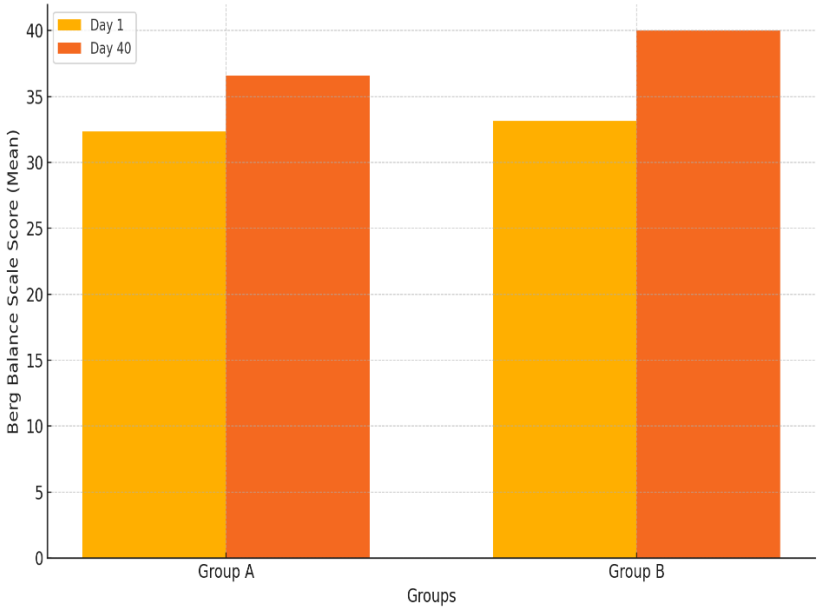
This table shows that there is no significant difference in DAY 1 values between Group A & Group B. This table shows that statistically highly significant difference in DAY 40 value between Group A & Group B **(P ≤ 0.001).**

Table-4: Comparison Of Fes Within Group– A & Group – B Between Day 1 And Day 40

FES	DAY 1		DAY 40		t – TEST	LEVEL OF SIGNIFICANCE
	MEAN	S.D	MEAN	S.D		
GROUP- A	22.33	1.48	26.07	1.69	-6.45	<0.0001
GROUP- B	22.00	1.51	25.33	2.00	-5.14	<0.0001

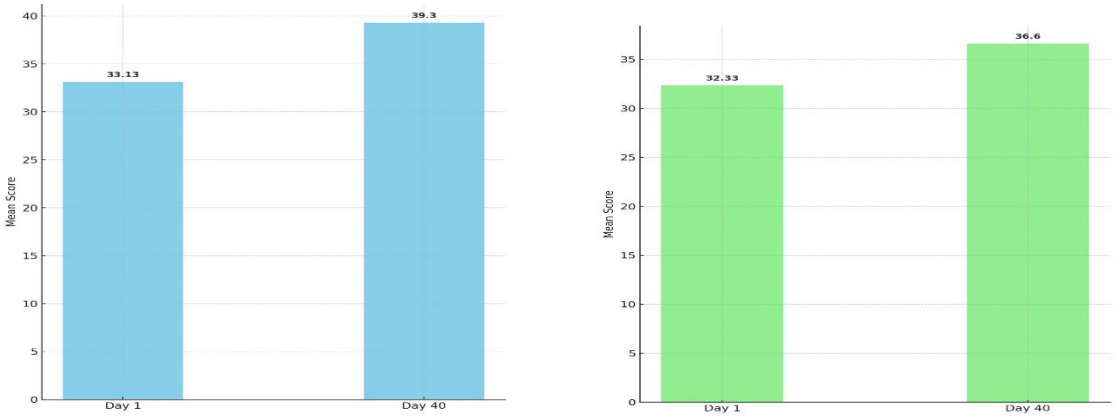
There is a high statistically significant difference between the DAY 1 and DAY 40 test values within Group B (P ≤ 0.001).

GRAPH-1: BERG BALANCE SCALE MEAN OF GROUP – A AND GROUP – B



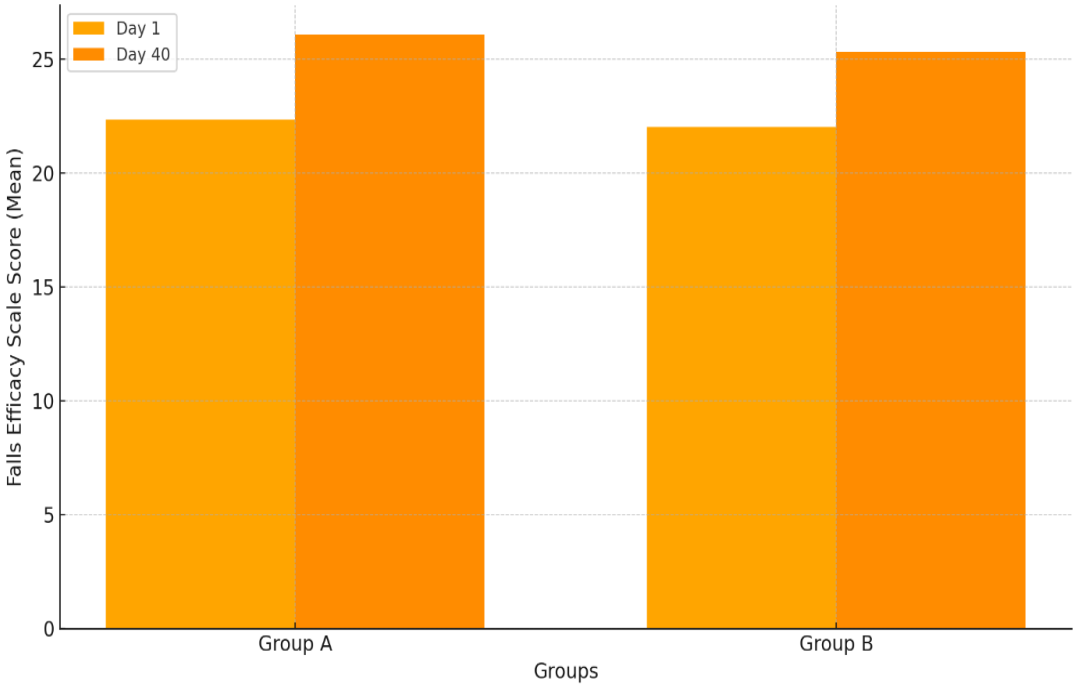
Both groups started with similar balance scores, and the difference was not statistically significant (t = -0.94, p = 0.354). Group A showed a greater improvement than Group B. The difference was statistically significant (t = -2.91, p = 0.007), indicating a meaningful difference in outcomes.

GRAPH-2: BERG BALANCE SCALE MEAN OF GROUP – A AND GROUP - B



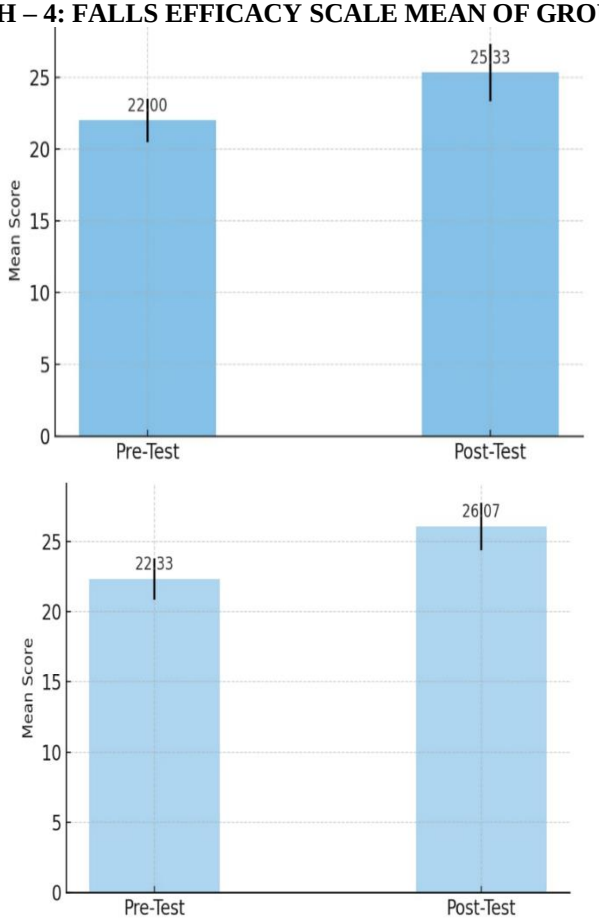
The graph representing the mean of group A in the DAY 1 (33.13) and DAY 40 (39.33) for the group A. This 4.27-point increase suggests that the intervention for Group A had a positive effect, though the change is modest and not statistically significant (p = 0.009). The graph representing the mean DAY 1 (32.33) and DAY 40 (36.6) scores, respectively for the group B.

GRAPH – 3: FALLS EFFICACY SCALE MEAN OF GROUP - A AND GROUP - B



This graph represents the mean FES scores for Group A and Group B during DAY 01 and DAY 40. Group A and Group B had similar DAY 01 scores. Both groups improved in DAY 40, but Group A had a slightly higher mean score improvement.

GRAPH – 4: FALLS EFFICACY SCALE MEAN OF GROUP - A



The graph representing the mean of Group A in the DAY 1 Mean: 22.33 and DAY 40 Mean: 26.07 for FES Scores. There is a clear increase in the mean FES score after the intervention. This indicates a notable improvement in FES scores for Group A after the intervention. The graph represents Group B of FES Scores DAY 01 Mean: 22.00 and DAY 40 Mean: 25.33**.** Group B also shows an increase in FES score, although slightly less than Group A.

DISCUSSION:

The results of this current study showed that dynamic balance has significantly enhanced in response to BBS along with FES in patients with stroke, based on dynamic balance scales. Balance deficits are common among stroke patients. After stroke, neurological impairments such as sensory loss, motor weakness, and coordination issues can result in balance deficiencies. The capacity of the brain to regulate balance reflexes and integrate sensory data for posture is compromised by the damage caused by the stroke. This results in impaired mobility, a higher chance of fall risk and trouble in maintaining balance.

Marigold (2005) [20] and Shin & Demura (2012) [21] concluded that static and dynamic standing balance were improved by combining aerobic and functional strengthening activities with exercise training. Smania (2008) [23] and Bayouk (2006) [22] concluded that, performing a specific exercise training in standing such as weight transfer exercises and balance exercises performed under different conditions of manipulation of sensory inputs, stroke patients achieved a significant improvement in their ability to maintain balance control. Additionally, they imply that standing balance and gait have a beneficial carryover impact. The somatic senses and proprioceptive receptors may be stimulated when posture is controlled on uneven terrain, which might be the cause. However, it has been shown that participants who were given instability lacked precise somatosensory information. This type of training has been utilised to improve the ability to manage one's bodily balance (Cressey, West, et al. 2007[24])

Stroke can cause hemiparesis, muscle weakness that leads to asymmetrical posture, poor weight distribution, and increased risk of falls and damage in sensorimotor cortex, cerebellum, or brainstem results in disrupting control of balance and gait. Weakness to muscles and disrupts gait patterns due to the due to damage in Primary Motor Cortex (M1) that controls voluntary leg movements, impaired awareness of limb position due to Somatosensory Cortex that processes proprioceptive input from muscles and joints.[28]

In this study the group A undergone with knee strengthening exercises which works in improving strength of the muscles of knee and stabilizes the knee. Knee biomechanics is very important for maintaining

dynamic balance especially during weight-bearing and movement-intensive tasks. Proprioception, knee joint alignment, neuromuscular control, and muscle strength are some of the components that affect dynamic balance. Dynamic balance is strongly correlated with quadriceps strength. People who have stronger quadriceps do better when it comes to dynamic balance.

Knee muscles especially quadriceps and hamstring are the key for weight support, shock absorption, controlling knee flexion/extension during gait. After stroke, strengthening exercises re-activate muscle spindles and joint receptors. This sends improved feedback to the somatosensory cortex, helping the brain re-learn limb positioning. Strengthening muscles around the knee, especially the quadriceps and hamstrings improves more muscle spindles and Golgi tendon organs with send high-quality proprioceptive signals to the somatosensory cortex, improving limb position awareness and movement precision. Hence this study concluded that implementing exercise to the muscle group such as quadriceps, hamstrings, gluteus, calf muscles lead to increase in strength, balance and decrease the fall risk among the stroke patients with balance deficit.

Knee strengthening exercises play a crucial rehabilitative role in restoring the brain's ability to maintain dynamic balance post-stroke.

- Enhance neural communication between muscles and the brain.
- Support reorganization of motor and sensory circuits.
- Reduce fall risk and improve confidence in mobility.

According to this study findings, the BBS and FES score of the experimental group increased more than the control group. These findings suggest that strengthening the muscles in knee joints improves balance and reduce fall risk.

CONCLUSION:

This study concluded that when compared to core strengthening exercises, knee strengthening exercises improved dynamic balance and decreased the fall risk significantly.

Implementing knee exercise for enhancing dynamic balance and thus reduce the risk of fall (Group A) had a significance result on balance improvement and reduce fall risk among stroke. Hence this study concludes that strengthening knee musculature helps improve dynamic balance and thereby decrease the fall risk.

LIMITATIONS OF THE STUDY:

- The sample size of the study was small and limited (30).
- The study was conducted for short duration (8weeks).
- The study includes only the subjects with age group above 40yrs.

RECOMMENDATIONS OF THE STUDY:

- Study can be done with larger sample size (more than 50)
- Study duration can be enhanced to evaluate gait, proprioception.
- Study can be done by combining two or more interventions together (such as combining knee strengthening along with core strengthening exercises) and the effects can be analyzed.
- Study can be done to assess for the gait components such as cadence, step length, stride length, step width.

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