RESEARCH

Comparison of Neuromuscular Joint Facilitation and Quadriceps Strengthening Exercise in Knee Osteoarthritis: a Randomized Controlled Trial

Shikha Lall, MPT, Venkatesan Prem, PhD,* H. Karvannan, PhD

Department of Physiotherapy, Manipal College of Health Professions, Manipal Academy of Higher Education, Manipal, Karnataka, India

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Objectives: To compare the effect of neuromuscular joint facilitation (NJF) and quadriceps strengthening exercises on pain, physical function, static posture, and balance control in subjects with knee osteoarthritis.

Design: Randomized controlled trial.

Setting: Department of Physiotherapy, Manipal Hospitals, Bangalore.

Participants: Subjects diagnosed with knee osteoarthritis according to the American College of Sports Medicine criteria. The mean age of subjects in the control group was 63.12 ± 8.08 years; in the experimental group was 61.77 ± 8.46 years.

Interventions: The intervention group received NJF treatment twice a week for six weeks, and the control group received quadriceps strengthening exercises. Standard knee exercises were given as a home program to both groups.

Outcome Measures: Numeric Pain Rating Scale (NPRS), 30-second chair stand (30s-CST), and single leg stance (SLS) were used to assess physical function, static posture, and balance control, respectively, at the end of the sixth week.

Results: Sixty subjects were randomly allocated to intervention and control groups. The experimental and control group showed a mean difference of 3.89 and 4.17 in NPRS, 4.19 and 4.17 in 30s-CST, 6.81 and 5.71 in SLS at the end of six weeks. This change was significant within both groups (p value .000) and not significant between groups (NPRS p value .303; 30s-CST p value .09; SLS p value .525) at the end of six weeks.

Conclusions: NJF and quadriceps strengthening exercises effectively reduced pain and improved physical function, static posture, and balance control in subjects with knee osteoarthritis. Both groups had the same effect on all clinical variables at six weeks of follow-up. Hence, further studies with long term follow-up are warranted.

KEYWORDS: knee osteoarthritis; physical therapy; neuromuscular exercise; quadriceps

INTRODUCTION

Osteoarthritis (OA) is a common chronic condition[1] and the knee joint is the large principal joint affected by OA, leading to disability in almost 10% of people older than 55 years.[2] The prevalence of OA in India is 22–39%,[3] while OA of the knee joint has a prevalence of 54.1% among the elderly in the Bangalore urban district.[4] Subjects with knee OA complain of pain, joint stiffness, proprioceptive deficits, and quadriceps muscle weakness.[5] This leads to progressive loss of function such as walking and climbing up and downstairs, which leads to disability.[6] The management of OA aims to educate the subjects, alleviate pain, improve function, decrease disability, and slow disease progression.[2] Strengthening programs have formed the cornerstone of the training programs in subjects with knee OA.[7] Studies suggest that subjects with knee OA have neuromuscular deficits. Hence, neuromuscular exercises are essential and can improve the effectiveness of training programs.[7]

Neuromuscular joint facilitation (NJF) is a type of exercise that integrates the principles of proprioceptive neuromuscular facilitation (PNF) and joint composition movement.[8] PNF is a dynamic approach[9] that applies neurophysiological principles of the sensory/motor system for low-velocity passive movements within or at the limit of the range of motion, to modulate the nervous tissue and help reduce pain and improve joint mobility.[10] NJF that combines with PNF and joint composition movement may be beneficial in alleviating pain and improving functional independence in subjects with knee OA. A study investigating the immediate effects of NJF on pain and walking ability in elderly with knee OA showed that NJF not only reduced pain but also improved walking ability.[11,12] A recent systematic review with the meta-analysis by Sabharwal et al. recommends that neuromuscular exercises (NEMEX) can be used as a potential intervention to reduce pain and improve strength and function in knee osteoarthritis patients.[11] The earlier study investigated the immediate effects of the NJF technique, and a systematic review included studies that did not consider physical function, particularly balance, as an outcome measure.

The present study is the first to explore the effects of six weeks of NJF on physical performance, static posture, and balance control among OA knee subjects compared to quadriceps strengthening exercises for the control group. The study's objectives are to compare the effects of a neuromuscular joint facilitation program versus quadriceps strengthening exercise on pain, physical function, static posture, and balance control in subjects with knee OA for six weeks using numeric pain rating scale (NPRS), 30-second chair stand (30s-CST), and single leg stance (SLS).

METHODS

The university research ethics committees approved the study. The subjects were recruited from the outpatient department of physiotherapy, Manipal Hospital, Bangalore. The study investigator screened OA knee subject who sought treatment from Physiotherapy OPD for a duration of one year. The study investigator explained subjects who fulfilled the study criteria and purpose of the research, and informed consent was obtained. The blinded outcome assessor collected demographic information and all baseline outcome measures. Once participants completed all baseline assessments, they were randomized into one of the two arms intervention groups by a blinded, random group allocator. The study investigator advocates the treatment of the exercise intervention for both groups, not blinded to group allocation. All procedures involving human participants in our study followed the institutional research committee's ethical standards, the 1964 Helsinki declaration.

Criteria

Inclusion criteria were 45 or more years of age, subjects diagnosed with knee OA according to American College of Rheumatology Criteria, and not engaged in any other physical therapy program for a minimum of the past three months. Subjects were excluded if they had a history of previous knee surgery, knee trauma, or other musculoskeletal problems related to the knee joint (such as tendon or ligament tears) leading to secondary OA, rheumatic diseases other than osteoarthritis, and any unstable medical condition or neurological disorder.

Sample Size Estimation

The sample size was calculated based on outcome measure NPRS with a 5% significance level and 80% power, anticipating a minimal clinically important difference of 2 points[12] with a 20% dropout rate and standard deviation of 2.40.[13] The sample size calculated was a total of 60 subjects. The subjects were randomly allocated by 1:1 ratio using the block randomization procedure with ten blocks of six subjects per block. Thus, each block had three subjects from each group, and each group had 30 subjects. These random numbers were generated using computer-generated random sequences by a statistician blinded to the study.

Study Procedure

Eighty subjects were screened for the inclusion criteria. Sixty subjects fulfilled the study criteria, and they were enrolled in the study. Sixty subjects were randomly allocated to either of the two groups using the block randomization method. Fifty subjects completed the study, comprising 16 males and 34 females. Enrollment and allocation of subjects are represented in the study flow chart in Figure 1.

The experimental group received the NJF technique comprised of PNF and joint composition movement. The control group received a quadriceps strengthening program, which progressed according to American College of Sports Medicine guidelines.[14,15] Standard knee exercises were given as a home program to both groups.

Experimental Group—NJF Technique

Subjects in the experimental group received PNF patterns and joint composition movement, aiming to improve joint movement through passive and active exercises.

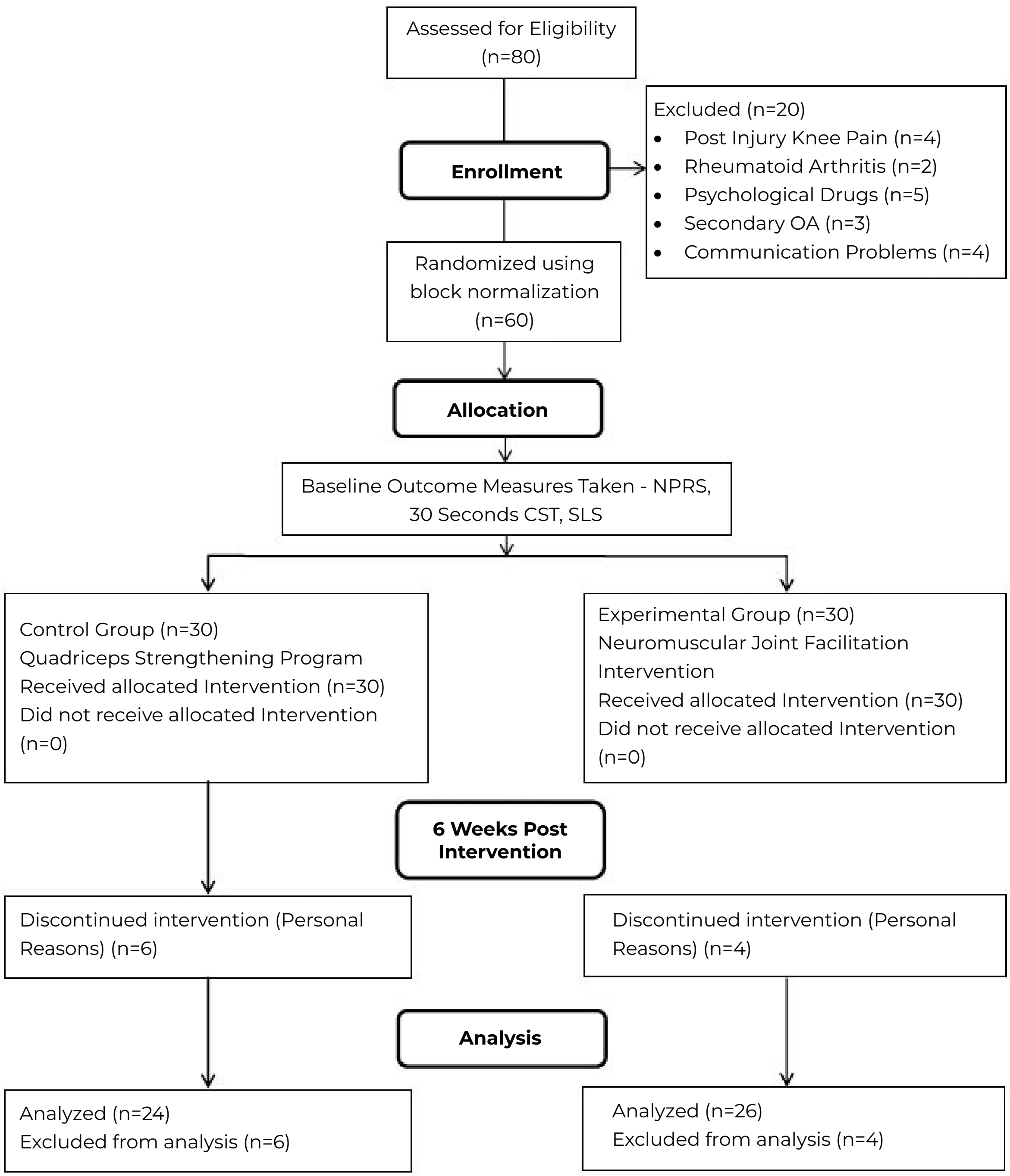


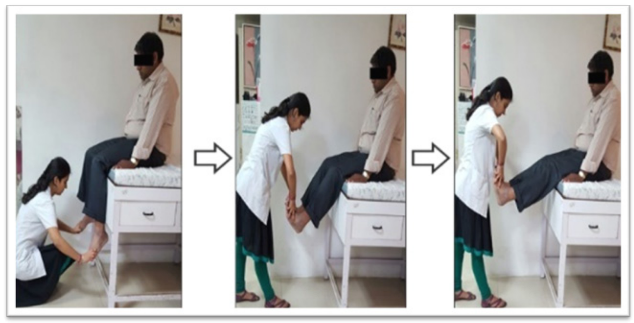
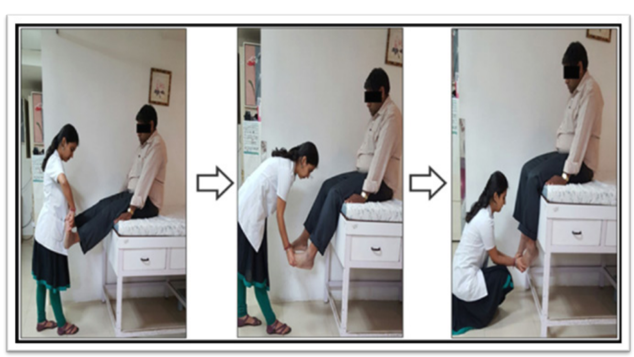
FIGURE 1. Consort flow diagram of study flow

The progression was carried according out according to PNF principles. Symmetrical bilateral patterns were performed. The patterns were performed with the subject sitting with hands gripping the table edge for stability.[8-11] The PNF patterns are described in Table 1.

Joint Composition Movement

Joint composition movement was done through passive and active knee joint exercises to increase the knee joint's flexibility and ROM. Active exercises were given in heel slides and dynamic knee flexion and

TABLE 1. Details of Neuromuscular Joint Facilitation Technique-PNF patterns

Patterns	*Description*	*Figure*
D1 Flexion	Flexion-adduction-external rotation with knee extension, left and right. Resisted - Left and right feet and ankles dorsiflex, invert, and initiate knee extension with external rotation.	
D1 Extension	Extension-abduction-internal rotation with knee flexion, left and right. Resisted - Left and right feet and ankles plantar flex, evert and initiate knee flexion with internal rotation.	
D2 Flexion	Flexion-abduction-internal rotation, with knee extension, left and right. Resisted - Feet and ankles dorsiflex, evert, and initiate knee extension with internal rotation.	
D2 Extension	Extension-adduction-external rotation, with knee flexion, left and right. Resisted - Feet and ankles plantar flex, invert and initiate knee flexion with external rotation bilaterally.	

extension to improve the knee ROM. In case of severe restriction of knee ROM, joint mobilization was done using Maitland's peripheral mobilization guidelines.

Control Group—Quadriceps Strengthening Program

The subjects in the quadriceps strengthening group completed four specific exercises that progressed gradually according to ACSM guidelines.[14,15] The exercises were:

1. Isometric quadriceps contraction in full extension (in supine lying).
2. Quadriceps extension over a roll using the resistance of the ankle. Straight leg raise-start supine, raise leg to 30° hip flexion using resistance of ankle.
3. Knee extension in sitting: start sitting with the knee at 90° of flexion, and fully extend using the resistance (weight cuff) of the ankle.

Outcome Measures

The primary outcome measure was the Numeric Pain Rating Scale (NPRS) to assess pain intensity. The secondary outcome measures used were the 30-s chair stand test (the 30s- CST) for assessment of physical function and the single leg stance (SLS) test for assessment of static posture and balance control. The blinded outcome assessor assessed all subjects at baseline and at the end of six weeks.

Numeric pain rating scale (NPRS)

The NRPS is a simple test that measures the specificity of pain. It is an 11-point scale, where "0" is no pain at all and "10" is the most intense pain imaginable. Subjects verbally select a value most in line with the intensity of pain they have experienced in the last 24 hours. The number that the respondent indicated on the scale to rate their pain intensity was recorded.[12]

30-second chair stand test (30s-CST)

The 30s-CST is a measurement to assess the lower extremity strength, mobility, and balance in older adults. It assessed the number of times a subject could stand and then sit in a chair in 30 s. At the sign of "start," the subject rose to a complete stand (body erect and straight) and then returned to the initial seated position. The subject was encouraged to complete as many full stands as possible within 30 s and to sit fully between each stand. If the subject complained of pain or difficulty while performing the test, they were asked to stop and take a rest. The therapist first demonstrated the test, and the subject practiced a repetition or two before completing the test. The score was the total number of stands within 30 s (more than halfway up at the end of 30 s was counted as a complete stand). Incorrectly executed stands were not counted. [16]

Single leg stance (SLS) test

The test measured static postural control of the stance knee and was used to assess balance. To perform the test, the length of time was recorded as the subject balanced on one leg while keeping their hands on their hips. The test lasted up to 30 s and was stopped if: a) the swing leg touched the floor, b) the stance foot was displaced on the floor, c) the swing leg touched the tested limb, or d) the arms swung away from the hips.[17]

For 30s-CST and STS tests, the better of the two trials after one practice trial was considered. Five minutes of rest time was given for each trial. The mean value of two trials was recorded and used for analysis.

Statistical Analysis

SPSS© version 22 statistical software (IBM SPSS Statistics, Armonk, NY) was used for data analysis. The Kolmogorov-Smirnov test was used to check the normality of the data. The data were normally distributed and not skewed. A paired *t* test was used for within-group differences, and a between-group difference independent *t* test was used. All statistical tests were considered significant when the *p* value was less than .05.

RESULTS

Table 2 presents the demographic information for the two groups. The control group had seven males and 17 females, whereas the experimental group had nine males and 17 females. Analysis showed that the female:male distribution was similar between the two groups (p = .68). The mean age of the subjects in the control group was 63.12 (± 8.08) years, whereas,

TABLE 2. Baseline Demographics of Included Study Subjects

Characteristics	*Control Group (n=24)*		*Intervention Group (n=26)*	
	Mean	*SD*	*Mean*	*SD*
Age (years)	63.12	8.08	61.77	8.46
Height (feet)	5.28	0.41	5.31	0.05
Weight (kg)	64.35	10.12	68.35	9.99
BMI (kg/m^2)	25.64	4.20	26.54	2.83
Knee ROM- Left (degrees)	127.50	10.53	123.62	23.91
Knee ROM-Right (degrees)	124.17	12.91	120.54	32.75
Duration (years)	4.08	3.06	3.12	2.61
NPRS (score)	6.71	1.23	5.73	1.40
30s-CST (stands)	7.88	2.93	9.04	2.32
SLS test (seconds)	10.29	8.85	17.15	10.71

N = number of subjects; SD = standard deviation; NPRS = Numeric Pain Rating Scale; BMI = Body Mass Index; ROM = range of motion; CST = chair stand test; SLS = single leg stance.

in the experimental group, it was 61.77 (± 8.46) years. Baseline homogeneity was assessed using the independent *t* test, and the characteristics of subjects were found to be statistically insignificant at baseline.

Experimental Group: Within-Group Analysis

The improvement in the mean value of NPRS was 1.84 (± 1.04), 30-s CST was 9.04 (± 2.32) stands, and SLS time was 17.15 s (± 10.71) at the end of six weeks. Analysis of the experimental group revealed a significant change in the NPRS values, 30s-CST, and SLS time (p = .00) from baseline to the end of six weeks.

Control Group: Within-Group Analysis

The improvement in the mean value of NPRS 2.54 (± 1.10), 30s-CST was 7.88 (± 2.93) stands, and SLS was 10.29 s (± 8.85) at the end of six weeks. The difference observed was of 6.81 s. Analysis of the control group revealed a significant change in the NPRS values, 30s-CST, and SLS time (p = .00) from baseline to the end of six weeks (see Table 3).

Between-Group Analysis

The change from baseline to the end of six weeks in the NPRS, 30s-CST, and SLS time was calculated for the control and experimental group, and the mean difference between the two groups was calculated. Table 4 contains the analysis, which showed no significant difference between the experimental and control groups in the mean values for all three characteristics at the end of six weeks ($p \geq$ =.05). This shows that both the groups improved equally from baseline to the end of six weeks in all three outcome measures (Table 4).

DISCUSSION

The current study aimed to investigate and compare the effects of neuromuscular joint facilitation and quadriceps strengthening exercise on pain, physical function,

TABLE 3. Within-Group Difference Analysis for the Experimental and Control Group

Clinical Variables	*Group*	*Baseline*		*Six Week*		*Mean Difference*	*95 % Confidence Interval*		*P Value*
		Mean	*SD*	*Mean*	*SD*		*Lower*	*Upper*	
NPRS	Experimental	5.73	1.4	1.84	1.04	3.89	3.597	4.17	.000
	Control	6.71	1.23	2.54	1.1	4.17	3.67	4.65	.000
30s-CST	Experimental	9.04	2.32	13.23	2.37	-4.19	-4.8	-3.57	.000
	Control	7.88	2.93	11.33	3.19	-3.45	-4.1	-2.81	.000
SLS Test	Experimental	17.15	10.71	23.96	8.82	-6.81	-9.48	-4.13	.000
	Control	10.29	8.85	16	10.81	-5.71	-7.99	-3.43	.000

SD = standard deviations; NPRS = Numeric Pain Rating Scale; CST = chair stand test; SLS = single leg stance.

TABLE 4. Analysis Between the Control and the Experimental Group

Clinical Variables	*Control Group*		*Experimental Group*		*Mean Difference (I-J)*	*95% Confidence Interval*		*p Value*
	Mean (I)	*SD*	*Mean (J)*	*SD*		*Lower*	*Upper*	
NPRS	4.17	1.16	3.89	0.71	0.28	-0.26	0.82	.303
30s-CST	3.45	1.53	4.19	1.52	-0.74	-1.6	0.14	.09
SLS test	5.71	5.39	6.81	6.63	-1.1	-4.55	2.35	.525

SD = standard deviations; NPRS = Numeric Pain Rating Scale; CST = chair stand test; SLS = single leg stance.

static posture, and balance control in subjects with knee osteoarthritis.

The experimental group improved by 3.89 points on the NPRS scale, which was significant as it exceeded the 3-point minimal detectable change (MDC).[12]

Neuromuscular joint facilitation causes muscles and tendons to stretch and contract at elongated lengths, decreasing the nociception and inhibiting the Golgi tendon organs.[18] This leads to reduced pain perception and greater force to be produced by the muscle. It also causes a reduction of pain by improving the distribution of forces and thereby reducing the functional stresses associated with knee OA.[9] The findings of the present study are in line with Nakata et al.[8] who reported a significant difference of 22 units in the pain intensity immediately after neuromuscular joint facilitation in subjects with knee OA. The findings show that NJF may effectively reduce pain in subjects with knee osteoarthritis.

The control group also significantly improved 4.17 scores in the NPRS. Studies conclude that weakness in the quadriceps muscle has been associated with pain, inflammation, degenerative changes, and disability in knee osteoarthritis. Quadriceps strengthening reduces shear forces and improves the distribution of forces on the knee joint. Hence progression strengthening of the quadriceps reduces pain and improves function in people with knee OA.[19,20] The present study's change in NPRS is similar to Bryk et al.[21], who conducted six weeks of quadriceps strengthening that found a mean change of 2.5 scores in the NPRS. The scores on the NPRS did not have a significant mean difference between both groups at the end of six weeks, and a possible reason may be both groups received quadriceps training as part of the therapy program. This shows that both groups had a similar reduction in pain scores after six weeks of therapy.

The 30s-CST was the functional ability test used in the present study. The experimental group had a mean change of 4.19 stands in the 30s-CST, which exceeded the 3-point MCID. Sit-to-stand movement is a complex functional movement affected by balance, strength, sensorimotor, and psychological factors. The relationship between hip, knee, and ankle joint strength may affect-the sit-to-stand activity.[22] Literature demonstrated that neuromuscular exercises improve coordinated muscle activity by improving sensorimotor control, and helped achieve functional stability with the appropriate hip, knee, and ankle joints. This leads to an even distribution of articular pressure, muscle co-activation, improvement in the functional alignment of the lower extremity, reduction of pain, and gains in physical function.[7] The present study had a mean change of 4.19 stands compared to 1.4 stands noticed by Skou et al.[23] in their study of six weeks of neuromuscular training. The more significant mean change in the present study could be due to patients' treatment adherence and standard quadriceps exercise, along with experimental intervention used in the present study. The results support neuromuscular exercises' applicability to improve knee OA function.

The control group showed a significant change of 3.45 stands in the 30s-CST. Previous studies have established a relationship between pain, self-reported knee instability, muscle strength, and knee confidence (an individual's belief of being capable of successfully performing exercising control over one's health habits).[24] Quadriceps muscle provides dynamic stability to the knee joint, and it has been suggested that pain leads to decreased voluntary activation of the quadriceps muscle (arthrogenic inhibition).[25] This leads to a lack of knee confidence during functional activities. Exercise not only leads to gains in muscle strength, but also helps to increase knee confidence.[24] This increased knee confidence helps to decrease the fear of performing previously strenuous functional activities.[26] Studies reported that increased quadriceps muscle activation following exercise leads to reduced pain.[25] Hence the improved confidence and gains in muscle activation lead to better performance of functional activities in the control group. The present study's improvement in the 30s-CST, similar to the improvement of 3.2, is noticed by Hruda et al.[27] in their ten-week progressive lower extremity resistance training. There was no significant difference in the 30s-CST times between the two groups at the end of six weeks. Because deficits in muscle strength are associated with decreased ability to do physical tasks, both groups' addressed quadriceps weakness and activation may lead to a similar improvement in the performance of functional activities.

The experimental group showed a significant mean improvement of 6.81 s (39.7%) in the SLS test. Studies suggest that the integrity of the sensorimotor system (proprioceptive acuity and muscle contraction) is essential for maintaining balance.[28] It has been hypothesized that eccentric muscle contractions are necessary for posture recovery after perturbation.[5,29] Neuromuscular joint facilitation technique applies neurophysiological principles of the sensory-motor system. It facilitates an optimal neuromuscular state by distributing the forces and reducing the functional stresses. It also provides gains in proprioception and enhances activation of muscles through the spiral, diagonal patterns (which are in line with the arrangement of muscle fibers).[9,30] Hence, NJF effectively improves balance and postural stability.[28] The control group showed a mean improvement of 5.71 seconds after six weeks of therapy. This is due to the fact that quadriceps strengthening exercises provide greater stability to the knee joint, optimize muscle strength and power, improve balance and reduce the risk of falls.

The present study showed significant differences within the group and did not find any significant difference in all outcomes (NPRS, 30s-CST, SLS test) between the two groups at the end of six weeks. This shows that the interventions improved physical function, static posture, and balance control over six weeks. Both interventions improved strength, reduced pain, and improved neuromuscular control, and both groups improved static balance and functional ability. The study by Sabharwal et al. supports the results of the current study in their systematic review and meta-analysis, concluding that neuromuscular exercise can be a potential intervention in reducing pain and improving strength and function in knee osteoarthritis patients.[11] The current study's results suggest an overall improvement in both groups' pain, function, and balance. Thus, both NMJF exercises and progressive quadriceps strengthening training programs are equally effective in addressing the deficits associated with knee OA.

Limitations:

The potential limitation of the present study was the 16.66% dropout in the estimated sample size. Lack of long-term follow-up period and blinding of the therapist was not done.

Recommendations:

Various PNF patterns, such as symmetrical, asymmetrical, reciprocal, and crossed diagonals, can be compared to find which patterns are most suited for knee osteoarthritis subjects. It is recommended to analyze the response of neuromuscular joint facilitation on other physical performance outcomes (balance of other components, proprioception, muscular endurance) and radiological diagnosing imaging (Rehabilitative Ultrasonography Imaging, MRI) in subjects with knee osteoarthritis.

CONCLUSION

The neuromuscular joint facilitation program and quadriceps strengthening exercises effectively reduced pain and improved physical function, static posture, and balance control in subjects with knee osteoarthritis. Both groups had the same effect on pain reduction and improved physical functions (lower body strength, dynamic balance during sit-to-stand, static posture, and balance control) at the end of the six weeks post-intervention. Hence, further high-quality clinical trials with long-term follow-up are warranted.

CONFLICT OF INTEREST NOTIFICATION

The authors declare there are no conflicts of interest.

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Corresponding author: Venkatesan Prem, PhD, Department of Physiotherapy, Manipal College of Health Professions, Manipal Academy of Higher Education, Manipal, Karnataka, India

E-mail: prem.v@manipal.edu