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Effects of neuromuscular exercises on pain and physical function in patients with medial knee osteoarthritis: An experimental study

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Abstract
Osteoarthritis is a degenerative joint disease occurring primarily in older persons and predominantly affecting medial tibiofemoral compartment leading to pain, loss of function and reduced quality of life. During walking, forces across the knee joint are not transmitted equally between the medial and lateral compartments. Increased mechanical load and damage to the medial side of the knee joint has been associated with increasing knee varus alignment, further loading the medial compartment which causes symptoms of medial knee osteoarthritis. This study was aimed to determine the effects of neuromuscular exercises for improving pain and physical function in patients with medial knee osteoarthritis. 30 subjects with medial knee osteoarthritis that fulfilled the inclusion criteria were randomly assigned into 2 groups; 15 in each group. Control group received conventional treatment and experimental group received neuromuscular exercises along with conventional treatment. The treatment duration was 45 minutes in each session for 6 days in a week and the trial stretching 8 weeks. Statistical analysis of inter group significance by independent sample t-test for WOMAC [t=2.356>table value, t= 2.048], isometric knee extension [t=7.941>table value, t=2.048] and Mann-Whitney test for VAS [p=0.007] reveals that experimental group showed significant difference between pre-test and post test values of WOMAC, isometric knee extension and VAS than the control group. Both groups show significant difference in their pre and post–test values. Participants with medial knee osteoarthritis in the experimental group that received neuromuscular exercise along with conventional treatment show greater improvement in pain and physical function. The findings of this study reveal a more effective exercise treatment option than currently exists for this important subgroup of people with knee osteoarthritis.

Keywords: Neuromuscular exercise, osteoarthritis of knee, pain, isometric knee strength

Introduction
Osteoarthritis (OA) is a degenerative joint disease occurring primarily in older person, characterized by erosion of the articular cartilage, hypertrophy of the bone at the margins that is osteophytes, subchondral sclerosis and a range of biochemical and morphological alteration of the synovial membrane and joint capsule [1]. Knee osteoarthritis predominantly affecting the medial tibiofemoral compartment, is a common chronic condition leading to pain, loss of function and reduced quality of life [2]. The prevalence of OA increases with age. Men are affected more commonly than women before 50 years of age whereas after 50 years of age the prevalence in women is 2-3 times greater than men [3]. OA is the second most common rheumatologic problem and the reported prevalence of knee OA in elderly in other studies is done in India ranged between 32% and 64% [4]. The associated factors were found to be female gender, obesity, age and sedentary work [5]. OA can be diagnosed by radiographic changes and/or by typical clinical symptoms. Radiographic findings which identify OA include osteophyte formation along the joint margins, joint space narrowing, subchondral sclerosis and cyst formation. Presence of osteophytes is the most specific radiographic marker of OA, although osteophytes are not present in early disease [6]. The knee joint is a complex structure with three joint compartments, including the medial and lateral tibio-femoral compartments and patella-femoral joint. During walking, forces across the knee joint are not transmitted equally between the medial and lateral compartments.

The load on the medial compartment is approximately 2.5 times greater than that on the lateral compartment [7]. Consistently higher loads on the medial compartment have been shown to result in degenerative changes of the articular cartilage. This imbalance in the load distribution may explain the higher prevalence of medial compartment involvement (75%) reported in subjects with knee OA relative to the lateral compartment (25%) [8]. Furthermore, with disease progression, increased mechanical load and damage to the medial side of the knee joint has been associated with increasing knee varus alignment, further loading the medial compartment [9]. The poorer prognosis for people with medial knee OA and varus malalignment is likely due to the greater compressive load borne on the diseased medial compartment in these people compared to those with more neutrally aligned knees. Varus malalignment causes the ground reaction force vector to pass more medially to the knee joint center during gait resulting in increased loads across the medial compartment [10].

Neuromuscular Exercise Programme (NEMEX) is typically performed in functional weight-bearing positions, emphasizing optimal alignment of trunk and lower limb joints related to one another, as well as quality of movement of performance while dynamically and functionally strengthening the lower limb muscles may be able to reduce the knee load [11]. The Neuromuscular training method is based on biomechanical and neuromuscular principles to improve sensorimotor control and achieve compensatory functional stability. Sensorimotor control is the ability to produce controlled movement through coordinated muscle activity, and functional stability is the ability of the joint to remain stable during physical activity [12]. A major goal of traditional knee OA rehabilitation is to enhance quadriceps muscle strength. The aim of NEMEX program is different since the intention is to improve postural control and functional performance by challenging lower-limb muscles in functional positions. Quadriceps strengthening aims to increase muscle force production. Unlike conventional strength training, neuromuscular exercise addresses the quality of movement and emphasizes joint control in all three biomechanical or movement planes. Neuromuscular exercise has effects on knee functional performance, knee biomechanics and muscle activation patterns of the surrounding knee musculature. Hence neuromuscular exercise helps to improve the overall function of the limb. This study was aimed to determine the effects of neuromuscular exercise in reducing pain and improving function in patients with medial knee osteoarthritis.

Materials and Methods

Study setting: This study was conducted at the the Department of Physiotherapy at Dhanalakshmi Hospital, Kannur, India.

Study design: Experimental study

Procedure: Eligible participants were randomly allocated in permuted blocks generated a priori by our statistician to either the group receiving the NEMEX therapy (experimental) or the group receiving the quadriceps strengthening exercises (control group). A total of 30 subjects were divided into two groups, control group [n=15] & experimental group [n=15]. Control group received quadriceps strengthening exercises and experimental group received a combination of quadriceps strengthening and neuromuscular exercise. Both groups received TENS for 10-15 minutes after exercise session to reduce pain. Participants were given a short introduction to the study. This study was approved by the Research Ethics Committee of the Co-operative Institute of Health Sciences, Thalassery, Kerala, India. Informed Consent was obtained from all patients.

Eligibility criteria: Patients with clinical diagnosis of medial knee osteoarthritis of knee confirmed by x-rays, symptoms lasting more than 3 months, pain / tenderness over the medial region, age between 55 to 60 years, both genders, Medial compartment osteophyte [Kellgren and Lawrence Scale: Grade 2- 3], and unilateral Involvement were included in the study.

Subjects were excluded from the study with any history of knee, hip and ankle surgery prior to the study, peripheral vascular disease, any local or systematic infection, mentally deficit patients, any deformities in the lower limbs, limb length discrepancy, intra articular injection to the knee within 6 months, patient undergone previous physiotherapy treatment, patient with poor balance.

Treatment protocol: Control group received Quadriceps strengthening and TENS. Quadriceps strengthening exercises included quads over a roll (inner range knee extension) against resistance of ankle weights, knee extension in sitting - sitting with knee at 90° flexion, and fully extend knee against resistance of ankle weight, knee extension with hold at 30° knee flexion- sitting with knee at 90° flexion and extend to 30° against resistance of ankle weights, supine straight leg raise – raise leg to 30° hip flexion against resistance of ankle weights and outer range knee extension- sitting with knee at 90° flexion, extend to 60° against resistance of elastic band. Each exercise was given in sets of 10 repetitions with 5–10-second hold. 1 set of exercise for 1st week, progressed to 2 sets in 2nd week and 3 sets in 3rd week.

Experimental group received neuromuscular exercises for 3 weeks along with quadriceps strengthening. Neuromuscular exercises included Forward and backward sliding or stepping - Standing on affected leg and sliding or stepping opposite leg forward and backward, Sideways exercises- Standing on affected leg and sliding or stepping opposite leg sideways, standing on foam and closing eyes during the movement, Functional hip muscle strengthening- Standing isometric abduction, Functional knee muscle strengthening - Squatting against a wall, with progressing to rising from sitting with increased weight taken through study leg, Step-ups and down-Stepping onto a step, with progression to add 2 kg hand weight, and Balance - Standing on affected leg, with progression by adding arm movements and then stepping forward into foam. All exercises were given in sets of 10 repetitions.1 set of 10 repetitions without resistance in 1st week, 2 sets of 10 repetitions by adding elastic resistance in 2nd and 3 sets of 10 repetitions by adding resistance in 3rd week of exercise.

High TENS was given for participants in both groups with the following parameters.

Electrode placement: Over supero-medial and infero-medial aspect of knee

Pulse pattern: Continuous

Pulse frequency: 100 to 150 pps,

Pulse duration: 50 to 80 microseconds

Pulse Amplitude: Increase intensity to produce a strong but comfortable tingling

Duration of stimulation: 10 minutes

Outcome measures

Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC): It is a self-administered questionnaire consisting of 24 items divided into 3 subscales; pain, stiffness and physical function. The WOMAC takes approximately 12 minutes to complete. The test questions are scored on a scale of 0-4, which correspond to: None (0), Mild (1), Moderate (2), Severe (3), and Extreme (4). Higher scores on the WOMAC indicate worse pain, stiffness, and functional limitations. The WOMAC Index has been used extensively in clinical trials, and has generally been shown to exhibit greater or comparable responsiveness to change than other tests [13].

Visual Analog Scale (VAS): The pain VAS is a unidimensional measure of pain intensity, used to record patients' pain progression, or compare pain severity between paints with similar conditions. Test–retest reliability has been shown to be good, with moderate to good reliability for disability in patients with chronic musculoskeletal pain [14]. Isometric strength of knee extensors: Handheld dynamometry (HHD) is a tool used to measure isometric muscle strength [15]. Isometric strength of knee extensors was measured using Isometric Base line Push/Pull Hand Held Dynamometer with 50lb/20 kg capacity, which can measure muscle strength in kilograms (kg) or in pounds (lb). Maximal isometric strength of knee extensors was measured with the participant seated, hip and knees flexed at 90°. Dynamometer was placed on the anterior aspect of the shank, proximal to the ankle joint. All outcomes were assessed at baseline and after treatment (8 weeks).

Statistical analysis: IBM SPSS Statistics v20 software was used for statistical analysis. Kolmogorov-Smirnov test was conducted to find out the normality. Paired t test was used as parametric test to calculate the intra group significance. Wilcoxon signed rank test was used as non parametric test to find out the intra group significance. Independent t-test and Mann Whitney u-test were used to analyze inter-group significance.

Results

Control group

Evaluation of WOMAC: By analyzing the pre-test and post-test values by paired t test, the calculated t value is 8.911 which is greater than the table value t= 2.144 (df=14 at p=0.05) which indicate that there is significant difference between pre and posttest values of WOMAC. Evaluation of VAS: By analyzing the pre and post-test values through Wilcoxon signed rank test, sig value is 0.001 which is less than p=0.05 which indicates that there is significant difference between pre and posttest values of VAS. Evaluation of isometric knee extension: By analyzing the pre-test and post-test values by paired t test, the calculated t value is 9.374 which is greater than the table value t= 2.144 (df=14 at p=0.05) which indicate that there is significant difference between pre and post test values of isometric knee extension.

Experimental group

Evaluation of WOMAC: By analyzing the pre-test and post-test values by paired t test, the calculated t value is 14.132 which is greater than the table value t= 2.144 (df=14 at p=0.05) which indicate that there is significant difference between pre and posttest values of WOMAC. Evaluation of VAS: By analyzing the pre and post-test values through Wilcoxon signed rank test, sig value is 0.001 which is less than p=0.05 which indicates that there is significant difference between pre and posttest values of VAS. Evaluation of isometric knee extension: By analyzing the pre-test and post-test values by paired t test, the calculated t value is 9.320 which is greater than the table value t= 2.144 (df=14 at p=0.05) which indicate that there is significant difference between pre and post test values of isometric knee extension. Table 1 shows the comparison after Analysis of the scores of outcome measures.

When comparing the post-test values of WOMAC, VAS & Isometric knee extension of both control and experimental groups through analysis of inter group significance, WOMAC shows sig value 0.026 in independent t-test [$p<0.05$], calculated t value 2.356 [>tabled t value 2.048 df=28]. Figure 1 shows comparison of pretest and posttest scores of WOMAC between control group and experimental group. VAS shows sig value 0.007 in Mann Whitney Test [$p<0.05$]. Figure 2 depicts comparison of pretest and posttest scores of VAS between control group and experimental group. Isometric knee extension sig value is 0.000 [$p<0.05$], calculated value 7.941> tabled t value 2.048, df=28 at p=0.05. Figure 3 shows the comparison of pretest and posttest scores of isometric knee extension between control group and experimental group. Experimental group shows significant difference from control group in WOMAC, VAS & Isometric knee extension. Neuromuscular Exercise has a significant effect over conventional treatment in reducing pain and improving function in patient with medial knee OA.

Table 1: Analysis of outcome measures

Group wise Descriptive Statistics						
Group		**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Control Group	WOMAC Pre Test	15	53.00	73.00	65.1333	6.32305
	WOMAC Post Test	15	40.00	58.00	49.5333	5.65517
	VAS Pre Test	15	5.00	8.00	6.8000	1.08233
	VAS Post Test	15	3.00	6.00	4.0667	.88372
	Knee Extension Pre Test	15	10.50	16.50	12.7667	1.86956
	Knee Extension Post Test	15	11.00	17.50	13.7333	1.84068
Experimental Group	WOMAC Pre Test	15	57.00	77.00	66.9333	5.54806
	WOMAC Post Test	15	39.00	55.00	44.5333	5.96258
	VAS Pre Test	15	5.00	8.00	7.0667	.79881
	VAS Post Test	15	1.00	4.00	3.0667	.88372
	Knee Extension Pre Test	15	12.50	18.50	15.6333	1.92230
	Knee Extension Post Test	15	15.50	20.50	18.7667	1.62422

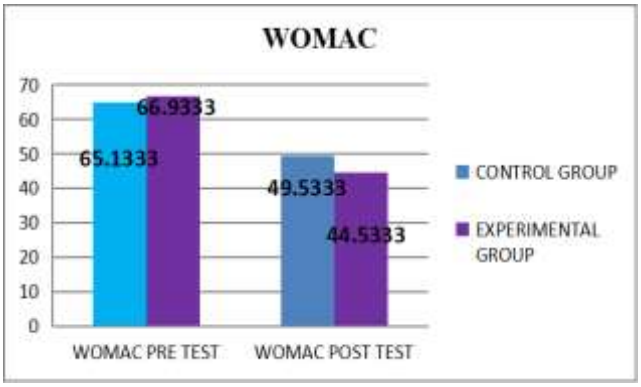

Fig 1: Bar chart comparing pretest and posttest scores of WOMAC between control group and experimental group

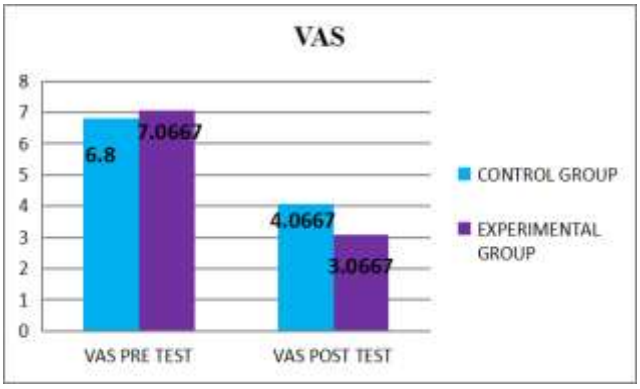

Fig 2: Bar chart comparing pretest and posttest scores of VAS between control group and experimental group

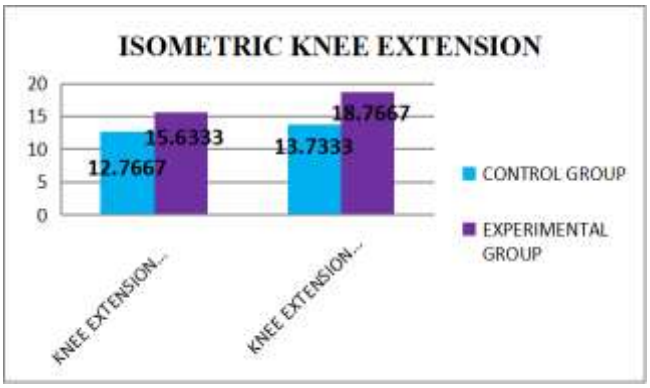

Fig 3: Bar chart comparing pretest and posttest scores of isometric knee extension between control group and experimental group

Discussion

This randomized, assessor-blinded, controlled trial evaluated the effects of neuromuscular exercises on pain and function in patients with medial knee osteoarthritis. We could confirm our hypothesis that patients undergoing the neuromuscular exercises training have shown improvement in pain and function at after eight weeks of the trial. The program was well tolerated based on our adverse event assessment. Statistical analysis revealed that neuromuscular exercises along with quadriceps strengthening shows significant effect over quadriceps strengthening exercise alone in reducing pain and improving physical function. Subjects with degenerative knee diseases are known to have deficiencies of sensory dysfunction, lower limb muscle weakness, altered muscle activation patterns and reduced functional performance. NEMEX has been applied to improve patient reported outcomes, functional performance and knee extensor strength in mild to moderate medial knee OA. During the stance phase of walking, relatively high loads are applied to the knee and loading of medial compartment associated with disease progression, severity and structural changes in patients with medial knee OA. People with knee OA have deficits in afferent and efferent neural pathways results decrease in proprioception, vibratory perception, muscle-force control and muscle strength. Intervention that focuses on increasing muscle strength and function are included in the management of medial knee OA.

Neuromuscular training aimed to enhance the unconscious motor response by calling upon both afferent signal and central mechanism responsible for dynamic control. It is based on biomechanical and neuromuscular principles, to improve sensorimotor control and achieve compensatory functional stability. Neuromuscular Exercise Program (NEMEX) is performed in functional weight bearing positions, emphasizing optimal alignment of trunk and lower limb joints related to one another as well as quality of movement of performance while dynamically and functionally strengthening the lower limb may be able to reduce the knee load.

Neuromuscular exercise increases functional knee stability and, in pilot studies, has shown potential to reduce knee-joint loads and improve cartilage matrix quality in those at risk or with mild disease [16]. Some evidence shows that the external peak knee-adduction moment (KAM) has a significant relation to *in vivo* measurement of medial compartment load [17]. and important clinical outcomes, including radiographic OA severity and knee pain [18]. In addition, neuromuscular exercise may have an effect on reducing medial knee joint load, pain and improving strength of quadriceps muscle. The outcome measures used in this study are WOMAC, VAS and Isometric hand-held dynamometer. On statistical analysis, the mean pre-treatment WOMAC of control group and experimental group is 65.13% and 66.93% and mean post treatment WOMAC is 49.53% and 44.53% [table no.1] respectively. This result shows that there is an increase of 20.8% in experimental group and 17.4% in the control group. This indicates that there is considerable decrease in WOMAC in experimental group in patients with medial knee OA. The mean pre-treatment VAS of control group and experimental group is 6.8% and 7.06% and mean post treatment VAS is 4.06% and 3.06% [table no.1] respectively. This result shows that there is an increase of 2.74% in control group and 4% in experimental group. This shows that there is considerable decrease of pain in experimental group. The mean pre-treatment knee extension strength of control group and experimental group is 12.76% and 15.63% and mean post treatment knee extension strength is 13.73% and 18.76% respectively. This result shows that there is an increase of 0.97% in control group and 3.13% in experimental group which shows that there is considerable increase of Knee extension strength in experimental group. Statistically significant improvement in function is seen in both the groups and between the groups. Findings show that the improvement in experimental group was greater than that of control group.

Strengths of the study design are the pragmatic nature of treatment delivery which occurs in community physiotherapy clinics by several practicing physiotherapists, and the reproducibility of both exercise programs. Our study is based on the premise that while the static structural mal-alignment itself cannot be altered in individuals with medial knee OA, except via surgical procedures, other factors contributing to higher knee load are potentially modifiable with exercise interventions. If the loading forces can be reduced within the medial tibiofemoral compartment during weight bearing,

structural degeneration may be slowed in addition to achieving symptom relief. This study proved that neuromuscular exercises will result in greater improvement in knee functional performance, knee biomechanics and muscle activation patterns of surrounding musculature. The advantages of NEMEX include improved sensory motor control and muscle activation pattern, reduction in the knee load and achievement of compensatory functional stability thus leading to improved overall function of the limb.

Conclusion

This trial evaluates an innovative neuromuscular exercise program that aims to reduce pain and improve function in people with medial compartment OA. The findings may lead to a more effective exercise treatment option than currently exists for this important subgroup of people with knee OA.

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Conflict of Interest: The authors declare no conflict of interest.

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