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Original Research Article

Effect of Neuromuscular Training [NEMEX] on Pain, Quadriceps Strength and Quality of Life in Osteoarthritis Knee - An Interventional Study

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ABSTRACT

Background: Osteoarthritis is complex disease resulting from multiple factors. Among all factors quadriceps weakness has been found to be a major factor in the progression of Osteoarthritis knee. Due to primary contribution of quadriceps in both joint stability and joint loading, its poor strength leads to functional impairments and reduced quality of life. Neuromuscular training (NEMEX) consists of various exercises to improve functional alignment, joint stability & muscle activation pattern.
Method: After approval from ethical committee, 46 Participants were randomly divided into 2 groups Group A (Experimental) received neuromuscular exercise plus conventional treatment while Group B (control) received only conventional treatment for 4 weeks. Pre and post intervention score for Pain [NPRS], Quadriceps strength [Hydraulic hand-held dynamometer] and quality of life [WOMAC] were measured.
Result: After 4 week of intervention, within group analysis showed significant improvement on NPRS, WOMAC and Quadriceps strength compared to pre data ($p<0.05$).In between group analysis, Group A showed significant improvement on NPRS, WOMAC and Quadriceps strength than group B ($p<0.05$).
Conclusion: Thus, group A with Neuromuscular training showed a statistically significant effect on Pain, Quadriceps strength and Quality of life compared to group B.

Keywords: Osteoarthritis knee, Neuromuscular training [NEMEX]

INTRODUCTION

Osteoarthritis Knee is the leading cause of pain and disability in elderly population with a prevalence of 28.7% in India. Prevalence was found to be higher in participants who used the western toilet (42.21%) and in sedentary people (82.9%). [1] Osteoarthritis is characterized by progressive destruction of articular cartilage, subchondral sclerosis and hypertrophy of bone at margins, which is clinically evident by pain which is aggravated by activity and relieved by rest, tenderness, joint stiffness, muscle weakness, swelling, and cracking noise. [2] With the progression of disease, knee osteoarthritis also affects the peri-articular structures like ligaments, capsules, tendons and muscles which causes sensory motor deficiency and resulting in reduced sensory motor skills like proprioception, static/dynamic balance and neuromuscular control. [3] Pain, inflammation, joint instability and swelling damages sensory receptors in the joint which leads to neural inhibition /arthrogenic muscle inhibition – AMI which results in an inability of muscle to be fully activated by affecting the excitability of spinal and supraspinal pathways, which is a major contributing factor for Quadriceps weakness and disease progression. [4] Weak Quadriceps are also prone to fatigue easily which leads to poor neuromuscular control, results in altered biomechanics of joints and leads to progressive loss of functions of lower limb like sit-to-stand, stair climbing, cross sitting, gait parameters, etc. which are directly correlated to disability and quality of life.

Neuromuscular training is a broad spectrum of close chain exercises directed towards, agility, functional activity and proprioception which are different from conventional strengthening exercises. As Exercises are performed in a closed kinetic chain at different positions for equal distribution of articulating pressure via muscle co-activation. Muscle co-activation is associated with different types of joint loading which helps in functional joint stabilization and joint load reduction. [5]

As there are less evidences of this study on the Indian population, hence this study is done to add evidence about the effect of neuromuscular exercises [NEMEX] on Pain measured by NPRS scale, Quadriceps strength measured by Hand held dynamometer and Quality of life by WOMAC score.

MATERIALS & METHODS

This study includes patients with knee osteoarthritis. Ethical approval was obtained from the institutional ethics committee. (Registration No: GSIIESC/56/22)

STUDY DESIGN: Interventional study.

STUDY SETTING: Physiotherapy department.

SAMPLING TECHNIQUE: Convenient sampling method (chit method)

STUDY DURATION: 1 year

INTERVENTION DURATION: 4 weeks (4 sessions per week)

SAMPLE SIZE: Total 46 (23 in each group)

SAMPLE SIZE CALCULATION: The sample size was calculated by statulator software using the formula given below.[6] :

$$n = (Z_{\alpha/2} + Z\beta)^2 \times 2 \times \sigma^2 / d^2$$

where,

$Z\alpha/2$ = Level of significance of difference for 5% of this 1.96

$Z\beta$ = power of 80%, β is 0.2 and critical value is 0.84

$\sigma 2$ = population variance

d = hypothesized difference you would like to detect

Anticipated a non-response or dropout percentage as 10%.

INCLUSION CRITERIA:

- Willing to participate
- Patients diagnosed by a medical practitioner with Osteoarthritis Knee.
- Patients with unilateral knee Osteoarthritis.
- Both male & Female
- Any stage of Osteoarthritis knee.
- Age group 40-75 years.
- Patients who were able to read Gujarati / English language.
- Patients who understand visual and verbal commands.

EXCLUSION CRITERIA:

- Any known history to the patient about neurological, and cardiopulmonary conditions.
- Any known history to the patient about orthopedic conditions other than Osteoarthritis knee.

WITHDRAWAL CRITERIA:

- If pain was aggravating.
- Patient who wished to discontinue.

MATERIAL REQUIRED:

- Pen, Pencil, Paper
- Treatment plinth
- Consent form (English / Gujarati)
- Assessment form

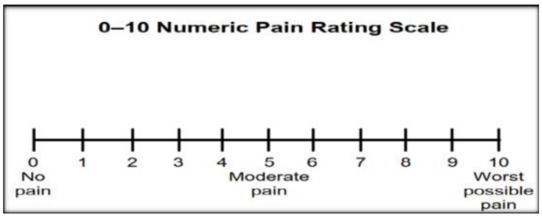
- WOMAC score sheet (English / Gujarati)
- Hydraulic hand-held dynamometer
- Hot packs
- Long towel
- Weight cuffs

Photograph 1.1 Materials required for the study

OUTCOME MEASURES: -

1. **Numerical pain rating scale (NPRS):** [7]

It is an 11-point numeric scale (NPRS11) with 0 representing one pain extreme (e.g. ‘no pain’) and 10 representing the other pain extreme (e.g. ‘pain as bad as you can imagine’) The patient is asked to indicate the numeric value on the segmented scale that best describes their pain intensity. Scores range from 0 – 10.
Reliability from 0.67 to 0.96 and Validity from 0.85 to 0.95. [23]



Photograph 1.2 Numeric pain rating scale

2. **Western Ontario and McMaster Universities osteoarthritis index (WOMAC):** [8]

It is self measurement tool which consists of 24 items divided into 3 subscales: Pain (5 items), Stiffness (2 items) and Physical function (17 items). These includes ordinal scale of 0-4. A higher score on WOMAC indicates worse pain, stiffness and physical limitation. WOMAC was used in English and Gujarati versions. [24] Reliability is 0.74, 0.58 and 0.92 for pain, stiffness and physical and functional function subscales respectively. Validity is 0.86 – 0.89, 0.90 – 0.91 and 0.95 for the pain, stiffness and function subscales, respectively.

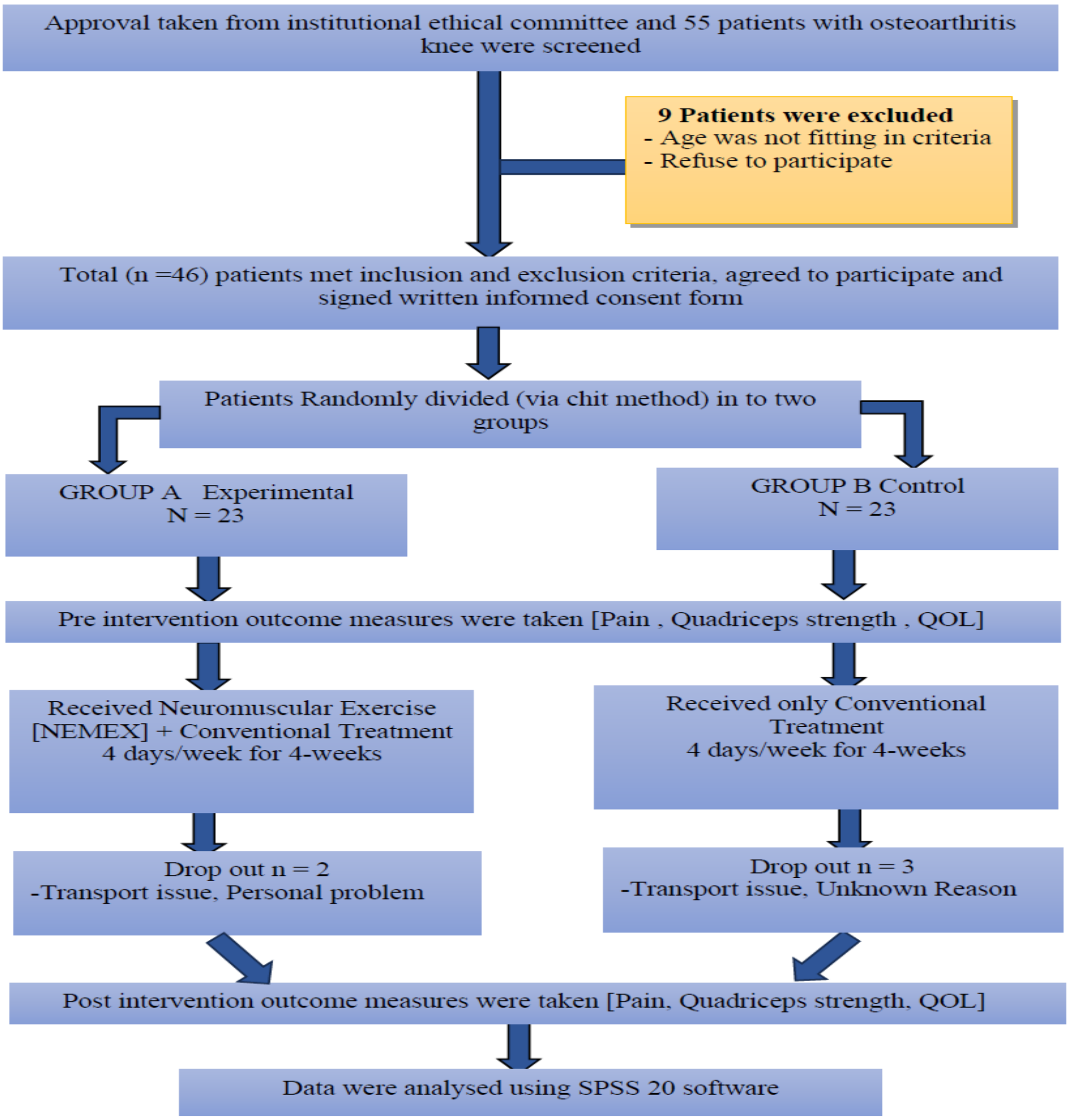
3. **Quadriceps Strength (Hand-held dynamometer):** [9] [10]

Isometric Quadriceps strength was assessed using the Baseline hydraulic Hand-held dynamometer.

For Quadriceps testing: The knee was positioned at 90° and maintained in the position using a standard goniometer, The examiner was seated in front of the subject with one of the feet against the wall, to be able to better resist the muscle contraction. The HHD was held on the anterior part of the lower leg, above the talo-tibial joint line. Patients were asked to do a maximal isometric contraction, held for 5 seconds. 3 readings were recorded for the quadriceps with 1 minute rest after each contraction. The mean of 3 trials was recorded in “kg”. Reliability is 0.77 to 0.97 and validity is ≥ 0.70 [25]

Photograph 1.3 Quadriceps strength by hand held dynamometer

METHODOLOGY FLOW CHART



GROUP – A: [EXPERIMENTAL GROUP]

Patients of group A in addition to conventional therapy also received one set of Neuromuscular training [NEMEX] which included, [11] [12]

EXERCISE	DESCRIPTION
1. Wedding March	Step forward and slightly cross to one side with the leading foot, bring the trailing foot together with the leading foot; alternate the leading foot.
2. Backward Wedding March	Same as above step backward
3. Side-stepping	Stand with feet together, Step to one side with the leading foot, and bring the trailing foot alongside with the leading foot. Repeat for the prescribed number of steps, then repeat in the opposite direction.
4. Semi tandem walk	Walk straight by placing one heel, medial to the great toe of the opposite foot
5. Tandem walk	Progressed version of the above, put the heel of one leg directly in front of the opposite foot.
6. Cross-over walk	Walk straight bringing each foot crossing the midline of the body
7. Modified grapevine walk	Step to the side with the right foot, bring left foot behind right, step to the side with the right, bring left in front of right; repeat for the prescribed number of steps; change leading foot and repeat in opposite direction.

Participants began each exercise with approximately **15 steps** and progressed up to a maximum of **75 steps**. This protocol was done for 4 sessions per week for 4-weeks. [13]

1 2 3

Photograph 1.4 Wedding March and Backward Wedding March

Photograph 1.5 Semi-tandem walk

Photograph 1.6 Tandem walk

1

2

Photograph 1.7 Cross over walk **Photograph 1.8 Side stepping**

1

2

Photograph 1.9 Modified grapevine walk

3

4

GROUP – B: [CONTROL GROUP]

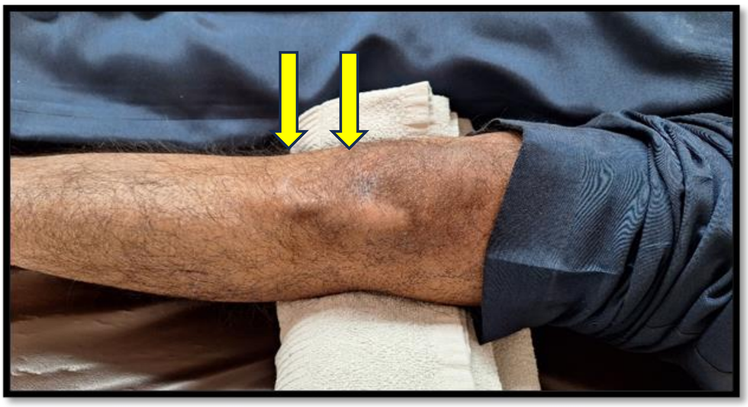
Patients of group B only received conventional treatment which included, [14]

1. **Hot packs**: For 10 minutes [14]

Photograph 1.10 Hot pack at the knee joint

2. Static Quadriceps exercise: [14]

In Supine or long sitting with knee extended (or flexed a few degrees) and towel underneath, Ask patient to contract the quadriceps isometrically, causing the patella to glide proximally, then hold for count 10, and repeat. Have the patient dorsiflex the ankle while holding the isometric contraction of quadriceps.



Photograph 1.11 Static quadriceps exercise

3. Short arc terminal knee extension [14]

In Supine or long sitting, Place a rolled towel or bolster under the knee to support it in flexion and ask the patient to extend the knee. Initially have the patient extend the knee only against the resistance of gravity. Later, add weights around the ankle to increase the resistance if the patient does not feel the pain or crepitation.

Photograph 1.12 Short arc terminal knee extension

4. Straight leg raises: [14]

Instruct the patient to set the quadriceps muscle and then lift the leg to about 45˚ of hip flexion while keeping the knee extended. Opposite hip and knee are flexed to stabilize the pelvis and low back. Hold the position for a count of 10 and then repeat.

Photograph 1.13 Straight leg raise

5. **Hip abductor strengthening in side lying:** [14]

In Side lying with affected leg upward. Hip and knee of the other leg is flexed for pelvic stability. Ask the patient to lift the leg while keeping the knee extended Resistance can be added with weights if patient does not feel pain.

Photograph 1.14 Hip Abduction Strengthening

6. **Hamstring strengthening in prone:** [14]

In Prone lying Weight cuff is tied around the ankle. Patient is asked to flex the knee only up to 90°

Photograph 1.15 Hamstring strengthening

7. **Quadriceps strengthening in high sitting position:** [14]

In High sitting ask the patient to extend the knee from 90° full extension. Apply resistance to motion as tolerated.

8. **Partial squatting up to 60 degrees:** [14]

Ask the patient to flex the hip and knee and slide the back down and then up the wall, lowering and lifting the body. As the control improves, have the patient into greater knee flexion, up to maximum of 60°. Knee flexion beyond 60° is not advised to avoid excessive shear forces on ligamentous structure of the knee and compressive force on the patellofemoral joint.

Photograph 1.16 High sitting knee extension

Photograph 1.17 Partial Squatting

- **All strengthening exercises were performed for 10 repetitions for 3 sets.** [11] [13]

9. Hamstring stretch: [14]

With the knee at 0˚ extension, and hip in neutral, flex the hip as far as possible.

10. Gastrocnemius stretch: [14]

Dorsiflex the talocrural joint of ankle by pulling the calcaneus in an inferior direction with your thumb and finger while gently applying pressure in a superior direction just proximal to the heads of metatarsals with your forearm.

Photograph 1.18 Hamstring stretch

Photograph 1.19 Gastrocnemius stretch

- **All stretching exercises were done for 3 repetitions with 30 sec hold each time** [11] [13]

STATISTICAL ANALYSIS

Statistical analysis was done for 41 patients using SPSS version 20.0 and Microsoft Excel 10. The level of significance was kept at 5 % and the confidence interval (CI) at 95 %. NPRS at rest and activity were not normally distributed according to the

Shapiro-Wilk test, so a non-parametric test has been applied for NPRS. WOMAC and Strength were normally distributed according to the Shapiro-Wilk test so parametric tests have been applied for WOMAC score and Quadriceps Strength. Descriptive analysis was obtained by mean and standard deviation. Within-group and Between-group analyses were done for outcome measures NPRS rest, NPRS activity, WOMAC score and Quadriceps strength at baseline and post 4 weeks of intervention. Normally distributed variables were analyzed within groups by Paired T-Test and between groups by Independent T-Test. And not normally distributed data were analyzed within groups by the Wilcoxon Signed test and between groups by the Mann-Whitney U test. The effect size was calculated by using Cohen's d and r's methods. [15] [16]

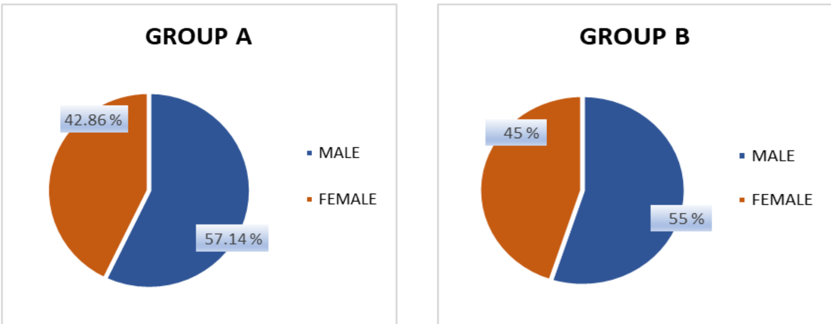
RESULT

Table 3.1 Baseline data comparison

Characteristic	Experimental group [A] Mean ± SD	Control group [B] Mean ± SD	T-test	P value
AGE [YEARS]	56.05 ± 7.89	59.65 ± 11.77	-1.125	0.268
BODY MASS INDEX	25.46 ± 1.90	25.05 ± 1.95	0.676	0.503
WOMAC SCORE	43.28 ± 9.63	43.35 ± 7.48	-0.24	0.981
QUADRICEPS STRENGTH	8.05 ± 2.76	7.45 ± 2.85	0.68	0.500

Table 3.2 Baseline data comparison

Characteristic	Experimental group [A] Mean ± SD	Control group [B] Mean ± SD	U value	P value
NPRS at Rest	0.67 ± 0.91	0.95 ± 0.94	248.00	0.285
NPRS at Activity	6.28 ± 0.90	6.1 ± 0.85	179.50	0.392



Graph 2.1 Gender Distribution of group A and group BWITHIN-GROUP ANALYSIS

EXPERIMENTAL GROUP (GROUP A):

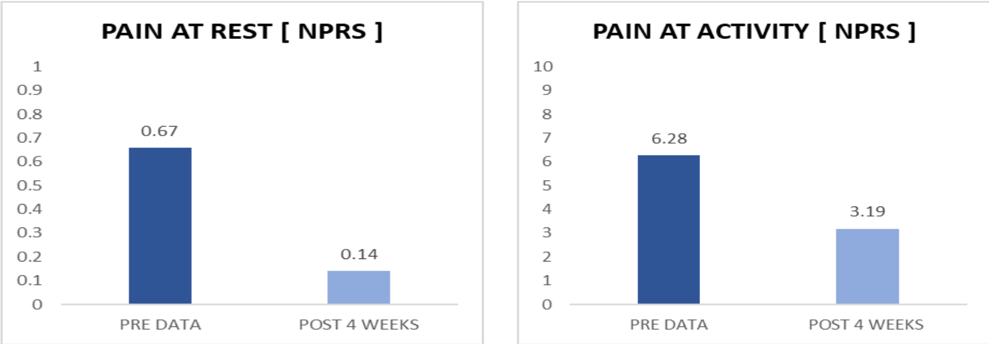
In the experimental group pre and post 4 week data analysis showed a statistically significant difference, $p < 0.05$ for Pain, Quadriceps strength and Quality of life (WOMAC)

Table 3.3 Within group A analysis of NPRS at rest and activity by Wilcoxon test

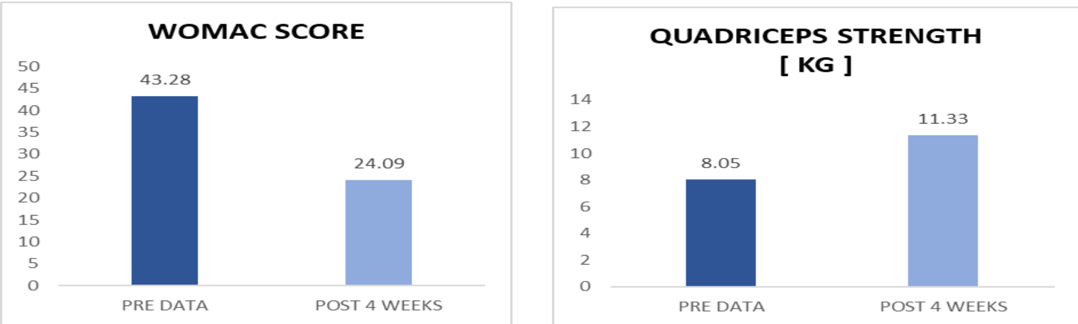
Variables	Pre-data Mean ± SD	Post 4-week data Mean ± SD	Z -value	P-value	Significance
NPRS at Rest	0.67 ± 0.91	0.14 ± 0.34	-2.810	0.005	Significant
NPRS at Activity	6.28 ± 0.90	3.19 ± 1.12	-4.111	0.00	Significant

Table 3.4 Within group A analysis of WOMAC and Strength by paired t-test

Variables	Pre-data Mean ± SD	Post 4-week data Mean ± SD	T-value	P-value	Significance
WOMAC score	43.28 ± 9.63	24.09 ± 7.30	10.613	0.000	Significant
Quadriceps Strength	8.05 ± 2.76	11.33 ± 2.69	-17.816	0.000	Significant



Graph 2.2 Pre-post mean difference of NPRS at rest and activity in group A



Graph 2.3 Pre-post mean difference of WOMAC score and strength in group A

CONTROL GROUP (GROUP B):

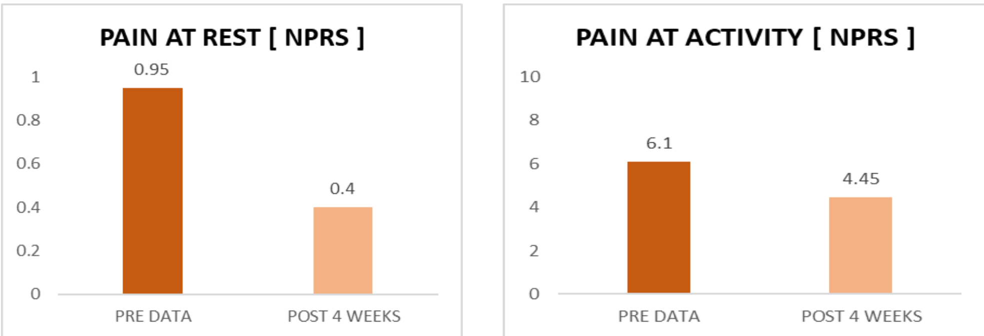
In the control group pre and post 4-week data analysis showed a statistically significant difference, $p < 0.05$ for Pain, Quadriceps strength and Quality of life (WOMAC).

Table 3.5 Within group B analysis of NPRS at rest and activity in by Wilcoxon test

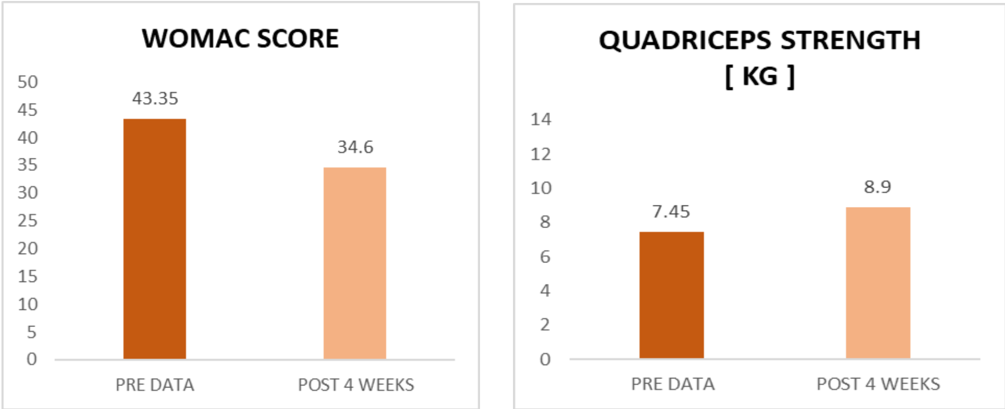
Variables	Pre-data Mean ± SD	Post 4-week data Mean ± SD	Z -value	P-value	Significance
NPRS at Rest	0.95 ± 0.94	0.4 ± 0.598	-3.317	0.001	Significant
NPRS at Activity	6.1 ± 0.85	4.45 ± 0.998	-4.072	0.000	Significant

Table 3.6 Within group B analysis of WOMAC and Strength by paired t-test

Variables	Pre-data Mean ± SD	Post 4-week data Mean ± SD	T-value	P-value	Significance
WOMAC score	43.35 ± 7.48	34.60 ± 9.22	11.834	0.000	Significant
Quadriceps Strength	7.45 ± 2.85	8.90 ± 3.08	9.448	0.000	Significant



Graph 2.4 Pre-post mean difference of NPRS at rest and activity in group B



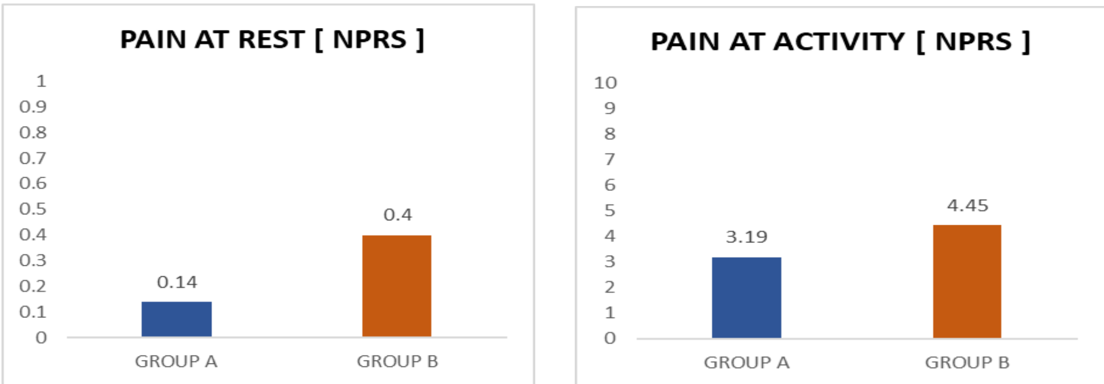
Graph 2.5 Pre-post mean difference of WOMAC score and strength in group B

BETWEEN-GROUP ANALYSIS

Comparison of pain at rest and activity, WOMAC score and quadriceps strength between two groups [Group A – Experimental and Group B – Control] After 4 weeks of intervention.

Table 3.7 Between-group analysis of NPRS at rest and activity by Mann Whitney U test

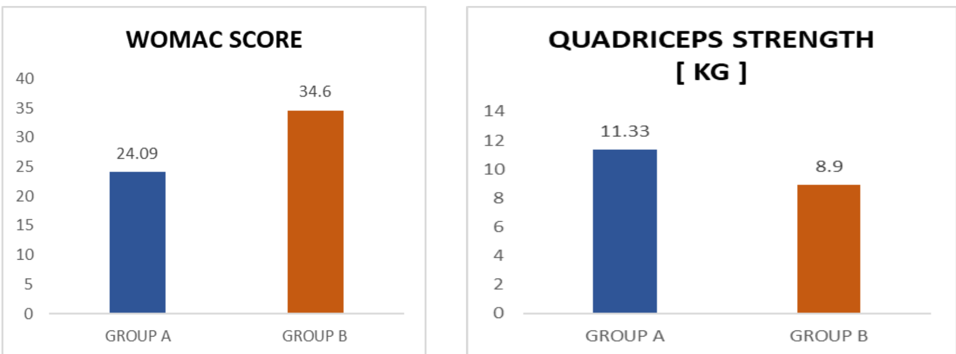
Variables	Group A Mean ± SD	Group B Mean ± SD	Mann-Whitney U	Z - value	P - value	Significance
NPRS at Rest	0.14 ± 0.34	0.4 ± 0.598	165.000	-1.572	0.116	Not Significant
NPRS at Activity	3.19 ± 1.12	4.45 ±0.998	89.000	-3.330	0.001	Significant



Graph 2.6 Mean difference of NPRS at rest and activity between groups A and B

Table 3.8 Between-group analysis of WOMAC and strength by independent t-test

Variables	Group A Mean ± SD	Group B Mean ± SD	T – value	P - value	Significance
WOMAC score	24.09 ± 7.30	34.60 ± 9.22	-4.031	0.000	Significant
Quadriceps Strength	11.33 ± 2.69	8.90 ± 3.08	2.691	0.011	Significant



Graph 2.7 Mean difference of WOMAC and strength between groups A and B

Null hypothesis is rejected as there was a statistically significant difference ($p < 0.05$) after 4 weeks of intervention on pain during activity, WOMAC score and Quadriceps strength noted between Group A (Experimental) and Group B (Control). There was no statistically significant difference ($p > 0.05$) noted between group A and group B for pain at rest.

Effect size calculation for WOMAC [d = 1.263], Quadriceps strength [d = 0.840] and Pain at activity [r = 0.520] showed a large effect size compared to the conventional group.

Where Effect size calculation for Pain at rest [r = 0.245] showed a small effect size compared to the conventional group. [15] [16]

DISCUSSION

The present study was designed to study the additional effect of Neuromuscular exercise along with conventional exercise in unilateral osteoarthritis knee on pain, Quadriceps strength and quality of life.

A total 46 patients with unilateral knee osteoarthritis were included in the study with age group 45 – 75 years according to inclusion and exclusion criteria. After taking informed written consent subjects were allocated into two groups via chit method. Group A received Neuromuscular training along with conventional exercise. Group B received only conventional exercise. All patients were assessed before the intervention and after 4 weeks (n=41) patients were assessed post-intervention, and analyzed using SPSS 20.

At the end of 16 sessions, patients in both groups showed improvement in pain (NPRS), Quadriceps strength (Hand-held dynamometer), and Quality of life (WOMAC score).

The result showed a statistically significant difference in pain at activity, Quadriceps strength and quality of life between group A (Experimental) and group B (control). Also, according to Cohen's d or r value, there is a statistically large effect size on quadriceps strength, WOMAC score and NPRS at activity in group A (Experimental) compared to group B (control).

But, no statistically significant difference with a small effect size was seen on pain at rest in group A (Experimental) compared to group B (Control) which can be due to a very low NPRS score at rest in pre-intervention assessment in both groups. Hunter hsu et al, also stated that typically pain in the Osteoarthritis knee gets worse with activity and is relieved by rest. [17]

As neuromuscular exercise increases the firing of A beta fibres through mechanoreceptors, leads to activation of the pain gait control mechanism which can result in greater pain reduction in the experimental group compared to the control group. [11]

These results were similar to Ganjave Pranita D et al in 2017 who also studied the effect of 12 sessions of 4-week neuromuscular training on pain, muscle strength, balance and function. Which showed greater improvement in pain, function and balance compared to the conventional group. [11] Chinta Meenakshi et al in 2021, [18] Shahzada Adil Rashid et al in 2022 [12] also conducted similar studies on neuromuscular exercise which showed that neuromuscular exercise improves sensory-motor control and enhances dynamic joint stability which leads to a reduction in quadriceps hamstring co- contraction index which leads to reduced compressive force and improved muscle activation pattern resulting in pain reduction and improved function in a patient with osteoarthritis knee.[12]

Significant improvement in quadriceps strength in the experimental group can be due to positive inter-relationship between proprioception and muscle strength. This shows that muscle performance can be effectively improved in patients with muscle weakness by utilizing close-chain exercises like kinaesthesia and balance training. [19] This quote was also supported by Aline Bassoli Gomiero et al (2018) in their study. [20] Caleb AdemolaGbiri et al did a study in 2013 comparing an 8-week close chain (kinaesthesia and balance) exercise with an open chain strengthening exercise in which close chain exercise (kinaesthesia and balance) had a greater effect on proprioception, strength gain and function compared to open chain strengthening exercise. [19]

Sazo-Rodríguez S et al in 2017 stated that Neuromuscular Exercises are mediated through proprioception of joints at three different levels of motor activation within the CNS which can lead to improved motor function in patients.[21]

The first level is reflexes at the spinal level which mediate movement patterns that are received from higher levels, this action provides reflex joint stabilization in response to abnormal stress on articulation.

The second level of motor control is located at the brainstem which receives input from joint mechanoreceptors, vestibular centres and visual input from the eyes to maintain posture and balance of the body.

The third level of CNS function provides cognitive awareness of body positions and movements in which motor commands are initiated for voluntary movements.[21]

Thus, the intensity and volume of the Neuromuscular Exercises were progressively increased to constantly challenge the body to adapt to the stress given and this leads to the adaptation of different neural and muscular adaptations.

Min Zhang et al, in 2022 studied a linear relationship between functional disability and quality of life. Thus, improvement in function can lead to enhanced quality of life.[22]

According to the narrative review done by Jyoti Sabharwal, et al in 2021.[5] joint loading plays an important role in the development and progression of the disease. Treatment directed towards mechanical load, sensorimotor control and muscle activation pattern can be useful in the treatment of knee osteoarthritis. [11]

Hence, the outcomes of this study are supported by all scientific evidences.

CONCLUSION

This study with 4 weeks of intervention on 41 patients with Osteoarthritis knee, showed a statistically significant effect on Pain, Quadriceps strength and Quality of life. Hence it can be concluded from this study that Neuromuscular exercise [NEMEX] along with conventional protocol reduces Pain and improves Quadriceps strength and Quality of life in Osteoarthritis knee.

Declaration by Authors

Ethical Approval: Approved (Registration No: GSIIESC/56/22)

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

REFERENCES

1. Yadav R, Verma AK, Uppal A, Chahar HS, Patel J, Pal CP. Prevalence of primary knee osteoarthritis in the urban and rural population in India. Indian Journal of Rheumatology. 2022 Sep 1;17(3):239-43.
2. E.Lane, K.Brandt,G.Hawker ,E.Peeva, E.Schreyer, W.Tsuji ,M.C.Hochberg. OARSI-FDA initiative: defining the disease state of osteoarthritis. Osteoarthritis and Cartilage Volume 19, Issue 5, May 201 1, Pages 478-482.
3. Ahmed AF. Effect of sensorimotor training on balance in elderly patients with knee osteoarthritis. Journal of Advanced Research. 2011 Oct 1;2(4):305-11
4. Rice DA, McNair PJ, Lewis GN. Mechanisms of quadriceps muscle weakness in knee joint osteoarthritis: the effects of prolonged vibration on torque and muscle activation in osteoarthritic and healthy control subjects. Arthritis research & therapy. 2011 Oct; 13(5):1-0
5. Sabharwal J, Joshi S. Neuromuscular exercises: A new perspective in knee osteoarthritis. Romanian Journal of neurology. 2021 Jul 1;20(3)
6. Kumar R. Sample size calculation. Indian J Ophthalmol. 2012;60(6):582. doi:10.4103/0301-4738.103809
7. Ferraz MB, Quaresma MR, Aquino LR, Atra E, Tugwell P, Goldsmith C. Reliability of pain scales in the assessment of literate and illiterate patients with rheumatoid arthritis. The Journal of rheumatology. 1990 Aug 1;17(8):1022-4.
8. Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee.

The Journal of rheumatology. 1988 Dec 1;15(12):1833-40
9. Mentiplay BF, Perraton LG, Bower KJ, Adair B, Pua YH, Williams GP, McGaw R, Clark RA. Assessment of lower limb muscle strength and power using hand-held and fixed dynamometry: a reliability and validity study. PloS one. 2015 Oct 28;10(10):e0140822.
10. Kelln BM, McKeon PO, Gontkof LM, Hertel J. Hand-held dynamometry: reliability of lower extremity muscle testing in healthy, physically active, young adults. Journal of sport rehabilitation. 2008 May 1;17(2):160-70
11. Ganjave Pranita D, Twinkle D. Efficacy of neuromuscular training on pain, balance and function in patients with grade I and II knee osteoarthritis. Journal of Exercise Science & Physiotherapy. 2017;13(2)
12. Rashid SA, Hussain ME, Bhati P, Veqar Z, Parveen A, Amin I, Rashid SM. Muscle activation patterns around knee following neuromuscular training in patients with knee osteoarthritis: secondary analysis of a randomized clinical trial. Archives of physiotherapy. 2022 Jul 7;12(1):19
13. Shah SV, Shukla YU. Effect of kinesthetic exercises versus agility exercises in unilateral osteoarthritis knee on pain, function and proprioception – an interventional study. International Journal of Science & Healthcare Research. 2020; 5(4): 165-180.
14. Cynthia C. Norkins, Joint Structure And Function. Jaypee publications. Fifth edition.
15. Fritz CO, Morris PE, Richler JJ. Effect size estimates: current use, calculations, and interpretation. Journal of experimental psychology: General. 2012 Feb;141(1):2.
16. Sullivan GM, Feinn R. Using effect size—or why the P value is not enough. Journal of graduate medical education. 2012 Sep 1;4(3):279-82.
17. Hsu H, Siwiec RM. Knee Osteoarthritis. [Updated 2023 Jun 26]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK507884/
18. Meenakshi C, Apparao P, Swamy G, Mounika RG, Prakash PK. Effectiveness of Neuromuscular Exercise And Pilates Exercises On Pain And Function In Subjects With Chronic Knee Osteoarthritis. Ejpmr. 2021;8(15):359-68.
19. Gbiri CA, Okafor UA, Alade MT. Comparative Efficacy of Open-chain and Close-chain Kinematics on Proprioception, Muscles' Strength and Functional Performances in Individual with Knee Osteoarthritis. Occup Med Health Aff. 2013;1(1):1-5.
20. Gomiero AB, Kayo A, Abraão M, Peccin MS, Grande AJ, Trevisani VF. Sensory-motor training versus resistance training among patients with knee osteoarthritis: randomized single-blind controlled trial. Sao Paulo Medical Journal. 2017 Dec 7; 136:44-50.
21. Sazo-Rodríguez S, Méndez-Rebolledo G, Guzmán-Muñoz E, Rubio-Palma P. The effects of progressive neuromuscular training on postural balance and functionality in elderly patients with knee osteoarthritis: a pilot study. Journal of physical therapy science. 2017;29(7):1229-35.
22. Zhang M, Zhu W, He X, Liu Y, Sun Q, Ding H. Correlation between functional disability and quality of life among rural elderly in Anhui province, China: a cross-sectional study. BMC Public Health. 2022 Feb 25;22(1):397.
23. Phan NQ, Blome C, Fritz F, Gerss J, Reich A, Ebata T, Augustin M, Szepietowski JC, Ständer S. Assessment of pruritus intensity: prospective study on validity and reliability of the visual analogue scale, numerical rating scale and verbal rating scale in 471 patients with chronic pruritus. Acta dermato-venereologica. 2012;92(5):502-7.
24. Vaittianadane DG, Rathod P. Translation and Validation of Gujarati Version of WOMAC and Lequesne Questionnaire in Subjects with Knee Osteoarthritis. Int J Health Sci Res. 2018;8(6):151-7
25. Muff G, Dufour S, Meyer A, Severac F, Favret F, Geny B, Lecocq J, Isner-Horobeti ME. Comparative assessment of knee extensor and flexor muscle strength measured using a hand-held vs. isokinetic dynamometer. Journal of physical therapy science. 2016;28(9):2445-51.

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