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Original Article

Physiotherapy Section

Effect of Low Level Laser Therapy with Neuromuscular Training Program on Pain, Function and Muscle Strength in Participants with Knee Osteoarthritis: A Randomised Controlled Trial

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ABSTRACT

Introduction: The predominantly encountered progressive musculoskeletal condition that may negatively impact joints is Osteoarthritis (OA), which often affects the joints of the lower extremities since they support more than half of the body weight. By 2020, OA was predicted to increase by almost 40% in prevalence, ranking as the fourth most prevalent cause of disability globally.

Aim: To compare the effect of Low Level Laser Therapy (LLLT) with a neuromuscular training programme and an aerobic exercise programme on pain, function, and muscle strength in participants with knee OA.

Materials and Methods: A randomised, double-blind study was carried out at Saveetha Medical College and Hospital, Chennai, Tamil Nadu, India, from 26 October 2024 to 20 January 2025, involving 36 participants aged 50-65 years, diagnosed with unilateral OA of the knee (Kellgren-Lawrence grade II/III) based on American College of Rheumatology criteria. Participants were randomly assigned to the neuromuscular training programme group (age: 60.27±3.05 years, Body Mass Index (BMI): 24.285±0.50) or the aerobic exercise programme group (age: 61.055±2.7 years, BMI: 23.88±0.52) using a simple random sampling technique (lottery method). Outcome measures included the pressure algometer, Timed Up and Go (TUG) test, and 30-second sit-to-stand test. Pre and post-tests were conducted before and after eight weeks of intervention. Statistical analysis was performed using independent t-tests, both paired and unpaired, with a significance level of $p<0.0001$.

Results: The post-test mean±SD values using the pressure algometer for the LLLT with the neuromuscular training group were 8.433±0.594, while for the LLLT with the aerobic exercise programme group, they were 6.661±0.566. The post-test mean±SD values using the 30 seconds sit to stand test for the LLLT with the neuromuscular training group were 18.67±1.24, but for the LLLT with the aerobic exercise programme group, they were 12.83±1.38. The post-test mean±SD values using the TUG test for the LLLT with the neuromuscular training group were 10.44±1.76, while for the LLLT with the aerobic exercise program group were 16.28±1.84.

Conclusion: This study concludes that the neuromuscular training programme showed a promising effect in reducing pain and improving function and muscle strength when compared with the aerobic exercise regimen.

Keywords: Kellgren and lawrence scale, Pressure algometer, Thirty seconds sit to stand test

INTRODUCTION

The challenges faced by individuals with OA extend to the financial burden it places on the health system. Currently, there are no viable therapeutic approaches to structurally change the OA disease process, other than joint replacement. The majority of treatments focus on symptomatic pain reduction [1]. OA is a major prevalent, progressive musculoskeletal disorder that can damage joints, commonly affecting the lower limb joints since they bear the majority of the body's weight. The primary characteristics of knee OA include structural changes to the cartilage, the bone just below the cartilage, as well as the synovia, muscles, and ligaments, leading to degenerative joint disease [2].

By 2020, OA was predicted to increase by almost 40% in prevalence, ranking as the fourth most prevalent cause of disability globally [3]. The prevalence of knee OA in individuals aged 60 years or older is estimated to be around 10% in men and 13% in women [4]. The most common radiographic characteristics are chondrocalcinosis, subchondral sclerosis, joint space narrowing, the formation of osteophytes at the joint edges, and subchondral cyst formation, especially in the knee joint [5].

OA has been linked to several specific risk factors, including female gender, advanced age, obesity, and coexisting co-morbid conditions (such as diabetes, peptic ulcer, anxiety, depression, hypertension, and stroke), which raise the difficulty and expense of managing the disease [6,7]. The primary symptom of knee OA is pain over the knee joint region. The pain can range in severity from moderate to severe, being dull or acute, intermittent (on and off), or persistent. It may also result in a restricted range of motion. Muscle weakness may be accompanied by popping or grinding noises. These pain related impairments often lead to challenges with household tasks, walking, standing, and ascending stairs [8].

The radiographic classification criteria for knee OA, created by Kellgren and Lawrence (K&L) in 1957, are the most commonly used. The K&L criteria are frequently employed in clinical research to classify patients with OA according to a specific grade or to observe the progression of the disease [9]. The clinical findings of OA indicate a dull, aching pain that gradually develops after sleep, tenderness over the joint line upon palpation, crepitus during movement, reduced Range of Motion (ROM), joint deformity, swelling, and muscle weakness [10].

LLLT is a non invasive modality that helps reduce inflammation [11]. Neuromuscular exercises can activate specific muscle groups by

aligning the knee with the hip and ankle, counteracting increased knee adduction moments [12].

An aerobic exercise programme can improve physical function and cardiovascular health for individuals with hip OA, potentially reducing the need for total hip replacement surgery. Aerobic exercise may enhance blood flow and decrease the severity of OA. Evidence suggests that exercise treatment can improve physical function, such as walking, without exacerbating pain [13]. The outcome measure used to assess physical function is the TUG test, which demonstrates excellent reliability, while muscle strength is assessed using the 30-second sit-to-stand test Pressure Pain Threshold (PPT) [14]. Pain is measured using a pressure algometer, with the PPT being assessed in the medial fat pad proximal to the joint line [15].

Tableau allows users to combine data from multiple sources, including Microsoft Excel and Access databases. While Tableau is relatively simple to use, individuals interested in producing layered, complex visuals with calculated fields and other advanced functions may need to devote considerable time to learning and becoming proficient with the software. Constructing intricate representations with calculated fields and other functions may require significant skill and expertise [16].

Therefore, the aim of this study is to compare the effectiveness of LLLT combined with a neuromuscular training programme and an aerobic exercise programme in participants with knee OA. The objective of the study is to evaluate the effect of LLLT combined with a neuromuscular training programme on pain, function, and muscle strength in participants with knee OA, as well as to assess the effect of LLLT combined with an aerobic exercise programme on pain, function, and muscle strength in participants with knee OA.

Null hypothesis: There is no significant difference between the LLLT combined with the neuromuscular training programme group and the LLLT combined with the aerobic exercise programme on pain, function, and muscle strength in participants with knee OA.

Alternative hypothesis: There is a significant difference between the LLLT combined with the neuromuscular training programme group and the LLLT combined with the aerobic exercise programme on pain, function, and muscle strength in participants with knee OA.

MATERIALS AND METHODS

A randomised, double-blind study was carried out at Saveetha Medical College and Hospital, Chennai, Tamil Nadu, India, from 26 October 2024 to 20 January 2025, involving 36 participants in a time-bound study. The Clinical Trial Registry of India (CTRI) number was CTRI/2024/10/075926. The experimental procedure was explained to all participants, and informed consent was obtained. The participants were recruited using a simple random sampling technique (lottery method) and were randomly allocated into two groups: the LLLT combined with the neuromuscular training programme group and the LLLT combined with the aerobic exercise programme group.

Inclusion criteria: The study included participants aged 50 to 65 years, comprising both males (n=15) and females (n=21), who were diagnosed with knee OA based on the American College of Rheumatology (ACR) criteria [17]. Participants were radiologically staged II and III with unilateral knee OA according to the Kellgren and Lawrence (KL) Scale and had a BMI of less than 30 [Table/Fig-1,2] [18,19].

Exclusion criteria: Participants who had taken corticosteroids within the last six months, those with recent or prior fractures of the knee joint, visual, hearing, or cognitive impairments, previous knee surgeries, self-reported inflammatory arthritis, cardiovascular diseases, or neurological disorders were excluded from the study, as these conditions would make exercise and testing unfeasible.

[Table/Fig-1]: The radiological finding Kellgren Lawrence grade III of knee joint (Multiple osteophytes formation with Joint space narrowing).

[Table/Fig-2]: The radiological finding of Kellgren Lawrence grade II of knee joint (Definite osteophytes formation with possible joint space narrowing).

Sample size calculation: The sample size was calculated using G*Power statistical software version 3.1.9.7. The alpha value was set at 0.05, with 80% power, resulting in a calculated sample size of 36.

Study Procedure

Homogeneity at baseline was checked. Both the assessor and the participants were blinded during the study. Concealed allocation was conducted by a researcher using opaque sealed envelopes.

Intervention: LLLT was administered to both groups, covering five synovial points on the medial aspect of the knee and four on the lateral aspect. LLLT was delivered at a wavelength of 904 nm, a frequency of 700 Hz, with an average power of 60 nm and peak power of 20 W over the joint line. LLLT was applied four days a week for eight weeks. The laser irradiation targeted the synovia and cartilage in the joint line. The regions exposed to radiation included the medial and lateral gaps of the knee joint, the medial portion of the tendon of the biceps femoris and semitendinosus muscles in the popliteal fossa, and the medial and lateral epicondyles of the tibia and femur [Table/Fig-3,4] [20-24].

Part-1 Circuit program	Procedure	Phase 1	Phase 2	Phase 3	Phase 4
Core stability [21,22]					
Pelvic lift	The participants were asked to lie down in supine position with the feet on a Swiss-ball (diameter 55-75 cm) with the knees bent up to a maximum of five degrees.	Slowly and deliberately raise and lower the pelvis while keeping both feet on the ball.	With the pelvis raised and both feet on the ball, the leg slowly and deliberately extended and flexed the knees.	Flex and extend the knee slowly and deliberately while keeping the hip extended, the one lower extremity resting on the ball, and the pelvis raised during the whole exercise. For stability, the upper limbs are supported to the sides.	The exercise is performed as level 3 with upper Limbs folded in front of the chest.
Sit ups	The participants were asked to Lie down in supine with knees flexed to 90 degrees with both legs on ball.	The participants with the arms along the side of the body, lift up the upper body towards the knees. (short lever)	With the arms crossed over the chest of the body, lift up the upper body towards the knees. (Medium lever)	With the arms behind the back of neck, lift up the upper body towards the knees. (long lever)	Follow as same as level 3
Lower limb muscle strength					
Hip abductors and adductors	The participants were asked to stand in the unaffected limb, theraband on other leg. By pulling the theraband out and in.	Ensure that the resistance band is taut while the lower extremities' joints are at rest in respect to the trunk and one another, without the hip or pelvic area being displaced laterally.	Follow as same as level 1, with rubber band with increasing resistance.	Follow as same, the participants were asked to stand on unstable surface (foam or thick mattress).	Follow as same as level 3.
Knee flexors and extensors	The participants were asked to sit down, with the rubber band around one foot	To activate your knee flexors and extensors, pull the theraband forward and backward. Ensure that the resistance band is taut and is in the resting position.	Follow as same as level 1, with theraband with increasing resistance.	Follow as same, with theraband and more increasing resistance.	Follow it with increase in resistance.
Squat	The participants were instructed to stand with the feet width apart in front of a chair or stool, the knee shall be flexed to an extent so the buttock just touches the chair without sitting down. ensure a soft, controlled landing.	No requirement of kettlebell and upper extremity can be used for support.	The exercise was executed with a jump at the end of the rise up. Bend knees to ensure a soft, controlled Landing	This exercise is executed as level I with a kettlebell in hands held in front of chest.	This exercise is performed as level 3, with jump on the rise-up. Bend the knees to ensure a soft, controlled landing.
Side lying jump jacks	In side lying with weight on the forearm and hip good alignment in the shoulder, spine, pelvis, and knees, in side lying with weight on the forearm and hip.	Then the upper leg's foot is placed in front of the lower leg's foot to provide more stability. Slowly lift your hips off the ground, then lower them back down with control.	Place the feet side by side.	Slowly lift your hips off the ground, then lower them back down and moving side to side with abducting the upper limb on the	Performed as level 3, abducting the lower limb in the top while the hip is lifted and the upper limb are abducted.
Lunges	Stand with hip apart. Without raising your back foot's toes, take a deep stride forward. Controlled and smooth movements are essential for the landing. The body is lowered down so the rear knee almost touches the floor and the heel of the front foot remains on the floor.	There are no restrictions on using the upper limb for balance. Both forward and sideways lunges to be done.	This exercise is performed with a kettlebell in hands held in front of chest.	This is a level 2 exercise where you rotate your upper body toward your front knee at the final position.	This exercise is performed as level 3 with a kettlebell on either shoulder.
Functional exercises					
Chair stands	Standing with the feet width hip apart in front of a chair or stool, the knee shall be flexed to an extent so the buttocks just touches the chair without sitting down.	No requirement of kettlebell and upper limb can be used for support	The exercise is executed with the jump at the end of the rise up. Bend knees to ensure a soft controlled landing.	This exercise is carried out as a level 1 with a kettlebell in hands held in front of chest.	This exercise is performed as level 3 with jump on the rise up. Bend knees to ensure a soft controlled landing.
Stair climbing (step up step down, side step up)	Stand with front to step bench. Height of step is (13, 18 or 23cm) is used for progression.	Step up with left foot first, put feet together, and step backwards down with the right foot (in this way the left lower limb must control movement throughout the exercise. Repeat with other limb.	Stand on 1 lower limb on the step bench. Alternate between touching the floor in front of and behind the bench with the heel and toes, respectively by flexing the weight bearing limb. Repeat with other limb.	Stand on 1 limb on the step bench and jump down in front of the bench and land on the standing limb with a soft and controlled landing.	Stand on 1 limb on the step bench and jump and alternate between jumping down in front of, to the side of, and behind the bench and land on the standing limb with the soft, controlled landing
PART-2 (Cool down)					
Stretches	Hamstring	Quadriceps, iliopsoas	Calf muscles	Triceps surae	15-20 seconds of stretch with 2-3 sec of rest. 5 times of stretch
Walking	Forward and backward walking in front of mirror	10 minutes			

[Table/Fig-3]: The neuromuscular training program (experimental group).

All exercises were performed four days a week for eight weeks, consisting of two sets of 12 repetitions.

Tableau: The version used is 2024.3.1. Tableau is one of the most popular and effective data visualisation tools for business

Aerobic exercises [23,24]	Procedure	Execution
Ergometer cycling	Ergometer cycling can be done for ten minutes.	The workload may be adjusted on an individual basis and increased over the course of the ten minutes.
Slow walking	The participants were instructed to walk in a slow phase and in an even surface for 10 minutes.	Walking progressed to 15-20 minutes.
Seated knee extensions	The participants were asked to be seated with knees leaned back on the chair, feet placed on the floor, and flexed to a 90-degree angle.	The participants were instructed to alternately extend their contralateral elbows while extending their knees and flexing their shoulders.
Seated march with alternate knee touch	Participants were instructed to sit with their feet flat on the floor, lean back in their chairs, and stretch their knees to a 90-degree angle.	The participants were asked to touch the contralateral knee alternately and vigorous walking movement.
Seated brisk walk hands on contralateral shoulders	The participants were asked to be seated with lean back on the chair with your knees at a 90-degree angle and your feet flat on the floor.	The participants were instructed to do brisk walking movement with the hands placed over the contralateral shoulders, in the front of trunk.
Strengthening exercises	**Procedure**	**Execution**
Quads over a roll	The participants were asked to sit down on a surface with the bodyweight supported by arms. Then the unaffected knee is to be bent and the affected knee is supported by a rolled towel (unaffected knees bent to 30 degrees).	Then the participants were asked to straighten the unaffected leg by gently lifting the heel of the ground. Hold the leg for 5 seconds and slowly lower down. Attach weights around the ankle for progression.
knee extension in sitting	The participants were asked to sit at the edge of the chair, with both the legs off the ground.	Then the participants were informed to gently straighten the knee and lift the ankle weight up as high as possible. Hold for 5sec then slowly down the legs. Attach weights for progression.
Knee extension with hold at 90 degrees	The participants were asked to sit at the edge of the chair, with both the legs off the ground.	Then the participants were asked to gently lift the ankle weights up to 30 degrees short of fully straightening the knee and hold for 5 seconds.
Straight leg raise	The participants were made to lie down in supine position. Flex the unaffected knee and affected side foot and ankle pulled up towards the participants.	Slowly raise the affected knee up to 30 cm from the ground. Make sure to keep the knee straight hold for 5 sec and slowly bring down. Add ankle weights for progression.
Short arc knee extension	The theraband is tied to the leg of chair. The participants were asked to put the legs into the looped theraband.	Then the participants were asked to gently straighten up the affected leg up until the participant feels a comfortable resistance (should be bent about 60 degrees. Slowly bring down to starting position.
Wall half squats	The participants were asked to stand with back supported in a wall with the feet 10 cm apart and 15 cm away from wall.	Then the participants were instructed to gently slide down until the knees are bent about 30 degrees and then hold for 5 seconds then slowly slide up gain.
Cool down		
Stretches	Hamstrings, triceps surae stretch.	Hip flexors and quadriceps stretch

[Table/Fig-4]: The aerobic exercises program (control group).

intelligence. It takes raw data and transforms it into a comprehensible format, allowing for faster data analysis. Worksheets containing the generated results are saved with the .twb or .twbx extension. A non-technical user can also customise their dashboard. Tableau's key features include data association, data merging, and streaming data analysis [25].

The role of Tableau software in this study was to statistically analyse the pretest and post-test data. Primarily a visualisation tool, it played a crucial role in visually analysing and comparing the pretest and post-test results, as well as in comparing post-test values. Tableau allows for faster and more intuitive exploration of descriptive statistics, cross-tabulations, and trend analyses, which is especially useful when working with large samples. Its ability to instantly update visuals based on data changes also makes it a practical tool for real-time statistical monitoring and presentation.

Outcome measures: Instrumental assessments were performed, and baseline homogeneity was checked prior to randomisation. The physiotherapist (assessor) was blinded to the intervention and the control group.

Pressure algometer: Mechanical pain was assessed using a pressure algometer. A handheld pressure algometer with a 1 cm^2 circular rubber application surface and a resolution of 0.2 N, with a maximum capacity of 250 N, was used for the test (Wagner Force One model FDIX50, Wagner Instruments, Greenwich, CT). It was configured to sample at 1000 Hz and included a maximum hold reading feature [26].

A female physical therapist who was blinded to the study's purpose served as the assessor. To ensure excellent reliability, the same examiner conducted all Pressure Pain Threshold (PPT) measures and maintained a consistent algometric pressure delivery rate. The algometric measures were taken while the patient was in a side-lying position. Localising knee and ankle algometric pressure is simpler when the patient is on their side rather than supine. Furthermore, holding the algometer vertically rather than horizontally allows for more effective application of pressure. Subsequently, the medial aspect of each patient's afflicted knee, approximately one to two centimetres medially from the medial femoral tubercle was assessed for PPT by a single rater.

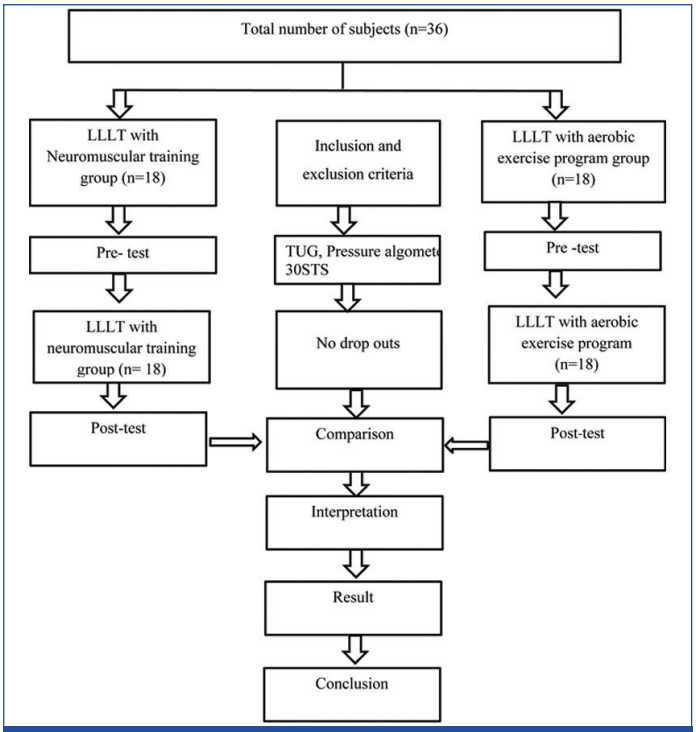
These body points were chosen because, in individuals with knee OA, these points are generally painful. The rater withdrew the algometer and recorded the score after instructing the subjects to verbally indicate when the pressure started to become uncomfortable. The patient was positioned on their side, and pressure was applied to the skin at a 90-degree angle using a 1 cm^2 algometer probe. Three PPT measurements were made on the medial aspect of the knee on both limbs [27].

Thirty-second sit-to-stand test: A 30-second sit-to-stand test was used to measure muscle strength. Participants were asked to sit on an armless chair, which was consistently used for all test episodes. To prevent the chair from moving during the test, it was positioned against a wall. Participants' arms were held against their chests and crossed at the wrists. The number of times the participants stood up and sat down within the 30-second time limit was recorded. Participants were instructed to fully sit down on the chair between each stand [28].

TUG test: Physical function was measured using the TUG test. The amount of time required for participants to get out of the chair, walk three metres on the ground, turn around, return to the chair, and sit down again was recorded using a stopwatch. The test was explained to the participants beforehand, and they wore comfortable shoes throughout. The average time from three test trials was calculated. The same researcher conducted each measurement. The TUG test demonstrated excellent intra- and inter-rater reliability (ICC 0.97 and 0.96) [29]. The study flow chart is described in [Table/Fig-5].

STATISTICAL ANALYSIS

According to the statistical analysis, there is a statistically significant difference in values between the LLLT combined with the neuromuscular training group and the LLLT combined with the aerobic exercise programme group, based on the quantitative data. Tableau software (AI-assisted) was used to calculate the independent paired and unpaired t-tests for the pretest and post-test values. The level of significance was set at <0.0001.



[Table/Fig-5]: The study flow chart.

RESULTS

The demographic data of the study participants is given in [Table/Fig-6]. [Table/Fig-7] compares the pretest and post-test values for the neuromuscular training and aerobic exercise training groups (Mean±SD). In the pressure algometer test, the neuromuscular training group improved from a mean of 6.717±0.842 (pretest) to 8.433±0.594 (post-test), while the aerobic exercise group improved from 6.150±0.776 to 6.661±0.566. In the 30-second sit-to-stand (30 STS) test, the neuromuscular training group increased from 8.22±1.11 to 18.67±1.24, whereas the aerobic exercise group improved from 8.17±1.15 to 12.83±1.38. For the TUG test, the neuromuscular training group showed a significant reduction in time, from 20.56±2.91 to 10.44±1.76, while the aerobic exercise group improved from 20.28±2.70 to 16.28±1.84.

Demographic data	LLLT with neuromuscular training group (Mean±SD)	LLLT with Aerobic exercise program group (Mean±SD)
Age (years)	60.27±3.05	61.055±2.7
Height (cm)	167.2±6.87	168.6±6.07
Weight (kg)	68±6.81	68.05±5.8
BMI (kg/m^2)	24.285±0.50	23.88±0.52
KL Grading	2.3±0.47	2.3±0.47

[Table/Fig-6]: Demographic data of participants.

Outcome	Groups	Test	Mean	S.D	p-value	t-value
Pressure algometer	Neuromuscular training group	Pretest	6.717	0.842	<0.0001	13.2133
		Post-test	8.433	0.594		
	Aerobic exercises training group	Pretest	6.150	0.776	<0.0001	5.4637
		Post-test	6.661	0.566		
30 STS	Neuromuscular training group	Pretest	8.22	1.11	<0.0001	29.4665
		Post-test	18.67	1.24		
	Aerobic exercises training group	Pretest	8.17	1.15	<0.0001	13.6056
		Post-test	12.83	1.38		
Time Up and Go (TUG) test	Neuromuscular training group	Pretest	20.56	2.91	<0.0001	12.6409
		Post-test	10.44	1.76		
	Aerobic exercises training group	Pretest	20.28	2.70	<0.0001	8.4853
		Post-test	16.28	1.84		

[Table/Fig-7]: Comparison of pretest and post-test values of neuromuscular training group and aerobic exercise program group.

[Table/Fig-8] compares the post-test values for the neuromuscular training and aerobic exercise programme groups (Mean±SD). In the pressure algometer test, the neuromuscular training group had a mean of 8.433±0.594, while the aerobic exercise group had a mean of 6.661±0.566. For the 30 STS test, the neuromuscular training group had a mean of 18.67±1.24, compared to the aerobic exercise group, which had a mean of 12.83±1.38. In the TUG test, the neuromuscular training group achieved a mean of 10.44±1.76, whereas the aerobic exercise group had a mean of 16.28±1.84. Overall, the neuromuscular training group demonstrated superior performance across all tests.

	Groups	Mean	SD	p-value	t-value
Pressure algometer	Neuromuscular training group	8.433	0.594	<0.0001	9.1646
	Aerobic exercise program group	6.661	0.566		
30 STS	Neuromuscular training group	18.67	1.24	<0.0001	13.3413
	Aerobic exercise program group	12.83	1.38		
Time Up and Go (TUG)	Neuromuscular training group	10.44	1.76	<0.0001	9.7268
	Aerobic exercise program group	16.28	1.84		

[Table/Fig-8]: Comparison of post-test values of neuromuscular training group and aerobic exercise program group.

As a result, with a p-value of less than 0.0001, the values are considered statistically significant.

DISCUSSION

Here, the current study aimed to investigate the effectiveness of LLLT combined with neuromuscular training compared with LLLT combined with an aerobic exercise programme in participants with knee OA. The main findings of this research indicate that LLLT with a neuromuscular training programme is more effective than the aerobic exercise programme in reducing pain and difficulty in physical function, as well as in increasing muscle strength in subjects with knee OA.

Additionally, both training methods improve physical function, enhance muscle strength, and reduce pain, with the 30-second sit-to-stand (30 STS) test demonstrating improved strength of knee muscles. However, the aerobic exercise programme combined with LLLT is not as effective when compared to the LLLT-neuromuscular training programme group. Importantly, there were no dropouts in the study.

Although there are many different types of exercise treatments available for those with lower limb OA, most exercise regimens for knee OA focus on strengthening muscles because weak muscles have a major impact on pain and function [30]. Ageberg and Roos (2015) concluded that neuromuscular exercises are more effective in improving physical function and cartilage quality than strength training. In the present study, LLLT was administered alongside a neuromuscular training programme and compared with LLLT combined with an aerobic exercise programme over eight weeks, showing improvements in pain, function, and muscle strength [31].

Similarly, a study by Sajo-Rodriguez S et al., (2017) concluded that progressive neuromuscular training has positive effects on balance and functionality in knee OA as a four-week intervention. In our study, LLLT was given with a neuromuscular training programme for eight weeks and compared with LLLT combined with aerobic exercise training, demonstrating improvement in pain, function, and muscle strength [32].

Villadsen A et al., (2014) conducted a study on the immediate effects of neuromuscular training in severe knee OA and found

a 20% reduction in pain and improvement in physical function, suggesting it is the best option prior to Total Knee Replacement (TKR). In the present study, the combination of LLLT with a neuromuscular training programme effectively reduced pain more than in that study [33].

On the other hand, Rashoud ASA et al., (2014) conducted a study on LLLT applied to acupuncture points in knee OA and concluded that short-term laser application to specific points results in pain reduction and improved quality of life. In this study, the group received laser treatment alongside a neuromuscular exercise programme [34].

Another supporting study by L Assis et al., (2016) examined aerobic exercise with LLLT in relation to inflammatory action in knee OA and found that when aerobic exercise is combined with strengthening and stretching, it has beneficial effects in reducing pain, improving physical function, and decreasing disability [35].

The results of this study strongly support the alternative hypothesis. The alternative hypothesis is accepted because the study shows a highly significant p-value (less than 0.0001), indicating a statistically significant effect. Thus, in this study, the null hypothesis is rejected, and the alternative hypothesis is accepted.

Limitation(s)

The limitation of the study was that only participants with Kellgren-Lawrence grades two and three were included.

CONCLUSION(S)

In this study, both the neuromuscular training programme and the aerobic exercise programme showed promising effects in reducing pain and improving muscle strength and physical function. When these exercises were combined with laser therapy, they provided better pain relief for participants with knee OA. However, when comparing these two interventions, it was demonstrated that the neuromuscular training programme had a more significant effect in decreasing pain and enhancing physical function and muscle strength compared to the aerobic exercise programme. The results, visualised using Tableau software, reveal significant and improved outcomes. The findings support the inclusion of neuromuscular exercises in the management of knee OA and highlight the utility of data visualisation tools in enhancing the understanding and communication of research results. This study underscores the role of Tableau software in visualising and exploring data, demonstrating its effective contribution to the study findings.

Recommendation: This study could be extended beyond eight weeks and incorporated into rehabilitation protocols, particularly following lower limb surgeries. Such integration could yield numerous functional outcomes. The study also highlights the need for future research to explore the long-term effects of the neuromuscular training programme across various populations to enhance health and quality of life.

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