



EFFECT OF INDOOR SLACKLINING EXERCISES ON PAIN, FUNCTIONAL PERFORMANCE AND BALANCE AMONG PATIENTS WITH GRADE I OSTEOARTHRITIS OF KNEE– A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: Knee osteoarthritis (OA) is one of the most prevalent musculoskeletal disorders affecting adults and is characterized by pain, reduced functional performance, decreased balance, and limitations in activities of daily living. Conventional physiotherapy interventions are commonly used to manage symptoms and improve function; however, novel exercise approaches that enhance neuromuscular control and postural stability may provide additional benefits. Indoor slacklining is a dynamic balance-training exercise that challenges proprioception, coordination, and lower-limb muscle activation. Limited evidence exists regarding its effectiveness in individuals with Grade I knee osteoarthritis.

Objective: To study the effect of indoor slacklining exercises on pain, functional performance, and balance in patients with Grade I knee osteoarthritis.

Methods: A randomized controlled trial was conducted after obtaining approval from the Institutional Ethics Committee. The purpose and procedure of the study were explained to all participants, and written informed consent was obtained. A total of 42 participants diagnosed with Grade I knee osteoarthritis based on clinical examination and radiographic findings were recruited. Subjects were screened according to predefined inclusion and exclusion criteria and were randomly allocated into experimental and control groups using a computerized random number sequence generator. Allocation concealment was ensured through the envelope method, and blinding was maintained for both participants and physiotherapists. Baseline assessments included the Numeric Pain Rating Scale (NPRS), Y Balance Test, and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). The experimental group received an indoor slacklining exercise protocol, while the control group received standard conventional physiotherapy for 4 weeks. During the intervention period, four participants dropped out (two from each group). Outcome measures were reassessed after 4 weeks, and data were analyzed using appropriate statistical methods. The study adhered to CONSORT guidelines.

Results: The experimental group demonstrated significantly greater improvements than the control group. Indoor slacklining exercises resulted in a statistically significant reduction in pain as measured by NPRS scores. Balance performance, assessed using the Y Balance Test, showed highly significant improvement in the experimental group. Additionally, WOMAC scores decreased significantly, indicating superior improvements in functional performance compared with conventional physiotherapy.

Conclusion: Indoor slacklining exercises are effective in reducing pain and enhancing functional performance and balance in patients with Grade I knee osteoarthritis. Therefore, indoor slacklining may be considered a valuable adjunct to conventional physiotherapy rehabilitation programs for individuals with early-stage knee osteoarthritis.

Keywords: Knee Osteoarthritis; Indoor Slacklining; Balance Training; Functional Performance; Pain; Y Balance Test; WOMAC.

INTRODUCTION

Osteoarthritis (OA) is one of the most common forms of musculoskeletal diseases worldwide. According to American College of Rheumatology [ACR]; Osteoarthritis is a degenerative joint disease, in which the tissues in the joint break down over time. Osteoarthritis affects the entire joint, including the tissues around it. Osteoarthritis (OA) is a common joint disease that most often affects middle age to elderly people. It is commonly referred to as "wear and tear" arthritis, but osteoarthritis is a disease of the entire joint, involving the cartilage, joint lining, ligaments, and bone. Many factors can contribute to developing osteoarthritis. Some include a history of joint injury or overuse, older age and being overweight. It affects women more than men.^[1]

Osteoarthritis (OA) is the most frequent cause of persistent joint pain in the elderly population and the main contributor to disability worldwide. Of all the musculoskeletal disorders, OA accounts for 50% of cases. Knee OA [osteoarthritis] is the leading cause of osteoarthritis worldwide and gets worse with ageing and obesity. The number of years lived with disability (YLDs) for hip and knee OA was ranked 11th highest in the 2010 Global Burden of Diseases (GBD) survey. About 13% of women and 10% of men 50 years and older worldwide have symptomatic knee osteoarthritis; the frequency increases to 40% for people over the age of 70 years. Data from community surveys in rural and urban parts of India show a wide range of prevalence of osteoarthritis [17-60.6%] among elderly people (<65 years), with point prevalence in rural areas being higher than urban.^[2] Kandasamy S, Vadivelu R et al conducted a study which reveals a high prevalence of knee osteoarthritis among over one-third of individuals aged 40 and above in rural South India, with significant risk factors including obesity, diabetes, hypertension, menopause, sedentary lifestyles, and Indian-style toilets. Severe functional impairment, indicated by high WOMAC [Western Ontario and McMaster Universities Osteoarthritis Index] scores, underscores limited healthcare access, emphasizing the need for community interventions in lifestyle modification and chronic disease management.^[3] Osteoarthritis affecting articular cartilage, joint cavity, synovial fluid, ligaments and tissues resulting in the subchondral bone erosion, meniscus deterioration, decrease ligament laxity and Impaired contractile function of the joint.^[2] Osteoarthritis (OA) mostly presents with the painful joints, stiff muscles and decrease in the muscle mass which ultimately leads to impairment and reduction in the joint movement. The subchondral bone becomes stiff with interspersed cystic changes which provide uneven support to the overlying articular cartilage resulting in further mechanical damage due to high stress and low cyclical loading or low stress and high cyclical loading.^[12] Overweight and having family history of osteoarthritis (OA) are two most important Risk factors for Osteoarthritis but heredity factors account more for the female in the development of Osteoarthritis. Sports player, special profession, diabetic neuropathies, accidents, bodybuilders, excessive knee bending and joint immobility are other factors.^[3] In India Harish Kumar et al found prevalence of clinically symptomatic osteoarthritis knee in Indians is around 10% in men and 20% in women aged 45 years and above, whereas radiographic Osteoarthritis, the prevalence increases between 27% and 80%.^[6] Diagnosis of KOA [knee osteoarthritis] is confirmed by a radiograph of the knee showing subchondral sclerosis, osteophytes, reduction in the joint space, subchondral cyst formation, and deformity of the knee.^[5] A study on the most common radiographic pattern in patients suffering from knee pain evidenced a great prevalence of the combined Tibiofemoral joint and Patellofemoral disease (40%), followed by isolated Tibiofemoral joint Osteoarthritis (24%).^[25] The Kellgren and Lawrence (KL) scale is a classification system widely used to assess the severity of osteoarthritis (OA) based on radiographic findings. According to Kellgren and Lawrence Scale Grade I Osteoarthritis knee is defined as possible joint space narrowing and osteophyte formation seen in radiograph.^[8]

Slacklining can be defined as standing or moving on a tightened band, while maintaining postural balance. In previous studies slacklining has also been reported to reduce patella subluxation within a physiotherapy supervised exercise program and enhance functional knee joint stability through preparatory activation of the

rectus femoris muscle.^[6] In Switzerland, Charles Gabel et al performed a study that balance and strength promotion are important for injury prevention, the use of an activity such as slacklining should be investigated in the early rehabilitation phase. This study aimed to investigate the effectiveness of slacklining as a rehabilitation exercise in spontaneously inducing quadriceps activation in the clinical rehabilitation environment for post surgical rehabilitation.^[5] In Slacklining the motor learning process involved in becoming proficient in slacklining involves 3 phases.

1. The **cognitive** phase involves rejection of ineffective strategies and adoption of effective strategies, which usually produces rapid improvement.
2. The **associative** phase lasts for weeks to months, during which skills are acquired and consolidated, and performance consistency improves.
3. The **autonomous** phase lasts for months to years, during which skills can be executed without conscious effort.^[2]

The activity of slacklining is defined as ‘the action of retaining balance while standing or moving on a tightened band’. It has been demonstrated to activate or provide training induced improvements in the rate of force development in lower limb activity prevention of injury in elite athletes, postural stability and postural control as a more challenging exercise for the knee and hip joints than multi-functional rocker boards and air cushions. In some studies; Slacklining has also and been reported to reduce patella subluxation within a physiotherapy supervised exercise program and enhance functional knee joint stability through preparatory activation of the rectus femoris muscle. This action is coupled with the ability to provide learned motor control, such as down regulation of the Hoffman reflex, as well as a training effect and mechanisms that are pre- rather than post- synaptic.^[2] This is a postural benefit for individuals with lower limb functional deficits of a central source. An additional benefit is that the Hoffman’s reflex (H-reflex) can be affected through the pre-synaptic pathway resulting in a learned activity that inhibits the reflex action from down regulation. However, it is considered to be a learned and temporary effect as withdrawal of the training stimulus results in reduction the training effect.^[26] Consequently, the effectiveness of the slacklining program as a rehabilitation therapy must be maintained through the ongoing practice of the activity. The anticipation is that this specific action within the training phase will then overflow to normal daily activity including the functional movements of walking and postural control. This in theory could subsequently improve the innate response action to perturbations and reduce the incidence of falls and in turn improve individual confidence while reducing health and socioeconomic costs. In addition, the activity of slacklining provides an innate activation of the lower limb muscles, particularly the quadriceps, calf, gluteals and also the trunk core muscles in normal and lower limb injured individuals. Slacklining is a novel adjunct therapy that is challenging and rewarding where quantifiable exercise specific gains can be achieved and potentially transformed into daily functional status improvements in the areas of ADL, gait and balance.^[26]

METHODOLOGY

Study Design: A double blinded single arm Randomised controlled trial

Study Setting :- Physiotherapy OPD Of Tertiary Care Hospital

Duration of study:- 1 year

Sample size:- 42 [n=21 in each group]

Inclusion criteria :- Participants included in this study were adults aged 45 to 55 years, diagnosed with Kellgren-Lawrence grade 1 osteoarthritis of the knee on radiographic examination. Eligible individuals reported a history of knee pain with a Numeric Pain Rating Scale (NPRS) score ranging from 3 to 6, along with a WOMAC score between 20% and 60%, indicating mild to moderate functional disability. Additionally, participants were required to be physically active and demonstrate a Y Balance Test composite score greater than 60%, reflecting moderate to minimal balance impairment.^[33] Body mass index was also considered as an inclusion parameter, with participants falling within the normal to overweight range of 18.5 to 29.9 kg/m² as per WHO classification.

Exclusion criteria:- Patients were excluded from the study if they had a history of recent knee surgery or soft tissue injury, or any other recent orthopaedic injury of the lower limb. Individuals who had received intra-articular injections were also excluded, as were those presenting with knee deformities such as fixed

flexion deformity (FFD), genu valgus, or genu varus. Patients with vertigo or acrophobia were not eligible for inclusion, nor were those with congenital deformities of the lower limb. Additionally, individuals classified as obese (Class I, II, or III) were excluded, along with patients diagnosed with any neurological disease affecting the lower limb.

Intervention/Procedure: Ethical clearance was obtained from the Institutional Ethical Committee prior to the commencement of the study. The purpose and procedure of the study were explained to each participant, following which written informed consent was obtained. A total sample size of 42 subjects was included, comprising individuals diagnosed with grade 1 osteoarthritis of the knee based on radiographic (X-ray) findings and clinical examination. Selected participants were evaluated for the presence of knee pain using standardized assessment criteria and were screened according to the predetermined inclusion and exclusion criteria. Subjects were then allocated into experimental and control groups by an independent person, with random allocation carried out using a randomized number sequence generator software; allocation concealment was maintained through the envelope method, and both the physiotherapist and patients remained blinded to group allocation. Prior to intervention, pretest outcome measures including NPRS, Y Balance Test, and WOMAC scale scores were recorded for all participants. The experimental group subsequently received the Indoor Slacklining exercise protocol, while the control group received standard conventional physiotherapy treatment. Both interventions were administered over a period of 4 weeks, during which two dropouts occurred in each group. Following completion of the 4-week protocol, post-test outcome measures of NPRS, Y Balance Test, and WOMAC were reassessed, and the collected data were analyzed using appropriate statistical tests. The results were presented in tabular format, and the study adhered to CONSORT guidelines throughout its conduct.

Outcome Measures:

1. Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC]
[Reliability 0.76]
2. Numerical pain rating scale[validity 0.86, reliability 0.96]
3. Y Balance test [reliability 0.88]

Intervention Protocol

Parameter	Experimental Group (Indoor Slacklining)	Control Group (Conventional Physiotherapy)
Warm-up	5 min: ankle-toe movements, hip-knee flexion, heel raises, trunk flexion-extension-rotations, hamstring stretch, TA stretch, quadriceps stretch	—
Exercise Components	Step up; Step down; Single leg stand – dominant; Single leg stand – nondominant; Walk forward 2 steps; Walk back 2 steps; Tandem stance dominant back; Tandem stance dominant forward.	Straight leg raising; Isometric quadriceps; Isometric hip adduction; Terminal knee extension; Vastus medialis oblique strengthening; Mini-squat.
Exercise Type	Balance and proprioceptive training on slackline	Closed kinetic chain and open kinetic chain exercises
Equipment/Setup	Slackline at standard house-step height of 250 mm (25 cm), anchored at 1.5 m length, with protective measures	Standard physiotherapy setup
Progression	Weeks 1–2: Performed with physiotherapist support (learning stage); Weeks 3–4: Performed independently (associative stage)	Maintained throughout the 4-week protocol
Repetitions/Sets	10 repetitions per activity	10 repetitions × 2 sets per exercise
Rest Interval	1 min between activities	1 min between sets
Frequency	3 alternate days/week	3 times/week, alternate days

Duration	4 weeks	4 weeks
Sessions	1 session/day	1 session/day
Outcome Reassessment	NPRS, WOMAC, Y Balance Test — post 4 weeks	NPRS, WOMAC, Y Balance Test — post 4 weeks

EXPERIMENTAL GROUP



Figure: Warm up protocol before starting indoor slacklining exercises



Figure: Therapist supporting patient on indoor slackline in initial stage

Figure: step up and down on indoor slackline



Figure: Tandem stance on slackline

Figure: 2 steps walk on indoor Slackline

CONTROL GROUP



Figure: Static adductor exercise



Figure : Terminal knee extension exercise



Figure: Straight leg raise exercise



Figure: Mini squat exercise

Statistical Analysis: The entire data of the study was entered and cleaned in MS Excel before it was statistically analyzed in “GRAPHPAD INSTAT 3.05 SOFTWARE”. All the results are shown in tabular as well as graphical format to visualize the statistically significant difference more clearly. The basic descriptions were presented in the form of Mean $\pm$ Standard Deviation (SD). The statistical significance of difference of pre-treatment and post-treatment quantitative characteristics in study group (Intra-group comparisons) was tested using paired t test after confirming the underlying normality assumption of pre- and post- treatment difference of parameters. The statistical significant difference of post-treatment quantitative characteristics in between intervention group and control group (Inter-group comparisons) was tested using unpaired t test after confirming the underlying normality assumption post- treatment difference of parameters in both groups. The p-values less than 0.05 are considered to be statistically significant all the hypothesis was formulated two tailed alternatives against null hypothesis (hypothesis of no difference).

RESULTS

Table 1 & Graph 1 - The age wise distribution of study subjects :

AGE DISTRIBUTION	NO. OF PATIENTS	PERCENTAGE	MEAN
45-50	24	60%	49 years
51-55	16	40%	
TOTAL	40	100%	

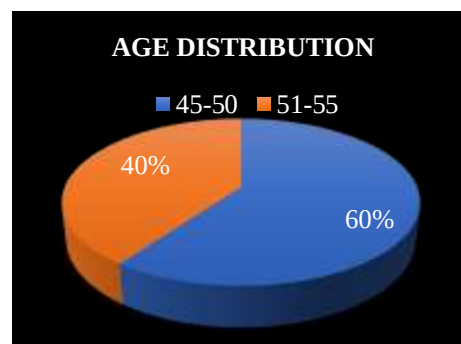
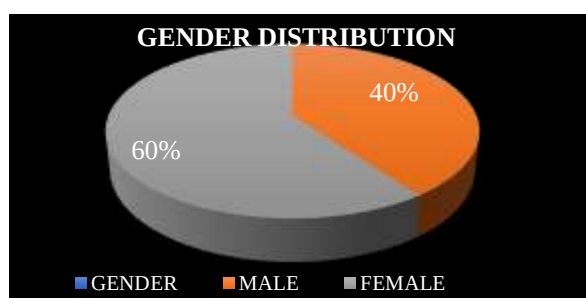
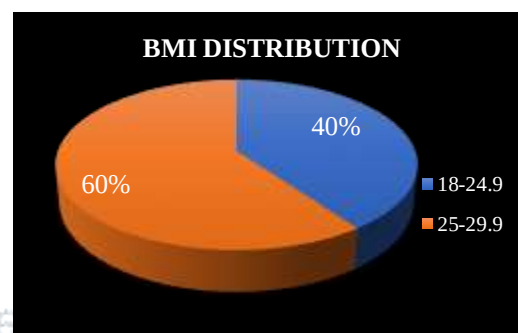


Table 2 & Graph 2 - The gender wise distribution of study subjects :

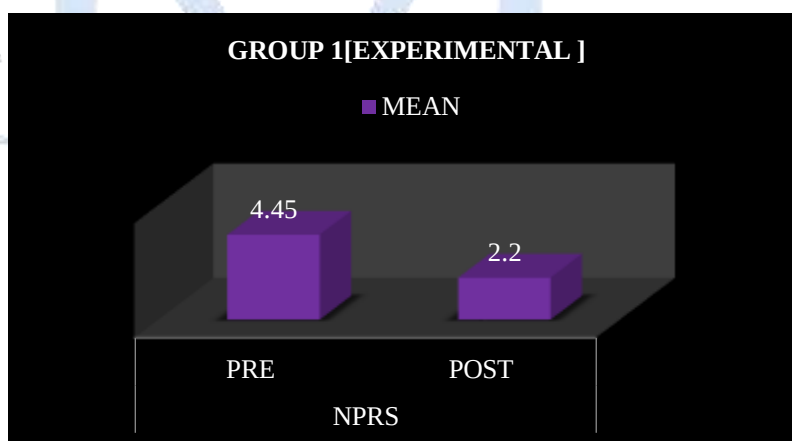
TOTAL	N=40	PERCENTAGE
GENDER		
MALE	16	40%
FEMALE	24	60%

**Table 3 & Graph 3 - The BMI distribution of study subjects :**

BMI DISTRIBUTION	NO. OF PATIENTS	PERCENTAGE	MEAN
18-24.9	16	40%	25.99 kg/m ²
25-29.9	24	60%	
TOTAL	N = 40	100%	

**Table 4 & Graph 4: Comparison of mean between Pre and Post treatment NPRS scores of Group 1 [Experimental group] [INTRAGROUP COMPARISON]**

Parameter	Follow up	Mean $\pm$ SD	t value	p value	Significance
NPRS	PRE	4.45 $\pm$ 1.191	6.957	<0.0001	Extremely significant
	POST	2.2 $\pm$ 1.24			

**Table 5 & Graph 5: Comparison of mean between Pre and Post treatment NPRS scores of Group 2 [Control group] [INTRAGROUP COMPARISON]**

Parameter	Follow up	Mean $\pm$ SD	t value	p value	Significance
NPRS	PRE	4.4 $\pm$ 1.188	3.865	0.001	Very significant
	POST	3.15 $\pm$ 1.226			

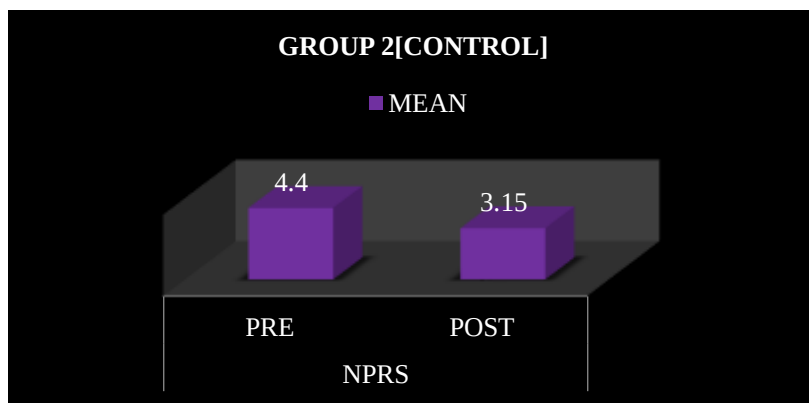


Table 6 & Graph 6: Comparison of mean between post treatment NPRS scores of Group 1 [Experimental group] and Group 2[Control group] [INTERGROUP COMPARISON]

Parameter	Follow up	Mean $\pm$ SD	t value	p value	Significance
NPRS	Experimental Group	2.2 $\pm$ 1.24	2.437	0.0196	Significant
	Control Group	3.15 $\pm$ 1.226			

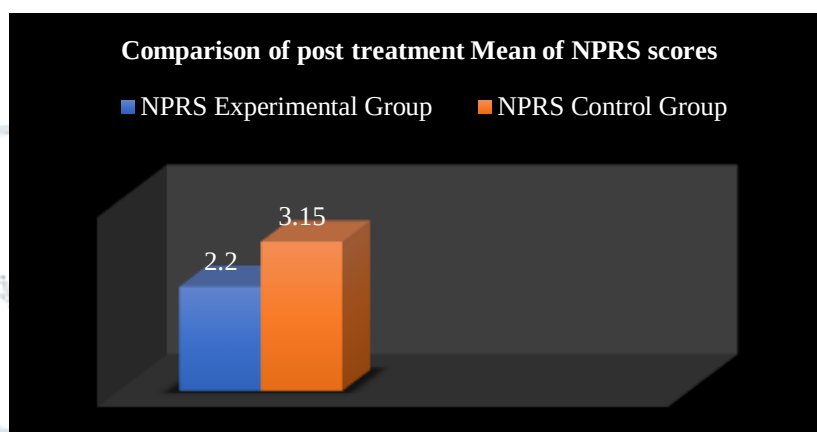


Table 7 & Graph 6: Comparison of mean between Pre and Post treatment Y Balance Test scores of Group 1 [Experimental group] [INTRAGROUP COMPARISON]

Parameter	Follow up	Mean $\pm$ SD	t value	p value	Significance
Y Balance Test	PRE	72.6 $\pm$ 9.522	4.432	0.0001	Extremely significant
	POST	77.8 $\pm$ 6.263			

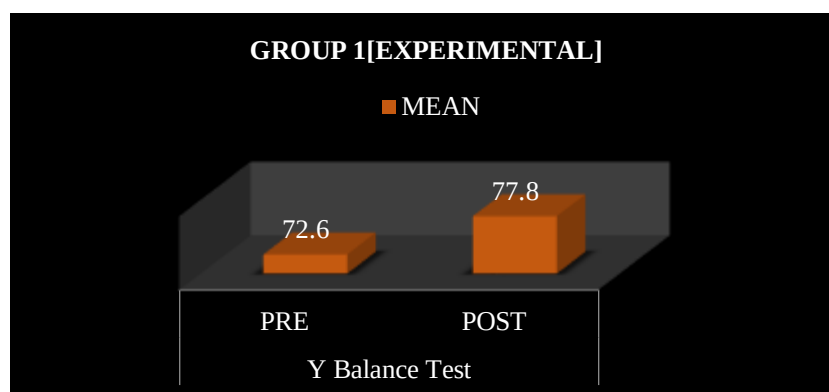


Table 8 & Graph 8: Comparison of mean between Pre and Post treatment Y Balance Test scores of Group 2 [Control group] [INTRAGROUP COMPARISON]

Parameter	Follow up	Mean $\pm$ SD	t value	p value	Significance
Y Balance Test	PRE	67.2 $\pm$ 11.176	2.665	0.0662	Significant
	POST	70.45 $\pm$ 8.884			

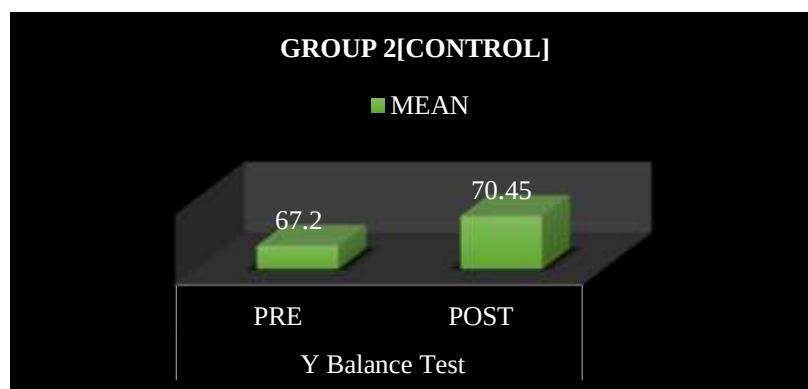


Table 9 & Graph 9: Comparison of mean between post treatment Y Balance Test scores of Group 1 [Experimental group] and Group 2[Control group] [INTERGROUP COMPARISON]

Parameter	Follow up	Mean $\pm$ SD	t value	p value	Significance
Y Balance Test	Experimental Group	77.8 $\pm$ 6.263	3.686	0.0007	Extremely Significant
	Control Group	70.45 $\pm$ 8.884			

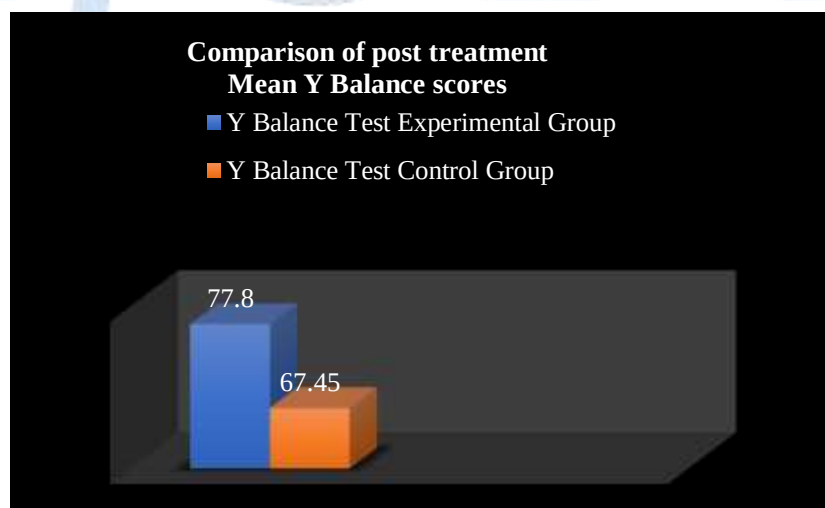
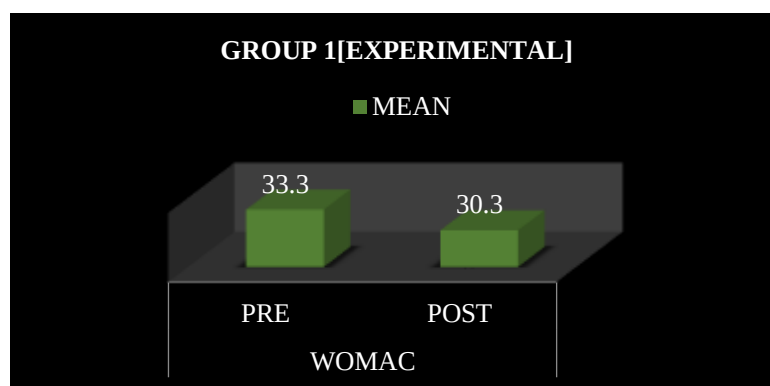
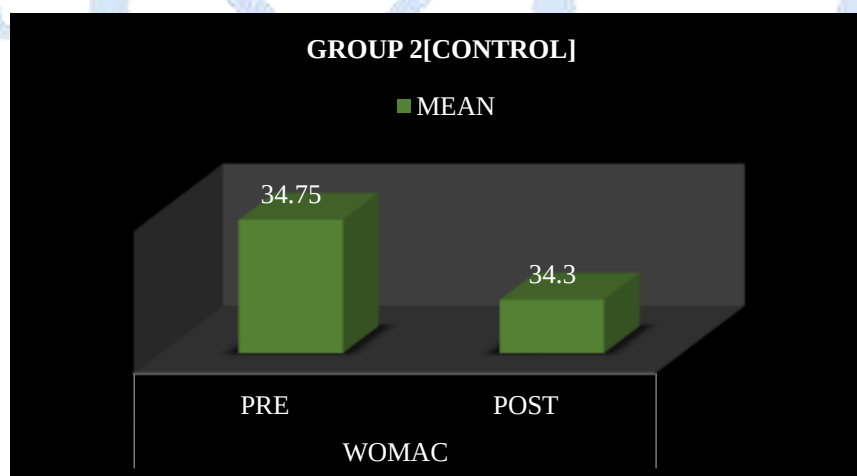


Table 10 & Graph 10: Comparison of mean between Pre and Post treatment WOMAC scores of Group 1 [Experimental group] [INTRAGROUP COMPARISON]

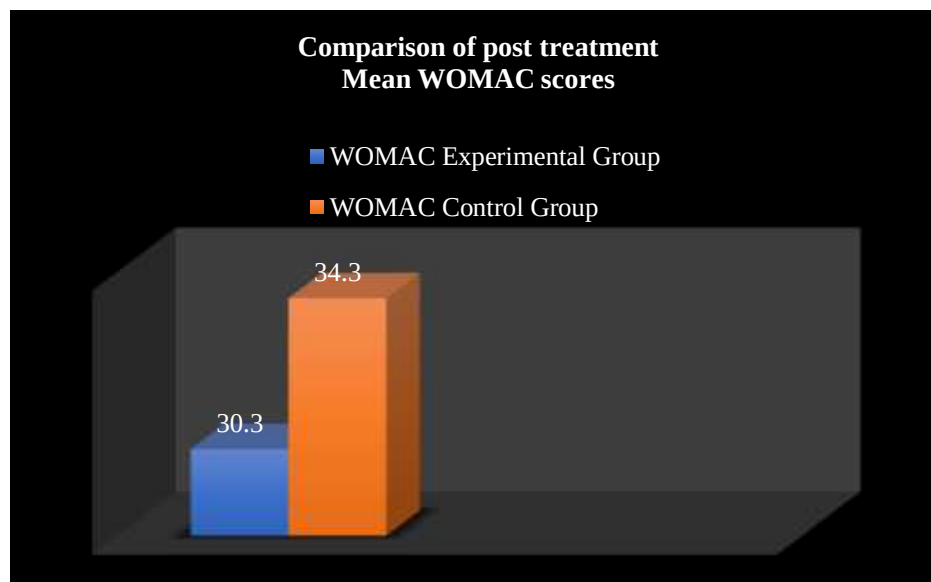
Parameter	Follow up	Mean $\pm$ SD	t value	p value	Significance
WOMAC	PRE	33.3 $\pm$ 5.162	7.198	<0.0001	Extremely Significant
	POST	30.3 $\pm$ 4.911			

**Table 11 & Graph 11 :** Comparison of mean between Pre and Post treatment WOMAC scores of Group 2 [Control group] [INTRAGROUP COMPARISON]

Parameter	Follow up	Mean $\pm$ SD	t value	p value	Significance
WOMAC	PRE	34.75 $\pm$ 3.37	2.651	0.0158	Significant
	POST	34.3 $\pm$ 3.358			

**Table 12 & Graph 12:** Comparison of mean between post treatment WOMAC scores of Group 1 [Experimental group] and Group 2[Control group] [INTERGROUPCOMPARISON]

Parameter	Follow up	Mean $\pm$ SD	t value	p value	Significance
WOMAC	Experimental Group	30.3 $\pm$ 4.911	3.007	0.0047	Very Significant
	Control Group	34.3 $\pm$ 3.358			



Total 42 subjects were included in study. There are total 2 drop-outs from 1 from experimental group and 1 from control group. Hence 40 subjects participated in complete study. Table 1 along with Graph 1 illustrates Age wise distribution of subjects in Experimental and Control group. In study, in total of 40 subjects; 24 subjects were between age group 45- 50 years and 16 subjects were between 50- 55 years. Mean age of study subjects was 49 years. Table 2 along with Graph 2 illustrates Gender wise distribution of subjects in Experimental and Control group. In study, in total of 40 subjects; 24 subjects were Females and 16 subjects were Males. Table 3 along with Graph 3 illustrates BMI distribution of subjects in Experimental and Control group. In study, in total of 40 subjects; 24 subjects had BMI between 25- 29.9 Kg/m² and 16 subjects had BMI between 18- 24.9 Kg/m². Mean BMI of study subjects is 25.99 kg/m².

In Experimental group intra group comparison of pre treatment and post treatment mean of NPRS i.e Numerical Pain Rating Scale; Result when performed paired T test implies that the mean difference between pre-treatment and post- treatment in experimental group was extremely significant to decrease NPRS mean score [P value is <0.0001]. In Experimental group intra group comparison of pre treatment and post treatment mean of Y Balance Test Scores; Result when performed paired T test implies that the mean difference between pre-treatment and post- treatment in experimental group was very significant to increase Y Balance Test mean score. [P value is 0.0001]. In Experimental group intra group comparison of pre treatment and post treatment mean of WOMAC i.e Western Ontario and McMaster Universities Osteoarthritis Index Scale Scores; Result when performed paired T test implies that the mean difference between pre-treatment and post- treatment in experimental group was extremely significant to decrease WOMAC mean score. [P value is <0.0001]. In Control group intra group comparison of pre treatment and post treatment mean of NPRS i.e Numerical Pain Rating Scale; Result when performed paired T test implies that the mean difference between pre-treatment and post- treatment in control group was very significant to decrease NPRS mean score. [P value is 0.001].

In Control group intra group comparison of pre treatment and post treatment mean of Y Balance Test Scores; Result when performed paired T test implies that the mean difference between pre-treatment and post- treatment in control group was significant to increase Y Balance Test mean score. [P value is 0.0662]. In Control group intra group comparison of pre treatment and post treatment mean of WOMAC i.e Western Ontario and McMaster Universities Osteoarthritis Index Scale Scores; Result when performed paired T test implies that the mean difference between pre-treatment and post- treatment in control group was significant to decrease WOMAC mean score. [P value is 0.0158]. For the Intergroup comparison between Experimental group post- treatment NPRS Score mean & Control group post-treatment NPRS Score mean between group 'unpaired T test' was used. The results in the present study shows that indoor slacklining exercises were statistically significant than standard conventional physiotherapy protocol to decrease pain in NPRS Scores. [P value is 0.0196]. For the Intergroup comparison between Experimental group post- treatment Y Balance Test Score mean & Control group post- treatment Y Balance Test Score mean between group 'unpaired T test' was used. The results in

the present study shows that indoor slacklining exercises were extremely significant than standard conventional physiotherapy protocol to increase in balance in Y Balance Test scores. [P value is 0.0007]. For the Intergroup comparison between Experimental group post- treatment WOMAC Score mean & Control group post- treatment WOMAC Score mean between group 'unpaired T test' was used. The results in the present study shows that indoor slacklining exercises were very significant than standard conventional physiotherapy protocol to decrease in mean scores of WOMAC Scale. [P value is 0.0047].

DISCUSSION

Osteoarthritis (OA) is a degenerative and non-inflammatory rheumatological disease of the joints characterized by the joint stiffness resulting in the joint immobility and dysfunction. It mostly affects the joints of the hands, knees, hips and spine. It is considered as second most common cause of disability around the globe, which is affecting about twenty percent of the people worldwide with more frequency in the females.^[9]

The present study was carried out to study the effect of indoor slacklining exercises on pain, functional performance and balance in Grade 1 Osteoarthritis knee patients. Initially 42 subjects with Grade 1 Osteoarthritis knee meeting the inclusion criteria were recruited into the study but due to loss of follow up and city migration 2 subjects were drop out from the study. Hence final intervention assessment analysis included 40 subjects. Study subjects was divided into 2 groups i.e. Group 1 [Experimental] and Group 2 [Control]. Group 1 subjects performed indoor slacklining exercises and Group 2 performed standard conventional physiotherapy protocol exercises. Outcome measures used were NPRS for pain, WOMAC for functional performance and Y Balance Test for balance. Pre intervention and post intervention assessment (at the end 4 weeks) were taken. In study, in total of 40 subjects; 24 subjects were between age group 45- 50 years and 16 subjects were between 50- 55 years. Mean age of study subjects was 49 years.[Table 1]

Chief objective was to find out the effect of indoor slacklining exercises on pain using Numerical pain rating scale [NPRS], on functional performance using Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC] and on balance using Y Balance test.

VARIABLE 1: Numerical Pain Rating Scale [NPRS]

EXPERIMENTAL GROUP:

In Experimental group intra group comparison of pre treatment and post treatment mean of NPRS i.e Numerical Pain Rating Scale; Result when performed paired T test implies that the mean $\pm$ SD difference between pre-treatment 4.45 ± 1.191 and post- treatment 2.2 ± 1.24 in experimental group was extremely significant to decrease NPRS mean score [P value is <0.0001]. [Table 4].

It may be because the structural damage and degenerative changes within the knee joint increase intra-articular tension and lead to more movement between joint surfaces, which triggers mechanoreceptors and reduces activation of pain-sensing nociceptors. Slacklining appears to lower the afferent signals from free nerve endings, an effect closely linked with arthrogenic muscle inhibition that ultimately reduces pain and initiates joint protection mechanisms. As osteoarthritis progresses, the altered mechanics resulting from tissue injury and degeneration enhance mechanoreceptor function while suppressing nociceptive input, decreasing discomfort and slowing further harm. Engaging in slacklining may therefore help activate protective pathways in the joint by modulating neural signals, supporting both pain reduction and muscle preservation in individuals with knee osteoarthritis.^[2]

CONTROL GROUP:

In Control group intra group comparison of pre treatment and post treatment mean of NPRS i.e Numerical Pain Rating Scale; Result when performed paired T test implies that the mean $\pm$ SD difference between pre-treatment 4.4 ± 1.188 and post- treatment 3.15 ± 1.226 in control group was very significant to decrease NPRS mean score.[P value is 0.001]. [Table 5]

This may be because Standard physiotherapy exercises can enhance patellar tracking and increase overall knee stability, which helps in reducing excess stress on the joint and limits further cartilage

damage and pain as osteoarthritis progresses.^[9] By strengthening muscles around the knee and promoting their co-contraction, these exercises stimulate joint mechanoreceptors, leading to decreased pain signaling and a notable analgesic effect.

COMPARISON OF POST TREATMENT OF BOTH THE GROUPS:

For the Intergroup comparison between Experimental group post- treatment NPRS Score mean 2.2 ± 1.24 & Control group post- treatment NPRS Score mean 3.15 ± 1.226 between group 'unpaired T test' was used. The results in the present study shows that indoor slacklining exercises were statistically significant than standard conventional physiotherapy protocol to decrease pain in NPRS Scores.[P value is 0.0196].[Table 6]

Our study results suggests that Indoor slacklining exercises appear to reduce pain mechanisms in individuals with knee osteoarthritis, particularly when arthrogenic muscle inhibition is present, by modulating peripheral sensitization and nociceptive signaling. This process leads to prolonged changes in tissue and joint sensitivity, which are attributed to a lowered activation threshold in articular free nerve endings due to reduced knee joint loading and suppression of quadriceps muscle activity. Therefore, early activation of the quadriceps—with minimal voluntary effort—is crucial for those experiencing degenerative changes in the knee joint. Slacklining provides a multifaceted, weightbearing exercise with a dynamic base of support, combining benefits of both open- and closed-chain movements, and is considered a superior option compared to traditional physiotherapy protocols. In knee osteoarthritis patients, slacklining enhances muscle activation, especially of the quadriceps, which is central to knee support. Additionally, slacklining engages sensorimotor systems and promotes balance through neuromuscular activation, thereby increasing proprioception and joint stability. This form of exercise is both challenging and accessible, and may be well tolerated in cases of pain and weakness, often resulting in a lower perceived exertion than conventional exercise methods.

Result of our study is in accordance with study done by **Gabel CP, Osborne J, Burkett B.** et al [2015] concluded that as compared to open and closed-chain exercises showed no difference, while composite-chain Slackline exercise showed significantly higher quadriceps activation and slacklining was an effective measure in activating quadriceps and was a better component in quadriceps rehabilitation.^[2]

VARIABLE 2: Y Balance Test

EXPERIMENTAL GROUP:

In Experimental group intra group comparison of pre treatment and post treatment mean of Y Balance Test Scores; Result when performed paired T test implies that the mean $\pm$ SD difference between pre-treatment 72.6 ± 9.522 and post- treatment 77.8 ± 6.263 in experimental group was very significant to increase Y Balance Test mean score.[P value is 0.0001].[Table 7]

It may be because the reactionary forces generated by the slackline are unique—they resist and push back against the slackliner's weight until stability is achieved. True equilibrium on the slackline occurs only when these physical forces are balanced with the slackliner's own cortical and neurological inputs, which include activity from the hippocampus and motivational centers in the brain. These neurological factors provide both preparatory and responsive actions, helping the individual reach temporary balance where all contributing factors are in harmony. This moment of complete stability may only last briefly before new imbalances arise as internal forces interact with the slackline's stored kinetic energy, causing another cycle of instability.^[24] Because slacklining challenges both dynamic and static stability, it stimulates complex balance adaptations and is an effective training method for enhancing overall balance skills.

CONTROL GROUP:

In Control group intra group comparison of pre treatment and post treatment mean of Y Balance Test Scores; Result when performed paired T test implies that the mean $\pm$ SD difference between pre-treatment 67.2 ± 11.176 and post- treatment 70.45 ± 8.884 in control group was significant to increase Y Balance Test mean score. [P value is 0.0662][Table 8]

This may be because standard physiotherapy protocols enhance proprioceptive feedback by stimulating

mechanoreceptors, which is vital for maintaining balance and equilibrium. Additionally, the simultaneous co-contraction of muscles improves joint stability and enhances postural control, contributing to better overall movement and reduced risk of injury. By improving the body's awareness of joint position and movement through these mechanisms, physiotherapy helps individuals achieve more stable control.^[9]

COMPARISON OF POST TREATMENT OF BOTH THE GROUPS:

For the Intergroup comparison between Experimental group post- treatment Y Balance Test Score mean 77.8 ± 6.263 & Control group post- treatment Y Balance Test Score mean 70.45 ± 8.884 between group 'unpaired T test' was used. The results in the present study shows that indoor slacklining exercises were extremely significant than standard conventional physiotherapy protocol to increase in balance in Y Balance Test scores. [P value is 0.0007]. [Table 9]

Our study results suggests that the unpredictable sway of the slackline triggers rapid postural responses, which strengthen automatic balance strategies and reduce the need for conscious control. This leads to improved reaction times. During the initial learning phase, spinal reflexes are pronounced, causing instability—for example, slacklining involves uncontrolled reciprocal contractions of ankle muscles during eversion and inversion. With continued slackline training, positive functional adaptations occur as centrally induced reflex inhibition reduces neurotransmitter release, thereby dampening spinal reflexes. To maintain balance, individuals revert to or build upon previously learned movement strategies. These strategies, shaped by experience, operate across multiple body response time scales and are refined with ongoing practice and knowledge accumulation.^[17] This integration not only helps maintain existing skills but also aids progression to higher levels of competence, influenced by training and social context. Consequently, slacklining offers advantages over standard exercise protocols by providing more intense training of both dynamic and static balance.

The result of our study is in accordance with study conducted by **Gabel CP, Guy B, Mokhtarinia HR, Melloh M.** et al [2021] concluded that Slacklining is an activity with increasing recreational use, but also has progressive adoption into prehabilitation and rehabilitation. Slacklining is achieved through self-learned strategies that optimize energy expenditure without conceding dynamic stability, during the neuromechanical action of balance retention on a tightened band. Consequently, specific patient and situational uses may be initiated within the framework of evidence based medicine that ensures a multi-tiered context of slacklining applications in movement, balance and stability.^[24]

VARIABLE 3: Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC]

EXPERIMENTAL GROUP:

In Experimental group intra group comparison of pre treatment and post treatment mean of WOMAC i.e Western Ontario and McMaster Universities Osteoarthritis Index Scale Scores; Result when performed paired T test implies that the mean $\pm$ SD difference between pre-treatment 33.3 ± 5.162 and post- treatment 30.3 ± 4.911 in experimental group was extremely significant to decrease WOMAC mean score. [P value is <0.0001]. [Table 10]

It may be because the rapid neuroplastic changes occur in the short to medium term when the brain learns new procedural sequences or memorizes cascades of reactions and events. Maintaining balance after deviating from an upright position requires integration from three sensory systems, each with different conduction delays: proprioception from the joints, vision from the eyes, and vestibular input from the inner ear. These systems help the body maintain equilibrium against gravity and vibrations, especially when vision is impaired.^[17] This complex sensory coordination supports spatial orientation, memory, and motor processing needed for daily activities and recreational tasks like slacklining. Slacklining, by engaging proprioceptive, visual, and vestibular systems simultaneously, improves functional performance not only in recreational contexts but also in daily life tasks.

CONTROL GROUP:

In Control group intra group comparison of pre treatment and post treatment mean of WOMAC i.e Western Ontario and McMaster Universities Osteoarthritis Index Scale Scores; Result when performed paired T test implies that the mean $\pm$ SD difference between pre-treatment 34.75 ± 3.37 and post- treatment 34.3 ± 3.358 in control group was significant to decrease WOMAC mean score. [P value is 0.0158]. [Table 11]

It may be because as quadriceps strength decreases, patients often experience increased disability. Exercises targeting the quadriceps may enhance motoneuron excitability, which in turn boosts voluntary muscle activation and improves proprioceptive acuity.^[10] Enhanced proprioception contributes to better joint stability, leading to improved functional performance in daily activities.

COMPARISON OF POST TREATMENT OF BOTH THE GROUPS:

For the Intergroup comparison between Experimental group post- treatment WOMAC Score mean 30.3 ± 4.911 & Control group post- treatment WOMAC Score mean 34.3 ± 3.358 between group 'unpaired T test' was used. The results in the present study shows that indoor slacklining exercises were very significant than standard conventional physiotherapy protocol to decrease in mean scores of WOMAC Scale. [P value is 0.0047]. [Table 12]

Our study results suggests that the increased sensorimotor integration resulting from challenging unstable surfaces, such as during slacklining, activates proprioceptors, enhancing sensory feedback and central nervous system integration. This dual effect improves neuromuscular coordination in the lower limbs and promotes co-contraction of muscles, which increases joint stability and enhances both dynamic and static postural control. These mechanisms contribute to slacklining's ability to improve overall functional performance compared to traditional exercises, which mainly focus on dynamic muscle strengthening. Slacklining, though often seen as a recreational activity, offers a novel and engaging alternative to monotonous exercise protocols in rehabilitation programs. It has been shown to significantly reduce pain, improve functional mobility, and enhance joint position sense by combining these benefits into a single activity rather than providing separate exercises for each component. Moreover, because slacklining mimics real-life balance challenges, it translates better into improved performance in daily activities, reduces fall risk, and boosts confidence in movement.

The result of our study is in accordance with study conducted by **Granacher U, Iten N, Roth R, Gollhofer A** et al [2010] concluded that the data strongly support that slacklining can improve postural control and enhance functional knee joint stability, which seems to be induced by enhanced preparatory muscle activation. When incorporated into a rehabilitation program, the slacklining protocol provided a systematic approach for progression to activities of increasing difficulty that built upon previously developed skills.^[17]

Slacklining has a positive overall impact on pain, functional performance, and balance. It represents a novel rehabilitation approach that is both recreational and distinct from traditional standardized physiotherapy protocols. When practiced under proper guidance and supervision, slacklining can alleviate symptoms in osteoarthritis knee patients effectively. Moreover, when combined with conventional rehabilitation protocols, slacklining acts as a valuable booster, offering a versatile and multipurpose exercise modality that enhances recovery.

CONCLUSION

The study concluded that indoor slacklining exercises and standard conventional physiotherapy protocol both are effective on reducing pain, improving functional performance and balance among patients with grade I osteoarthritis knee. But indoor slacklining exercises are more effective than standard physiotherapy protocol on reducing pain, improving functional performance and balance among patients with grade I osteoarthritis knee.

LIMITATIONS

The sample size for this study was limited as compared to osteoarthritis knee patients. Safety concerns of patients and counseling of patient prior to treatment. This study was limited to Grade I osteoarthritis knee patients. No follow up was done after the said duration of study hence, long-term outcomes of the treatment techniques were not evaluated, and it is not assured if the differences observed at Post treatment could be maintained over longer periods of time.

FUTURE SCOPE

The study combined with electromyography can be more beneficial and precise and In future use of 3 D motion analysis to capture and measure forces of slacklining can be considered. Also in future use slacklining can be a part of fall prevention program for geriatric patients.

CLINICAL IMPLICATIONS

Indoor Slacklining can be used in clinical settings as a part of intervention for individuals with knee osteoarthritis and Indoor slacklining exercises can be used as adjunct to physiotherapy intervention protocols.

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FIGURES & TABLES

Table 13: CONSORT Table

