

Comparing The Effectiveness of Combined Proprioceptive and Sensorimotor Training On Pain, Range of Motion, Functional Ability and Quality of Life in Individuals with Mechanical Low Back Pain and Knee Malalignment with and Without Knee Osteoarthritis.

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ABSTRACT

BACKGROUND:

Mechanical low back pain (MLBP) and knee osteoarthritis (KOA) are major causes of disability worldwide and are biomechanically linked through the lower-limb–spine kinetic chain. Coexisting knee malalignment and lumbopelvic dysfunction disrupt load distribution, impair proprioception and contribute to persistent pain. Rehabilitation strategies addressing both conditions simultaneously remain limited.

AIM:

To evaluate the effectiveness of combined proprioceptive and sensorimotor training on pain, range of motion (ROM), functional ability and quality of life in individuals with MLBP and knee malalignment, with and without KOA.

Methods: Forty-four participants were divided into Group A (with KOA) and Group B (without KOA). Both groups underwent combined proprioceptive and sensorimotor training along with conventional exercises, three times per week for six weeks. Outcomes included Numeric Pain Rating Scale (NPRS), ROM, functional ability (WOMAC.MODI) and quality of life, analysed using SPSS ($p < 0.05$).

RESULTS:

Both groups showed significant post-intervention improvements. In Group A, NPRS scores for low back pain decreased from 6.95 ± 0.78 to 3.95 ± 0.78 and knee pain from 7.10 ± 0.85 to 4.20 ± 0.82 ; WOMAC improved from 62.40 ± 5.30 to 42.15

± 4.80 ($p < 0.001$). Group B demonstrated greater reductions in pain (low back pain: 6.86 ± 0.77 to 2.91 ± 0.86 ; knee pain: 6.75 ± 0.80 to 2.70 ± 0.75) and superior functional gains compared with Group A ($p < 0.001$).

CONCLUSION:

Integrating proprioceptive and sensorimotor training with conventional exercises effectively reduces pain and improves functional ability and quality of life in individuals with MLBP and knee malalignment, with greater benefits in participants without KOA.

KEYWORDS:

Modified Schober's test, , Musculoskeletal Disorders, Range of Motion.

1. INTRODUCTION

Musculoskeletal disorders such as mechanical low back pain and knee osteoarthritis are among the most prevalent causes of disability worldwide, substantially affecting mobility, independence and overall quality of life. The Global Burden of Disease Report indicates that low back pain is the primary cause of years lived with disability worldwide and osteoarthritis is listed among the top ten debilitating conditions in older individuals [1]. These conditions are not merely isolated joint disorders, instead they signify intricate biomechanical and neuromuscular impairments that affect the whole kinetic chain. Growing evidence indicates that spinal and lower limb disorders frequently coexist and influence each other, worsening functional limitations and long-term disability.

The spine and lower limbs operate as a cohesive mechanical system where motion or impairment in one area inevitably affects neighbouring segments. Knee malalignment or degenerative alterations change the distribution of loads while standing, walking and performing transitional movements. These modified force vectors might travel proximally, influencing pelvic alignment, lumbar curvature and the activation patterns of trunk muscles. With time, these compensatory changes might lead to the onset or continuation of mechanical low back pain [2].

Knee malalignment especially varus and valgus deformities results in uneven load distribution across the tibiofemoral compartments. Varus alignment raises loading in the medial compartment, while valgus alignment redirects stress to the lateral side. These deviations increase local joint stress and also activate nearby compensatory mechanisms like pelvic tilting, modified hip rotation and variations in lumbar lordosis. The mechanical stress on the lumbar spine may lead to recurring strain and persistent low back issues. Likewise, persistent trunk instability or inadequate spinal motor control can modify gait mechanics and shock absorption methods, consequently increasing joint loading at the knee. The existence of proprioceptive impairments and neuromuscular inefficiencies in both scenarios exacerbates this mechanical imbalance [3,4].

Knee osteoarthritis (OA), commonly known as degenerative joint disease, is marked by the gradual deterioration of cartilage, changes in subchondral bone, the development of osteophytes and differing levels of synovial inflammation [5]. Historically thought to be due to “wear and tear,” modern insights view knee OA as a complex disease affected by mechanical, metabolic, inflammatory and neuromuscular elements. Factors such as age, weight and joint trauma from repetitive actions, especially squatting and kneeling, are common risks for knee OA. Various elements such as cytokines, leptin and mechanical forces contribute to the pathology of knee OA [6]. Risk factors associated with the onset of knee OA can be categorized into nonmodifiable and modifiable. Nonmodifiable risk factors comprise hereditary (genetic variations that might make a person more susceptible to developing OA of the knee) and

congenital (inherited irregularities in the bone structure around the knee joint) factors and Knee osteoarthritis affects all three compartments of the knee (medial, lateral and patellofemoral joints) and usually advances slowly over 10 to 15 years, interfering with daily routines [7]. The prevalence of knee OA was identified as 16% in the postindustrial group, while it was only 6% and 8% in the early industrial and prehistoric groups, respectively [8].

In addition to structural deterioration, those with KOA frequently exhibit compromised joint position sense, slow quadriceps activation, diminished balance and modified walking patterns. These neuromuscular limitations decrease dynamic stability, elevate the risk of falling and restrict functional performance [9]. LBP, characterized as discomfort in the lower back or buttocks, commonly occurs in 54.6–58.1% of individuals with knee OA, in patients with knee OA, LBP increases the degree of disability owing to its interaction with knee pain [10]. Similarly, individuals with chronic MLBP show diminished proprioception, altered muscle recruitment patterns and impaired sensorimotor control, contributing to recurrent pain and dysfunction. Since proprioception and sensorimotor control are critical for maintaining joint stability and coordinated movement, interventions that target these systems could be beneficial for improving function in both the lumbar spine and lower limbs [11,12]. LBP impacts the intensity of knee pain and influences the degree of disability in individuals with knee OA. The coexistence of LBP and knee pain had a greater impact on disability levels than either LBP or knee pain alone [13]. Since proprioception and sensorimotor control are crucial for sustaining joint stability and coordinated movement, rehabilitation approaches focusing on these systems are significant for both lumbar and knee issues. Proprioceptive training improves joint position awareness and kinaesthetic perception by activating mechanoreceptors found in muscles, tendons and joint capsules. Sensorimotor training, conversely, combines sensory information with motor actions, reconditioning the central nervous system to react effectively to dynamic challenges. Collectively, these approaches foster better afferent feedback and more accurate efferent motor responses, boosting postural stability, movement coordination and functional adaptability. Numerous studies have demonstrated that proprioceptive or sensorimotor training alone can effectively reduce pain and improve function in people with knee osteoarthritis or chronic lower back pain [12,14,15].

These interventions have demonstrated effectiveness in improving balance, enhancing muscle activation timing, reducing asymmetry in joint loading and increasing functional capacity. The presence of these conditions implies that interventions solely targeting joints may not be enough to completely restore functional biomechanics. When both the knee and lumbar spine are affected, dysfunction can continue due to mutual mechanical interactions. For instance, ongoing knee valgus can elevate trunk lateral flexion during walking which cause lumbar instability and can decrease hip extension in the stance phase, subsequently heightening knee joint stress. Thus, a combined approach that focuses on both spinal and lower limb mechanics at the same time could lead to better rehabilitation results.

However, limited research has explored the combined application of these training modalities in individuals presenting with both mechanical low back pain and knee malalignment—with or without osteoarthritic changes. Given the reciprocal influence of the spine and lower limb through the kinetic chain, an integrated intervention addressing both regions simultaneously could provide more comprehensive rehabilitation outcomes. Additionally, the presence of osteoarthritic changes may modify the responsiveness to such interventions due to factors like joint degeneration and chronic inflammation.

Therefore, there is a clear need to investigate the comparative effectiveness of combined proprioceptive and sensorimotor training on pain, range of motion, functional ability and quality of life in individuals with mechanical low back pain and knee malalignment, both with and without knee osteoarthritis. The results of such research could guide physiotherapists toward more holistic, evidence-based rehabilitation strategies that address interconnected biomechanical dysfunctions rather than treating individual joints in isolation.

1.1 BACKGROUND OF THE STUDY:

Musculoskeletal conditions rank among the leading causes of chronic pain and disability globally. The Global Burden of Disease Study indicates that low back pain is the primary reason for years lived with disability worldwide, whereas knee osteoarthritis is among the most prevalent chronic degenerative joint diseases impacting older individuals. These conditions diminish physical function and significantly affect quality of life as well as healthcare systems.

Mechanical low back pain and knee osteoarthritis frequently coexist or affect one another owing to the biomechanical linkage within the kinetic chain. Correct alignment of the knee joint is essential for distributing forces while standing and walking. Knee malalignment leads to uneven load distribution, which raises joint stress and speeds up degenerative changes. With time, this could advance to radiographic knee osteoarthritis, typically categorized as Kellgren–Lawrence grade ≥ 2 .

People with knee osteoarthritis often show diminished proprioception, lower neuromuscular control and modified gait mechanics. These alterations may deliver irregular forces to the hip and lumbar spine. Likewise, individuals suffering from chronic mechanical low back pain frequently exhibit deficiencies in trunk muscle activation, impaired proprioception and balance issues. When both conditions are present, these sensorimotor deficits can influence and exacerbate one another, resulting in ineffective movement patterns, compensatory approaches, heightened joint stress and ongoing pain.

While earlier research has separately investigated rehabilitation methods for knee osteoarthritis and low back pain, scant studies have concentrated on individuals experiencing both mechanical low back pain and knee malalignment, whether or not osteoarthritic changes are present.

1.2 NEED FOR THE STUDY:

Although the connection between the knee and lumbar spine is acknowledged biomechanically and neuromuscular, rehabilitation programs frequently aim to address each issue independently. This segmented method might miss the interrelated nature of these dysfunctions within the kinetic chain.

Knee malalignment or osteoarthritic changes can coexist with mechanical low back pain, leading to synergistic interactions involving proprioceptive deficits and altered sensorimotor control. This may increase pain severity, hinder functional ability and further diminish overall quality of life. Additionally, structural deterioration in knee osteoarthritis might alter neuromuscular responsiveness, possibly impacting patients' reactions to proprioceptive and sensorimotor training.

At present, there is sparse evidence assessing the efficacy of integrated proprioceptive and sensorimotor rehabilitation in people with mechanical low back pain, both with and without concurrent knee osteoarthritis. It is still uncertain if structural knee degeneration affects the results of treatment.

Consequently, it is evident that a thorough exploration of the joint implementation of proprioceptive and sensorimotor training in this group is necessary. Grasping these interactions will aid in creating focused, evidence-driven rehabilitation strategies that tackle both spinal and lower-limb issues collectively, ultimately enhancing pain alleviation, functional recovery and long-term results for patients.

1.3 AIM:

To compare the effectiveness of combined proprioceptive and sensorimotor training plus conventional exercise on pain, range of motion, functional ability, and quality of life in individuals with mechanical low back pain and knee malalignment with and without knee osteoarthritis.

1.4 OBJECTIVES:

To determine the effects of combined proprioceptive and sensorimotor training on pain, range of motion, functional ability and quality of life in individuals with mechanical low back pain and knee malalignment with knee osteoarthritis.

To determine the effects of combined proprioceptive and sensorimotor training on pain, range of motion, functional ability and quality of life in individuals with mechanical low back pain and knee malalignment without knee osteoarthritis.

To compare the effects of combined proprioceptive and sensorimotor training plus conventional exercise on pain, range of motion, functional ability, and quality of life between individuals with mechanical low back pain and knee malalignment with and without knee osteoarthritis.

1.5 HYPOTHESIS:

Null hypothesis (H_0): There will be no significant difference in the effects of combined proprioceptive training, sensorimotor training on pain, range of motion, functional ability and quality of life in individuals with mechanical low back pain and knee malalignment with and without knee osteoarthritis.

Alternative hypothesis (H_1): There will be significant difference in the effects of combined proprioceptive training, sensorimotor training on pain, range of motion, functional ability and quality of life in individuals with mechanical low back pain and knee malalignment with and without knee osteoarthritis.

2. REVIEW OF LITERATURES

1. **S Tanamas, FS Hanna, et al., (2009)** conducted a systematic review that consolidates current evidence regarding the link between knee malalignment and the onset or advancement of knee osteoarthritis (OA), providing an extensive assessment of biomechanical and longitudinal studies available until then. Previous research has pinpointed malalignment—especially varus or valgus malalignment as a major factor affecting unequal load distribution within the tibiofemoral compartments, thus leading to

cartilage deterioration. They examined observational and cohort studies that utilized radiographic assessments of alignment and OA severity, observing that varus alignment was consistently linked to progression of medial compartment OA, whereas results for valgus alignment and lateral OA were less definitive due to a lack of high-quality studies. Their thorough evaluation revealed the methodological differences in past studies, such as inconsistencies in defining malalignment, the duration of follow-up and the measures of outcomes. Regardless of these constraints, the review determined that malalignment significantly contributes to OA pathomechanics by enhancing joint-loading asymmetry and hastening structural alterations in impacted compartments. Significantly, the study highlighted the necessity for more thorough longitudinal research to elucidate causal mechanisms and enhance the comprehension of valgus alignment's impact on lateral OA, establishing a groundwork for subsequent large-scale cohort studies that bolstered this evidence base.

2. DT Felson, J Niu, et al., (2013) The research offers significant longitudinal proof connecting valgus malalignment to the development and advancement of lateral knee osteoarthritis (OA). Previous biomechanical studies highlighted varus malalignment as a significant factor in medial compartment OA due to heightened medial joint loading, whereas valgus alignment garnered less focus even though it may influence lateral compartment degeneration. Previous imaging and gait-analysis research indicated that a valgus orientation alters ground-reaction forces to the side heightening compressive stress on the lateral tibiofemoral joint and hastening cartilage degradation. Expanding on these discoveries, the study employed extensive well-defined cohorts from the Multicenter Osteoarthritis Study (MOST) and the Osteoarthritis Initiative providing solid sample sizes, uniform radiographic evaluations and extended follow-up. Their findings showed that even slight valgus malalignment raised the chances of both developing and exacerbating lateral OA supporting the mechanical loading theory suggested in previous biomechanical studies. Moreover, the research tackled the shortcomings of earlier cross-sectional studies by using a prospective approach thus enhancing causal interpretations. Together, this study emphasizes the clinical significance of lower-limb alignment in the development of OA and stresses the necessity for focused preventive and rehabilitative approaches for those with valgus malalignment.

3. Gomiero AB, Kayo A, et al., (2017) Current research underscores an active interplay among lower-limb malalignment, neuromuscular weaknesses and spinal mechanics that influences on pain, mobility, functional capacity and quality of life in individuals experiencing mechanical low back pain and knee malalignment regardless of knee osteoarthritis (KOA) presence. Research consistently demonstrates that varus–valgus deformities and modified tibiofemoral angles elevate compartmental stress resulting in expedited cartilage deterioration and compensatory adjustments in hip rotation, pelvic tilt and lumbar curvature. Research highlights that proprioceptive and sensorimotor training shows diminished joint position sense, slowed muscle activation and weaker quadriceps strength and further destabilize the kinetic chain exacerbating symptoms and functional deterioration. Studies on KOA indicate that sensory-motor and proprioceptive training enhance neuromuscular coordination, balance and pain management as illustrated in this randomized trial, which revealed significant improvements in strength, mobility and quality of life via sensorimotor-focused programs. Similar results in chronic low back pain populations indicate that proprioceptive and sensorimotor training improve lumbar repositioning accuracy and postural control more efficiently than conventional therapy alone. Comprehensive imaging studies demonstrate that spinal sagittal imbalance, knee flexion contracture and modified pelvic alignment are biomechanically

interconnected highlighting the necessity for treatments that focus on both spinal and lower-limb biomechanics. The literature collectively indicates that integrating proprioceptive and sensorimotor training with conventional therapy may provide enhanced enhancements in pain, function and overall movement control for individuals with mechanical LBP and knee malalignment irrespective of KOA status warranting further exploration via a quasi-experimental approach.

4. **Van Tunen JA, Dell’Isola A, et al., (2018)** Research consistently emphasizes the significant link between biomechanical elements and the onset and advancement of knee osteoarthritis (KOA). Tibiofemoral KOA is generally acknowledged as a mechanically induced condition in which modified joint mechanics lead to cartilage deterioration and discomfort. Systematic reviews indicate that people with KOA often exhibit skeletal malalignment especially varus or valgus deformities which heighten irregular medial or lateral joint loading and hasten structural degradation. Research also indicates considerable muscular impairment in KOA patients characterized by weakened quadriceps and hamstrings shows diminished endurance and changed activation patterns all of which undermine knee stability and shock absorption. Proprioceptive impairments including diminished joint position awareness and heightened repositioning mistakes are well-documented leading to incorrect movement patterns and a higher risk of additional joint injury. Moreover, heightened medial varus–valgus laxity and diminished lateral joint stability are commonly noted indicating weakened passive joint constraints. Unusual loading patterns during walking particularly heightened knee adduction moments are closely associated with pain, functional impairment and severity of disease. In general, the literature indicates that malalignment, weakened muscles, loss of proprioception and excessive joint loading work together synergistically, strengthening the mechanical foundation of KOA and highlighting the necessity for specific biomechanical interventions.

5. **McCaskey MA, Wirth B, et al., (2018)** The literature extensively emphasizes the significant interrelationship among spinal alignment, pelvic posture and lower-limb joint mechanics in the onset of musculoskeletal conditions like knee osteoarthritis and mechanical low back pain. Research consistently shows that changes in sagittal spinal alignment especially diminished lumbar lordosis, heightened pelvic tilt and forward trunk lean result in compensatory adjustments in the lower extremities, frequently resulting in greater knee flexion, modified loading patterns and advancement of degenerative knee conditions. Studies utilizing advanced full-body imaging technologies like EOS indicate that people with a larger mismatch between pelvic incidence and lumbar lordosis show notably higher knee flexion angles, malalignment at the hip-knee-ankle and worse functional results. Previous research has shown that chronic knee issues can mutually affect spinal alignment due to factors such as weakened quadriceps, diminished proprioception and changed gait patterns, leading to lumbar muscle fatigue and low back pain. Research on the "knee-spine syndrome" illustrates that issues in one area can transmit biomechanical stress along the kinetic chain, highlighting a two-way interaction. The existing literature indicates that spinal imbalance and knee degeneration are linked through common compensatory mechanisms, making comprehensive rehabilitation strategies that focus on both spinal and lower-limb alignment crucial for enhancing pain relief, posture and functional abilities.

6. **McClure PK, Herzenberg JE, et al., (2019)** Research on lower limb malalignment consistently shows that irregular coronal or sagittal alignment can change joint loading and lead to early degenerative

changes, especially in the knee. Biomechanical research shows that minor angular deformities considerably alter load distribution in knee compartments, with proximal deformities causing larger increases in joint stress compared to distal ones. Animal models provide additional evidence that both varus and valgus malalignments promote degenerative alterations in articular cartilage and adjacent structures as time progresses. Clinical evidence, although constrained, indicates that malunited fractures and deformities in childhood may make individuals more susceptible to early arthritis, particularly when the deformity surpasses 5–10 degrees. Research on femoral and tibial malunions indicates increased arthritis rates in the overloaded compartment, with varus deformities typically leading to earlier degeneration compared to valgus. Gait assessments show that static malalignment doesn't always directly relate to dynamic joint loading, as compensatory movement patterns can change mechanical stresses. Furthermore, studies on patellofemoral joint mechanics indicate that valgus alignment raises the load on the lateral compartment, whereas varus alignment heightens medial wear. While corrective measures can alter force distribution and possibly slow progression, substantial proof for preventive realignment in asymptomatic individuals is still insufficient. In general, the literature supports that malalignment leads to atypical biomechanics and chronic joint deterioration.

7. Vos, T., et al., (2020) The literature widely emphasizes the complex interaction between biomechanical, neuromuscular and structural factors in the development and progression of lower-limb and spinal musculoskeletal disorders. Studies consistently show that malalignment of the lower extremity—such as genu varum, genu valgum, or altered tibiofemoral angles—leads to abnormal load distribution across joint surfaces, accelerating degenerative changes particularly in the knee. Research using gait analysis and radiographic assessments demonstrates that deviations as small as 5–10 degrees can significantly increase medial or lateral compartment loading, contributing to early cartilage wear and osteoarthritis. Simultaneously, neuromuscular deficits, including reduced proprioception, delayed muscle activation and imbalance in quadriceps–hamstring strength, further compromise joint stability and movement efficiency. Literature on the kinetic chain shows that lower-limb malalignment can induce compensatory changes in pelvic tilt, hip rotation and lumbar curvature, linking knee pathology to mechanical low back pain. Advanced imaging studies indicate that altered spinal alignment, especially reduced lumbar lordosis and increased pelvic tilt, often correlates with increased knee flexion and patellofemoral stress. Additionally, longitudinal studies highlight that uncorrected malunion following childhood fractures or developmental deformities increases long-term risk of knee and hip osteoarthritis. Interventional studies focusing on realignment procedures, proprioceptive training and sensorimotor rehabilitation show promising outcomes, although evidence remains mixed regarding long-term prevention of degenerative changes. Overall, the literature supports a multidimensional view where malalignment, neuromuscular impairment and compensatory biomechanical strategies interact synergistically, underscoring the need for integrated assessment and rehabilitation approaches to improve joint health, reduce pain and prevent functional decline.

8. Prabhakar AJ, Joshua AM, et al., (2020) Proprioceptive impairments and postural instability are clearly established characteristics in those with early knee osteoarthritis, leading to modified joint mechanics, heightened postural sway and gradual functional deterioration. Research indicates that neuromuscular alterations like decreased quadriceps strength, compromised joint position sense and delayed muscle activation are closely linked to early OA, frequently resulting in instability, valgus-varus

deformities and gait irregularities. Studies show that unusual stress on

9. the knee joint diminishes cartilage quality, hastening symptoms and functional difficulties. conventional exercise therapy, such as strength training and cycling, is commonly advised to enhance pain relief and functionality; however, some high-impact or open-kinetic-chain movements might elevate joint stress. Recent findings indicate that proprioceptive training—incorporating balance tasks, perturbation exercises and closed-chain functional activities—can enhance joint position awareness, muscle activation patterns, balance and overall functional results. Initial research cited in the protocol, such as studies by Modam et al., Ju et al., and Kirthika et al., indicate notable enhancements in proprioception, pain and mobility through proprioceptive-based interventions compared to standard therapy. Although there is encouraging evidence, research on proprioceptive training for early OA is still scarce, emphasizing the necessity for well-structured randomized controlled trials to assess its efficacy in decreasing postural sway, enhancing neuromuscular function and hindering disease advancement.

10. **Alasar S, Abdallah G, et al., (2022)** Proprioceptive and sensorimotor deficits are frequently observed in people with chronic non-specific low back pain (CLBP), leading to changes in trunk muscle activation, decreased joint position sense and compromised spinal stability. Existing research indicates that focused proprioceptive or sensorimotor training can successfully tackle these shortcomings. Randomized trials indicate that adding proprioceptive exercises to conventional physiotherapy results in more significant advancements in trunk muscle strength, lumbar repositioning accuracy, pain thresholds and functional disability than just strengthening and stretching alone. Research employing isokinetic dynamometry, repositioning error assessments and pressure pain threshold evaluations consistently shows that sensorimotor-targeted programs improve neuromuscular coordination and postural stability, likely via enhanced mechanoreceptor feedback and neuroplastic changes. Nonetheless, certain studies present inconsistent results, primarily because of differences in training methods, sample sizes and outcome assessments. A significant drawback in various studies is the limited duration of follow-up, which obscures long-term effectiveness. Even with these limitations, the existing literature endorses proprioceptive and sensorimotor training as helpful complements to standard therapy for CLBP, especially in enhancing function and movement control. Further studies involving larger, more diverse samples and standardized methods are suggested to gain a deeper insight into ideal dosage, long-term effects and responses of different subgroups.

11. **Fu P, Xu W., et al., (2023)** The literature consistently shows a robust connection among spinal sagittal imbalance, pelvic alignment and knee osteoarthritis (KOA). Proper standing posture relies on the coordinated alignment of the spine, pelvis and lower limbs and disruptions in this alignment can trigger compensatory mechanisms that result in musculoskeletal issues. Multiple studies indicate that diminished lumbar lordosis, heightened pelvic tilt and forward trunk inclination correlate with compensatory knee flexion, elevated quadriceps fatigue and increased loading on the patellofemoral joint. Research additionally indicates that people with KOA frequently unknowingly assume flexed-knee positions and modified lower-limb alignment to preserve stability when spinal alignment declines. Recent advancements in imaging, especially EOS full-body radiography, have offered clearer insights into these relationships, indicating that a larger pelvic incidence–lumbar lordosis mismatch ($PI-LL > 20^\circ$) is associated with higher knee flexion angles, varus alignment and diminished functional scores. Research

suggests that spinal deformities lead to increased knee pain and the reverse is also true, reinforcing the idea of the spine-knee syndrome. The literature emphasizes that spinal malalignment can hasten degeneration of the knee joint, while knee issues can additionally interfere with spinopelvic mechanics, underlining the importance of cohesive evaluation and treatment strategies throughout the kinetic chain.

12. Katsumi R, Mannen EM., et al., (2023) The literature increasingly emphasizes the intricate biomechanical reliance among the knee, hip, pelvis and spine, frequently characterized by terms like knee–spine or hip–spine syndromes. Previous research has indicated that knee osteoarthritis (OA), often linked to knee flexion contracture, results in compensatory decreases in lumbar lordosis (LL) and plays a role in overall sagittal imbalance. Experimental studies simulating knee bending have shown reduced LL and heightened hip flexion even in healthy subjects, indicating that modified lower-limb mechanics can greatly affect spinopelvic parameters. Nonetheless, previous studies were constrained by incomplete imaging and failed to accurately represent whole-body sagittal alignment. Expanding on these foundational studies, Katsumi et al. (2023) employed EOS 3D full-body imaging to evaluate sagittal alignment in individuals with end-stage knee OA, providing a more thorough and precise view of multi-joint interactions. Their results showed important associations between the angle of knee flexion, the femoral tilt angle (FTA) and overall balance metrics like the sagittal vertical axis (SVA) and odontoid–hip axis angle, suggesting that femoral alignment plays a crucial role in anterior sagittal imbalance. They additionally verified decreases in LL linked to greater knee flexion and femoral tilt, aligning with previous clinical and experimental findings. Notably, pelvic incidence and pelvic tilt exhibited little correlation with knee deformity, indicating that compensation primarily occurs through lumbar and hip modifications instead of pelvic rotation. This research enhances the comprehension of lower-limb roles in sagittal balance by measuring alterations in whole-body alignment, highlighting the significance of tackling knee contractures in managing global postural dysfunction in patients with OA.

13. Amarasinghe P, Wadugodapitiya S, et al., (2023) The simultaneous presence of knee osteoarthritis (KOA) and lower back pain (LBP) has been extensively examined in recent studies because of their common biomechanical and clinical effects. The study indicates that approximately 57% of people with KOA also suffer from LBP, emphasizing a significant comorbidity. Research indicates that changes in spinopelvic alignment, especially heightened pelvic incidence, pelvic tilt and decreased lumbar lordosis, play a crucial role in the advancement of KOA and degenerative lumbar disorders. This malalignment leads to increased compensatory bending of the knee and irregular load distribution, hastening joint deterioration. Clinical evidence shows that KOA patients who also have LBP suffer from increased pain intensity, elevated disability levels and worse functional outcomes than those without LBP. People with degenerative spondylolisthesis exhibit increased occurrences of severe KOA, indicating a biomechanical relationship between lumbar instability and stress on the knee joint. Moreover, lumbar kyphosis and LBP are separately related to diminished knee function, especially in the elderly. While a few studies present varying results concerning particular alignment factors, the general evidence supports a significant relationship between lumbar dysfunction and knee issues.

3. METHODS

3.1 SUBJECTS: Long-Standing Workers

3.2 SAMPLING TECHNIQUE: Stratified sampling

3.3 SAMPLE SIZE: 58

3.4 SELECTION CRITERIA:

3.4.1 INCLUSION CRITERIA:

1. Both genders.
2. Age from 30 to 70 years.
3. Those who will to participate.
4. Patient is medically fit to perform physical training.
5. Clinical diagnosis of mechanical low back pain.
6. Presence of knee malalignment in at least one lower limb by clinical or radiographic criteria.
7. For the KOA group: Radiographic evidence of tibiofemoral KOA with Kellgren Lawrence
8. grade: ≥ 2 in the symptomatic knee(s).
9. For the non-OA malalignment group: K-L grade is 0-1.

3.4.2 EXCLUSION CRITERIA:

1. Tumor
2. Inflammatory Arthritis.
3. Major Lower limb or lumbar spine surgery.
4. Knee Joint replacement.
5. Recent (< 6 months) intra articular steroid injection in the knee.
6. Neurological conditions affecting sensorimotor function.
7. Severe Cardiovascular/Pulmonary disease or other medical comorbidity precluding exercise participation.
8. Inability to comprehend directions or engage in exercise routines.
9. Pregnancy.
10. Severe musculoskeletal injuries or trauma affecting the lower back or knees.

3.5 STUDY PROCEDURE:

The research received the Institutional Scientific Review Board (ISRB) certificate from Saveetha College of Physiotherapy, SIMATS, under the approval number (036/10/2025/ISRB/UGSR/SCPT), in compliance with established ethical research guidelines. This study was conducted as quasi-experimental study to evaluate the effectiveness of combined proprioceptive and sensorimotor training on pain, range of motion, functional ability and quality of life in individuals with Mechanical Low Back Pain (MLBP) and knee malalignment with and without radiographic Knee Osteoarthritis.

The study was carried out in accordance with ethical research principles. All participants were informed in detail about the purpose, methodology, potential benefits and possible risks of the study prior to enrolment. Written informed consent was obtained from each participant before inclusion in the study. Participants were recruited from physiotherapy outpatient departments. Individuals who satisfied the predetermined inclusion and exclusion criteria were selected for participation.

In total, 58 participants who fulfilled the inclusion and exclusion criteria were initially selected for the study through stratified sampling. Participants were divided into two groups according to radiographic assessment of knee osteoarthritis (Kellgren–Lawrence criteria). During the intervention period, 14 participants dropped out of the study for personal reasons, inconsistent attendance, failure to finish the 6-week training program.

As a result, the final sample included 44 participants who successfully finished the intervention and post-test evaluation. The participants were evenly divided between the two groups in this quasi-experimental study, with 22 participants in each group. All participants underwent baseline assessment prior to initiation of the intervention. Assessment tools included Numeric Pain Rating Scale (NPRS) to measure knee and lumbar pain, goniometry and Modified Schober's test methods to assess knee and lumbar range of motion. Functional ability was evaluated using the WOMAC index for knee-related disability and the Modified Oswestry Disability Index (MODI) for lumbar disability. Quality of life was assessed using the SF-36 Health Survey questionnaire. The Standardized data recording sheets and assessment forms were used to ensure uniformity.

Following baseline assessment and group allocation, Group A (Mechanical Low Back Pain + Knee Malalignment + with Knee Osteoarthritis) and Group B (Mechanical Low Back Pain + Knee Malalignment + without Knee Osteoarthritis) were both administered a systematic Combined Proprioceptive and Sensorimotor Training Program in conjunction with Conventional Exercise Therapy. The intervention occurred three times a week for a total of 6 weeks, with each session lasting about 45–60 minutes (Warm-up (5–10 min), Proprioceptive Training (15 min), Sensorimotor Training (20–25 min), Cool-down (5–10 min)) under supervision. Participants were asked to carry out a formal conventional exercise routine at home. The unified training program was methodically advanced and comprised static and dynamic balance activities, closed kinetic chain strengthening, perturbation training, core stabilization and dynamic sensorimotor control exercises combined with conventional mobility, stretching, strengthening, postural correction and functional training. The program aimed to improve joint proprioception, neuromuscular coordination, lumbopelvic stability, lower limb alignment control and overall functional ability in people experiencing mechanical low back pain and knee malignment, with or without osteoarthritic changes.

Participants were monitored throughout the intervention period for adherence and safety. Post-intervention assessment was conducted after completion of 6 weeks using the same outcome measures as baseline to evaluate changes in pain, range of motion, functional ability and quality of life.

SAMPLE SIZE ESTIMATION:

This research was structured as a quasi-experimental study to assess the efficacy of integrated proprioceptive and sensorimotor training with conventional exercise on pain, range of motion, functional

ability and quality of life in individuals with Mechanical Low Back Pain (MLBP) and knee malalignment, both with and without radiographic Knee Osteoarthritis (KOA). A sample size of 44 participants was established based on practicality, the availability of qualified long-term employees and institutional time limitations. Participants were selected through stratified sampling and divided into two groups based on Kellgren–Lawrence radiographic grading (with OA and without OA), comprising 22 participants in each group. The chosen sample size was deemed sufficient to facilitate a significant comparison of treatment responses between the two clinical subgroups, while also staying manageable within the undergraduate research schedule. Methodological rigor was maintained through uniform outcome assessment instruments, organized and incremental intervention protocols, monitored training sessions and regular pre- and post-intervention evaluation processes to improve the internal validity and reliability of results.

A total of 58 participants were initially recruited. Fourteen participants were lost to follow-up during the six-week intervention period. Therefore, 44 participants completed the study and were included in the final analysis, with 22 participants in each group.

INTERVENTION:

Proprioceptive Training Protocol:

S. No.	Exercise	Dosage
1	Single-leg stance	3 sets × 20–30 sec
2	Tandem stance	3 sets × 20–30 sec
3	Foam surface standing	3 sets × 20–30 sec
4	Step-ups / step-downs	2–3 sets × 10 repetitions
5	Lateral weight shifting	2–3 sets × 10 repetitions
6	Mini-squats on balance board	2–3 sets × 10 repetitions

Proprioceptive training was designed to improve joint position awareness, postural stability, balance and neuromuscular control.

The training included static and dynamic balance exercises performed on stable and unstable surfaces. Exercises were progressed according to the participant's tolerance and functional ability, with emphasis on maintaining proper lower-limb alignment and controlled movement throughout the exercises.

Sensorimotor Training Protocol:

SL. No.	Exercise	Dosage
1	Wall slides / partial squats (0–45°)	2–3 sets × 10 repetitions
2	Step-ups with alignment focus	2–3 sets × 10 repetitions
3	Heel raises	2–3 sets × 10–12 repetitions
4	Mini-lunges	2–3 sets × 8–10 repetitions
5	Perturbation training	3 sets × 20–30 sec

6	Marching on soft surface	2–3 sets × 10 repetitions
7	Mini-hops on soft surface	2 sets × 8–10 repetitions
8	Obstacle stepping	2–3 sets × 5–10 repetitions
9	Catching/throwing ball during stance	2–3 sets × 10 repetitions
10	Abdominal drawing-in manoeuvre	3 sets × 10 repetitions / 5–10 sec hold
11	Multifidus activation	3 sets × 10 repetitions / 5–10 sec hold
12	Bird-dog	2–3 sets × 8–10 repetitions each side
13	Bridge with perturbation	2–3 sets × 8–10 repetitions
14	Swiss-ball rollout/walkout	2–3 sets × 8–10 repetitions

Sensorimotor training was designed to improve neuromuscular coordination, postural control, dynamic balance, joint stability and functional movement. The training included closed kinetic chain exercises, perturbation training, coordination and functional drills, core stabilization and dynamic sensorimotor control exercises. The exercises were performed with emphasis on controlled movement, proper alignment and coordinated activation of the trunk and lower-limb muscles. The difficulty of the exercises was progressively increased according to the participant's tolerance and functional ability.

Conventional Exercise Protocol:

SL. No.	Exercise	Dosage
1	Pelvic tilts	2–3 sets × 10–15 repetitions
2	Cat-camel	2–3 sets × 10 repetitions
3	Heel slides	2–3 sets × 10–15 repetitions
4	Quadriceps setting	3 sets × 10 repetitions / 5–10 sec hold
5	Hamstring stretching	3 repetitions × 20–30 sec hold
6	Hip-flexor stretching	3 repetitions × 20–30 sec hold
7	Calf stretching	3 repetitions × 20–30 sec hold
8	Quadriceps stretching	3 repetitions × 20–30 sec hold
9	Bridging	2–3 sets × 10–12 repetitions
10	Curl-ups	2–3 sets × 8–10 repetitions
11	Back extension	2–3 sets × 8–10 repetitions
12	Straight-leg raise (SLR)	2–3 sets × 10 repetitions
13	Neutral spine training	2–3 sets × 10 repetitions

14	Hip-hinge training	2–3 sets × 10 repetitions
15	Sit-to-stand	2–3 sets × 10 repetitions
16	Walking training	5–10 minutes

Conventional exercise therapy was provided to improve mobility, flexibility, muscle strength, postural control and functional performance. The programme included mobility, stretching, strengthening, postural and functional exercises targeting the lumbar spine and lower-limb muscles. Exercises were performed with controlled movements and progressed according to the participant's tolerance and functional capacity.

Session Structure:

Each treatment session lasted approximately 45–60 minutes and was conducted three times per week for six weeks. The session consisted of 5–10 minutes of warm-up, 15 minutes of proprioceptive training, 20–25 minutes of sensorimotor training, and 5–10 minutes of cool-down and stretching.

Exercise Progression

The intensity and complexity of the exercises were progressively increased based on the participant's tolerance, balance ability and functional performance. Progression was achieved by reducing external support, increasing repetitions, changing the base of support and introducing unstable surfaces and dynamic movements.

Therapist Supervision

All exercises were performed under the supervision of a physiotherapist to ensure correct technique, appropriate alignment and safe execution of the exercises throughout the intervention period.

Safety Monitoring

Participants were monitored throughout each session for pain, fatigue, loss of balance or discomfort. Exercises were modified or discontinued when necessary according to the participant's tolerance and safety.

Adherence

Attendance and adherence to the prescribed exercise programme were monitored throughout the six-week intervention period. Participants were encouraged to complete the prescribed home exercises regularly.

Warm-up and Cool-down

Each treatment session began with 5–10 minutes of warm-up and ended with 5–10 minutes of cool-down and stretching exercises. The warm-up was performed to prepare the participants for the exercise programme, while the cool-down was used to facilitate recovery following exercise.



Figure – 1 Single leg stance.



Figure – 2 Step up and Step downs.



Figure – 3 Wall slides



Figure – 4 Tandem stance.

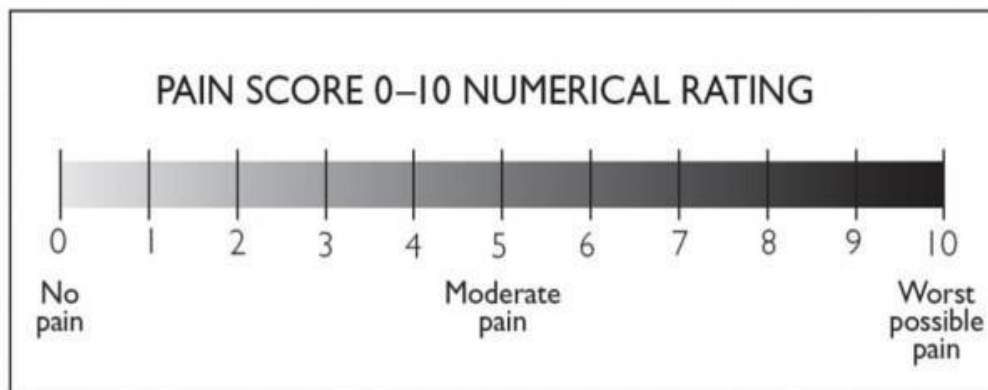
3.1 OUTCOME MEASURES:

Numeric Pain Rating Scale:

The Numeric Pain Rating Scale (NPRS) is an extensively utilized self-reported tool aimed at evaluating pain intensity in both clinical and research environments. Participants are asked to choose the number that most accurately reflects their present pain intensity, typical pain, or pain experienced during a designated time frame in 11-point scale that goes from 0 (no pain) to 10 (the worst pain possible). The NPRS represents an individual's subjective view of pain intensity and is frequently used in musculoskeletal, orthopaedic and rehabilitation contexts because of its simple administration and low time demand.

The NPRS has shown good to excellent test-retest reliability across different musculoskeletal groups, with Intraclass Correlation Coefficient (ICC) values typically ranging from 0.70 to 0.95, reflecting high consistency in stable individuals. The scale demonstrates robust construct validity, with pain scores displaying substantial correlations with measures of functional disability and indices of quality of life [16]. Regarding responsiveness, the NPRS is reactive to clinical changes after therapeutic treatments. The Minimum Detectable Change (MDC) is said to vary from 1.5 to 2.5 points, whereas the Minimum Clinically Important Difference (MCID) is typically regarded as around 2 points in people experiencing chronic musculoskeletal pain [17].

Existing psychometric data endorse the NPRS as a dependable, valid, responsive and practical instrument



for evaluating pain severity in individuals with mechanical low back pain and knee osteoarthritis. Its robust measurement attributes support its role as a key pain outcome measure in rehabilitation studies.

Figure- 5 NPRS

Goniometry and Modified Schober's test:

Range of Motion (ROM) with a universal goniometer is a standardized and commonly utilized approach for measuring joint mobility in musculoskeletal rehabilitation. The goniometer quantifies the angle between two anatomical parts and is frequently utilized to evaluate movements of the lumbar spine, hip and knee joints. In the assessment process, the goniometer's stationary and moving arms are positioned with particular anatomical markers to guarantee precision and consistency. ROM measurement offers

quantitative information about joint flexibility, capsular limitations and functional impairments, rendering it a crucial outcome metric for individuals with mechanical low back pain and knee osteoarthritis.

Goniometric evaluations have shown strong to outstanding intra-rater and inter-rater reliability for lower limb and spinal joints, with Intraclass Correlation Coefficient (ICC) values generally between 0.80 and 0.95 [18]. ROM measurements indicate a response to treatments, demonstrating notable variations after physiotherapy programs designed to enhance joint mobility and functional performance [19]. The uniqueness of goniometry is in its capacity to directly measure angular joint motion, enabling accurate tracking of mobility progress over time.

The Modified Schober's Test (MST) is a widely utilized clinical assessment to evaluate lumbar spine flexion mobility in patients experiencing mechanical low back pain. The procedure is carried out with the participant in an upright standing posture. A point is designated at the lumbosacral junction level (located at the posterior superior iliac spine line aligned with S2) and another point is positioned 15 cm above this reference. The participant is subsequently instructed to execute maximal forward trunk flexion while maintaining the knees straight. The measuring tape is used to assess the greater distance between the two markings when in full flexion. The contrast between the starting and ending measurement indicates the range of motion for lumbar flexion. The Modified Schober's Test is easy to perform, non-invasive, affordable and suitable for use in both clinical and research environments.

The Modified Schober's Test shows strong intra-rater and inter-rater reliability in individuals suffering from chronic low back pain, with Intraclass Correlation Coefficient (ICC) values typically between 0.72 and 0.93 [20].

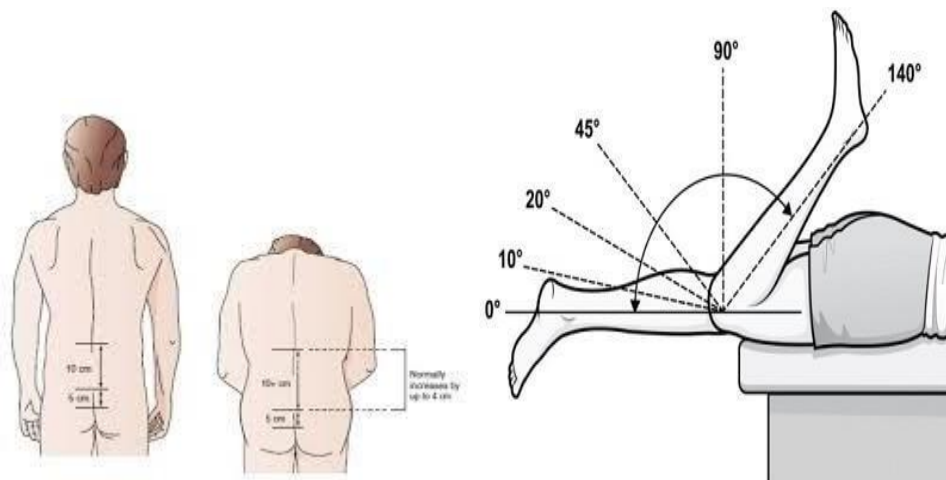


Figure- 6 Modified Schober's test and Goniometry.

Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)

The WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) is a self-reported specific outcome measure designed to evaluate pain, stiffness and physical function limitations in

individuals with knee osteoarthritis. The instrument consists of 24 items divided into three subscales: pain (5 items), stiffness (2 items) and physical function (17 items). Answers are usually documented using a 5-point scale or a 0–10 numeric rating system. Increased scores reflect more severe pain, stiffness and functional impairment. WOMAC is commonly utilized in clinical trials and rehabilitation studies concerning knee osteoarthritis patients because of its disease specificity and thorough symptom coverage.

The WOMAC scale has shown remarkable reliability, with intra-rater and inter-rater Intraclass Correlation Coefficient (ICC) values generally surpassing 0.80, signifying robust consistency in repeated assessments. Internal consistency is also strong, with Cronbach's alpha values often noted to exceed 0.85 across various subscales [21].

WOMAC has demonstrated effective responsiveness to clinical changes after physiotherapy, exercise therapy and surgical procedures. The Minimum Clinically Important Difference (MCID) for the total WOMAC score is generally recognized to be between 9 and 12 points (normalized scale of 0–100), indicating its capacity to detect meaningful improvement [22].

The WOMAC scale serves as a dependable, valid and responsive tool for evaluating pain, stiffness and functional impairments in people with knee osteoarthritis. Its robust psychometric characteristics and disease-specific emphasis support its use as a main functional outcome measure in comparative research addressing knee malalignment with or without osteoarthritis.

The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)

Name: _____ Date: _____

Instructions: Please rate the activities in each category according to the following scale of difficulty:

0 = None 1 = Slight 2 = Moderate 3 = Very 4 = Extremely

Pain	0 None	1 Slight	2 Moderate	3 Very	4 Extremely
1. Walking	☐	☐	☐	☐	☐
2. Stair climbing	☐	☐	☐	☐	☐
3. Nocturnal	☐	☐	☐	☐	☐
4. Rest	☐	☐	☐	☐	☐
5. Weight bearing	☐	☐	☐	☐	☐
Stiffness					
1. Morning stiffness	☐	☐	☐	☐	☐
2. Stiffness occurring later in the day	☐	☐	☐	☐	☐
Physical function					
1. Descending stairs	☐	☐	☐	☐	☐
2. Ascending stairs	☐	☐	☐	☐	☐
3. Rising from sitting	☐	☐	☐	☐	☐
4. Standing	☐	☐	☐	☐	☐
5. Bending to floor	☐	☐	☐	☐	☐
6. Walking on flat surface	☐	☐	☐	☐	☐
7. Getting in/out of car	☐	☐	☐	☐	☐
8. Going shopping	☐	☐	☐	☐	☐
9. Putting on socks	☐	☐	☐	☐	☐
10. Lying in bed	☐	☐	☐	☐	☐
11. Taking off socks	☐	☐	☐	☐	☐
12. Rising from bed	☐	☐	☐	☐	☐
13. Getting in/out of bath	☐	☐	☐	☐	☐

Physical function	0 None	1 Slight	2 Moderate	3 Very	4 Extremely
14. Sitting	☐	☐	☐	☐	☐
15. Getting on/off toilet	☐	☐	☐	☐	☐
16. Heavy domestic duties	☐	☐	☐	☐	☐
17. Light domestic duties	☐	☐	☐	☐	☐
Total score:	[Indicate total score] / 96 = [Indicate total score in percentage]%				
Comments/interpretation					
<i>To be completed by therapist only:</i>					

Figure- 6 Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)

Modified Oswestry Disability Index (MODI)

The Modified Oswestry Disability Index (MODI) is a self-reported outcome tool tailored to evaluate the level of disability and functional limitations related to low back pain. The survey contains 10 parts assessing pain levels and restrictions in activities like personal hygiene, lifting, walking, sitting, standing, sleeping, social interactions, traveling and job/household responsibilities. Every section is rated on a scale from 0 to 5 and the total scores are transformed into a percentage. Larger percentages signify increased disability. The MODI is commonly utilized in clinical settings and studies concerning mechanical low back pain because of its accuracy in identifying functional impairments associated with spinal issues.

The MODI has shown remarkable dependability in people suffering from chronic and mechanical low back pain. Test–retest reliability investigations show Intraclass Correlation Coefficient (ICC) values usually between 0.84 and 0.96, signifying strong measurement consistency in stable patients. Internal consistency is robust as well, with Cronbach’s alpha values often surpassing 0.85, indicating strong homogeneity among the items in the questionnaire [23]. The MODI has shown strong sensitivity to clinical improvements after physiotherapy and exercise-focused rehabilitation programs. The Minimum Clinically Important Difference (MCID) is typically stated to be between 8 and 12 percentage points, demonstrating its effectiveness in identifying significant functional enhancement [24].

The MODI is a reliable, valid and sensitive instrument for evaluating disability in individuals with mechanical low back pain. Its emphasis on particular illnesses and strong psychometric traits supports its position as a critical functional outcome measure in rehabilitation studies assessing treatment effectiveness.

Patient Name: _____ Date: _____

Modified Oswestry Low Back Pain Disability Questionnaire^a

This questionnaire has been designed to give your doctor information as to how your back pain has affected your ability to manage in everyday life. Please answer every section and mark in each section only ONE box that best describes your condition today. We realize you may feel that two of the statements may describe your condition, but **please mark only the box that MOST CLOSELY describes your current condition.**

Pain Intensity

- ☐ I can tolerate the pain I have without having to use pain medication.
- ☐ The pain is bad, but I can manage without having to take pain medication.
- ☐ Pain medication provides me with complete relief from pain.
- ☐ Pain medication provides me with moderate relief from pain.
- ☐ Pain medication provides me with little relief from pain.
- ☐ Pain medication has no effect on my pain.

Personal Care (e.g., Washing, Dressing)

- ☐ I can take care of myself normally without causing increased pain.
- ☐ I can take care of myself normally, but it increases my pain.
- ☐ It is painful to take care of myself, and I am slow and careful.
- ☐ I need help, but I am able to manage most of my personal care.
- ☐ I need help every day in most aspects of my care.
- ☐ I do not get dressed, I wash with difficulty, and I stay in bed.

Lifting

- ☐ I can lift heavy weights without increased pain.
- ☐ I can lift heavy weights, but it causes increased pain.
- ☐ Pain prevents me from lifting heavy weights off the floor, but I can manage if the weights are conveniently positioned (e.g., on a table).
- ☐ Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned.
- ☐ I can lift only very light weights.
- ☐ I cannot lift or carry anything at all.

Walking

- ☐ Pain does not prevent me from walking any distance.
- ☐ Pain prevents me from walking more than 1 mile. (1 mile = 1.6 km).
- ☐ Pain prevents me from walking more than 1/2 mile.
- ☐ Pain prevents me from walking more than 1/4 mile.
- ☐ I can walk only with crutches or a cane.
- ☐ I am in bed most of the time and have to crawl to the toilet.

Sitting

- ☐ I can sit in any chair as long as I like.
- ☐ I can only sit in my favorite chair as long as I like.
- ☐ Pain prevents me from sitting for more than 1 hour.
- ☐ Pain prevents me from sitting for more than 1/2 hour.
- ☐ Pain prevents me from sitting for more than 10 minutes.
- ☐ Pain prevents me from sitting at all.

Standing

- ☐ I can stand as long as I want without increased pain.
- ☐ I can stand as long as I want, but it increases my pain.
- ☐ Pain prevents me from standing for more than 1 hour.
- ☐ Pain prevents me from standing for more than 1/2 hour.
- ☐ Pain prevents me from standing for more than 10 minutes.
- ☐ Pain prevents me from standing at all.

Sleeping

- ☐ Pain does not prevent me from sleeping well.
- ☐ I can sleep well only by using pain medication.
- ☐ Even when I take medication, I sleep less than 6 hours.
- ☐ Even when I take medication, I sleep less than 4 hours.
- ☐ Even when I take medication, I sleep less than 2 hours.
- ☐ Pain prevents me from sleeping at all.

Social Life

- ☐ My social life is normal and does not increase my pain.
- ☐ My social life is normal, but it increases my level of pain.
- ☐ Pain prevents me from participating in more energetic activities (e.g., sports, dancing).
- ☐ Pain prevents me from going out very often.
- ☐ Pain has restricted my social life to my home.
- ☐ I have hardly any social life because of my pain.

Traveling

- ☐ I can travel anywhere without increased pain.
- ☐ I can travel anywhere, but it increases my pain.
- ☐ My pain restricts my travel over 2 hours.
- ☐ My pain restricts my travel over 1 hour.
- ☐ My pain restricts my travel to short necessary journeys under 1/2 hour.
- ☐ My pain prevents all travel except for visits to the physician / therapist or hospital.

Employment / Homemaking

- ☐ My normal homemaking / job activities do not cause pain.
- ☐ My normal homemaking / job activities increase my pain, but I can still perform all that is required of me.
- ☐ I can perform most of my homemaking / job duties, but pain prevents me from performing more physically stressful activities (e.g., lifting, vacuuming).
- ☐ Pain prevents me from doing anything but light duties.
- ☐ Pain prevents me from doing even light duties.
- ☐ Pain prevents me from performing any job or homemaking chores.

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Score: /50 x 100 = _____ % points

Scoring: For each section the total possible score is 5: if the first statement is marked the section score = 0, if the last statement is marked it = 5. If all ten sections are completed the score is calculated as follows: Example: 16 (total scored)

50 (total possible score) x 100 = 32%

If one section is missed or not applicable the score is calculated: 16 (total scored)

45 (total possible score) x 100 = 35.5%

Minimum Detectable Change (90% confidence): 10% points (Change of less than this amount may be attributed to error in the measurement.)

Source: Fritz JM, Irrgang JJ. A comparison of a modified Oswestry Low Back Pain Disability Questionnaire and the Quebec Back Pain Disability Scale.

Physical Therapy. 2001;81:770-785.

Modified by Fritz & Irrgang with permission of The Chartered Society of Physiotherapy, from Fairbanks JC1, Couper J, Davies JB, et al. The Oswestry Low Back Pain Disability Questionnaire. Physiotherapy. 1980;66:217-213.

Figure- 7 Modified Oswestry Disability Index (MODI)

Short Form 36 Health Survey (SF-36)

The Short Form 36 Health Survey (SF-36) is a widely used generic questionnaire for assessing health-related quality of life (HRQoL), focusing on the evaluation of overall physical and mental health status. It consists of 36 items divided into eight categories: Physical Functioning, Role Limitations due to Physical Health, Role Limitations due to Emotional Issues, Energy/Fatigue (Vitality), Emotional Well-being (Mental Health), Social Functioning, Bodily Pain and Overall, Health Perception. These domains can be summarized into two overall metrics: the Physical Component Summary (PCS) and the Mental Component Summary (MCS). Scores are adjusted to a 0–100 scale, with higher scores indicating a more favourable perceived health status. Owing to its multidimensional design, the SF-36 is widely utilized in musculoskeletal and rehabilitation studies to assess the wider effects of conditions like mechanical low back pain and knee osteoarthritis on quality of life. The SF-36 has shown robust reliability among various musculoskeletal groups. Most domains exhibit high internal consistency, with Cronbach's alpha values usually above 0.80 and test–retest reliability demonstrates Intraclass Correlation Coefficient (ICC) values typically between

0.75 and 0.95 [25]. The SF-36 has demonstrated effective responsiveness to clinical changes after physiotherapy, exercise-focused rehabilitation and multidisciplinary treatments in individuals with chronic low back pain and knee osteoarthritis [26].

36-item Short Form Survey (SF-36)

Name: _____ Date: _____

The SF-36 asks for your perspective on your health. The information gathered from this survey will help monitor how you feel and how well you can do certain activities. Please answer the questions thoroughly and honestly.

1. In general, would you say your health is:

- ☐ 1. Excellent ☐ 2. Very good ☐ 3. Good ☐ 4. Fair ☐ 5. Poor

2. Compared to one year ago, how would you rate your health in general now?

- ☐ 1. Much better now than one year ago ☐ 4. Somewhat worse now than one year ago
☐ 2. Somewhat better now than one year ago ☐ 5. Much worse than one year ago
☐ 3. About the same

The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

3. Vigorous activities, such as running, lifting heavy objects, and participating in strenuous sports.

- ☐ 1. Yes, limited a lot ☐ 2. Yes, limited a little ☐ 3. No, not limited at all

4. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf.

- ☐ 1. Yes, limited a lot ☐ 2. Yes, limited a little ☐ 3. No, not limited at all

5. Lifting or carrying groceries.

- ☐ 1. Yes, limited a lot ☐ 2. Yes, limited a little ☐ 3. No, not limited at all

6. Climbing several flights of stairs.

- ☐ 1. Yes, limited a lot ☐ 2. Yes, limited a little ☐ 3. No, not limited at all

7. Climbing one flight of stairs.

- ☐ 1. Yes, limited a lot ☐ 2. Yes, limited a little ☐ 3. No, not limited at all

8. Bending, kneeling, or stooping.

- ☐ 1. Yes, limited a lot ☐ 2. Yes, limited a little ☐ 3. No, not limited at all

9. Walking more than a mile.

- ☐ 1. Yes, limited a lot ☐ 2. Yes, limited a little ☐ 3. No, not limited at all

10. Walking several blocks.

- ☐ 1. Yes, limited a lot ☐ 2. Yes, limited a little ☐ 3. No, not limited at all

11. Walking one block.

- ☐ 1. Yes, limited a lot ☐ 2. Yes, limited a little ☐ 3. No, not limited at all

12. Bathing or dressing yourself.

- ☐ 1. Yes, limited a lot ☐ 2. Yes, limited a little ☐ 3. No, not limited at all

During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

13. Cut down the amount of time you spent on work or other activities.

- ☐ 1. Yes ☐ 2. No

14. Accomplished less than you would like.

- ☐ 1. Yes ☐ 2. No

15. Were limited in the kind of work or other activities.

- ☐ 1. Yes ☐ 2. No

16. Had difficulty performing the work or other activities (for example, it took extra effort).

- ☐ 1. Yes ☐ 2. No

During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

17. Cut down the amount of time you spent on work or other activities.

- ☐ 1. Yes ☐ 2. No

18. Accomplished less than you would like.

- ☐ 1. Yes ☐ 2. No

19. Didn't do work or other activities as carefully as usual.

- ☐ 1. Yes ☐ 2. No

20. Emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?

- ☐ 1. Not at all ☐ 2. Slightly ☐ 3. Moderately ☐ 4. Severe ☐ 5. Very severe

21. How much bodily pain have you had during the past 4 weeks?

- ☐ 1. None ☐ 2. Very mild ☐ 3. Mild ☐ 4. Moderate ☐ 5. Severe ☐ 6. Very severe

22. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

- ☐ 1. Not at all ☐ 2. Slightly ☐ 3. Moderately ☐ 4. Quite a bit ☐ 5. Extremely

These questions are about how you feel and how things have been with you during the last 4 weeks. For each question, please give the answer that comes closest to the way you have been feeling.

23. Did you feel full of pep?

- | | | |
|---|---|---|
| ☐ 1. All the time | ☐ 3. A good bit of the time | ☐ 5. A little bit of the time |
| ☐ 2. Most of the time | ☐ 4. Some of the time | ☐ 6. None of the time |

24. Have you been a very nervous person?

- | | | |
|---|---|---|
| ☐ 1. All the time | ☐ 3. A good bit of the time | ☐ 5. A little bit of the time |
| ☐ 2. Most of the time | ☐ 4. Some of the time | ☐ 6. None of the time |

25. Have you felt so down in the dumps that nothing could cheer you up?

- | | | |
|---|---|---|
| ☐ 1. All the time | ☐ 3. A good bit of the time | ☐ 5. A little bit of the time |
| ☐ 2. Most of the time | ☐ 4. Some of the time | ☐ 6. None of the time |

26. Have you felt calm and peaceful?

- | | | |
|---|---|---|
| ☐ 1. All the time | ☐ 3. A good bit of the time | ☐ 5. A little bit of the time |
| ☐ 2. Most of the time | ☐ 4. Some of the time | ☐ 6. None of the time |

27. Did you have a lot of energy?

- | | | |
|---|---|---|
| ☐ 1. All the time | ☐ 3. A good bit of the time | ☐ 5. A little bit of the time |
| ☐ 2. Most of the time | ☐ 4. Some of the time | ☐ 6. None of the time |

28. Have you felt downhearted and blue?

- | | | |
|---|---|---|
| ☐ 1. All the time | ☐ 3. A good bit of the time | ☐ 5. A little bit of the time |
| ☐ 2. Most of the time | ☐ 4. Some of the time | ☐ 6. None of the time |

29. Did you feel worn out?

- | | | |
|---|---|---|
| ☐ 1. All the time | ☐ 3. A good bit of the time | ☐ 5. A little bit of the time |
| ☐ 2. Most of the time | ☐ 4. Some of the time | ☐ 6. None of the time |

30. Have you been a happy person?

- | | | |
|---|---|---|
| ☐ 1. All the time | ☐ 3. A good bit of the time | ☐ 5. A little bit of the time |
| ☐ 2. Most of the time | ☐ 4. Some of the time | ☐ 6. None of the time |

31. Did you feel tired?

- | | | |
|---|---|---|
| ☐ 1. All the time | ☐ 3. A good bit of the time | ☐ 5. A little bit of the time |
| ☐ 2. Most of the time | ☐ 4. Some of the time | ☐ 6. None of the time |

32. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)?

☐ 1. All the time ☐ 3. A good bit of the time ☐ 5. A little bit of the time

☐ 2. Most of the time ☐ 4. Some of the time ☐ 6. None of the time

How true or false is each of the following statements for you?

33. I seem to get sick a little easier than other people.

☐ 1. Definitely true ☐ 2. Mostly true ☐ 3. Don't know ☐ 4. Mostly false ☐ 5. Definitely false

34. I am as healthy as anybody I know.

☐ 1. Definitely true ☐ 2. Mostly true ☐ 3. Don't know ☐ 4. Mostly false ☐ 5. Definitely false

35. I expect my health to get worse

☐ 1. Definitely true ☐ 2. Mostly true ☐ 3. Don't know ☐ 4. Mostly false ☐ 5. Definitely false

36. My heart is excellent

☐ 1. Definitely true ☐ 2. Mostly true ☐ 3. Don't know ☐ 4. Mostly false ☐ 5. Definitely false

Total score:

Figure- 8 Short Form 36 Health Survey (SF-36)

3.1 DATA ANALYSIS:

The measures of outcomes utilized in this research comprised the Numeric Pain Rating Scale (NPRS) to measure the intensity of lumbar and knee pain, goniometry and Modified Schober's test measurements to determine lumbar and knee range of motion, the Modified Oswestry Disability Index (MODI) for assessing lumbar functional disability, the WOMAC Index for knee pain and functional limitation and the SF-36 questionnaire for evaluating health-related quality of life. All outcome measures were documented before the start of the intervention (pre-test) and following the conclusion of the 6-week training program (post-test).

Descriptive statistics, such as mean and standard deviation (SD), were computed for all continuous variables. A paired t-test was applied to analyse the mean values before and after the intervention in each group (Group A: MLBP + Knee Malalignment with OA; Group B: MLBP + Knee Malalignment without OA) to assess the impact of the combined proprioceptive and sensorimotor training over time. An independent t-test was used to compare the post-intervention average values of the two groups to detect variations in treatment response between those with and without knee osteoarthritis.

All statistical analyses were conducted with IBM SPSS Software Version 27.0.1.0. The statistical significance threshold was established at $p < 0.05$. A p-value under

0.05 was deemed statistically significant and viewed as proof of substantial enhancement in pain, range of

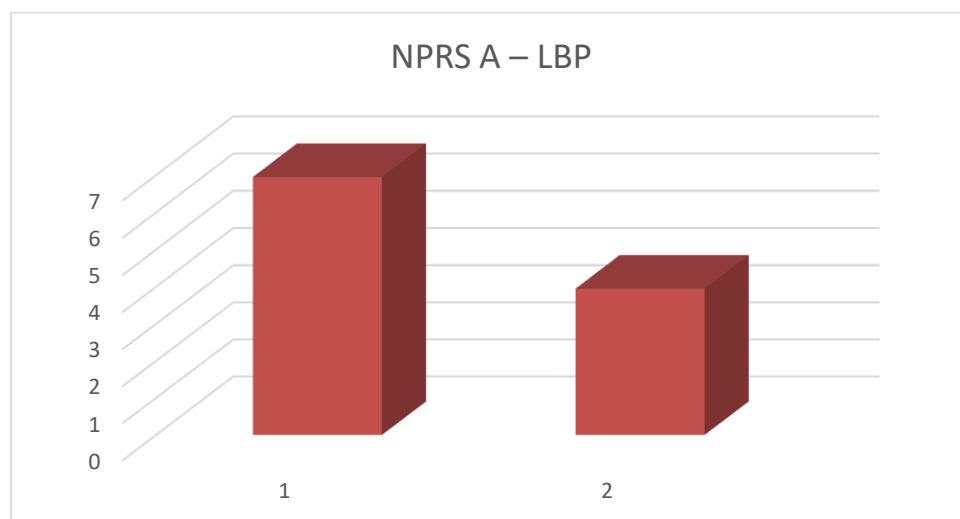
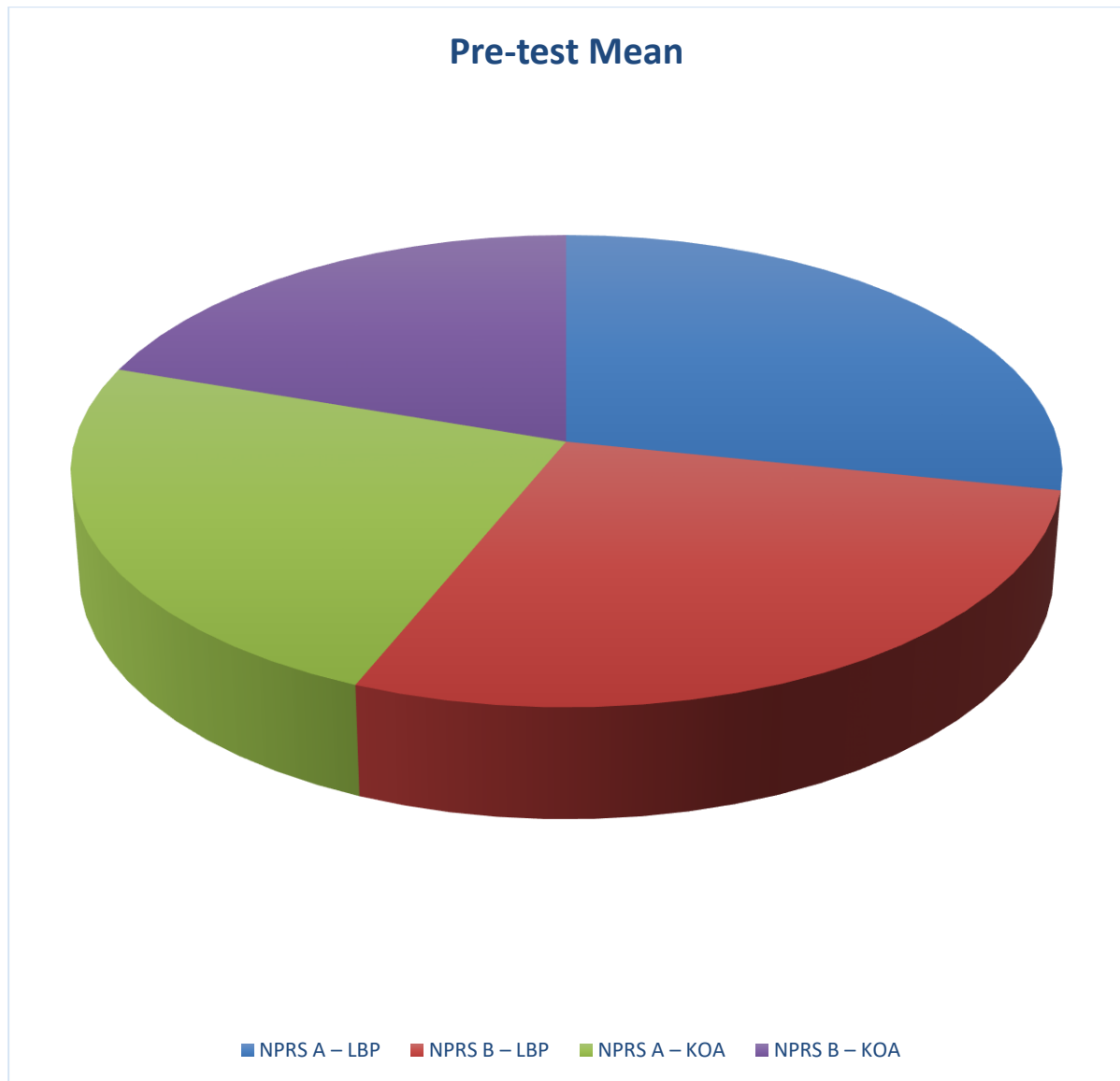
motion, functional capacity and quality of life after the intervention. CHAPTER IV

RESULTS

The collected data were compiled and analyzed using descriptive and inferential statistics through SPSS software. All outcome variables, including pain intensity (Numeric Pain Rating Scale – NPRS for low back and knee), range of motion (lumbar and knee ROM), functional ability (WOMAC for knee, Modified Oswestry Disability Index – MODI for low back) and quality of life (SF-36), were expressed as Mean $\pm$ Standard Deviation (SD).

Table 1 Pre-Test and Post-Test values of Numeric Pain Rating Scale (NPRS)

Outcome measure	Group	Pre-test (Mean $\pm$ SD)	Post -test (Mean $\pm$ SD)	t value	p value
NPRS	A - LBP	6.95 $\pm$ 0.785	3.95 $\pm$ 0.785	36.708	<0.001
NPRS	B - LBP	6.86 $\pm$ 0.774	2.91 $\pm$ 0.868	36.708	<0.001
NPRS	A-KOA	5.91 $\pm$ 0.811	3.86 $\pm$ 0.774	28.077	<0.001
NPRS	B-KOA	4.86 $\pm$ 0.774	1.91 $\pm$ 0.868	28.077	<0.001



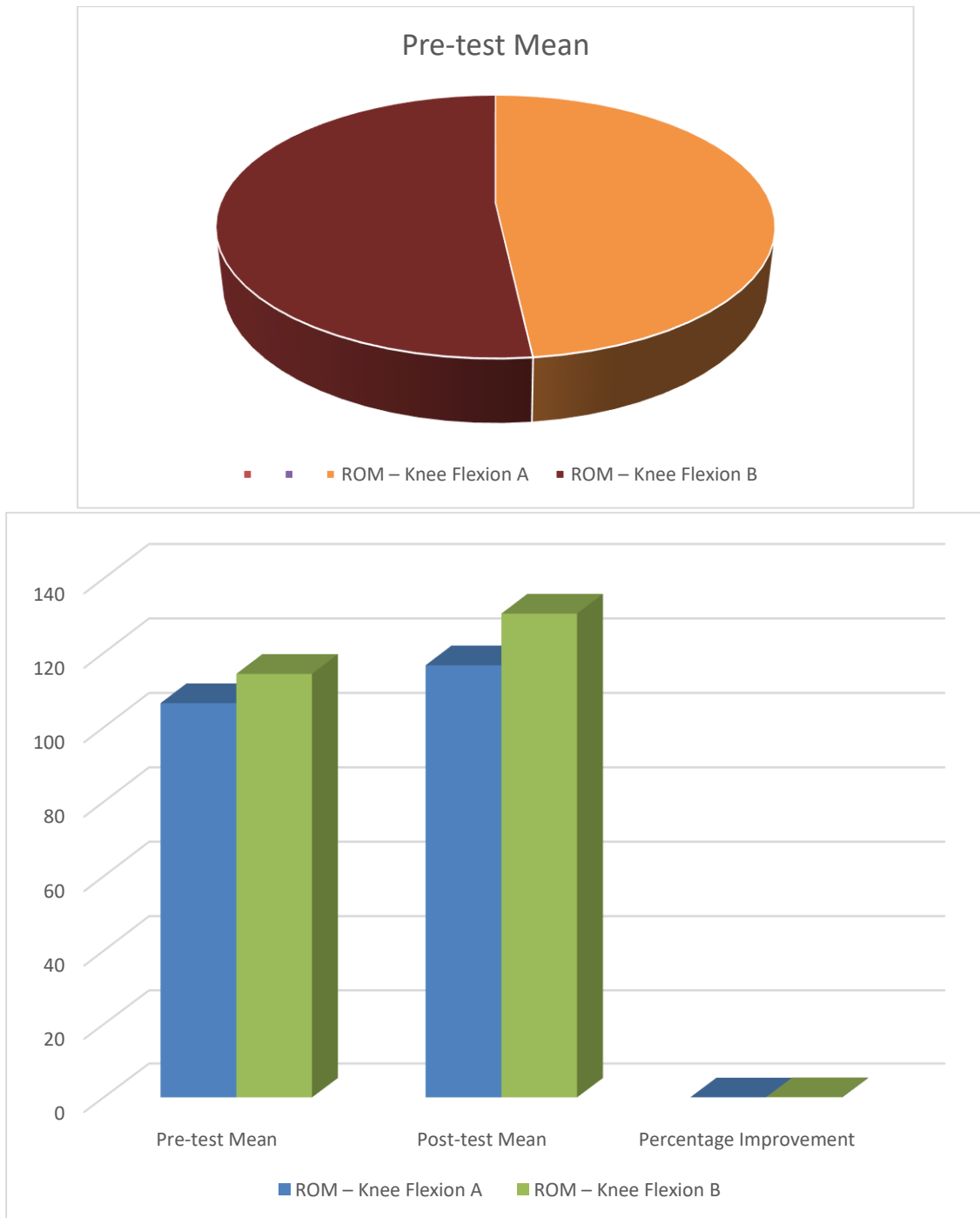
Graph-1 compare the Pre-Test and Post-Test values of Numeric Pain Rating Scale (NPRS)

From Table – 1, it is evident that both groups demonstrated significant reduction in pain intensity following the intervention period. In Group A (Mechanical Low Back Pain + Knee Malalignment with OA), the NPRS score for low back pain decreased from 6.95 ± 0.785 to 3.95 ± 0.785 ($t = 36.708$, $p < 0.001$), indicating a highly significant improvement. Similarly, in Group B (Mechanical Low Back Pain + Knee Malalignment without OA), the NPRS score for low back pain reduced from 6.86 ± 0.774 to 2.91 ± 0.868 ($t = 36.708$, $p < 0.001$).

For knee pain, Group A showed a decrease in NPRS from 5.91 ± 0.811 to 3.86 ± 0.774 ($t = 28.077$, $p < 0.001$), while Group B demonstrated a reduction from 4.86 ± 0.774 to 1.91 ± 0.868 ($t = 28.077$, $p < 0.001$). Although both groups exhibited statistically significant improvements, Group B demonstrated a slightly greater reduction in pain, suggesting that participants without OA experienced more pronounced pain relief following the intervention.

Table 2 Pre-Test and Post-Test values of Range of Motion (ROM).

Outcome measure	Group	Pre-test (Mean $\pm$ SD)	Post -test (Mean $\pm$ SD)	t value	p value
ROM	A LUMBAR	3.700 $\pm$ 0.4298	5.159 $\pm$ 0.4847	-25.102	<0.001
ROM	B LUMBAR	3.809 $\pm$ 0.3504	6.132 $\pm$ 0.2607	-25.102	<0.001
ROM	A – KNEE FLEXION	106.50 $\pm$ 3.985	116.68 $\pm$ 3.578	-27.697	<0.001
ROM	B - KNEE FLEXION	114.36 $\pm$ 2.854	130.55 $\pm$ 3.247	-27.697	<0.001



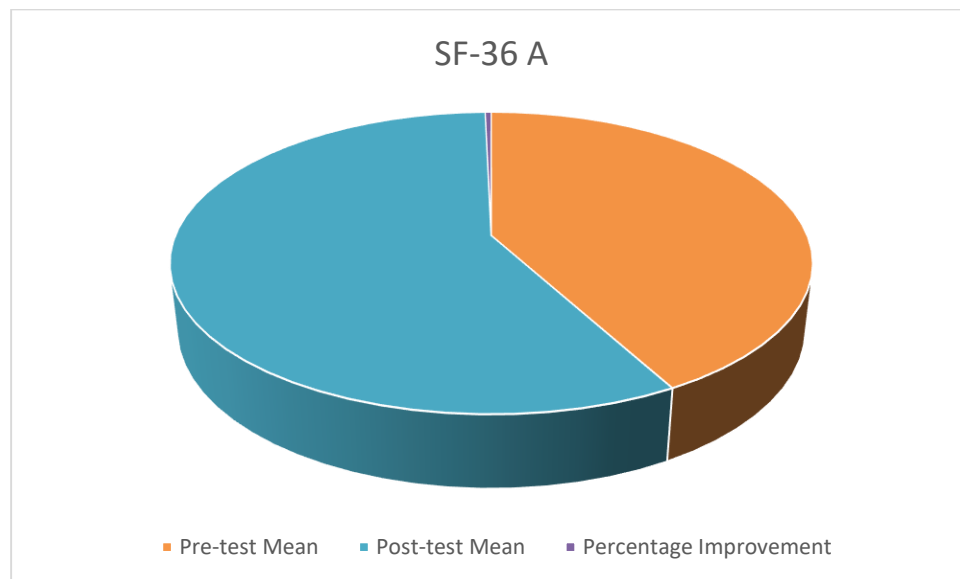
Graph- 2 compare the Pre-Test and Post-Test values of Range of Motion (ROM)

From Table – 2, it is evident that both groups demonstrated significant improvement in range of motion following the intervention period. In Group A (Mechanical Low Back Pain + Knee Malalignment with OA), lumbar ROM increased from 3.700 ± 0.430 to 5.159 ± 0.485 ($t = -25.102$, $p < 0.001$), indicating a highly significant enhancement. Similarly, Group B (Mechanical Low Back Pain + Knee Malalignment without OA) showed an increase in lumbar ROM from 3.809 ± 0.350 to 6.132 ± 0.261 ($t = -25.102$, $p < 0.001$).

For knee flexion, Group A demonstrated an improvement from $106.50 \pm 3.985^\circ$ to $5.159 \pm 3.578^\circ$ ($t = -27.697$, $p < 0.001$), while Group B showed an increase from $114.36 \pm 2.854^\circ$ to $6.132 \pm 3.247^\circ$ ($t = -27.697$, $p < 0.001$). Both groups exhibited statistically significant gains in ROM; however, Group B showed a greater magnitude of improvement, suggesting that participants without OA experienced more pronounced flexibility adaptations following the intervention.

Table 3 Pre-Test and Post-Test values of Short Form Survey – 36 (SF- 36)

Outcome measure	Group	Pre-test (Mean $\pm$ SD)	Post -test (Mean $\pm$ SD)	t value	p value
SF- 36	A	43.27 $\pm$ 3.508	59.32 $\pm$ 3.859	-27.324	<0.001
SF- 36	B	46.32 $\pm$ 2.495	72.47 $\pm$ 2.520	-27.324	<0.001



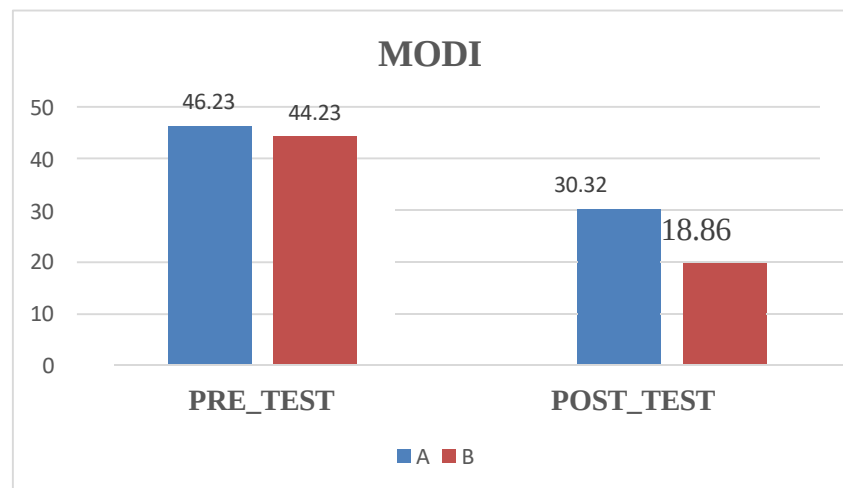
Graph- 3 compgraph 3 compare the Pre-Test and Post-Test values of Short Form Survey – 36 (SF- 36)

From Table – 3, it is evident that both groups demonstrated significant improvement in quality of life following the intervention period. In Group A (Mechanical Low Back Pain + Knee Malalignment with OA), the SF-36 score increased from 43.27 ± 3.508 to 59.32 ± 3.859 ($t = -27.324$, $p < 0.001$), indicating a highly significant enhancement. Similarly, Group B (Mechanical Low Back Pain + Knee Malalignment without OA) showed an increase in SF-36 score from 46.32 ± 2.495 to 72.47 ± 2.520 ($t = -27.324$, p

< 0.001).

Table 4 Pre-Test and Post-Test values of Modified Oswestry Disability Index (MODI)

Outcome measure	Group	Pre-test (Mean ± SD)	Post -test (Mean ± SD)	t value	p value
MODI	A	46.23 ± 3.677	30.32 ± 3.591	28.021	<0.001
MODI	B	44.23 ± 3.206	18.86 ± 2.100	28.021	<0.001

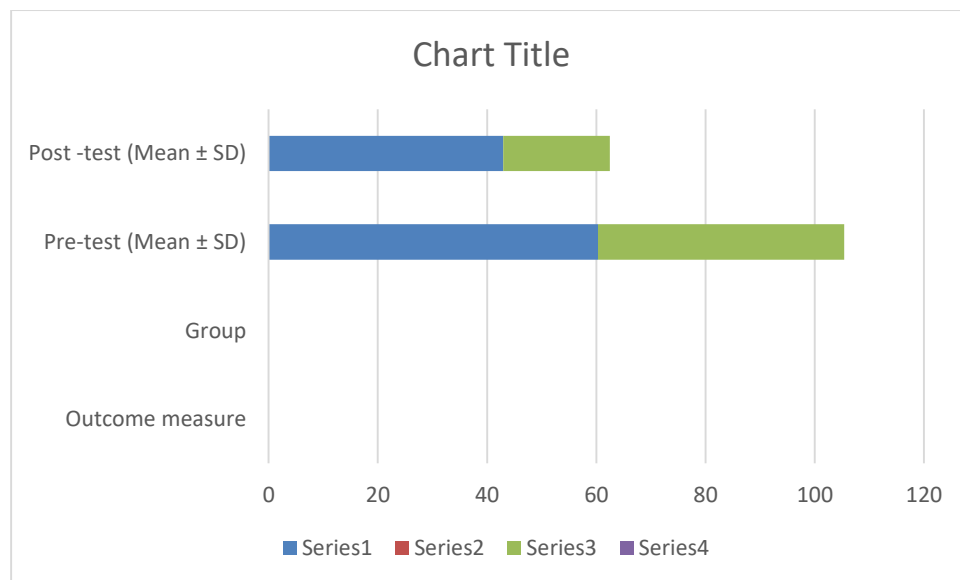


Graph- 4 compare the Pre-Test and Post-Test values of Modified Oswestry Disability Index (MODI)

From Table – 4, it is evident that both groups demonstrated significant improvement in functional disability following the intervention period. In Group A (Mechanical Low Back Pain + Knee Malalignment with OA), the MODI score decreased from 46.23 ± 3.677 to 30.32 ± 3.591 ($t = 28.021$, $p < 0.001$), indicating a highly significant reduction in disability. Similarly, Group B (Mechanical Low Back Pain + Knee Malalignment without OA) showed a decrease in MODI score from 44.23 ± 3.206 to 18.86 ± 2.100 ($t = 28.021$, $p < 0.001$).

Table 5 Pre-Test and Post-Test values of Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)

Outcome measure	Group	Pre-test (Mean ± SD)	Post -test (Mean ± SD)	t value	p value
WOMAC	A	60.32 ± 3.797	42.95 ± 3.659	33.842	<0.001
WOMAC	B	45.05 ± 2.935	19.55 ± 2.686	33.842	<0.001

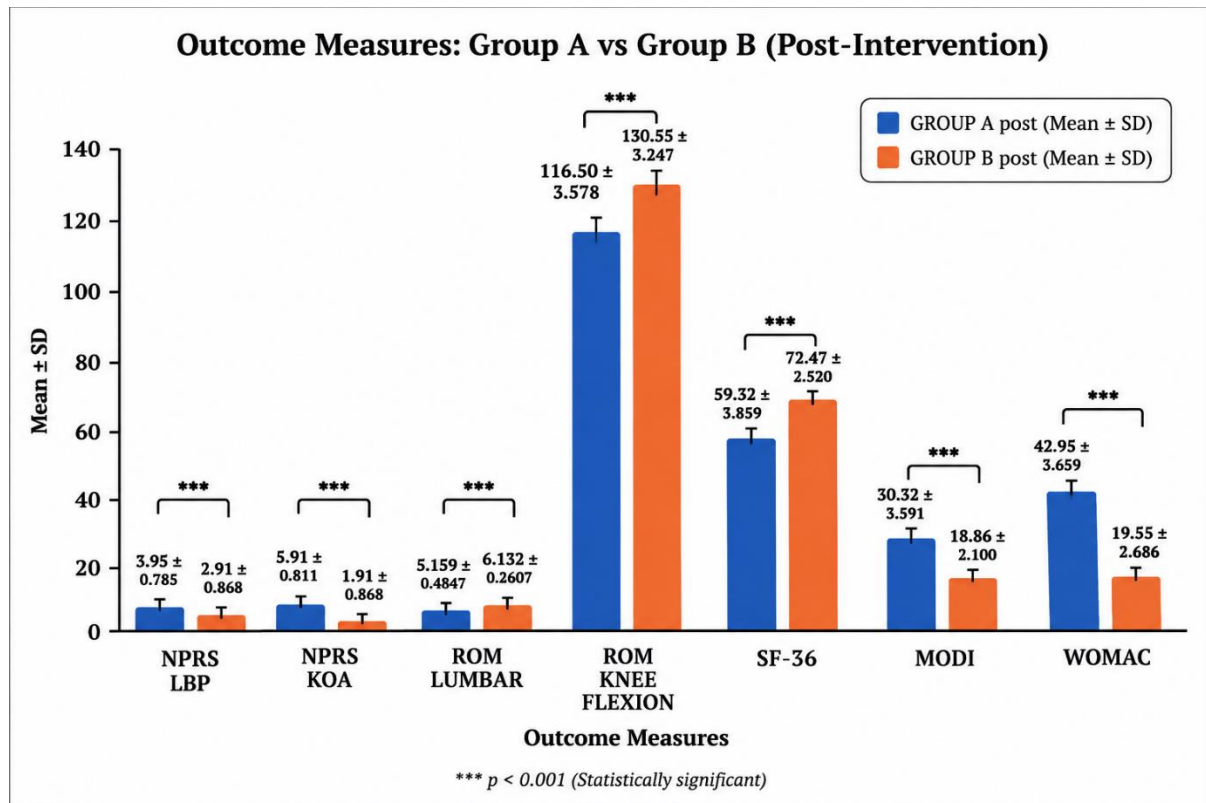


Graph- 5 compare the Pre-Test and Post-Test values of Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)

From Table – 5, it is evident that both groups demonstrated significant improvement in knee-related pain, stiffness and functional limitation following the intervention period. In Group A (Mechanical Low Back Pain + Knee Malalignment with OA), the WOMAC score decreased from 60.32 ± 3.797 to 42.95 ± 3.659 ($t = 33.842$, $p < 0.001$), indicating a highly significant reduction in symptoms and functional impairment. Similarly, Group B (Mechanical Low Back Pain + Knee Malalignment without OA) showed a decrease in WOMAC score from 45.05 ± 2.935 to 19.55 ± 2.686 ($t = 33.842$, $p < 0.001$).

Unpaired T-test Table 6: Post-test Values of the Outcome Measures.

Outcome Measure	GROUP A post (Mean ± SD)	GROUP B post (Mean ± SD)	t value	P value
NPRS_ LBP	3.95 ± 0.785	2.91 ± 0.868	36.708	<0.001
NPRS_ KOA	5.91 ± 0.811	1.91 ± 0.868	28.077	<0.001
ROM_ LUMBAR	5.159 ± 0.4847	6.132 ± 0.2607	-25.102	<0.001
ROM_ KNEE FLEXION	116.50 ± 3.578	130.55 ± 3.247	-27.697	<0.001
SF- 36	59.32 ± 3.859	72.47 ± 2.520	-27.324	<0.001
MODI	30.32 ± 3.591	18.86 ± 2.100	28.021	<0.001
WOMAC	42.95 ± 3.659	19.55 ± 2.686	33.842	<0.001



Graph-6 Compare the Post-test Values of the Outcome Measures

All outcome measures showed statistically significant improvements ($p < 0.001$) in both groups. However, Group B (Mechanical Low Back Pain + Knee Malalignment without OA) consistently demonstrated a greater magnitude of improvement in pain intensity, lumbar and knee range of motion, functional ability (MODI), quality of life (SF-36) and knee function (WOMAC) compared to Group A (Mechanical Low Back Pain + Knee Malalignment with OA).

These findings suggest that the absence of osteoarthritis may allow participants to respond more effectively to combined proprioceptive and sensorimotor training WIT conventional exercise resulting in enhanced pain reduction, improved flexibility, better functional recovery and greater improvements in overall quality of life. The intervention appears to optimize neuromuscular control and joint mechanics, thereby improving functional performance and reducing disability in individuals with mechanical low back pain and knee malalignment.

4. DISCUSSION

The present study was conducted to evaluate the effectiveness of integrated proprioceptive and sensorimotor training combined with conventional exercise therapy on pain, range of motion, functional ability and quality of life in individuals experiencing mechanical low back pain associated with knee malalignment, both with and without knee osteoarthritis. The findings of this investigation demonstrated statistically significant improvements across all measured outcome variables, including pain intensity assessed using the Numeric Pain Rating Scale (NPRS), lumbar and knee joint range of motion, functional disability measured through the Modified Oswestry Disability Index (MODI) and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and overall health-related quality of life assessed using the SF-36 questionnaire. Although both intervention groups showed meaningful improvements following the six-week rehabilitation program, participants who received integrated proprioceptive and sensorimotor training in addition to conventional exercises exhibited comparatively greater improvements than those who received conventional exercise therapy alone. These results suggest that rehabilitation strategies targeting neuromuscular control and sensorimotor integration may enhance clinical outcomes in individuals presenting with complex musculoskeletal conditions involving both the lumbar spine and lower extremity.

Pain reduction was one of the most prominent outcomes observed in the present study. Among participants experiencing mechanical low back pain, NPRS scores in Group A decreased from 6.95 ± 0.785 to 3.95 ± 0.785 after the intervention period. In contrast, participants in Group B demonstrated a greater reduction in pain, with NPRS scores decreasing from 6.86 ± 0.774 to 2.91 ± 0.868 . A similar trend was observed among participants with knee osteoarthritis. Pain scores in Group A decreased from 5.91 ± 0.811 to 3.86 ± 0.774 , whereas Group B showed a more substantial reduction from 4.86 ± 0.774 to 1.91 ± 0.868 . These findings indicate that although conventional exercise therapy alone was effective in reducing pain levels, the addition of proprioceptive and sensorimotor training resulted in a greater magnitude of improvement. The observed reduction in pain may be explained by improvements in neuromuscular coordination and enhanced joint stability achieved through sensorimotor training.

Exercise interventions that emphasize neuromuscular control are known to improve movement quality and reduce abnormal loading patterns across joints, thereby alleviating mechanical stress on musculoskeletal structures. These findings are consistent with the work of (Louw et al., 2016), who reported that rehabilitation programs addressing neuromuscular control deficits can significantly reduce pain intensity in individuals with chronic low back pain by improving motor coordination and minimizing maladaptive movement patterns [27]. Similarly, (Bennell et al., 2014) demonstrated that neuromuscular exercise programs incorporating balance and proprioceptive components effectively reduce pain in individuals with knee osteoarthritis by enhancing joint stability and improving biomechanical alignment during movement [28]. (Akila B et al., 2024) reported that structured physiotherapy programs incorporating neuromuscular and strengthening exercises significantly reduced pain intensity in individuals with chronic low back pain [29].

Further support for the pain-reducing effects of structured exercise interventions can be found in the systematic review and meta-analysis conducted by (Fransen et al., 2015), which concluded that exercise therapy incorporating neuromuscular components significantly improves pain and physical function in individuals with knee osteoarthritis [30]. The greater improvement observed in the experimental group in

the present study may therefore be attributed to improved sensorimotor integration, which likely facilitated better neuromuscular coordination and more efficient movement patterns. Improved neuromuscular coordination may reduce abnormal joint loading and minimize compensatory movement strategies, ultimately contributing to pain relief.

Additional evidence supporting these findings was provided by **(Smith et al., 2014)**, who reported that sensorimotor-based rehabilitation programs improve postural control and reduce pain intensity in individuals with chronic musculoskeletal conditions. Improvements in proprioceptive awareness and balance control may enhance the body's ability to maintain optimal joint alignment during movement, thereby decreasing mechanical stress on both spinal and lower-limb structures [31]. The findings of the present study align closely with this perspective, suggesting that training interventions focusing on proprioceptive awareness and postural control can play a significant role in reducing pain in individuals with combined spinal and knee pathologies.

Despite these encouraging findings, some studies have reported that different forms of exercise therapy may produce similar improvements in pain outcomes. For example, **(Saragiotto et al., 2016)** suggested that various exercise approaches, including strengthening, stretching and motor control exercises, can all contribute to pain reduction in individuals with chronic low back pain, with no single exercise modality demonstrating clear long-term superiority [32]. Similarly, **(Øiestad et al., 2015)** reported that strengthening exercises alone may effectively reduce pain levels in individuals with knee osteoarthritis [33]. The improvements observed in both groups in the present study partially support this perspective, as participants receiving conventional exercise therapy alone also experienced significant pain reduction. However, the greater magnitude of improvement observed in the experimental group indicates that incorporating proprioceptive and sensorimotor training may further enhance the effectiveness of conventional exercise interventions.

In addition to pain reduction, significant improvements in joint range of motion were observed following the intervention program. Lumbar range of motion in Group A improved from 3.700 ± 0.4298 to 5.159 ± 0.4847 , whereas Group B demonstrated a larger increase from 3.809 ± 0.3504 to 6.132 ± 0.2607 . Improvements were also observed in knee joint mobility. Knee flexion increased from $106.50^\circ \pm 3.985$ to $116.68^\circ \pm 3.578$ in Group A, while Group B showed a more pronounced increase from $114.36^\circ \pm 2.854$ to $130.55^\circ \pm 3.247$. These results indicate that both rehabilitation approaches contributed to improved joint mobility; however, the integration of proprioceptive and sensorimotor training resulted in superior improvements in movement capacity.

These findings are consistent with the work of **(Tsao and Hodges et al., 2007)**, who demonstrated that sensorimotor retraining can improve lumbar segmental control and enhance coordination between trunk muscles in individuals with chronic low back pain. Improved coordination of deep stabilizing muscles allows the spine to move more efficiently while maintaining stability, which may contribute to greater mobility and reduced stiffness [34]. The study by **(Monali KC et al., 2024)** highlighted that improved muscle flexibility and coordinated joint movement contribute to increased functional range of motion [35]. Similarly, **(Hall et al., 2012)** reported that neuromuscular training improves knee biomechanics and movement confidence in

individuals with early degenerative knee conditions, resulting in improved joint range of motion and functional performance [36].

The greater improvements in range of motion observed in the experimental group may therefore be explained by enhanced proprioceptive feedback and improved neuromuscular coordination. Sensorimotor training exercises typically challenge balance and joint position awareness, encouraging individuals to develop greater control over joint movements. As neuromuscular coordination improves, individuals may be able to perform movements with reduced muscle guarding and improved movement efficiency, leading to increased joint mobility.

However, previous studies have also suggested that improvements in joint mobility may occur through general exercise therapy alone. For instance, **(Steiger et al., 2012)** reported that stretching and strengthening exercises can significantly improve lumbar mobility in individuals with chronic low back pain [37]. The findings of the present study support this observation to some extent, as both groups demonstrated improvements in range of motion. Nevertheless, the greater improvements observed in the experimental group highlight the potential value of incorporating sensorimotor elements into rehabilitation programs.

Functional disability outcomes in the present study also demonstrated substantial improvements following the intervention period. MODI scores decreased from 46.23 ± 3.677 to 30.32 ± 3.591 in Group A, whereas Group B showed a larger reduction from 44.23 ± 3.206 to 18.86 ± 2.100 . Similarly, WOMAC scores improved from 60.32 ± 3.797 to 42.95 ± 3.659 in Group A, while Group B demonstrated a greater improvement from 45.05 ± 2.935 to 19.55 ± 2.686 . These findings indicate significant improvements in functional capacity and the ability to perform daily activities, with greater improvements observed among participants who received integrated proprioceptive and sensorimotor training.

The improvements in functional outcomes may be explained by enhanced neuromuscular control and improved dynamic joint stability. **(Ageberg et al., 2002)** reported that neuromuscular training improves functional performance by enhancing joint control during dynamic activities in individuals with knee osteoarthritis. Improved neuromuscular control may allow individuals to perform functional tasks such as walking, climbing stairs and transitional movements with greater efficiency and reduced discomfort [38].

Similarly, **(Shum et al., 2007)** reported that individuals with chronic low back pain often exhibit impaired coordination between the lumbar spine and hip joints, which can contribute to functional limitations and movement inefficiency. Motor control training aimed at improving lumbopelvic coordination may restore more efficient movement patterns and reduce disability levels [39]. The integrated training approach used in the present study likely addressed these coordination deficits by simultaneously targeting both spinal and lower-limb neuromuscular control.

Nevertheless, previous research has suggested that the long-term superiority of specific exercise approaches may be limited. **(Ferreira et al., 2007)** reported that motor control exercises improve pain and disability in individuals with chronic low back pain but may not demonstrate clear superiority over general exercise programs over extended follow-up periods [40]. The improvements observed in both groups in

the present study align with this perspective, as conventional exercise alone also produced meaningful improvements in disability scores. However, the greater improvements observed in the experimental group suggest that incorporating proprioceptive and sensorimotor training may accelerate functional recovery in individuals with combined spinal and knee dysfunction.

Quality of life outcomes also improved significantly following the rehabilitation program. SF-36 scores increased from 43.27 ± 3.508 to 59.32 ± 3.859 in Group A, whereas Group B demonstrated a greater improvement from 46.32 ± 2.495 to 72.47 ± 2.520 . These results indicate that the intervention not only improved physical symptoms but also positively influenced overall well-being and perceived health status. Improvements in quality of life may be closely related to reductions in pain and disability, as well as increased confidence in performing daily activities. **(Bunzli et al., 2017)** emphasized that reductions in fear-avoidance behaviours and improved movement confidence play a significant role in enhancing quality of life among individuals with chronic musculoskeletal conditions. Sensorimotor training may help individuals regain confidence in movement by improving balance, coordination and joint stability [41]. These findings are also consistent with the systematic review conducted by **(Sharma et al., 2024)**, which reported that structured exercise interventions significantly improve health-related quality of life in individuals with knee osteoarthritis [42]. Similarly, **(Tagliaferri et al., 2020)** concluded that exercise therapy can produce moderate improvements in quality of life in individuals with chronic low back pain by reducing disability and psychological distress [43].

From a biomechanical perspective, the improvements observed in the present study may be explained by the interconnected relationship between the lumbar spine and lower extremity within the kinetic chain. **(Powers et al., 2003)** reported that lower-limb malalignment can influence proximal hip and trunk mechanics, potentially increasing mechanical stress on the lumbar spine [44]. The findings of the present study support this concept as interventions targeting both lumbopelvic stability and knee joint control resulted in improvements in pain, mobility and functional performance.

Additional biomechanical explanations are supported by studies such as **(van Dieën et al., 2019)** and **(Neumann et al., 2017)**, which describe how alterations in knee alignment can affect trunk movement patterns and spinal loading. Abnormal knee alignment, such as dynamic valgus, may increase hip internal rotation and pelvic instability, thereby disrupting normal lumbopelvic rhythm and increasing stress on spinal structures. By improving neuromuscular control and joint stability, proprioceptive and sensorimotor training may help restore more optimal movement patterns throughout the kinetic chain [45,46].

Neuromuscular adaptations may also play an important role in the improvements observed in the present study. **(Hodges and Tucker., 2011)** reported that sensorimotor training enhances feed-forward activation of stabilizing muscles and improves joint position awareness. Improved activation of muscles such as the gluteus Medius, quadriceps and deep trunk stabilizers may contribute to improved lower-limb alignment and greater spinal stability during functional tasks [47].

More recent research further supports the role of sensorimotor rehabilitation in musculoskeletal disorders. **(Rüger et al., 2023)** reported that sensorimotor training significantly reduces pain-related disability in individuals with chronic low back pain by improving neuromuscular coordination and postural control [48]. Similarly, systematic reviews by **(Tong et al., 2017)** and **(Goh et al., 2019)** concluded that

proprioceptive and balance-based interventions can significantly improve pain, joint stability and functional ability in individuals with chronic low back pain and knee osteoarthritis [49,50].

Taken together, the findings of the present study suggest that while conventional exercise therapy remains a fundamental component of rehabilitation for mechanical low back pain and knee osteoarthritis, the integration of proprioceptive and sensorimotor training may further enhance clinical outcomes. By addressing neuromuscular control deficits and improving coordination throughout the kinetic chain, these interventions may promote more efficient movement patterns and reduce abnormal joint loading.

Therefore, rehabilitation programs that combine strengthening, flexibility training and sensorimotor exercises may offer a more comprehensive and effective approach for managing complex musculoskeletal conditions involving both the lumbar spine and lower extremities. Such integrated approaches may not only reduce pain and improve mobility but also enhance functional independence and overall quality of life for individuals experiencing chronic musculoskeletal disorders.

4.1 LIMITATIONS AND RECOMMENDATIONS:

Limitations:

Relatively small sample size limits generalizability.

Short intervention duration (6 weeks) prevents evaluation of long-term effects.

Outcome measures were limited to pain, ROM, functional ability and quality of life; objective biomechanical data were not collected.

Adherence to home-based conventional exercises was not strictly monitored.

Recommendations:

Conduct randomized controlled trials to provide stronger evidence of effectiveness.

Include larger and more diverse participant populations to enhance generalizability.

Incorporate long-term follow-up to evaluate the durability of improvements.

Explore longer intervention periods to assess additional functional gains.

Include objective biomechanical outcome measures such as gait analysis, muscle activation patterns and balance assessments.

Evaluate similar interventions in other musculoskeletal conditions, such as hip osteoarthritis or chronic non-specific low back pain.

5. CONCLUSION

The present research examined the effectiveness of combining proprioceptive and sensorimotor training with conventional exercise in individuals experiencing mechanical low back pain related to knee malalignment, regardless of the presence of knee osteoarthritis. The results of the research revealed notable advancements in pain levels, mobility, functional capacity and overall quality of life after the intervention phase. These findings emphasize the need to focus on neuromuscular control and joint proprioception as essential factors in the rehabilitation of individuals with concurrent lumbar and knee dysfunction.

The integration of proprioceptive and sensorimotor training probably increased afferent feedback, enhanced muscle coordination and fostered improved postural control, which could have led to better movement patterns and decreased mechanical stress on the lumbar spine and knee joint. Since mechanical low back pain and knee malalignment are frequently linked to modified biomechanics and weakened neuromuscular control, approaches that address these foundational issues seem crucial for functional recovery. Incorporating these training methods with conventional exercises could lead to greater muscle activation, improved joint stability and enhanced balance management. These enhancements can minimize compensatory actions and encourage better load distribution throughout the kinetic chain, thus enhancing functional performance in everyday tasks.

The research endorses the clinical importance of integrating proprioceptive, sensorimotor training and conventional exercise into a holistic physiotherapy rehabilitation plan for those experiencing mechanical low back pain linked to knee malalignment and knee osteoarthritis. The findings of the present study indicate that both intervention groups demonstrated significant improvements in pain, range of motion, functional ability and quality of life following the six-week rehabilitation program. However, the group B (without KOA) that received integrated proprioceptive and sensorimotor training along with conventional exercises showed greater improvements compared to the group A (with KOA).

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