RESEARCH PAPER

Immediate Effect of Medial Joint Release Technique to Realign the Mechanical Axis in Patients with Primary Osteoarthritis

[1*]Dr Pallavi Chopade, [2]Sudeshna Rao, [3]Dr Tushar.J.Palekar, [4]Dr M. Vijayakumar and [5]Dr Neha Chitale

[1](PT) MPT, Professor, Dr D.Y Patil College of Physiotherapy, D.Y. Patil Vidyapeeth, Pimpri, Pune,India 411018
[2]PG resident, Dr D.Y Patil College of Physiotherapy, D.Y. Patil Vidyapeeth, Pimpri, Pune,India 411018
[3]Ph.D. Principal, Dr D.Y Patil College of Physiotherapy, D.Y. Patil Vidyapeeth, Pimpri, Pune,India 411018
[4]Ph.D, Professor, P.E.S Modern College of Physiotherapy, Pune, India 411005
[5](PT) Assistant Professor, Dr D.Y Patil College of Physiotherapy, D.Y Patil Vidyapeeth Pimpri Pune,India 411018
Email Id: [1]pallavi.chopade@dpu.edu.in, [2]raosudeshna1506@gmail.com, [3]principal.physio@dpu.edu.in, [4]atlasvijayakumar@gmail.com and [5]neha.chitale@dpu.edu.in
Orcid Id: [1]0000-0001-5467-7357, [2]0009-0000-4445-4627, [3]0000-0001-9931-4023, [4]0009-0005-8575-565X and [5]0000-0003-1586-0612
***Corresponding Author:** Dr Pallavi Chopade (PT) MPT (Professor) Dr D.Y Patil College of Physiotherapy, D.Y. Patil Vidyapeeth, Pimpri, Pune,India 411018*
Email Id: pallavi.chopade@dpu.edu.in
Orcid Id: 0000-0001-5467-7357

Received: 28th Feb, 2026; Revised: 6th March 2026; Accepted: 7th April, 2026; Available Online: 20th April, 2026

ABSTRACT

Background: Medial compartment knee osteoarthritis (OA) is a mechanically driven degenerative disorder characterized by varus malalignment, increased medial compartment loading, altered gait biomechanics, pain, impaired balance, reduced range of motion, and functional limitations. Increased knee adduction moment and medial shift of the mechanical axis accelerate cartilage degeneration and functional decline. Mechanical correction interventions aimed at reducing medial compartment compression may improve alignment and neuromuscular control. This study aimed to evaluate the immediate effect of Medial Joint Release Technique (MJRT) combined with sustained strapping on mechanical axis realignment and functional outcomes in individuals with primary knee OA.

Methods: A single-group pre–post experimental study was conducted among 60 participants diagnosed with Grade II and III primary knee osteoarthritis according to the Kellgren–Lawrence classification with age criteria of 40–65-year sampling was purposive sampling.The participants underwent MJRT combined with sustained non-elastic strapping. Outcome measures included tibiofemoral alignment, line of gravity sway, pelvic inclination, knee range of motion, pain intensity using the Visual Analog Scale, Western Ontario and McMaster Universities Osteoarthritis Index scores, and 2 min walk test. Statistical analysis was performed using IBM SPSS Statistics version 26.0. Normality of data distribution was assessed using the Shapiro–Wilk test. Normally distributed variables were analysed using paired t-tests, whereas non-normally distributed variables were analysed using the Wilcoxon signed-rank test. Statistical significance was set at $p < 0.05$.

Results: Significant improvements were observed in all measured outcomes following intervention ($p < 0.001$). Standing tibiofemoral alignment improved from $178.3 \pm 0.9°$ to $174.03 \pm 0.8°$ on the right side and from $177.47 \pm 0.77°$ to $173.47 \pm 0.84°$ on the left side. Pelvic inclination improved from $10.23 \pm 1.02°$ to $6.92 \pm 0.67°$ in the frontal plane and from $21.98 \pm 1.33°$ to $17.9 \pm 0.95°$ in the sagittal plane. Line of gravity sway decreased significantly under eyes-open and eyes-closed conditions, indicating improved postural stability. Significant reductions in pain and Western Ontario and McMaster Universities Osteoarthritis Index scores, along with improvements in range of motion and 2 min walk test were also observed.

Conclusion: MJRT combined with sustained strapping demonstrated immediate biomechanical and functional improvements in individuals with medial compartment knee OA and mayserve as an effective adjunct physiotherapy intervention for short-term correction of malalignment and improvement of functional performance.

Trial-registration:
Clinical Trial Registry–India (CTRI/2025/07/091616) on 24/07/2025

Keywords: Biomechanics, tibiofemoral alignment, posturalstability, manual therapy

How to cite this article: Chopade P, Rao S, Palekar TJ, Vijayakumar M, Chitale N, Immediate Effect of Medial Joint Release Technique to Realign the Mechanical Axis in Patients with Primary Osteoarthritis. Int J Drug Deliv Technol. 2026;16(6): 498-506. DOI: 10.25258/ijddt.16.6.57

**Author for Correspondence: pallavi.chopade@dpu.edu.in*

Source of support: Nil.
Conflict of interest: None

INTRODUCTION

Knee osteoarthritis (OA) is one of the most prevalent musculoskeletal disorders worldwide and a major cause of pain, disability, and reduced quality of life among older adults. The medial compartment is more commonly affected because of altered load distribution, varus malalignment, and increased knee adduction moment during weight-bearing activities. Progressive degeneration of articular cartilage, subchondral sclerosis, osteophyte formation, and meniscal degeneration contribute to pain, instability, and functional decline. [1–13]

Medial compartment knee OA is considered a mechanically driven disorder in which abnormal gait biomechanics and malalignment accelerate structural degeneration. Increased knee adduction moment and medial displacement of the mechanical axis increase compressive stress across the medial tibiofemoral compartment during activities such as walking and stair climbing, thereby worsening cartilage degeneration and joint space narrowing. [5–10]

Neuromuscular dysfunction, impaired proprioception, altered pelvic mechanics, and postural instability further contribute to disease progression and reduced functional mobility. Hip abductor weakness, trunk lean, altered pelvic inclination, and impaired balance increase medial compartment loading and compromise lower-limb biomechanics. [14–20]

Recent biomechanical evidence highlights the importance of gait modification and mechanical correction strategies in reducing knee adduction moment and improving functional performance in individuals with knee OA. Interventions such as mobilization techniques, strengthening exercises, and corrective taping have shown beneficial effects on pain and function. Mechanical correction interventions targeting alignment may temporarily reduce medial compartment compression and improve neuromuscular control. [5–10]

The Medial Joint Release Technique (MJRT) is a biomechanical intervention intended to reduce medial compartment compression through valgus-directed correction combined with sustained strapping. The technique aims to improve tibiofemoral alignment, optimize weight distribution, and enhance postural stability. However, limited evidence exis7Ets regarding the immediate effects of MJRT on tibiofemoral alignment, pelvic inclination, postural control, and functional performance in individuals with medial compartment knee OA.

Therefore, the present study aimed to evaluate the immediate effects of MJRT combined with sustained strapping on tibiofemoral alignment, line of gravity sway, pelvic inclination, pain, range of motion, and functional performance in individuals with primary medial compartment knee osteoarthritis. [1,6,7]

METHODS

Study-Design:

A single-arm experimental study was conducted at Dr. D.Y. Patil College of Physiotherapy, Pune, India. Ethical clearance was obtained from the Institutional Ethics Committee (Ref No: DYPCPT/IEC/06/2025), and the study was registered with the Clinical Trial Registry–India (CTRI/2025/07/091616). Written informed consent was obtained from all participants before inclusion in the study. Pre assessment of outcome measures was taken Intervention:

Sample Size Calculation

The sample size was estimated using G*Power software (version 3.1.9.7, Germany) for paired mean comparison between pre- and post-intervention outcomes. Based on an anticipated moderate effect size ($d = 0.5$), alpha error probability of 0.05, and power ($1-\beta$) of 0.80 the calculated minimum sample size was 54 participants. To account for potential attrition and incomplete datasets, 60 participants were recruited.

Participants:

Sixty participants aged 40–65 years diagnosed with Grade II and III primary knee osteoarthritis according to the Kellgren–Lawrence classification were recruited using purposive sampling.

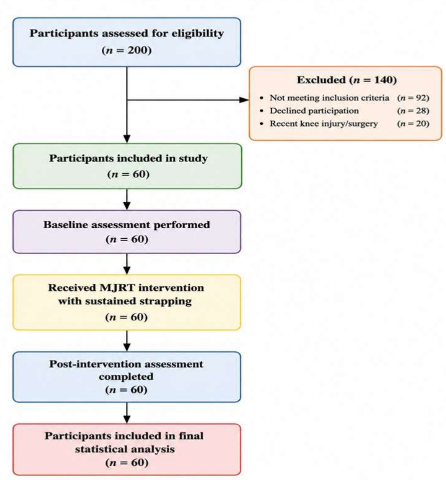
Inclusion Criteria:

- Individuals aged 40–65 years
- Grade II and III primary knee osteoarthritis
- Both male and female participants
- BMI within normal or overweight range

Exclusion Criteria:

- Recent knee injury or surgery
- Intra-articular steroid injections within six months
- Neurological or vascular disorders
- Pathological fractures
- Genu recurvatum

Figure 1. Participant Recruitment and Study Flowchart



Procedure:

Intervention

Pre-intervention assessment of all outcome measures was performed .The Medial Joint Release Technique (MJRT) was applied in both open and closed kinematic chain positions. In supine lying, the therapist stood lateral to the plinth while the participant actively performed knee flexion and extension (Figure 1). One hand stabilized the distal femur near the medial epicondyle, while the other hand applied lateral overpressure to the proximal tibia to create medial joint decompression and facilitate tibial rotation with controlled strain not exceeding 10%. Three to five repetitions were performed for approximately 10 minutes (Figure 2). In standing, the participant performed forward lunges while the therapist applied lateral overpressure with correction of tibial rotation and medial joint release for 8–10 repetitions. Following the intervention, non-elastic strapping was applied between both knees with approximately 30% corrective load based on intercondylar distance and maintained for 20 minutes to sustain mechanical alignment and improve joint position awareness (Figure-3). The total duration of the intervention session was approximately 1 hour, after which all post-intervention outcome measures were reassessed immediately.

Figure1-Application of Medial Joint Release Technique in supine position for valgus-directed correction and medial compartment decompression.

Figure 2: Application of Medial Joint Release Technique in closed kinematic chain standing position.

Figure3: Sustained non-elastic strapping applied to maintain lower-limb mechanical alignment following intervention.

Primary Outcome Measures

The primary outcome measures were (1) Tibiofemoral Alignment, (2) Line of Gravity (LOG) Sway, and (3) Pelvic Inclination. These measures were selected because the primary objective of the study was to evaluate the immediate biomechanical effects of the Medial Joint Release Technique (MJRT) on lower-limb alignment and mechanical axis correction in individuals with medial compartment knee osteoarthritis. Tibiofemoral alignment was assessed to determine changes in varus malalignment and medial compartment loading, while LOG sway was measured to evaluate postural stability and proprioceptive control. Pelvic inclination was assessed to determine changes in proximal kinetic chain alignment and postural symmetry. Together, these outcomes provided objective measures of biomechanical correction, weight-bearing redistribution, and postural control following the intervention.

Secondary Outcome Measures

The secondary outcome measures included (4) Knee Range of Motion (ROM), (5) Visual Analogue Scale (VAS), (6) Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and (7) Two-Minute Walk Test (2MWT). These measures were selected to evaluate the clinical and functional effects of the intervention. Knee ROM was assessed to determine improvements in joint mobility and movement capacity. VAS was used to quantify pain intensity during rest and functional activities. WOMAC was used to assess pain, stiffness, and physical function related to knee osteoarthritis, whereas the 2MWT was used to evaluate walking capacity, functional mobility, and physical performance. These outcome measures provided information regarding symptomatic relief, functional improvement, and overall rehabilitation outcomes following the biomechanical changes achieved through MJRT and sustained strapping.

Statistical-Analysis

Data were analysed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Normality of data distribution was assessed using the Shapiro–Wilk test. Paired t-tests and Wilcoxon signed-rank tests were used where appropriate. Statistical significance was set at $p < 0.05$.

The study was reported in accordance with the TREND reporting guideline for non-randomized intervention studies.

RESULTS

Participants were middle-aged adults with a mean age of 53.80 ± 6.40 years and a mean BMI of 23.80 ± 1.62 kg/m². These baseline characteristics provide context for the observed post-intervention changes in tibiofemoral alignment, postural sway, pelvic inclination, range of motion, pain, and functional outcomes following the medial joint release technique (Table 1). The study sample included a higher proportion of females (61.70%) compared to males (38.30%). This demographic distribution should be considered while interpreting and generalizing the findings to broader populations with knee osteoarthritis (Table 2).

Statistically significant improvements were observed immediately following intervention. Measures of mechanical alignment and postural control demonstrated significant enhancement, including reductions in LOG sway (Table 3,Figure 4) and improvements in tibiofemoral alignment (Table 4,Figure 5) and pelvic inclination (Table 5,Figure 6). Significant increases in knee range of motion were also observed bilaterally. Clinical outcomes showed meaningful reductions in pain intensity during rest, activity, and sit-to-stand tasks, accompanied by significant improvements in WOMAC pain, stiffness, physical function, and total scores (Table 6). Functional mobility also improved, with participants demonstrating better performance during the Two-Minute Walk Test. These findings suggest that the intervention was effective in producing immediate biomechanical, symptomatic, and functional benefits in patients with primary knee osteoarthritis.

Table 1. Demographic Characteristics of Participants (N = 60)

Characteristic	N = 60	Mean	SD	Median	Min	Max
Age (years)		53.8	6.4	54	40	65
BMI (kg/m²)		23.8	1.62	23.6	20.9	28.8

Table 2. Gender Distribution of Participants (N = 60)

Gender		N	Percent
Female		37	61.7
Male		23	38.3

Table 3. Changes in Line of Gravity (LOG) Sway Following Intervention

Outcome	Pre-Mean	Pre SD	Post Mean	Post SD	Test	P
LOG sway (Right, Eyes Open)	1.8	0.18	1.25	0.16	Wilcoxon signed-rank	< .001
LOG sway (Right, Eyes Closed)	2.48	0.52	1.79	0.29	Wilcoxon signed-rank	< .001
LOG sway (Left, Eyes Open)	1.6	0.23	1.18	0.15	Wilcoxon signed-rank	< .001
LOG sway (Left, Eyes Closed)	2.37	0.49	1.66	0.26	Wilcoxon signed-rank	< .001

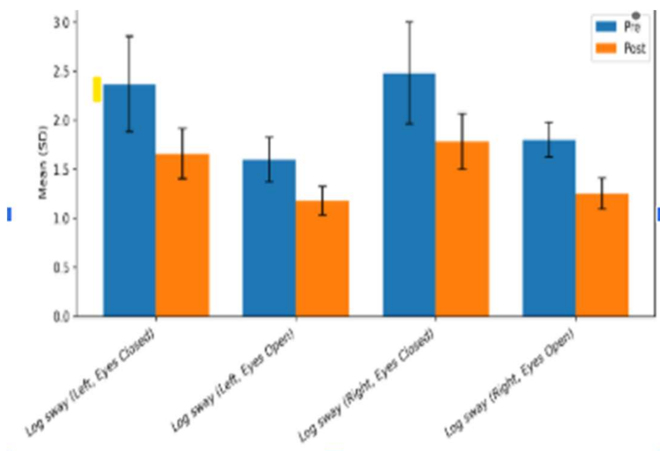


Figure4. Significant reduction in LOG sways following intervention under eyes-open and eyes-closed conditions.

Table4. Changes in Tibiofemoral Alignment in Standing and Squatting Positions Following Intervention

Outcome	Pre-Mean	Pre SD	Post Mean	Post SD	Test	P
Standing tibiofemoral alignment (Right)	178.3	0.9	174.03	0.8	Wilcoxon signed-rank	< .001
Standing tibiofemoral alignment (Left)	177.47	0.77	173.47	0.84	Wilcoxon signed-rank	<.001
Squatting tibiofemoral alignment (Right)	177.27	0.83	173.26	0.9	Wilcoxon signed-rank	< .001
Squatting tibiofemoral alignment (Left)	177	0.71	172.85	0.87	Wilcoxon signed-rank	< .001

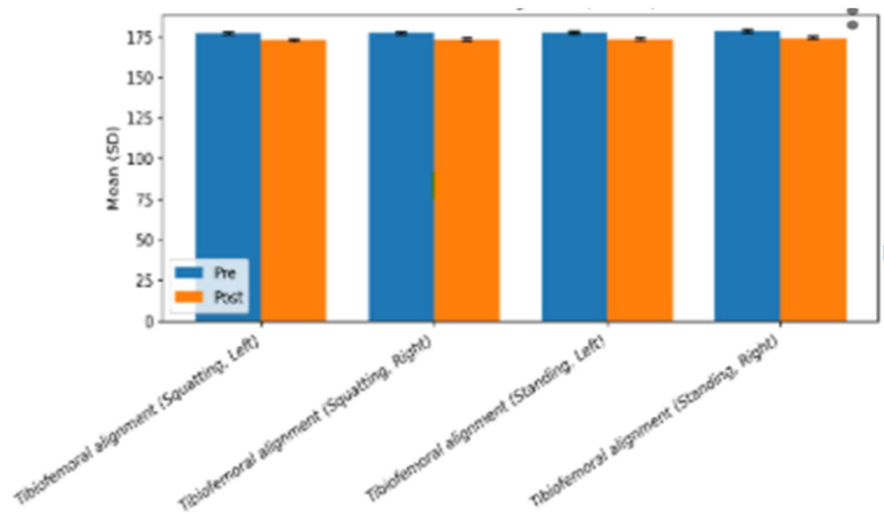


Figure5. Significant improvement in tibiofemoral alignment following intervention

Table 5. Changes in Pelvic Inclination in Frontal and Sagittal Planes Following Intervention

Outcome	Pre-Mean	Pre SD	Post Mean	Post SD	Test	P
Pelvic inclination (Frontal plane)	10.23	1.02	6.92	0.67	Wilcoxon signed-rank	< .001
Pelvic inclination (Sagittal plane)	21.98	1.33	17.9	0.95	Wilcoxon signed-rank	< .001

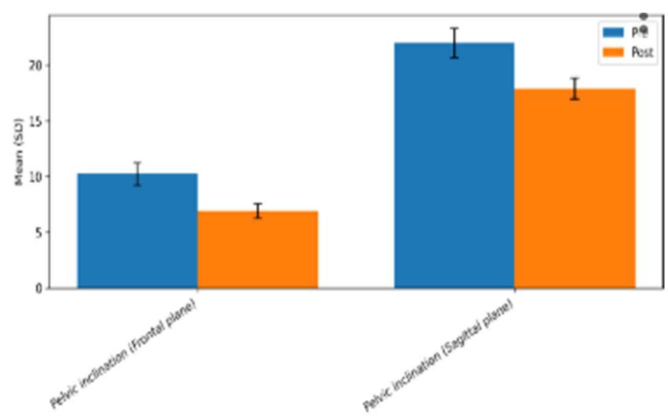


Figure 6. Significant reduction in pelvic inclination following intervention

Table 6. Comparison of Pre- and Post-Intervention Outcome Measures

Outcome Category	Outcome Measure	Pre-Mean	Pre SD	Post Mean	Post SD	Statistical Test	p-value
Range of Motion (ROM)	Knee ROM (Left)	66.75	7.00	75.75	7.06	Wilcoxon signed-rank	<0.001
	Knee ROM (Right)	64.83	7.19	73.75	6.61	Wilcoxon signed-rank	<0.001
Pain (VAS)	Rest (mm)	51.63	3.26	45.22	3.34	Wilcoxon signed-rank	<0.001
	Sit-to-Stand (mm)	66.97	5.26	50.93	3.54	Paired t-test	<0.001
	Activity (mm)	54.60	4.65	44.30	3.01	Wilcoxon signed-rank	<0.001
WOMAC	Total Score	65.87	4.81	48.05	5.14	Paired t-	<0.001

						test	
	Pain Subscale	13.53	1.42	10.22	1.59	Wilcoxon signed-rank	<0.001
	Stiffness Subscale	5.55	0.77	3.92	0.72	Wilcoxon signed-rank	<0.001
	Physical Function	46.95	4.03	34.17	3.31	Paired t-test	<0.001
2 Minute walk test (No. of laps)	N=60	8.47	1.57	11	1.55	Wilcoxon signed-rank	< .001

DISCUSSION

The present study demonstrated that Medial Joint Release Technique (MJRT) combined with sustained strapping produced significant immediate improvements in tibiofemoral alignment, postural stability, pelvic inclination, pain, range of motion, and functional performance in individuals with medial compartment knee osteoarthritis. These findings support the biomechanical concept that abnormal joint loading and varus malalignment contribute substantially to disease progression and functional limitation [5–10]. A significant reduction in LOG sway under both eyes-open and eyes-closed conditions indicated improved postural control following intervention. Pai et al. [17], Wegener et al. [18], Hassan et al. [19], and Levinger et al. [20] reported that individuals with knee osteoarthritis demonstrate impaired proprioception, reduced balance, and increased postural sway.The observed reduction in LOG sway may be attributed to improved proprioceptive input and more symmetrical weight distribution across the lower limbs. Restoration of frontal plane alignment may enhance sensorimotor control and reduce compensatory postural adjustments commonly observed in individuals with medial compartment knee osteoarthritis. Significant improvements in tibiofemoral alignment were also observed. Andriacchi and Mündermann [7] highlighted the role of altered ambulatory mechanics in the progression of knee osteoarthritis, while Felson [8] described osteoarthritis as a mechanically driven disease. Miyazaki et al. [9] demonstrated that increased dynamic loading predicts disease progression, and Sharma et al. [10] identified varus alignment as an important factor contributing to structural deterioration and functional decline. The valgus-directed correction applied during MJRT may have temporarily shifted the mechanical axis laterally, thereby reducing excessive medial compartment loading. Such changes may contribute to reduced knee adduction moments and improved distribution of joint reaction forces during weight-bearing activities. Pelvic inclination improved significantly following intervention, supporting the relationship between knee osteoarthritis and altered lower-limb kinetic chain mechanics. Lewek et al. [14] reported that altered lower-limb mechanics influence movement patterns and loading strategies, while Chang et al. [15] emphasized the role of dynamic malalignment during gait. Improved pelvic alignment may indicate more symmetrical weight-bearing and improved postural control during functional activities. Pain intensity decreased significantly, accompanied by improvements in knee range of motion, WOMAC scores, and 2-minute walk test Tsokanos et al. [1], Kulkarni and Kamat [2], and Somaiya et al. [6] highlighted the beneficial effects of physiotherapy and manual therapy approaches in reducing pain and improving function in individuals with knee osteoarthritis. Reduction in medial compartment stress and improvement in joint mechanics may have contributed to the clinical improvements observed in the present study. The strength of the present study was the inclusion of objective biomechanical measures such as tibiofemoral alignment, LOG sway, and pelvic inclination alongside clinical and functional outcomes. However, the single-group design, absence of a control group, and evaluation of only immediate effects limit conclusions regarding long-term effectiveness. Overall, MJRT combined with sustained strapping demonstrated immediate biomechanical and functional benefits in individuals with medial compartment knee osteoarthritis and may serve as a useful adjunct physiotherapy intervention for short-term correction of malalignment and improvement of functional performance.

LIMITATIONS

The present study has several limitations. First, the study utilized a single-arm pre–post experimental design without a control group, which limits the ability to establish causal relationships between the intervention and observed outcomes. Second, the study evaluated only the immediate effects of the Medial Joint Release Technique (MJRT) combined with sustained strapping, and long-term retention of biomechanical and functional improvements was not assessed. Third, the sample was recruited from a single centre using purposive sampling, which may limit the generalizability of the findings to broader populations with knee osteoarthritis. Additionally, advanced gait analysis and radiographic assessment of dynamic knee loading were not performed. Future randomized controlled trials with larger sample sizes and long-term follow-up are recommended to further validate the clinical effectiveness of MJRT.

Clinical Implications

The findings of this study suggest that MJRT combined with sustained strapping may serve as a clinically applicable physiotherapy intervention for short-term correction of lower-limb malalignment, reduction of medial compartment loading, improvement of postural stability, and enhancement of functional performance in individuals with medial compartment knee osteoarthritis. The technique may be incorporated as an adjunctive biomechanical correction strategy within rehabilitation programs aimed at improving pain and functional mobility.

FUTURE RECOMMENDATIONS

Future studies should investigate the long-term biomechanical and functional effects of MJRT using randomized controlled trial designs with larger sample sizes. Incorporation of gait analysis, kinetic and kinematic assessment, electromyographic evaluation, and radiographic measurement of mechanical axis alignment may provide additional insight into the mechanism of action of the intervention. Comparative studies evaluating MJRT against conventional physiotherapy interventions are also recommended.

Adverse Events

Participants were monitored throughout the intervention session for any adverse events such as increased pain, discomfort, muscle soreness, dizziness, or instability. No serious adverse events were reported during the study period.

Authors' Contributions

SR conceptualized the study, collected data, performed statistical analysis, and drafted the manuscript. PC supervised the study methodology and contributed to manuscript review and editing. TP contributed to study design and statistical guidance. MV assisted in interpretation of biomechanical findings and manuscript review. NC contributed to participant assessment, data validation, and manuscript editing. All authors read and approved the final manuscript.

Funding

No external funding was received for this study.

Availability Of Data And Materials

The datasets used and analysed during the current study are available from the corresponding author upon reasonable request.

Ethics Approval And Consent To Participate

Ethical clearance was obtained from the Institutional Ethics Committee of Dr.D.Y.Patil college of Physiotherapy (Ref No: DYPCPT/IEC/06/2025), and the study was registered with the Clinical Trial Registry–India (CTRI/2025/07/091616) on 24/07/2025. Written informed consent was obtained from all participants before inclusion in the study

Consent For Publication

Written informed consent for the publication of anonymised clinical images and data was obtained from all participants in the study.

Competing Interests

The authors declare that they have no competing interests.

Confidentiality

Participant confidentiality was maintained throughout the study. All collected data were coded and anonymized prior to statistical analysis, and access to data was restricted to the research team.

Declaration Of Ai

Generative AI was used for grammar check and language editing

Abbreviations

OA: Osteoarthritis

MJRT: Medial Joint Release Technique

VAS: Visual Analogue Scale

WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index

LOG: Line of Gravity

ROM: Range of Motion

BMI: Body Mass Index

CTRI: Clinical Trial Registry–India

REFERENCES

1. Tsokanos A, Krommidas G, Comachio J, Papadopoulos EC, Papadimitriou K, Kottaras G, et al. The efficacy of manual therapy in patients with knee osteoarthritis: a systematic review. Medicina (Kaunas). 2021;57(7):696. doi:10.3390/medicina57070696.

2. Kulkarni AV, Kamat MM. Mobilization techniques in knee osteoarthritis pain. Int J Health Sci Res. 2017;7(4):250–256.

3. Hafez AR, Alenazi AM, Kachanathu SJ, Alroumi AM, Mohamed ES. Knee osteoarthritis: a review of literature. Phys Med Rehabil Int. 2014;1(5):8.

4. Pal CP, Singh P, Chaturvedi S, Pruthi KK, Vij A. Epidemiology of knee osteoarthritis in India and related factors. Indian J Orthop. 2016;50(5):518–522. doi:10.4103/0019-5413.189608.

5. Asay JL, Mündermann A, Andriacchi TP. Adaptive patterns of movement during stair climbing in patients with knee osteoarthritis. J Orthop Res. 2018;36(9):2373–2379. doi:10.1002/jor.24035.

6. Somaiya KJ, Samal S, Boob MA. Physiotherapeutic intervention techniques for knee osteoarthritis: a systematic review. Cureus. 2024;16(3):e56789. doi:10.7759/cureus.56789.

7. Andriacchi TP, Mündermann A. The role of ambulatory mechanics in the initiation and progression of knee osteoarthritis. Curr OpinRheumatol. 2006;18(5):514–518. doi: 10.1097/01.bor.0000240365.16842.4e.

8. Felson DT. Osteoarthritis as a disease of mechanics. Osteoarthritis Cartilage. 2013;21(1):10–15. doi:10.1016/j.joca.2012.09.012.

9. Miyazaki T, Wada M, Kawahara H, Sato M, Baba H, Shimada S. Dynamic load at baseline can predict radiographic disease progression in medial compartment knee osteoarthritis. Ann Rheum Dis. 2002;61(7):617–622. doi:10.1136/ard.61.7.617.

10. Sharma L, Song J, Felson DT, Cahue S, Shamiyeh E, Dunlop DD. The role of knee alignment in disease progression and functional decline in knee osteoarthritis. Ann Intern Med. 2001;134(9 Pt 1):800–808. doi:10.7326/0003-4819-134-9_Part_1-200105010-00008.

11. Burr DB, Gallant MA. Bone remodelling in osteoarthritis. Nat Rev Rheumatol. 2012;8(11):665–673. doi:10.1038/nrrheum.2012.130.

12. Loeser RF, Collins JA, Diekman BO. Ageing and the pathogenesis of osteoarthritis. Nat Rev Rheumatol. 2016;12(7):412–420. doi:10.1038/nrrheum.2016.65.

13. Englund M, Guermazi A, Lohmander LS. The meniscus in knee osteoarthritis. Ann Rheum Dis. 2012;71(7):1076–1082. doi:10.1136/annrheumdis-2011-200867.

14. Lewek MD, Rudolph KS, Axe MJ, Snyder-Mackler L. The effect of insufficient quadriceps strength on gait after anterior cruciate ligament reconstruction. Osteoarthritis Cartilage. 2004;12(9):745–751. doi: 10.1016/j.joca.2004.05.009.

15. Chang A, Hayes K, Dunlop D, Hurwitz D, Song J, Cahue S, et al. Thrust during ambulation and the progression of knee osteoarthritis. Arthritis Rheum. 2004;50(12):3897–3903. doi:10.1002/art.20669.

16. Hortobágyi T, Westerkamp L, Beam S, Moody J, Garry J, Holbert D, et al. Altered hamstring-quadriceps muscle balance in patients with knee osteoarthritis. Clin Biomech (Bristol, Avon). 2005;20(1):97–104. doi: 10.1016/j.clinbiomech.2004.08.006.

17. Pai YC, Rymer WZ, Chang RW, Sharma L. Effect of age and osteoarthritis on knee proprioception. Arthritis Rheum. 1997;40(12):2260–2265. doi:10.1002/art.1780401223.

18. Wegener L, Kisner C, Nichols D. Static and dynamic balance responses in persons with bilateral knee osteoarthritis. J Orthop Sports Phys Ther. 1997;25(1):13–18. doi:10.2519/jospt.1997.25.1.13.

19. Hassan BS, Mockett S, Doherty M. Static postural sway, proprioception, and maximal voluntary quadriceps contraction in patients with knee osteoarthritis and normal control subjects. Ann Rheum Dis. 2001;60(6):612–618. doi:10.1136/ard.60.6.612.

20. Levinger P, Menz HB, Wee E, Feller JA, Bartlett JR, Bergman NR. Physiological risk factors for falls in people with knee osteoarthritis before and early after knee replacement surgery. Arthritis Care Res (Hoboken). 2011;63(4):473–478. doi:10.1002/acr.20338.