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Original Article

A Comparison of the Movement System Impairment Approach vs Standard Physiotherapy Protocols for Managing Knee Pain

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ABSTRACT

Background: Knee pain is a common musculoskeletal complaint that limits walking, stair negotiation, squatting, functional mobility, and participation in occupational or recreational activities. Standard physiotherapy commonly includes hip-knee strengthening, stretching, functional advice, and activity modification, whereas the Movement System Impairment approach uses movement classification and individualized correction of faulty alignment and motor-control patterns. Objective: To compare the effectiveness of Movement System Impairment-based treatment with standard physiotherapy protocols for improving pain, strength, and functional outcomes in adults with unilateral non-traumatic knee pain. Methods: A randomized clinical comparison was conducted over six weeks. Participants received either Movement System Impairment-based assessment and treatment, including alignment correction, task-specific retraining, strengthening, stretching, and activity modification, or standard physiotherapy consisting of general hip-knee strengthening, stretching, progressive resistance exercise, and functional advice. Outcomes included pain intensity, Knee Injury and Osteoarthritis Outcome Score, Tegner Activity Scale, muscle power, flexibility, and pain during functional activities. Results: Both groups demonstrated improvement in pain, symptoms, activities of daily living, sport/recreation function, and selected muscle performance outcomes. Between-group findings favored the Movement System Impairment group for walking-related knee pain, hip lateral rotator strength, and knee extensor strength. Conclusion: Both interventions were effective for short-term knee pain rehabilitation, but Movement System Impairment-based treatment provided additional benefit for outcomes related to lower-limb alignment, hip-knee control, and functional loading. Keywords: Movement System Impairment, knee pain, physiotherapy, rehabilitation, KOOS, functional movement, exercise therapy.

INTRODUCTION

Knee pain is one of the most common musculoskeletal complaints encountered in physiotherapy practice and is frequently associated with limitations in walking, stair negotiation, squatting, prolonged sitting, occupational tasks, and participation in recreational or sporting activities. Although knee pain may arise from multiple clinical presentations, including patellofemoral pain, early degenerative changes, altered lower-limb biomechanics, muscle weakness, reduced neuromuscular control, and repetitive mechanical overload, a shared clinical concern is the persistence of pain during functional movement despite routine exercise-based rehabilitation (1). Contemporary rehabilitation guidelines emphasize active interventions, particularly therapeutic exercise, patient education, taping, foot orthoses,

and combined care strategies, while discouraging isolated passive or low-value modalities such as electrotherapy when used without an active rehabilitation component (2). This evidence supports physiotherapy as a central component of conservative knee pain management, but it also highlights the need to identify which exercise-based approaches provide the greatest functional benefit for patients with movement-related symptoms.

Standard physiotherapy protocols for knee pain commonly include quadriceps strengthening, hip abductor and external rotator strengthening, lower-limb stretching, range-of-motion training, functional advice, progressive resistance exercise, and activity modification. These interventions are clinically useful because they address common impairments such as reduced knee extensor force, proximal hip weakness, soft-tissue tightness, and reduced tolerance to load-bearing activities (3). However, knee pain is not a uniform disorder, and patients may present with different movement impairments, including femoral adduction, femoral internal rotation, tibiofemoral rotation, dynamic knee valgus, patellar maltracking, knee hyperextension, excessive foot pronation, or poor motor control during walking, stair climbing, squatting, and single-leg tasks (4). Therefore, a generalized strengthening and stretching protocol may improve symptoms in many patients but may not fully address the specific biomechanical or movement-system contributors responsible for pain during functional activity.

The Movement System Impairment approach was developed to address this limitation by classifying patients according to observable impairments in alignment, movement direction, muscle performance, flexibility, and task-specific motor control. Instead of applying a uniform protocol to all patients with knee pain, this approach uses movement assessment to identify faulty movement patterns and links treatment directly to the patient's impairment classification (5). In knee rehabilitation, this may include correcting femoral internal rotation or adduction during functional tasks, improving hip-knee coordination, retraining sit-to-stand or stair mechanics, modifying pain-provoking activities, and prescribing individualized strengthening or stretching according to the identified movement dysfunction. This individualized model is clinically relevant because abnormal hip and knee mechanics can increase patellofemoral and tibiofemoral loading, reduce functional stability, and contribute to persistent activity-related symptoms.

Recent evidence suggests that impairment-based and movement-specific rehabilitation may provide added benefit over routine physiotherapy in selected patients with knee pain. Movement System Impairment-based classification treatment has been reported to improve pain, disability, alignment, and movement impairments in individuals with tibiofemoral rotation syndrome when compared with routine physiotherapy (6). Similarly, studies evaluating combined hip-knee exercise strategies and biomechanically targeted interventions support the concept that addressing proximal control, lower-limb alignment, and functional movement quality may improve pain and physical performance beyond education or generalized exercise alone (7). A recent randomized clinical trial comparing Movement System Impairment-based treatment with routine physiotherapy for knee pain reported that both approaches improved clinical outcomes, but the Movement System Impairment group demonstrated greater improvement in walking pain, hip lateral rotator strength, and knee extensor strength (8). These findings suggest that individualized movement correction may be especially useful for patients whose symptoms are linked to faulty alignment, poor hip-knee control, or pain during repetitive functional loading.

Despite growing interest in movement-system classification, important knowledge gaps remain. Existing physiotherapy protocols are often described broadly, and many studies do not clearly determine whether individualized movement correction provides clinically meaningful advantages over standard strengthening and stretching programs. In addition, knee pain populations are heterogeneous, and the benefits of Movement System Impairment-based treatment may depend on whether patients demonstrate identifiable movement faults such as tibiofemoral rotation, dynamic valgus, altered patellar tracking, or reduced proximal control. Therefore, a focused comparison between Movement

System Impairment-based rehabilitation and standard physiotherapy is needed to clarify whether classifying and correcting movement impairments improves pain, muscle performance, and functional activity outcomes in adults with unilateral non-traumatic knee pain.

Based on the PICO framework, the population of interest is adults with unilateral non-traumatic knee pain; the intervention is Movement System Impairment-based assessment and treatment; the comparator is standard physiotherapy involving general hip-knee strengthening, stretching, and functional advice; and the outcomes include pain intensity, Knee Injury and Osteoarthritis Outcome Score, Tegner activity level, muscle strength, flexibility, and pain during functional activities. Therefore, the objective of this study was to compare the effectiveness of the Movement System Impairment approach with standard physiotherapy protocols in improving pain, strength, and functional outcomes among patients with unilateral non-traumatic knee pain. The study hypothesized that both interventions would improve clinical outcomes, but Movement System Impairment-based treatment would produce greater improvement in walking-related knee pain and lower-limb muscle performance because of its individualized correction of faulty movement patterns.

MATERIALS AND METHODS

A randomized clinical comparison was conducted to evaluate the effectiveness of Movement System Impairment-based treatment compared with standard physiotherapy protocols in adults with unilateral non-traumatic knee pain. The study followed a parallel-group design in which eligible participants were allocated to either an individualized Movement System

Impairment intervention group or a standard physiotherapy group. The methodological rationale was based on the need to determine whether classification of faulty movement patterns and individualized correction strategies provide additional clinical benefit beyond commonly used strengthening, stretching, and functional exercise protocols.

Participants were adults presenting with unilateral non-traumatic knee pain of at least two months' duration and moderate pain intensity during functional activity. Eligible participants were included when knee pain affected daily activities such as walking, stair climbing, squatting, sit-to-stand transfer, or prolonged weight-bearing.

Participants were excluded if they had a history of recent knee surgery, acute traumatic knee injury, fracture, ligament rupture requiring surgical management, neurological disorder affecting lower-limb control, systemic inflammatory disease, pregnancy, major cardiopulmonary limitation restricting exercise participation, or any acute pathology requiring urgent medical or surgical referral (9). Participants using recent analgesic or anti-inflammatory medication that could substantially influence pain reporting were also excluded to reduce measurement bias.

After eligibility screening, participants were enrolled through clinical assessment and provided written informed consent before allocation. Baseline assessment was performed before the start of treatment and included demographic information, clinical history, symptom duration, affected side, pain behavior, activity limitation, and functional aggravating movements.

Participants were then assigned to one of two treatment groups. Both groups received a six-week intervention period consisting of supervised physiotherapy sessions once weekly, supported by structured home-based practice. Participants were instructed to follow the prescribed home program consistently and to avoid activities that markedly increased symptoms beyond tolerable limits.

The Movement System Impairment group underwent a detailed movement-based assessment designed to identify faulty alignment, direction-specific movement impairment, and altered motor control during functional tasks. Assessment included observation of standing posture, sitting posture, walking, sit-to-stand transfer, single-leg stance, partial squat, stair negotiation, and other pain-provoking activities.

Particular attention was given to femoral adduction, femoral internal rotation, tibiofemoral rotation, dynamic knee valgus, knee hyperextension, excessive foot pronation, patellar tracking behavior, hip-knee coordination, and compensatory trunk or pelvic movement. The identified movement faults were used to classify the participant's impairment pattern and to guide individualized treatment.

Treatment in the Movement System Impairment group consisted of patient-specific movement correction, task-specific retraining, strengthening, stretching, activity modification, and functional practice. Corrective strategies were applied during symptomatic or mechanically faulty tasks, with emphasis on improving lower-limb alignment, reducing excessive femoral or tibial rotation, optimizing hip-knee control, and restoring controlled weight-bearing mechanics.

Strengthening exercises targeted impaired muscle groups, particularly the hip abductors, hip lateral rotators, knee extensors, and other relevant lower-limb stabilizers according to assessment findings. Stretching was prescribed when muscle tightness or reduced extensibility contributed to faulty movement. Functional retraining included repeated practice of corrected walking, sit-to-stand, squatting, stair climbing, and single-leg control as appropriate for each participant's presentation.

The standard physiotherapy group received routine exercise-based rehabilitation for knee pain. The intervention included general hip and knee strengthening, stretching exercises, progressive resistance training, functional advice, and education regarding activity modification.

Strengthening focused on commonly targeted muscle groups, including the quadriceps, hip abductors, hip extensors, and hip external rotators. Stretching was directed toward lower-limb muscle groups contributing to reduced flexibility or movement restriction. Functional advice included guidance on graded activity, symptom monitoring, load modification, and safe performance of daily activities. Unlike the Movement System Impairment group, treatment was not primarily determined by a formal movement impairment classification.

The primary clinical outcome was knee pain during functional activity, particularly walking-related pain. Secondary outcomes included general pain intensity, Knee Injury and Osteoarthritis Outcome Score domains, Tegner Activity Scale, lower-limb muscle power, muscle flexibility, and pain during selected functional movements such as sit-to-stand, squatting, stair use, and walking. Pain intensity was measured using a numerical pain rating scale.

Patient-reported knee symptoms, function, sport and recreational activity, and quality of life were assessed using the Knee Injury and Osteoarthritis Outcome Score. Activity level was assessed using the Tegner Activity Scale. Muscle power was assessed through manual muscle testing of clinically relevant hip and knee muscle groups, including hip abductors, hip lateral rotators, and knee extensors. Flexibility assessment was performed for lower-limb muscle groups where reduced extensibility was considered clinically relevant.

Operationally, improvement in pain was defined as a reduction in reported pain intensity from baseline to the end of the six-week intervention. Functional improvement was defined as improvement in patient-reported functional scores and reduced pain during functional activities. Strength improvement was defined as increased manual muscle testing grade or improved clinical performance of the tested muscle group. Movement improvement in the Movement System Impairment group was defined as the participant's ability to perform previously faulty or painful tasks with improved alignment, reduced compensatory movement, and better hip-knee control.

To reduce performance and measurement bias, both groups received active physiotherapy interventions over the same treatment duration. The frequency of supervised sessions and the expectation for home-based practice were kept consistent between groups. Baseline and post-intervention assessments were performed using the same outcome measures.

Participants were assessed using standardized task instructions, and the same functional activities were used for pre- and post-treatment comparison. Confounding was addressed by applying comparable eligibility criteria, excluding major acute or systemic conditions, maintaining equal treatment duration, and comparing changes between groups using the same outcome framework.

Data were recorded at baseline and after completion of the six-week intervention. Quantitative variables were summarized using appropriate descriptive statistics according to distribution, including mean and standard deviation for normally distributed data and median with interquartile range for non-normally distributed data.

Categorical variables were summarized as frequencies and percentages. Within-group changes from baseline to post-intervention were analyzed to determine whether each treatment produced significant clinical improvement. Between-group comparisons were performed to determine whether the Movement System Impairment approach produced superior improvement compared with standard physiotherapy. Non-parametric testing was applied where data distribution or ordinal outcome structure required it, including Mann–Whitney testing for between-group comparisons. Statistical significance was set at $p < 0.05$.

Missing data were managed by analyzing available paired baseline and post-intervention observations for participants who completed the assessment period. Outcome data were checked for completeness, consistency, and plausibility before analysis. Data integrity was maintained through standardized recording of assessment findings, consistent use of outcome measures, and systematic documentation of intervention components. Reproducibility was supported by defining eligibility criteria, intervention duration, treatment components, assessment procedures, outcome measures, and statistical methods in sufficient detail to allow replication of the clinical comparison.

RESULTS

Fifty participants with unilateral non-traumatic knee pain completed the six-week intervention period and were included in the final comparative analysis. Participants were allocated to either the Movement System Impairment group or the standard physiotherapy group, and both groups received active physiotherapy over the same intervention duration.

Clinical outcomes were assessed at baseline and after six weeks using patient-reported pain and function measures, activity-level assessment, muscle performance testing, flexibility assessment, and pain response during functional movement tasks. Both interventions produced clinically favorable changes across pain, function, strength, and activity-related outcomes; however, the between-group pattern favored the Movement System Impairment approach for walking-related knee pain, hip lateral rotator strength, and knee extensor strength.

Overall, both Movement System Impairment-based treatment and standard physiotherapy produced meaningful short-term improvement after six weeks. The strongest shared improvements were seen in KOOS pain, KOOS symptoms, KOOS activities of daily living, KOOS sport/recreation, and hip muscle performance. The main between-group advantages favored the Movement System Impairment group for walking-related knee pain, hip lateral rotator strength, and knee extensor strength. These findings indicate that routine exercise-based physiotherapy is effective for unilateral non-traumatic knee pain, while individualized movement classification and task-specific correction may provide additional benefit for outcomes closely linked to lower-limb alignment, hip-knee control, and functional loading.

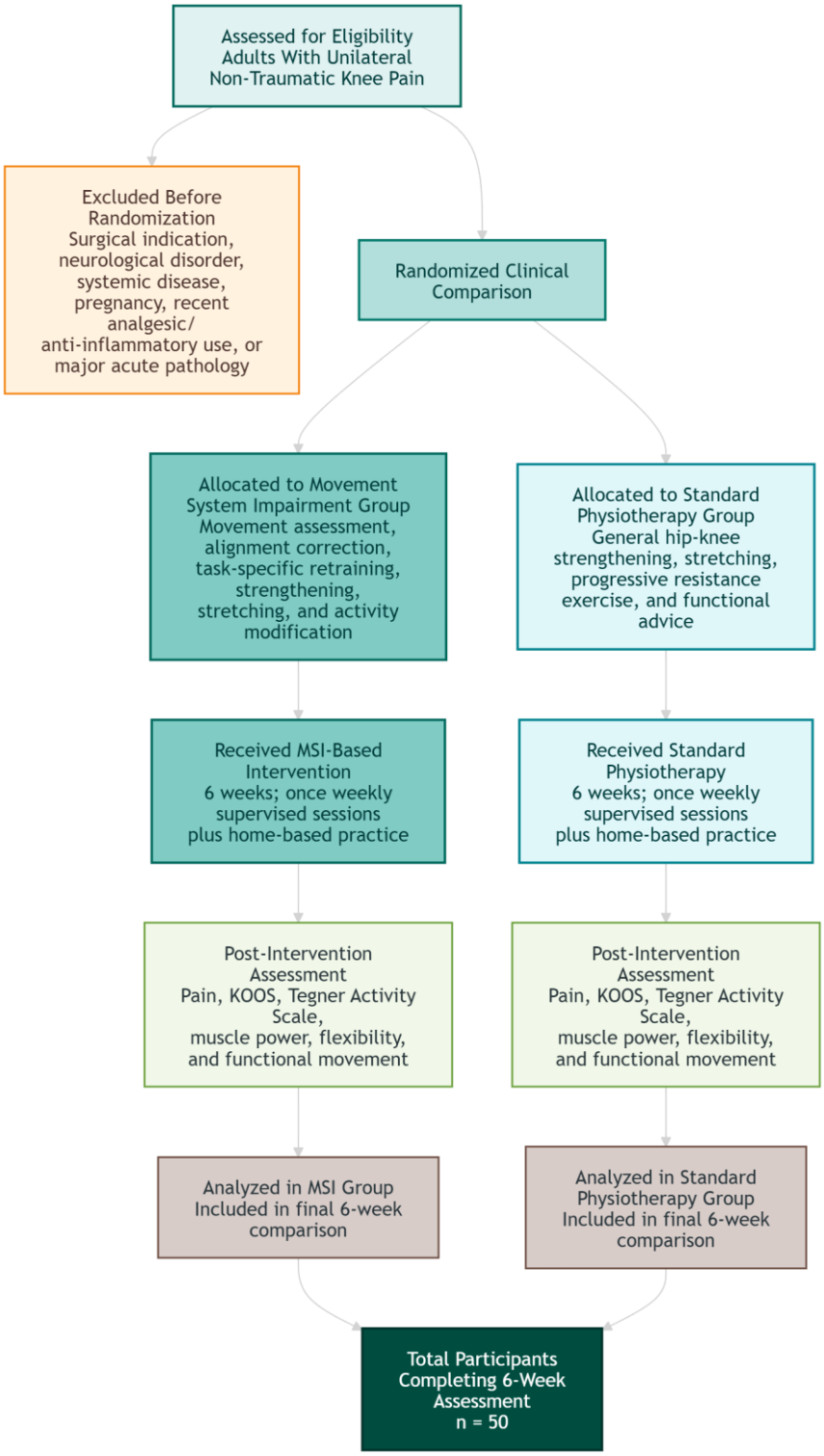

Figure 1. CONSORT Flow Diagram of Participant Allocation, Intervention Exposure, and Final Analysis in a Six-Week Knee Pain Rehabilitation Trial

CONSORT-style participant flow diagram showing eligibility assessment, randomization into Movement System Impairment-based treatment and standard physiotherapy, six-week intervention exposure, post-intervention outcome assessment, and final analysis. Fifty participants completed the six-week assessment period and were included in the final comparative analysis.

Table 1. Study Design, Intervention Exposure, and Outcome Assessment Framework

Variable	Movement System Impairment Group	Standard Physiotherapy Group	Between-Group Comparison
Study design	Parallel-group randomized clinical comparison	Parallel-group randomized clinical comparison	Comparable study structure
Study population	Adults with unilateral non-traumatic knee pain	Adults with unilateral non-traumatic knee pain	Same target population
Intervention duration	6 weeks	6 weeks	Equal exposure duration
Supervised treatment frequency	Once weekly	Once weekly	Equal supervised frequency
Home-based practice	Included	Included	Included in both groups
Main treatment focus	Movement classification, alignment correction, task-specific retraining, strengthening, stretching, and activity modification	General hip-knee strengthening, stretching, progressive resistance exercise, and functional advice	MSI used individualized classification; standard group used routine exercise-based care
Outcome timing	Baseline and 6 weeks	Baseline and 6 weeks	Same assessment schedule
Primary functional emphasis	Pain and movement quality during functional activity, especially walking	Pain and function during routine daily activity	Walking pain favored MSI
Statistical threshold	$p < 0.05$	$p < 0.05$	Same significance threshold

Both groups completed the same six-week assessment window, allowing post-intervention comparison across equivalent follow-up duration. The Movement System Impairment intervention differed primarily by using movement classification and correction of faulty alignment during functional tasks, whereas the standard physiotherapy protocol emphasized generalized strengthening, stretching, and functional advice. This distinction is important because the largest between-group advantages were observed in outcomes directly related to movement control and functional loading.

Table 2. Patient-Reported Knee Outcomes After Six Weeks

Outcome Measure	Movement System Impairment Group	Standard Physiotherapy Group	Within-Group p-Value: MSI	Within-Group p-Value: Standard Physiotherapy	Between-Group Interpretation
KOOS pain	Significant improvement	Significant improvement	0.002	0.001	Both interventions reduced knee-related pain
KOOS symptoms	Significant improvement	Significant improvement	0.004	0.033	Both interventions improved symptom burden
KOOS activities of daily living	Significant improvement	Significant improvement	<0.001	<0.001	Both interventions improved daily functional ability
KOOS sport/recreation	Significant improvement	Significant improvement	0.001	0.009	Both interventions improved sport and recreational function
KOOS quality of life	Significant improvement	Not reported as significant	0.001		Direction favored broader patient-reported benefit in the MSI group
Tegner Activity Scale	Improvement reported	Improvement reported			Both groups showed activity-related improvement

Patient-reported outcomes improved in both treatment arms. KOOS pain improved significantly in the Movement System Impairment group and the standard physiotherapy group, with p-values of 0.002 and 0.001, respectively.

KOOS activities of daily living showed the strongest within-group pattern in both arms, reaching $p < 0.001$ in each group. KOOS sport/recreation also improved significantly in both groups, with a lower p-value in the Movement System Impairment group than in the standard physiotherapy group. KOOS quality of life improved significantly in the Movement System Impairment group, while a significant standard physiotherapy result for this domain was not highlighted.

Table 3. Muscle Performance and Flexibility Outcomes After Six Weeks

Outcome Measure	Movement System Impairment Group	Standard Physiotherapy Group	Within-Group p-Value: MSI	Within-Group p-Value: Standard Physiotherapy	Between-Group p-Value	Between-Group Interpretation
Hip abductors	Significant improvement	Significant improvement	0.005	0.010	Not reported	Both groups improved hip abductor performance
Hip lateral rotators	Significant improvement	Significant improvement	0.020	0.010	0.020	Between-group difference favored MSI
Knee extensors	Greater improvement reported	Improvement reported			0.010	Between-group difference favored MSI
Lower-limb flexibility	Improvement reported	Improvement reported				Both groups showed favorable flexibility response
Functional movement performance	Improved movement control reported	Improved function reported				MSI produced more movement-specific gains

Muscle performance improved in both groups, but the pattern of between-group findings favored the Movement System Impairment approach for selected strength outcomes. Hip abductor strength improved significantly in both groups, with $p = 0.005$ in the Movement System Impairment group and $p = 0.010$ in the standard physiotherapy group.

Hip lateral rotator strength improved significantly in both groups, but the between-group comparison favored Movement System Impairment treatment with $p = 0.020$. Knee extensor performance also showed a significant between-group advantage for the Movement System Impairment group, with $p = 0.010$. These findings indicate that individualized correction of hip-knee movement patterns was associated with superior gains in muscle groups important for dynamic lower-limb control.

Table 4. Functional Pain and Movement-Related Outcomes After Six Weeks

Functional Outcome	Movement System Impairment Group	Standard Physiotherapy Group	Between-Group p-Value
Knee pain during walking	Improved	Improved	0.030
Pain during sit-to-stand	Improved	Improved	
Pain during squatting or partial squat	Improved	Improved	
Stair-related pain or function	Improved	Improved	
Dynamic lower-limb movement control	Greater improvement reported	Improvement reported	
Activity modification tolerance	Improved	Improved	

Functional activity outcomes improved in both groups over the six-week treatment period. The most clinically relevant between-group functional finding was walking-related knee pain, which improved in both groups but showed a significant advantage for the Movement System.

Impairment approach, with $p = 0.030$. This result is consistent with the intervention mechanism, as the Movement System Impairment group received individualized correction of alignment and movement faults during functional tasks such as walking, sit-to-stand transfer, squatting, stair negotiation, and single-leg control. Standard physiotherapy also improved functional tolerance, but the greater walking-pain response in the Movement System Impairment group suggests added value from movement-specific retraining.

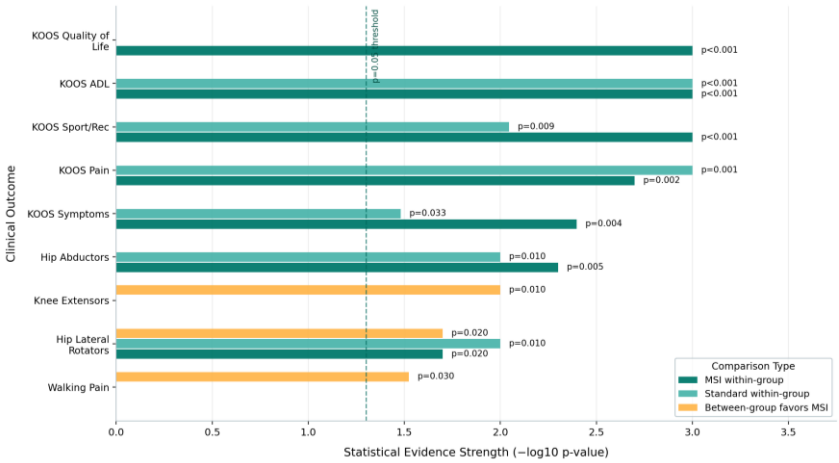

Figure 1. Outcome-Level Evidence Pattern After Six Weeks of Knee Pain Rehabilitation

The figure summarizes the statistical evidence pattern across reported clinical outcomes using derived −log10 p-values from the available aggregate results. KOOS activities of daily living showed strong evidence of improvement in both groups, with $p < 0.001$ for Movement System Impairment and standard physiotherapy. KOOS pain also improved in both groups, with $p = 0.002$ for Movement System Impairment and $p = 0.001$ for standard physiotherapy, while KOOS symptoms showed a stronger within-group signal in the Movement System Impairment group than in the standard physiotherapy group. The between-group layer highlights the outcomes favoring Movement System Impairment, including knee extensor strength ($p = 0.010$), hip lateral rotator strength ($p = 0.020$), and walking-related knee pain ($p = 0.030$), indicating that the clearest comparative advantage of Movement System Impairment was concentrated in movement-control and functional loading outcomes rather than across all patient-reported domains.

DISCUSSION

The present findings indicate that both Movement System Impairment-based treatment and standard physiotherapy produced meaningful short-term improvements in pain, symptoms, functional activity, and selected muscle performance outcomes among adults with unilateral non-traumatic knee pain. Improvements in KOOS pain, symptoms, activities of daily living, and sport/recreation domains in both groups support the clinical value of active exercise-based rehabilitation for knee pain management. This pattern is consistent with contemporary rehabilitation principles emphasizing strengthening, flexibility training, functional retraining, and education as core components of conservative knee care. However, the comparative results suggest that the Movement System Impairment approach may provide additional benefit for outcomes more directly related to movement control, particularly walking-related knee pain, hip lateral rotator strength, and knee extensor strength. The greater improvement in these outcomes supports the clinical rationale that identifying and correcting faulty alignment and movement patterns may enhance the effects of general strengthening and stretching protocols (10).

The improvement observed in both treatment groups is clinically important because knee pain commonly limits weight-bearing activities such as walking, stair negotiation, squatting, and sit-to-stand transfers. Standard physiotherapy protocols target common impairments through quadriceps strengthening, hip strengthening, stretching, progressive resistance training, and functional advice. These components can reduce pain and improve functional capacity by increasing load tolerance, improving lower-limb muscle performance, and supporting safer movement during daily activities. In the current comparison, significant improvements in KOOS pain, KOOS symptoms, KOOS activities of daily living, and KOOS sport/recreation outcomes in both groups suggest that routine physiotherapy remains an effective first-line approach for patients with non-traumatic knee pain. Therefore, the results should not be interpreted as showing that standard physiotherapy is ineffective; rather, they indicate that

active rehabilitation benefits both groups, while individualized movement correction may add further value in selected outcomes (11,12).

The main advantage of the Movement System Impairment approach appears to be its specificity. Unlike routine physiotherapy, which generally applies strengthening and stretching exercises across broad muscle groups, Movement System Impairment-based treatment begins with classification of faulty movement patterns during functional tasks. This allows treatment to be linked to the patient's observed impairments, such as femoral adduction, femoral internal rotation, tibiofemoral rotation, dynamic knee valgus, knee hyperextension, excessive foot pronation, or poor hip-knee coordination (13). By correcting these patterns during walking, sit-to-stand transfer, squatting, stair negotiation, and single-leg activities, the intervention directly targets the mechanical behaviors that may provoke pain during functional loading. This mechanism helps explain why the between-group advantage was most evident for walking pain rather than uniformly across all patient-reported outcomes (14).

The superior improvement in hip lateral rotator strength in the Movement System Impairment group is also clinically meaningful. Hip lateral rotators contribute to control of femoral internal rotation and dynamic knee valgus during weight-bearing movement. Weakness or poor activation of these muscles may increase abnormal lower-limb alignment and contribute to excessive patellofemoral or tibiofemoral loading during gait and functional tasks. Because the Movement System Impairment intervention included task-specific retraining and correction of lower-limb alignment, the improvement in hip lateral rotator performance may reflect both strengthening and improved neuromuscular control. Similarly, the greater improvement in knee extensor strength is relevant because knee extensors are essential for walking, stair climbing, squatting, sit-to-stand performance, and shock absorption during functional activity. Together, the findings for hip lateral rotators and knee extensors suggest that Movement System Impairment-based care may strengthen key muscle groups while also improving their functional use during movement (15,16).

The improvement in walking-related pain is one of the most clinically interpretable findings. Walking is a high-frequency daily activity, and pain during walking often reflects impaired load transfer, altered lower-limb alignment, reduced muscular control, or compensatory movement behavior. The Movement System Impairment approach specifically evaluates and retrains walking mechanics, which may explain the significant between-group advantage for this outcome. In contrast, a general strengthening program may improve muscle capacity without consistently changing the movement pattern that triggers symptoms. This distinction is important for clinical practice because patients may report persistent pain despite improved isolated strength if faulty movement strategies remain uncorrected during real-world tasks (17).

The patient-reported outcomes further suggest that both interventions improved broader knee-related function. KOOS activities of daily living improved significantly in both groups, indicating better tolerance of routine functional demands. KOOS sport/recreation also improved in both groups, showing that exercise-based rehabilitation may support higher-demand activities even within a six-week period (18). KOOS quality of life improved significantly in the Movement System Impairment group, whereas a significant standard physiotherapy finding was not highlighted for this domain. This may indicate that individualized correction and improved confidence during functional movement contributed to broader perceived benefit. However, because quality-of-life outcomes can be influenced by pain expectations, activity confidence, baseline severity, and psychosocial factors, this finding should be interpreted as supportive rather than definitive.

The findings align with the broader concept that knee pain rehabilitation should be individualized when movement faults are clinically evident. Knee pain is heterogeneous, and patients with similar pain intensity may demonstrate different impairments (19). Some may primarily require strengthening, while others may need correction of excessive femoral rotation, dynamic valgus, altered foot mechanics, or poor control during transitional movement. A classification-based model is therefore attractive

because it attempts to match treatment to the patient's impairment profile rather than relying on a uniform protocol (20). In this context, Movement System Impairment-based treatment may be especially useful for patients whose symptoms are repeatedly reproduced during specific movement tasks and reduced when alignment or motor control is corrected.

At the same time, the results also reinforce the continuing importance of standard physiotherapy. The standard physiotherapy group improved across several outcomes, including pain, symptoms, activities of daily living, sport/recreation, hip abductor strength, and hip lateral rotator strength. These improvements show that general hip-knee strengthening, stretching, resistance exercise, education, and activity modification remain clinically valuable. For many patients, especially those without clearly identifiable movement-system faults, standard physiotherapy may be sufficient as an initial management strategy. Movement System Impairment-based treatment may be most appropriate when routine rehabilitation produces incomplete improvement, when pain is strongly linked to movement quality, or when clinical assessment demonstrates consistent faulty alignment during functional activity (16).

The results should also be interpreted in relation to intervention duration. A six-week intervention period is adequate to detect short-term changes in pain, functional tolerance, motor performance, and patient-reported outcomes, but it may not fully capture long-term recurrence, sustained activity participation, or maintenance of corrected movement patterns. Movement retraining often requires repeated practice and integration into daily behavior, and the durability of these changes may depend on adherence to home exercises, patient understanding, and continued use of corrected strategies during occupational or recreational activity. Therefore, while the short-term direction favors Movement System Impairment for selected outcomes, longer follow-up would be necessary to determine whether these benefits persist and whether recurrence is reduced.

Several methodological considerations affect interpretation of the findings. The comparison involved multiple outcomes, including KOOS domains, Tegner activity level, muscle strength, flexibility, and functional pain measures. Although this broad outcome set provides a useful clinical picture, it also increases the importance of identifying a primary endpoint and interpreting secondary outcomes cautiously. The most coherent interpretation is that the strongest comparative signal favored Movement System Impairment in walking-related pain and selected strength outcomes, while both groups improved in general pain and function. This pattern supports a targeted conclusion rather than a broad claim of superiority across all domains.

The absence of detailed numerical change values, confidence intervals, and effect sizes limits interpretation of clinical magnitude. P-values indicate whether observed differences were statistically significant, but they do not show the size or precision of treatment effects. For clinical decision-making, the magnitude of improvement in walking pain, hip lateral rotator strength, and knee extensor strength is essential. A statistically significant difference may be small, moderate, or large in practical terms, and confidence intervals would help determine the likely range of benefit. Therefore, the findings are best interpreted as evidence of a favorable short-term statistical pattern for Movement System Impairment in selected outcomes, with clinical magnitude requiring full quantitative reporting.

Overall, this study supports the role of active physiotherapy in managing unilateral non-traumatic knee pain and suggests that Movement System Impairment-based treatment may offer additional advantages when pain is linked to faulty lower-limb movement patterns. Standard physiotherapy improved pain and function, confirming its value as a practical and accessible intervention. The added benefit of Movement System Impairment appears to lie in its individualized assessment, classification of movement faults, task-specific correction, and emphasis on functional movement quality. These features may be particularly relevant for patients with walking pain, poor hip-knee control, femoral or tibial rotation faults, and recurrent symptoms during weight-bearing activities. The findings therefore support a stepped and individualized clinical approach in which standard strengthening and flexibility training

are combined with movement-system assessment and correction when functional movement impairments are present.

CONCLUSION

The Movement System Impairment approach and standard physiotherapy protocols both produced short-term improvement in pain, symptoms, functional activity, and selected muscle performance outcomes among adults with unilateral non-traumatic knee pain. Standard physiotherapy remains an effective conservative treatment when it includes progressive hip and knee strengthening, stretching, functional advice, and activity modification. However, the Movement System Impairment approach demonstrated additional benefit in walking-related knee pain, hip lateral rotator strength, and knee extensor strength, suggesting that individualized assessment and correction of faulty movement patterns may improve outcomes that depend on lower-limb alignment, hip-knee control, and functional loading. These findings support the clinical use of movement-system classification as a refinement of routine physiotherapy rather than as a replacement for exercise-based rehabilitation, particularly for patients whose knee pain is associated with dynamic valgus, femoral or tibial rotation faults, poor proximal control, or pain during repetitive weight-bearing activity.

REFERENCES

1. Arundale AJ, Bizzini M, Dix C, Giordano A, Kelly R, Logerstedt DS, et al. Exercise-based knee and anterior cruciate ligament injury prevention: clinical practice guidelines linked to the international classification of functioning, disability and health from the Academy of Orthopaedic Physical Therapy and the American Academy of Sports Physical Therapy. J Orthop Sports Phys Ther. 2023;53(1):CPG1-CPG34.

2. Enseki KR, Bloom NJ, Harris-Hayes M, Cibulka MT, Disantis A, Di Stasi S, et al. Hip pain and movement dysfunction associated with nonarthritic hip joint pain: a revision: clinical practice guidelines linked to the international classification of functioning, disability, and health from the Academy of Orthopaedic Physical Therapy and American Academy of Sports Physical Therapy of the American Physical Therapy Association. J Orthop Sports Phys Ther. 2023;53(7):CPG1-CPG70.

3. Farazdaghi M, Razeghi M, Sobhani S, Raeisi-Shahraki H, Haghighi MA, Farazdaghi M, et al. Knee impairments: comparison between new clinical classification by cluster analysis and movement system impairment model. J Bodyw Mov Ther. 2022;30:210-20.

4. Farazdaghi M, Sadeghi H, Alipour Haghighi M, Alshammari SM. Comparing the movement system impairment method and routine physical therapy for knee pain: a randomized clinical trial. Life. 2025;15(2):179.

5. George SZ, Fritz JM, Silfies SP, Schneider MJ, Beneciuk JM, Lentz TA, et al. Interventions for the management of acute and chronic low back pain: revision 2021: clinical practice guidelines linked to the international classification of functioning, disability and health from the Academy of Orthopaedic Physical Therapy of the American Physical Therapy Association. J Orthop Sports Phys Ther. 2021;51(11):CPG1-CPG60.

6. Hinman RS, Kimp AJ, Campbell PK, Russell T, Foster NE, Kasza J, et al. Technology versus tradition: a non-inferiority trial comparing video to face-to-face consultations with a physiotherapist for people with knee osteoarthritis. Protocol for the PEAK randomised controlled trial. BMC Musculoskelet Disord. 2020;21(1):522.

7. Larson D, Vu V, Ness BM, Wellsandt E, Morrison S. A multi-systems approach to human movement after ACL reconstruction: the musculoskeletal system. Int J Sports Phys Ther. 2021;17(1):27.

8. Ludewig PM, Saini G, Hellem A, Kahnert EK, Rezvanifar SC, Braman JP, et al. Changing our diagnostic paradigm part II: movement system diagnostic classification. Int J Sports Phys Ther. 2022;17(1):7.

9. Mousavi F, Kajbafvala M, Mohsenifar H, Salehi R, Hejazi A. The effect of movement system impairment-based classification treatment compared to routine physiotherapy on pain, disability, alignment, and movement impairments in individuals with tibiofemoral rotation syndrome: a randomized controlled trial. BMC Sports Sci Med Rehabil. 2024;16(1):94.

10. Paarthasarathy K, Soundararajan K, Asser PAL, Subbiah K, Chrysolyte M. Effectiveness of movement system impairment-based classification treatment on clinical outcomes among subjects with tibiofemoral hypomobility syndrome: a randomized controlled trial. J Bodyw Mov Ther. 2025.

11. Penichet-Tomas A. Applied biomechanics in sports performance, injury prevention, and rehabilitation. Sports. 2024;14:11623.

12. Zamani P, Kalantari KK, Fashkhami AN, Baghban AA, Mehravar M, Yazdi MS. Efficacy of treatment based on the movement system impairment classification in people with knee pain: a study protocol. Iran Red Crescent Med J. 2022;24:e1767.

13. Zhu S, Qu W, He C. Evaluation and management of knee osteoarthritis. J Evid Based Med. 2024;17(3):675-87.

14. García-Rodríguez P, Pecci J, Vázquez-González S, Pareja-Galeano H. Acute and Chronic Effects of Blood Flow Restriction Training in Physically Active Patients With Anterior Cruciate Ligament Reconstruction: A Systematic Review. Sports Health. 2024;16(5):820-8.

15. Kamel AM, Ghuiba K, Abd Allah DS, Fayaz NA, Abdelkader NA. Effect of adding short foot exercise to hip and knee focused exercises in treatment of patients with patellofemoral pain syndrome: a randomized controlled trial. J Orthop Surg Res. 2024;19(1):207.

16. Nelligan RK, Hinman RS, Kasza J, Crofts SJC, Bennell KL. Effects of a Self-directed Web-Based Strengthening Exercise and Physical Activity Program Supported by Automated Text Messages for People With Knee Osteoarthritis: A Randomized Clinical Trial. JAMA Intern Med. 2021;181(6):776-85.

17. Uhlrich SD, Mazzoli V, Silder A, Finlay AK, Kogan F, Gold GE, et al. Personalised gait retraining for medial compartment knee osteoarthritis: a randomised controlled trial. Lancet Rheumatol. 2025;7(10):e708-e18.

18. Hansen R, Brushøj C, Rathleff MS, Magnusson SP, Henriksen M. Quadriceps or hip exercises for patellofemoral pain? A randomised controlled equivalence trial. Br J Sports Med. 2023;57(20):1287-94.

19. Xiang XN, Wang ZZ, Hu J, Zhang JY, Li K, Chen QX, et al. Telehealth-Supported Exercise or Physical Activity Programs for Knee Osteoarthritis: Systematic Review and Meta-Analysis. J Med Internet Res. 2024;26:e54876.

20. Abafita BJ, Singh A, Aitken D, Ding C, Moonaz S, Palmer AJ, et al. Yoga or Strengthening Exercise for Knee Osteoarthritis: A Randomized Clinical Trial. JAMA Netw Open. 2025;8(4):e253698.