Effects Of Mulligan Mobilization on Neuromechanical Changes, Weight-Bearing Function and Clinical Outcomes in Knee Osteoarthritis: A Systematic Review

Nidhi S Shetty[1], Rushikesh Patil[2], Aishwarya Shinde[3], Tanvi Bhujbal[4], Shantanu Kshirsagar[5], Siddhi Patrekar[6], Sakshi Desai[7]
[1,2,3]*MPTh, Krishna Vishwa Vidyapeeth (Deemed to be University), Karad*

***Abstract*—Knee osteoarthritis (KOA) is a leading cause of chronic pain, muscle weakness, and functional decline in adults. Mulligan's mobilization with movement (MWM) is a manual therapy technique that combines a sustained accessory glide with active physiological movement, and has been proposed to reduce pain, correct altered joint arthrokinematics, and restore neuromuscular control during weight-bearing activity. This systematic review aimed to evaluate the effects of Mulligan mobilization on neuromechanical changes, weight-bearing function, and clinical outcomes in individuals with knee osteoarthritis. A comprehensive literature search was conducted using PubMed, Google Scholar, Scopus, ScienceDirect, Web of Science, PEDro, and ClinicalTrials.gov for studies published between 2010 and 2026. Only randomized controlled trials and cross-sectional studies were eligible for inclusion. Risk of bias was assessed using the Revised Cochrane Risk of Bias tool (RoB 2) for randomized controlled trials and the Appraisal tool for Cross-Sectional Studies (AXIS) for cross-sectional studies. A total of 10 studies (6 randomized controlled trials and 4 cross-sectional studies) met the eligibility criteria and were included in this review. The included randomized controlled trials showed that Mulligan MWM, whether delivered alone, combined with isometric or proprioceptive exercise, or compared against Maitland mobilization, produced consistent short-term improvements in pain, quadriceps strength, functional mobility, and disability scores in individuals with knee osteoarthritis. The cross-sectional studies demonstrated that weight-bearing asymmetry, trunk movement asymmetry, reduced quadriceps rate of force development, and diminished weight-bearing quadriceps strength are clinically important neuromechanical impairments associated with pain and disability in knee osteoarthritis, providing a mechanistic rationale for weight-bearing manual therapy. Most randomized controlled trials were judged to raise 'some concerns' on the RoB 2 tool, chiefly due to the inherent difficulty of blinding participants and treating therapists to a manual therapy intervention, while the cross-sectional studies demonstrated generally good methodological quality on the AXIS tool, with the principal limitations relating to sample representativeness and non-response bias. This review concludes that Mulligan mobilization is a safe and clinically useful adjunct for improving pain, neuromuscular activation, weight-bearing symmetry, and functional performance in knee osteoarthritis, and that the observed neuromechanical impairments in this population including weight-bearing and trunk movement asymmetry and reduced quadriceps force generation support its proposed mechanism of action. Larger, long-term, high-quality randomized controlled trials incorporating objective biomechanical outcome measures are needed to confirm these findings and to establish standardized treatment protocols.**

***Index Terms*—Mulligan mobilization; mobilization with movement; knee osteoarthritis; weight-bearing asymmetry; neuromechanics; systematic review.**

I. INTRODUCTION

Knee osteoarthritis (KOA) is a prevalent, progressive degenerative joint disorder characterized by articular cartilage loss, subchondral bone remodeling, and synovial inflammation, and it remains one of the leading global causes of chronic pain and physical disability in middle-aged and older adults [1,2]. Pain, stiffness, and quadriceps weakness are the dominant clinical features of the condition, and together they compromise activities of daily living such as walking, stair negotiation, and rising from a chair [2,9].

Beyond pain and strength loss, knee osteoarthritis is increasingly recognized to disturb the neuromechanical control of movement. Individuals with knee OA frequently display asymmetrical weight-bearing during functional tasks such as sit-to-stand transitions, altered trunk movement patterns during gait, and a disproportionate loss of the quadriceps' capacity to generate force rapidly (rate of force development), independent of maximal strength loss alone [7,8,10]. These impairments are not simply consequences of pain; they are believed to reflect arthrogenic muscle inhibition, altered afferent input from the joint, and compensatory motor strategies that further load the joint asymmetrically, potentially accelerating disease progression [8,9].

Mulligan's mobilization with movement (MWM) is a manual therapy technique developed by Brian Mulligan that combines a therapist-applied, pain-free, sustained accessory glide of the joint with the patient's simultaneous active physiological movement, typically performed in a functional or weight-bearing position [2]. The proposed mechanism of MWM is correction of a minor positional fault within the joint, together with neurophysiological effects such as stimulation of mechanoreceptors, modulation of nociceptive input, and facilitation of pain-free motor activation, which in turn is thought to restore more normal weight-bearing and neuromuscular control during functional movement [3,4].

A growing body of randomized controlled trial evidence has examined the clinical effects of Mulligan mobilization on pain and disability in knee OA, both in isolation and combined with exercise-based rehabilitation, and several trials have directly compared it against alternative manual therapy techniques such as Maitland mobilization [1–6]. In parallel, a separate body of cross-sectional evidence has characterized the neuromechanical and weight-bearing impairments that are believed to underlie MWM's proposed mechanism of benefit, including weight-bearing asymmetry, trunk movement asymmetry, and deficits in quadriceps strength and rate of force development [7–10]. However, no recent systematic review has brought together randomized controlled trial evidence on the clinical effects of Mulligan mobilization alongside cross-sectional evidence characterizing the underlying neuromechanical and weight-bearing impairments in knee osteoarthritis.

Therefore, the present systematic review aimed to synthesize randomized controlled trial and cross-sectional evidence, published between 2010 and 2026, on the effects of Mulligan mobilization on neuromechanical changes, weight-bearing function, and clinical outcomes in individuals with knee osteoarthritis. The findings of this review are intended to inform evidence-based use of Mulligan mobilization in the physiotherapeutic management of knee osteoarthritis and to identify the neuromechanical impairments most relevant to targeted rehabilitation.

II. METHODOLOGY

Study design

This systematic review was conducted according to evidence-based systematic review methodology and reported in line with the general principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. Only randomized controlled trials and cross-sectional studies were considered eligible for inclusion. Risk of bias was assessed using the Revised Cochrane Risk of Bias tool (RoB 2) for randomized controlled trials and the Appraisal tool for Cross-Sectional Studies (AXIS) for cross-sectional studies.

Search strategy

A comprehensive electronic literature search was performed across PubMed, Google Scholar, Scopus, ScienceDirect, Web of Science, PEDro, and ClinicalTrials.gov to identify studies examining the effects of Mulligan mobilization and related neuromechanical and weight-bearing outcomes in individuals with knee osteoarthritis, published between January 2010 and July 2026. Medical Subject Headings (MeSH) terms and free-text keywords including “Mulligan mobilization,” “mobilization with movement,” “MWM,” “knee osteoarthritis,” “weight-bearing asymmetry,” “neuromechanics,” “quadriceps strength,” “rate of force development,” “trunk movement asymmetry,” “gait,” and “clinical outcomes” were combined using the Boolean operators “AND” and “OR.” Reference lists of relevant systematic reviews and meta-analyses were manually screened to identify additional eligible primary studies. The search was restricted to peer-reviewed articles published in English.

The initial search identified 624 records. After removal of duplicate records,268 titles and abstracts were screened. Of these, 172 records were excluded as clearly irrelevant (wrong condition, wrong joint, animal or cadaveric studies, or non-English language). The full texts of the remaining 96 articles were assessed for eligibility, of which 76 were excluded (27 were narrative reviews, systematic reviews, or meta-analyses; 21 used study designs other than randomized controlled trials or cross-sectional studies, such as case series, case reports, or study protocols without reported outcome data; 15 did not report an eligible outcome measure related to Mulligan mobilization, neuromechanics, or weight-bearing function in knee osteoarthritis; and 13 were duplicate reports of the same trial). A total of 10 studies (6 randomized controlled trials and 4 cross-sectional studies) satisfied the eligibility criteria and were included in the final synthesis.

Inclusion criteria

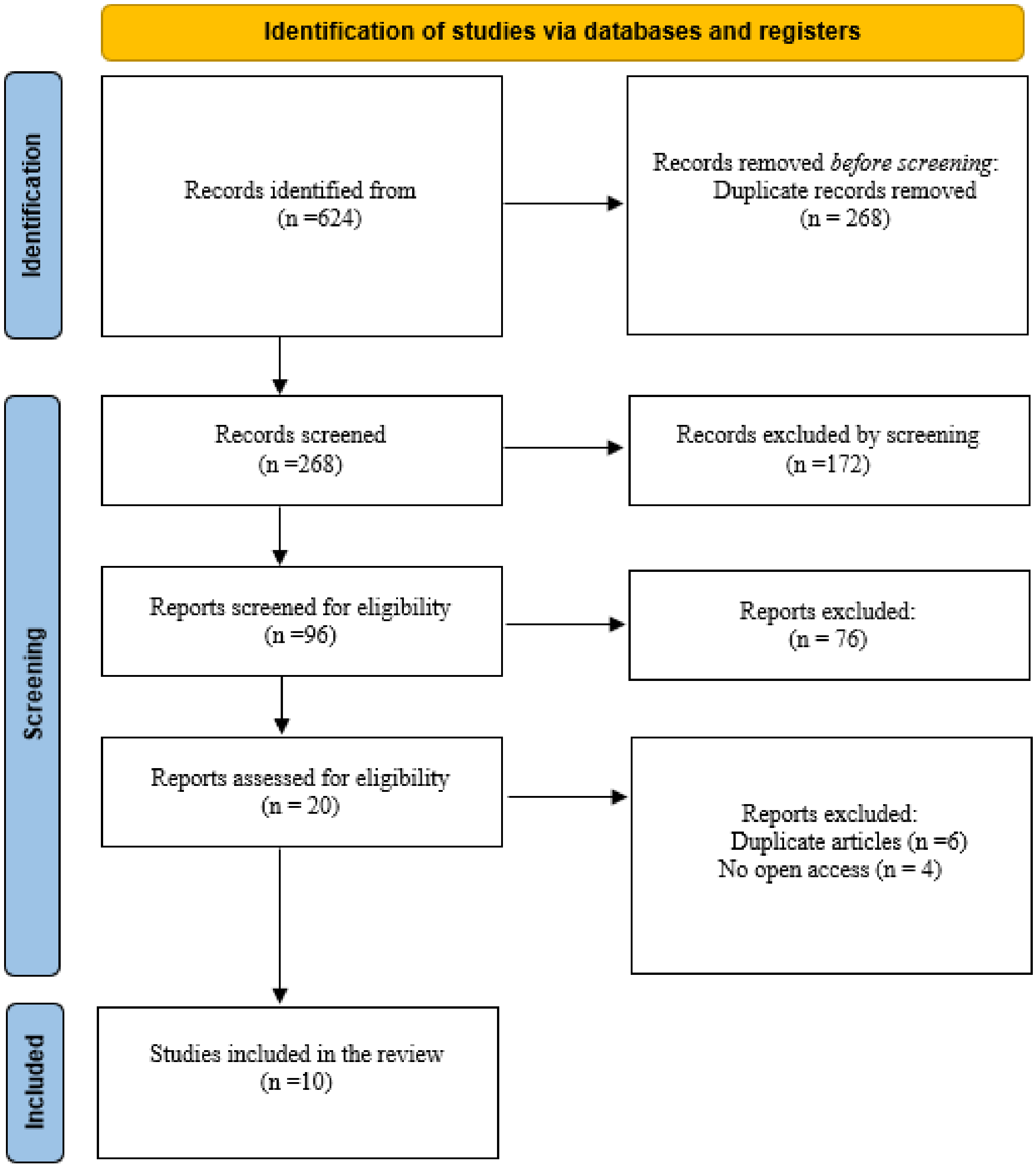
Studies were included if they: (1) were published as a randomized controlled trial or a cross-sectional study; (2) were published in a peer-reviewed English-language journal between January 2010 and July 2026; (3) enrolled adult participants (≥18 years) with a clinical or radiographically confirmed diagnosis of knee osteoarthritis; (4) evaluated Mulligan's mobilization with movement as an intervention, or reported a neuromechanical, weight-bearing, or functional/clinical outcome directly relevant to the mechanism or effect of Mulligan mobilization in knee osteoarthritis (for example, weight-bearing asymmetry, trunk movement asymmetry, quadriceps strength or rate of force development, pain, functional mobility, or disability); and (5) reported extractable outcome data.

Exclusion criteria

Studies were excluded if they were narrative reviews, systematic reviews, meta-analyses, case reports, case series, qualitative studies, conference abstracts without full data, animal or cadaveric studies, or unpublished study protocols without reported results. Studies examining knee joints other than osteoarthritic knees (for example, post-traumatic, inflammatory arthritic, or post-arthroplasty knees studied in isolation from an osteoarthritis population), studies of pediatric populations, and studies not available in English were also excluded. Studies published before 2010 or after July 2026 were not considered for inclusion.

Quality assessment

The methodological quality of the included studies was independently appraised in accordance with study design. The Revised Cochrane Risk of Bias tool (RoB 2) was used to appraise the six included randomized controlled trials across five domains: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in measurement of the outcome, and bias in selection of the reported result, with an overall judgement of low risk, some concerns, or high risk. The Appraisal tool for Cross-Sectional Studies (AXIS) was used to appraise the four included cross-sectional studies across 20 items addressing study aims, design, sample selection, measurement validity, statistical analysis, and reporting quality. Because Mulligan mobilization is a hands-on manual therapy, blinding of participants and treating therapists to group allocation is inherently difficult; this was anticipated and considered when interpreting the performance- and detection-bias-related domains of the RoB2assessment.


Identification of studies via databases and registers
Identification
Records identified from
(n =624)
Records removed before screening:
Duplicate records removed
(n = 268)
Screening
Records screened
(n =268)
Records excluded by screening
(n =172)
Reports screened for eligibility
(n =96)
Reports excluded:
(n = 76)
Reports assessed for eligibility
(n = 20)
Reports excluded:
Duplicate articles (n =6)
No open access (n = 4)
Included
Studies included in the review
(n =10)

III. RESULT

A total of 10 studies met the predefined eligibility criteria for this review: six randomized controlled trials evaluating the clinical effects of Mulligan mobilization in knee osteoarthritis [1–6], and four cross-sectional studies characterizing weight-bearing and neuromechanical impairments relevant to knee osteoarthritis [7–10]. Study characteristics, interventions, outcome measures, results, and conclusions are summarized in Table 1.

Table 1. Characteristics and findings of included studies (n = 10).

Author(s) / Year	Study Design	Sample Size	Outcome Measures	Intervention	Results	Conclusion
Nazir SNB & Rathore FA (2024) [1]	Three-arm Randomized Controlled Trial	60	KOOS (pain, ADL) VAS (rest, stairs) 6-Minute Walk Test 11-Stair Climb Test	Mulligan MWM + kinesiotaping + isometric knee strengthening vs. trunk stabilization exercise (TSE) vs. isometric strengthening alone; 24 sessions over 6 weeks	All groups improved significantly from baseline ($p<0.05$). MWM produced significant reductions in pain and gains in 6MWT/SCT, though TSE showed the largest mean improvements.	Mulligan MWM is an effective adjunct for pain and functional mobility in KOA, though trunk-focused exercise showed comparatively greater efficacy in this cohort.
Hasan S et al. (2026) [2]	Two-arm, Double-masked Randomized Controlled Trial	50	VAS pain Isometric quadriceps peak torque (dynamometry) WOMAC disability	Mulligan MWM (tibiofemoral glide, non-weight-bearing progressing to weight-bearing) + isometric training vs. isometric training alone; 5 sessions/week for 6 weeks	Significant Group×Time interaction favouring MWM+IT for pain, quadriceps strength and disability (all $p<0.0001$), indicating faster and larger six-week gains than isometric training alone.	Adding Mulligan MWM to isometric training accelerates early neuromuscular activation and functional recovery in knee OA.
Bhagat M et al. (2020) [3]	Randomized Controlled Trial (sham-controlled)	30	Numeric Pain Rating Scale Timed Up and Go (TUG) test	Single-session Mulligan MWM (medial tibiofemoral glide) vs. sham mobilization	Both groups showed a statistically significant reduction in pain; the MWM group additionally showed a significant improvement in TUG performance compared with sham.	A single session of Mulligan MWM produces immediate, measurable gains in functional mobility beyond a sham effect.
Gupta R & Heggannavar A (2015) [4]	Randomized Controlled Trial	30	Proprioceptive acuity Functional/pain status	Mulligan MWM (medial glide and medial rotation glide, weight-bearing and non-weight-bearing) plus conventional therapy vs. proprioceptive exercise and conventional therapy alone; 7-day protocol	The MWM-added group demonstrated greater quantitative improvement in proprioceptive acuity and functional performance than the proprioceptive-exercise-only group.	Mulligan MWM enhances the neuromuscular and proprioceptive benefit of exercise-based therapy in knee OA.

Author(s) / Year	Study Design	Sample Size	Outcome Measures	Intervention	Results	Conclusion
Lalnunpuii A et al. (2017) [5]	Double-blind Randomized Controlled Trial (females only)	Not fully reported (two-arm parallel design)	Pain Range of motion Functional score	Mulligan mobilization vs. Maitland mobilization, both combined with standard exercise therapy	The Mulligan group showed significantly greater improvement in flexibility and functional outcome scores than the Maitland group.	Mulligan mobilization produced superior short-term functional gains compared with Maitland mobilization in women with knee OA.
Kiran A et al. (2018) [6]	Randomized Clinical Trial	Two-arm parallel design (sample not fully reported in available abstract)	Pain Disability / functional score	Mulligan MWM with conventional therapy vs. Maitland mobilization with conventional therapy	The Mulligan MWM group achieved superior functional outcomes relative to the Maitland-based comparison group.	Incorporating Mulligan MWM into conventional rehabilitation yields better functional results than Maitland-based mobilization alone.
Christiansen CL & Stevens-Lapsley JE (2010) [7]	Cross-sectional study (age-matched control group)	67 (50 knee OA; 17 healthy controls)	Weight-bearing asymmetry (vertical ground reaction force, sit-to-stand) Knee extensor strength asymmetry Knee motion asymmetry 6MWT, Stair-Climb Test	Observational comparison; no intervention delivered	The knee OA group displayed significantly greater weight-bearing asymmetry than healthy controls; asymmetry correlated with quadriceps strength asymmetry and reduced functional mobility.	Weight-bearing asymmetry is a clinically relevant, modifiable impairment in knee OA, supporting the rationale for weight-bearing manual therapy such as Mulligan MWM.
Iijima H et al. (2019) [8]	Cross-sectional study	131	Trunk movement asymmetry (inertial measurement unit, harmonic ratio) Quadriceps and hip-abductor isometric strength Pain and disability questionnaire	Observational gait analysis; no intervention delivered	Greater medio-lateral trunk movement asymmetry was associated with greater knee pain, disability, and inter-limb quadriceps strength asymmetry.	Trunk movement asymmetry is a neuromechanical marker of impairment in knee OA and a plausible target for mobilization-based rehabilitation.
Muraki S et al. (2015) [9]	Cross-sectional study (population-based cohort, ROAD study)	2,152	Quadriceps isometric strength Weight-bearing index Knee pain Radiographic K-L grade	Observational; no intervention delivered	Quadriceps strength and weight-bearing index were independently associated with knee pain after adjustment for radiographic severity, age, and BMI; grip strength	Weight-bearing quadriceps strength, rather than muscle mass, is an independent determinant of knee pain, reinforcing a mechanistic

Author(s) / Year	Study Design	Sample Size	Outcome Measures	Intervention	Results	Conclusion
					and muscle mass were not.	rationale for weight-bearing neuromuscular interventions.
Suzuki Y et al. (2022) [10]	Cross-sectional study (preliminary)	Mild K-L 1–2 and severe K-L 3–4 knee OA groups	Quadriceps rate of force development (RFD) Maximum isometric quadriceps strength	Observational; no intervention delivered	Individuals with severe knee OA had significantly lower quadriceps RFD than those with mild OA; the decline in RFD exceeded the decline in maximal strength.	Rapid force-generation capacity of the quadriceps deteriorates disproportionately as knee OA progresses, identifying a neuromechanical impairment relevant to rehabilitation targeting.

Assessment of Risk of Bias

Every included study underwent a formal risk-of-bias assessment appropriate to its design in order to evaluate the reliability of the synthesized evidence.

According to the RoB 2 assessment (Table 2), the six included randomized controlled trials generally demonstrated a low risk of bias arising from the randomization process, with most trials employing computer-generated allocation sequences and, where reported, concealed allocation. However, because Mulligan mobilization is a manually delivered, hands-on technique, blinding of participants and treating therapists to their allocated intervention was not feasible in any of the included trials, which raised some concerns regarding deviations from intended interventions across all six trials. Missing outcome data were generally low risk, reflecting short intervention periods (1 session to 6 weeks) and low attrition. Measurement of the outcome was judged low risk where a blinded outcome assessor was explicitly reported [1,2,3,5], and some concerns where blinding of assessment was not clearly reported [4,6]. Selection of the reported result was judged low risk for prospectively registered trials with pre-specified outcomes [1,2] and some concerns for the remaining trials, where outcome pre-specification could not be confirmed from the published report. Overall, all six randomized controlled trials were rated as raising "some concerns," indicating generally acceptable methodological quality tempered by the performance-bias limitations inherent to manual therapy research.

According to the AXIS tool assessment (Table 3), the four included cross-sectional studies demonstrated generally good methodological quality. All four studies clearly stated their aims, used an appropriate cross-sectional design, defined their target population, and used an appropriate sampling frame. The large, population-based ROAD study [9] additionally justified its sample size and reported information on non-respondents, whereas the remaining three studies [7,8,10], being smaller clinical-laboratory investigations, raised some concerns regarding sample size justification and the representativeness of the selection process, and did not report detailed information about non-participants. All four studies used validated, previously published outcome measurement tools, described their statistical methods and results in adequate detail, and reported ethical approval and conflicts of interest. Overall, the cross-sectional evidence was judged to be of good methodological quality, with the principal limitations relating to sample representativeness and non-response bias rather than to measurement validity or internal consistency of reporting.

Table 2. Risk of bias assessment of included randomized controlled trials using the RoB 2 tool.

Study	Bias arising from the randomization process	Bias due to deviations from intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall risk of bias
Nazir SNB & Rathore FA (2024)	Low risk	Some concerns	Low risk	Low risk	Low risk	Some concerns
Hasan S et al. (2026)	Low risk	Some concerns	Low risk	Low risk	Low risk	Some concerns
Bhagat M et al. (2020)	Some concerns	Some concerns	Low risk	Low risk	Some concerns	Some concerns
Gupta R & Heggannavar A (2015)	Some concerns	Some concerns	Low risk	Some concerns	Some concerns	Some concerns
Lalnunpuii A et al. (2017)	Low risk	Some concerns	Low risk	Low risk	Some concerns	Some concerns
Kiran A et al. (2018)	Some concerns	Some concerns	Low risk	Some concerns	Some concerns	Some concerns

Table 3. Quality assessment of included cross-sectional studies using the AXIS tool.

AXIS appraisal question	Christiansen & Stevens-Lapsley (2010)	Iijima et al. (2019)	Muraki et al. (2015)	Suzuki et al. (2022)
Were the aims/objectives of the study clear?	Yes	Yes	Yes	Yes
Was the study design appropriate for the aims?	Yes	Yes	Yes	Yes
Was the sample size justified?	Some concerns	Yes	Yes	Some concerns
Was the target population clearly defined?	Yes	Yes	Yes	Yes
Was the sampling frame appropriate?	Yes	Yes	Yes	Yes
Was the selection process likely to be representative?	Some concerns	Some concerns	Yes	Some concerns
Were measures taken to address non-responders?	No	No	Yes	No
Were the outcome variables measured appropriately?	Yes	Yes	Yes	Yes
Were the measurement tools previously piloted/validated?	Yes	Yes	Yes	Yes
Was statistical significance clearly determined?	Yes	Yes	Yes	Yes
Were the methods described in enough detail?	Yes	Yes	Yes	Yes
Were the basic data adequately described?	Yes	Yes	Yes	Yes
Is there concern regarding non-response bias?	Some concerns	Some concerns	Low	Some concerns
Was information about non-respondents described?	No	No	Yes	No
Were the results internally consistent?	Yes	Yes	Yes	Yes
Were all pre-specified results presented?	Yes	Yes	Yes	Yes
Were discussions and conclusions justified by the results?	Yes	Yes	Yes	Yes
Were study limitations discussed?	Yes	Yes	Yes	Yes
We’re funding sources / conflicts of interest reported?	Yes	Yes	Yes	Yes
Was ethical approval / informed consent obtained?	Yes	Yes	Yes	Yes

IV. DISCUSSION

This systematic review synthesized evidence from six randomized controlled trials and four cross-sectional studies to evaluate the effects of Mulligan mobilization on neuromechanical changes, weight-bearing function, and clinical outcomes in individuals with knee osteoarthritis. Taken together, the findings indicate that Mulligan MWM produces consistent short-term improvements in pain, quadriceps strength, and functional performance, and that these clinical benefits are biologically plausible given the well-documented weight-bearing and neuromechanical impairments that characterize knee osteoarthritis (Table 1).

The randomized controlled trials included in this review consistently demonstrated that Mulligan MWM improves pain and functional outcomes in knee osteoarthritis, whether delivered as a single-session intervention or as a multi-week rehabilitation program. Hasan et al. (2026) found that adding Mulligan MWM to a structured isometric strengthening program produced significantly faster and larger six-week improvements in pain, quadriceps strength, and WOMAC disability than isometric strengthening alone, with large Group×Time interaction effects across all three outcomes [2]. This finding is consistent with the proposed mechanism of MWM: by providing pain-free accessory glide during active movement, MWM is thought to reduce nociceptive inhibition of the quadriceps and thereby facilitate more effective neuromuscular strengthening, particularly during the early, pain-limited phase of rehabilitation [2,4].

Similarly, Bhagat et al. (2020) demonstrated that even a single session of Mulligan MWM produced an immediate, clinically meaningful improvement in functional mobility, as measured by the Timed Up and Go test, beyond the effect achieved with sham mobilization [3]. This immediate benefit supports the hypothesis that MWM acts, at least in part, through rapid neurophysiological mechanisms, such as stimulation of mechanoreceptors and modulation of pain-related motor inhibition, rather than solely through cumulative tissue adaptation over multiple sessions [3,4]. Gupta and Heggannavar (2015) extended this mechanistic picture by showing that adding Mulligan MWM, delivered in both weight-bearing and non-weight-bearing positions, to a proprioceptive exercise program produced greater gains in proprioceptive acuity and function than proprioceptive exercise alone, suggesting that the weight-bearing component of MWM may be particularly important for restoring joint position sense and neuromuscular control during functional loading [4].

Two of the included trials directly compared Mulligan mobilization with Maitland mobilization, a related but distinct passive joint-mobilization technique. Lalnunpuii et al. (2017) reported that Mulligan mobilization produced significantly greater improvements in flexibility and functional scores than Maitland mobilization in a cohort of women with knee osteoarthritis [5], and Kiran et al. (2018) similarly found that Mulligan MWM combined with conventional therapy produced superior functional outcomes compared with Maitland mobilization combined with conventional therapy [6]. These comparative findings suggest that the active, patient-driven movement component that distinguishes MWM from purely passive mobilization techniques may confer an additional neuromuscular training benefit, consistent with the concept that combining accessory glide with active physiological movement encourages more functional, task-specific motor relearning [5,6].

Not all comparative evidence favoured Mulligan mobilization over alternative approaches. Nazir and Rathore (2024) found that although Mulligan MWM combined with kinesiotaping and knee strengthening produced significant within-group improvements in pain, the Knee Injury and Osteoarthritis Outcome Score, the 6-minute walk test, and the stair-climb test, a trunk stabilization exercise program delivered with the same adjuncts produced numerically greater improvements across most of these outcomes over a six-week, 24-session protocol [1]. This finding is a useful reminder that Mulligan MWM should be regarded as one effective component within a broader, multimodal rehabilitation strategy for knee osteoarthritis rather than a stand-alone replacement for structured exercise therapy, a conclusion echoed by Hasan et al. (2026), who similarly framed MWM as a complementary adjunct to isometric training rather than a substitute for it [1,2].

The cross-sectional evidence included in this review provides an important mechanistic complement to the randomized controlled trial findings by characterizing the specific neuromechanical and weight-bearing impairments that Mulligan mobilization is theorized to address. Christiansen and Stevens-Lapsley (2010) demonstrated that individuals with end-stage unilateral knee osteoarthritis exhibit significantly greater weight-bearing asymmetry during a sit-to-stand task than healthy age-matched controls, and that this asymmetry is correlated with quadriceps strength asymmetry and reduced functional mobility [7]. Because Mulligan MWM is frequently applied in a weight-bearing position with the explicit aim of restoring pain-free, symmetrical loading of the affected limb, this cross-sectional finding lends direct biomechanical support to the weight-bearing application of MWM described in several of the included trials [2,4,7].

Iijima et al. (2019) extended this line of evidence to the trunk, demonstrating that greater medio-lateral trunk movement asymmetry during gait was independently associated with greater knee pain, disability, and inter-limb quadriceps strength asymmetry in a cohort of 131 individuals with knee osteoarthritis [8]. This finding suggests that the neuromechanical consequences of knee osteoarthritis extend proximally beyond the knee joint itself, and it raises the possibility that interventions such as Mulligan MWM, which aim to restore more normal knee joint arthrokinematics during functional movement, may have secondary benefits for whole-limb and trunk movement control that were not directly measured in the included randomized controlled trials [8].

The large, population-based cross-sectional study by Muraki et al. (2015), drawn from the ROAD cohort of 2,152 participants, showed that quadriceps strength and the weight-bearing index (quadriceps strength relative to body weight) were independently associated with knee pain, whereas grip strength and lower-limb muscle mass were not [9]. This finding reinforces that weight-bearing muscular strength, rather than muscle bulk alone, is the more clinically relevant neuromuscular target in knee osteoarthritis, providing further rationale for interventions such as Mulligan MWM that specifically combine joint mobilization with active, loaded movement [2,4,9]. Complementing this, Suzuki et al. (2022) demonstrated that individuals with severe knee osteoarthritis show a disproportionately greater decline in quadriceps rate of force development than in maximal quadriceps strength compared with individuals with mild osteoarthritis, indicating that the speed of neuromuscular activation, and not only its magnitude, deteriorates as the disease progresses [10]. This observation suggests that future trials of Mulligan mobilization and related neuromuscular interventions should consider incorporating rate-of-force-development measures, rather than relying on maximal strength testing alone, to more fully capture treatment-related neuromechanical change [10].

Collectively, the cross-sectional findings support a coherent mechanistic narrative: knee osteoarthritis is associated with weight-bearing asymmetry, proximal (trunk) movement asymmetry, and a disproportionate decline in the speed and magnitude of quadriceps force generation, all of which are plausible physiological targets for a manual therapy technique such as Mulligan MWM that is specifically designed to restore pain-free, symmetrical, weight-bearing movement [7–10]. The randomized controlled trial evidence, in turn, demonstrates that Mulligan MWM produces measurable short-term improvements in pain, strength, and function that are consistent with this mechanistic rationale, whether delivered alone, in combination with exercise, or against an active comparator [1–6].

Several limitations of the included evidence base should be considered. Sample sizes across the randomized controlled trials were generally modest (ranging from approximately 30 to 60 participants), which limits statistical power to detect between-group differences and constrains the generalizability of the findings. Intervention protocols, treatment duration, and comparator interventions varied considerably across trials, introducing clinical heterogeneity that precluded meta-analytic pooling of effect sizes in this review. As is inherent to manual therapy research, blinding of participants and treating therapists to group allocation was not achieved in any of the included trials, raising the possibility of performance bias, although outcome assessors were blinded in several trials. Long-term follow-up data beyond six weeks were limited across the included trials, so the durability of the clinical benefits of Mulligan mobilization remains uncertain. Similarly, none of the included randomized controlled trials incorporated objective, instrumented measures of weight-bearing or trunk movement asymmetry as outcome measures, meaning that the mechanistic link between Mulligan MWM and the neuromechanical impairments identified in the cross-sectional literature remains inferential rather than directly demonstrated within a single study.

Despite these limitations, the overall methodological quality of the included studies was judged to be moderate to good, and the body of evidence consistently favored a beneficial short-term effect of Mulligan mobilization on pain, strength, and function in knee osteoarthritis. Future research should prioritize larger, multicenter randomized controlled trials with standardized Mulligan MWM protocols, active comparator arms, extended follow-up beyond six weeks, and the incorporation of objective biomechanical outcome measures such as instrumented weight-bearing asymmetry, gait-based trunk movement asymmetry, and quadriceps rate of force development, in order to directly link the clinical effects of Mulligan mobilization to the underlying neuromechanical impairments characterized in the cross-sectional literature.

V. CONCLUSION

This systematic review of six randomized controlled trials and four cross-sectional studies indicates that Mulligan mobilization with movement produces consistent short-term improvements in pain, quadriceps strength, functional mobility, and disability in individuals with knee osteoarthritis, whether applied alone, combined with exercise-based rehabilitation, or compared against Maitland mobilization. The cross-sectional evidence demonstrates that knee osteoarthritis is characterized by clinically relevant weight-bearing asymmetry, trunk movement asymmetry, and a disproportionate decline in quadriceps rate of force development, providing a coherent neuromechanical rationale for the weight-bearing, movement-based design of Mulligan mobilization. These findings support the use of Mulligan mobilization as an effective, low-risk adjunct within a broader, multimodal physiotherapy program for knee osteoarthritis. Given the modest sample sizes, short follow-up periods, and absence of instrumented biomechanical outcome measures across the current randomized controlled trial evidence, larger and longer-term trials incorporating objective neuromechanical assessment are recommended to confirm these findings and to establish standardized, evidence-based Mulligan mobilization protocols for clinical practice.

REFERENCES

[1] S. N. B. Nazir and F. A. Rathore, "Efficacy of Mulligan joint mobilizations and trunk stabilization exercises versus isometric knee strengthening in the management of knee osteoarthritis: A randomized controlled trial," *BMC Sports Science, Medicine and Rehabilitation*, vol. 16, p. 105, 2024.

[2] S. Hasan, A. Iqbal, A. R. Ibrahim, R. H. Diab, Z. A. Iqbal, T. Hasan, S. Anwer, and A. H. Alghadir, "Mobilization with movement enhances early rehabilitation outcomes in knee osteoarthritis: A six-week randomized controlled trial," *Chiropractic & Manual Therapies*, vol. 34, p. 11, 2026.

[3] M. Bhagat, Y. V. R. Neelapala, and R. Gangavelli, "Immediate effects of Mulligan's techniques on pain and functional mobility in individuals with knee osteoarthritis: A randomized control trial," *Physiotherapy Research International*, vol. 25, p. e1812, 2020.

[4] R. Gupta and A. Heggannavar, "Quantitative effects of proprioceptive exercises and Mulligan's MWM in subjects with osteoarthritis knee – A randomized controlled trial," *International Journal of Therapy and Rehabilitation Research*, vol. 4, no. 4, p. 191, 2015.

[5] A. Lalnunpuii, B. Sarkar, S. Alam, A. Equebal, and A. Biswas, "Efficacy of Mulligan mobilisation as compared to Maitland mobilisation in females with knee osteoarthritis: A double blind randomized controlled trial," *International Journal of Therapy and Rehabilitation Research*, vol. 6, no. 2, p. 37, 2017.

[6] A. Kiran *et al*., "Comparison of efficacy of Mulligan's mobilization with movement with Maitland mobilization along with conventional therapy in the patients with knee osteoarthritis: A randomized clinical trial," *Libyan International Medical University Journal*, vol. 3, no. 1, pp. 26–30, 2018.

[7] C. L. Christiansen and J. E. Stevens-Lapsley, "Weight-bearing asymmetry in relation to measures of impairment and functional mobility for people with knee osteoarthritis," *Archives of*

Physical Medicine and Rehabilitation, vol. 91, no. 10, pp. 1524–1528, 2010.

[8] H. Iijima, R. Eguchi, T. Aoyama, and M. Takahashi, “Trunk movement asymmetry associated with pain, disability, and quadriceps strength asymmetry in individuals with knee osteoarthritis: A cross-sectional study,” *Osteoarthritis and Cartilage*, vol. 27, no. 2, pp. 248–256, 2019.

[9] S. Muraki, T. Akune, M. Teraguchi, R. Kagotani, Y. Asai, M. Yoshida, F. Tokimura, S. Tanaka, H. Oka, H. Kawaguchi, K. Nakamura, and N. Yoshimura, “Quadriceps muscle strength, radiographic knee osteoarthritis and knee pain: The ROAD study,” *BMC Musculoskeletal Disorders*, vol. 16, p. 305, 2015.

[10] Y. Suzuki, H. Iijima, M. Nakamura, and T. Aoyama, “Rate of force development in the quadriceps of individuals with severe knee osteoarthritis: A preliminary cross-sectional study,” *PLoS One*, vol. 17, no. 1, p. e0262508, 2022.