Effects of combined exercise and manual therapy on pain and physical function in overweight older adults with knee osteoarthritis: A randomized controlled trial

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ABSTRACT

Background: Knee osteoarthritis (KOA) is a prevalent musculoskeletal disorder that leads to pain, reduced mobility, and functional limitations, particularly among overweight older adults. While exercise therapy is widely recommended as a primary non-pharmacological intervention, its effectiveness as a standalone approach may be limited due to increased biomechanical stress in this population.
Objectives: This study aimed to evaluate and compare the effectiveness of exercise therapy alone and a combination of exercise and manual therapy on pain, joint function, range of motion (ROM), and physical performance in overweight older adults with KOA.
Methods: A randomized controlled trial design was employed, involving 40 participants who were randomly allocated (1:1 ratio) using a computer-generated simple randomization sequence. Forty overweight older adults (mean age 58.3 ± 4.9 years; BMI 34.8 ± 3.2 kg/m²) with clinically diagnosed KOA participated in the study. Both groups underwent a 12-session physiotherapy program. Data were collected using the Visual Analog Scale (VAS) for pain, WOMAC for joint function, goniometry for ROM, and the Timed Up and Go (TUG) test for physical performance. Statistical analysis was conducted using JASP, including descriptive statistics, independent-samples t-tests, paired-samples t-tests, repeated-measures ANOVA, and ANCOVA to control for potential confounders.
Results: Both groups demonstrated significant improvements in all outcome measures. Compared with exercise alone, the combined intervention resulted in greater pain reduction (adjusted mean difference = -1.07 points, $p < 0.001$, $\eta^2 = 0.52$), greater improvement in knee ROM ($p < 0.001$, $\eta^2 = 0.61$), and better TUG performance ($p = 0.001$, $\eta^2 = 0.46$). No significant between-group difference was observed for WOMAC scores ($p = 0.234$, $\eta^2 = 0.03$).
Conclusions: The combination of exercise and manual therapy is more effective than exercise alone in improving pain and physical performance in overweight older adults with KOA. A multimodal physiotherapy approach is recommended to optimize rehabilitation outcomes in this population.

Keywords: exercise therapy, knee osteoarthritis, manual therapy, overweight older adults, physical performance.

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INTRODUCTION

Knee osteoarthritis (KOA) is one of the most common musculoskeletal disorders, characterized by progressive degeneration of joint structures, and is a major contributor to pain, limited mobility, and reduced quality of life, particularly among the elderly population (Wolf et al., 2024). This condition becomes increasingly complex in overweight older adults, where excessive mechanical stress on the knee joint accelerates cartilage damage and exacerbates clinical symptoms such as pain and dysfunction (Bliddal et al., 2014). Additionally, age-related physiological changes also contribute to reduced muscle strength and joint stability, thereby exacerbating functional limitations. Therefore, KOA is not only an individual clinical problem but also a significant public health burden. As a result, KOA in overweight older adults represents not only a complex clinical condition but also a growing public health concern due to its impact on independence, disability risk, and healthcare utilization.

Overweight status represents a clinically relevant factor in KOA management because excessive body mass not only increases compressive forces across the knee joint but also contributes to systemic inflammatory processes associated with disease progression. Previous biomechanical studies have demonstrated that each additional kilogram of body weight may substantially increase knee joint loading during walking. Consequently, overweight older adults often experience greater pain severity, reduced mobility, and poorer rehabilitation outcomes than normal-weight individuals, highlighting the need for targeted intervention strategies in this high-risk population.

The importance of this research is underscored by the high prevalence of knee osteoarthritis (KOA), its substantial impact on functional independence among older adults, and the associated long-term healthcare burden. Non-pharmacological interventions, particularly physiotherapy-based exercise therapy, are widely recommended as a primary approach in KOA management due to their effectiveness in reducing pain and improving physical function (Fransen et al., 2015). However, the effectiveness of exercise therapy alone may be limited, especially in individuals with overweight conditions, where increased biomechanical load and altered movement patterns can further complicate joint function and rehabilitation outcomes.

Several recent studies indicate that multimodal approaches, such as combining exercise therapy and manual therapy, may yield better outcomes than single-modality interventions. For example, a study by Runge et al. (2022) reported that the combination of manual therapy and exercise resulted in significant short-term improvements in pain and function among patients with osteoarthritis. Another study by Deyle et al. (2005) also showed that the combination of manual therapy and exercise resulted in greater functional improvement compared to exercise alone. Additionally, Tsokanos et al. (2021) emphasized in their systematic review that manual therapy plays a crucial role in improving joint mobility and reducing pain. A recent study by Espírito Santo et al. (2024) further supports the effectiveness of manual therapy in reducing musculoskeletal pain in the menopausal population. However, most of these studies still focus on the general population or postmenopausal women and have not specifically explored the population of overweight older adults.

Although previous studies generally support the use of combined exercise and manual therapy for knee osteoarthritis, the evidence remains inconsistent. Some randomized controlled trials have reported superior improvements in pain and function when manual therapy is added to exercise programs. In contrast, other studies have found only modest or short-term benefits, particularly for self-reported functional outcomes such as WOMAC scores. Furthermore, many studies have included heterogeneous populations without considering body weight status as a potential modifier of treatment response. As obesity and overweight substantially increase knee joint loading, alter gait mechanics, and contribute to chronic low-grade inflammation, intervention effects observed in the general KOA population may not be directly transferable to overweight older adults.

Previous research by Hosseini & Dudonienė (2025) showed that a combination of exercise and manual therapy is more effective than exercise alone in improving pain and mobility in postmenopausal women with KOA. However, that study did not consider overweight as a key variable that could influence treatment outcomes. This highlights a research gap, particularly regarding the effectiveness of multimodal physical therapy interventions in overweight older adults with KOA.

In light of the identified gap, this study examines the effects of combining exercise therapy with manual therapy in overweight older adults with knee osteoarthritis, a group with unique biomechanical and physiological characteristics. Furthermore, the study applies a comprehensive assessment framework encompassing pain, joint function, range of motion (ROM), and physical performance to capture the intervention's multidimensional impact.

No randomized controlled trial has specifically investigated the added value of manual therapy when combined with exercise therapy in overweight older adults with knee osteoarthritis. Unlike previous studies conducted in general KOA populations or postmenopausal women, the present study focuses on a high-risk subgroup characterized by increased biomechanical loading and functional limitations. Furthermore, this study simultaneously evaluates pain, self-reported function, knee range of motion, and objective physical performance outcomes, providing a comprehensive assessment of treatment effectiveness. Pain was selected as the primary outcome because it is the most common symptom driving disability and treatment seeking in KOA. WOMAC was included to assess disease-specific functional limitations, ROM to evaluate mechanical joint mobility, and TUG to capture objective functional performance and mobility capacity in daily activities.

METHODS

Study Design and Participants

This study employed a randomized controlled trial (RCT) design with two parallel groups: an exercise-only control group and a combined exercise plus manual therapy intervention group. A total of 40 participants were recruited and randomly allocated to two groups: 20 to the control group and 20 to the intervention group. The study population comprised overweight older adults diagnosed with knee osteoarthritis.

Participants were eligible for inclusion if they were aged 50 years or older, had a Body Mass Index (BMI) of ≥25 kg/m² (classified as overweight), had a clinical diagnosis of knee osteoarthritis, and were able to perform moderate physical activity. Participants were excluded if they had a history of knee surgery within the past six months, suffered from severe cardiovascular or neurological disorders, or were

currently participating in other rehabilitation programs. Randomization was conducted using a simple random allocation method, and all participants completed a 12-week intervention program. Randomization was performed using a simple lottery method conducted by an independent researcher (Figure 1).

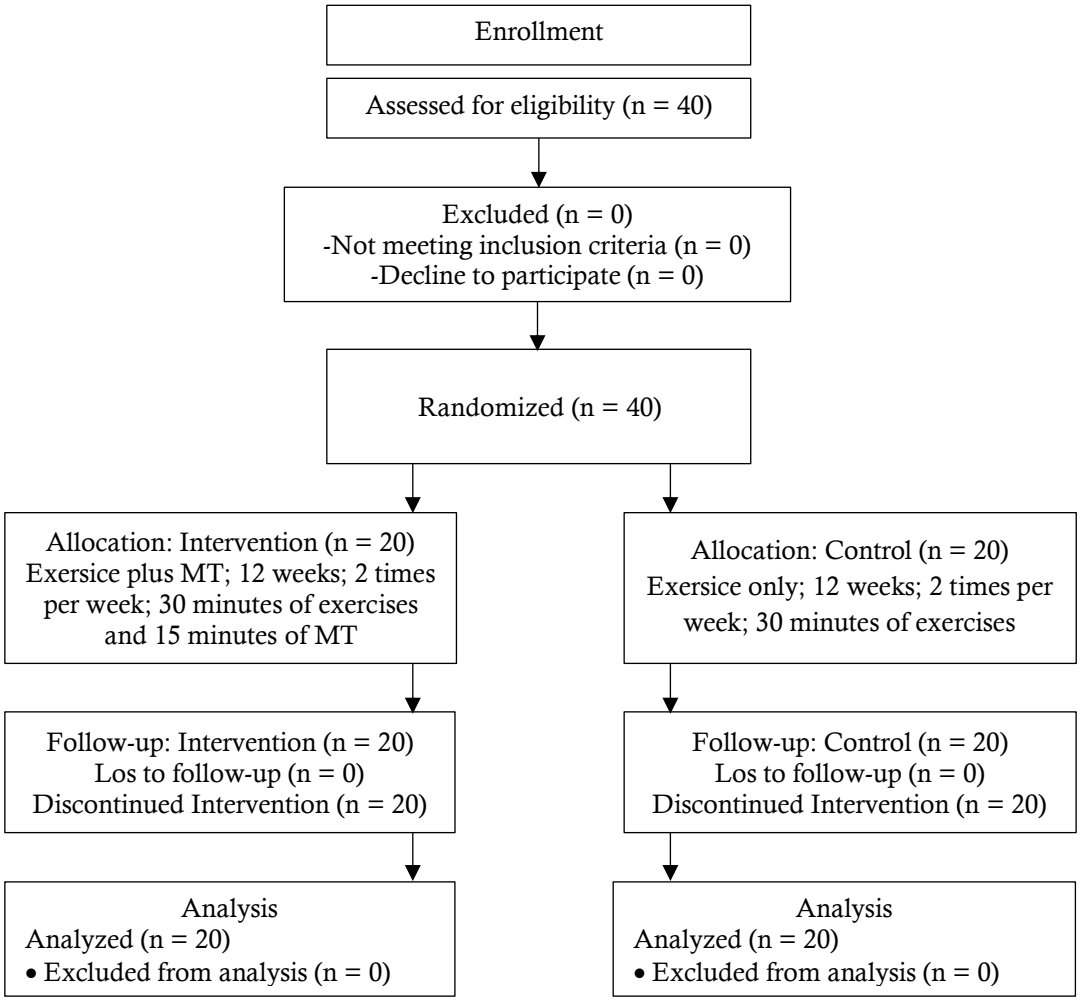

Figure 1. CONSORT Flow Diagram Illustrating Participant Enrollment, Randomization, Allocation, Follow-Up, and Analysis.

Ethical approval statement

This study received ethical approval from the Ethics Committee of the Lithuanian Sports University (approval number MNL-KIN (M)-2025-755, dated September 14, 2025). All assessments were conducted at the Physiotherapy and Rehabilitation Clinic in Tehran, Iran, following standardized protocols to ensure consistency and reliability of measurements.

Due to the nature of the intervention, blinding of participants and therapists was not feasible. Outcome assessments were performed using standardized measurement procedures; however, assessors were not blinded to group allocation. To minimize bias, all measurements were conducted according to predefined protocols, and data were recorded in anonymized form.

Research Instruments

Pain intensity was assessed using the Visual Analog Scale (VAS) (Zhang et al., 2023). Participants rated their current knee pain on a scale ranging from 0 (no pain) to 10 (worst possible pain). Joint function was evaluated using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). The validated Persian

version of the WOMAC (VAS 100 mm format) was used, comprising three subscales: pain (5 items), stiffness (2 items), and physical function (17 items). The total score ranges from 0 to 2400, with higher scores reflecting greater symptom severity (Eftekhar-Sadat et al., 2015).

Knee range of motion (ROM), specifically knee flexion, was measured using a 360° goniometer. Measurements were taken with participants in a supine position, and the hip was maintained in a neutral alignment. Participants were instructed to actively flex their knee to the maximum comfortable range, while the examiner recorded the angle achieved.

Physical performance was assessed using the Timed Up and Go (TUG) test. This test measures the time required for a participant to stand from a seated position, walk 3 meters, turn around, return to the chair, and sit down. Shorter completion times indicate better functional mobility and a lower risk of falls (Bagheri Roochi et al., 2021).

Intervention Protocol

Both groups participated in a structured exercise therapy program designed to improve lower limb strength, joint mobility, proprioception, and functional performance in individuals with knee osteoarthritis (Bennell et al., 2020; Eymir et al., 2021; Genç & Atılgan, 2024). The program consisted of approximately 8 to 10 exercises targeting lower extremity strength, flexibility, and balance. Each exercise session lasted approximately 45–60 minutes, including a 5-minute warm-up, 35–45 minutes of therapeutic exercises, and a 5-minute cool-down period. Exercise intensity was individualized and progressed according to participant tolerance. Strengthening exercises were performed at a moderate intensity corresponding to approximately 11–13 on the Borg Rating of Perceived Exertion scale. Licensed physiotherapists delivered all interventions with at least three years of clinical experience in musculoskeletal rehabilitation.

Exercises were performed in various positions, including sitting (e.g., knee extensions), supine (e.g., bridging exercises), standing (e.g., mini squats and step-ups), and prone (e.g., hamstring curls). Each exercise was completed in three sets of 10–15 repetitions, with intensity and progression adjusted according to individual tolerance and capability. Each session began with a five-minute warm-up and concluded with a cool-down phase to ensure safety and optimize performance. The intervention consisted of 12 sessions delivered over 12 weeks.

In addition to the exercise program, participants in the intervention group received 15 minutes of manual therapy following each session. The manual therapy protocol included joint mobilization techniques applied to the patellofemoral joint using controlled, sustained forces. At the same time, participants actively performed knee flexion and extension movements, typically from 90° of flexion to the maximum achievable extension. This approach aimed to reduce pain and enhance joint mobility.

Furthermore, myofascial release techniques were applied to areas of increased muscle tension, particularly in the anterior thigh region (Kandada & Heggannavar, 2015; Nath, 2015). The overall intervention program was well tolerated by participants, with no reported adverse events throughout the 12-week study period.

Data Analysis

Statistical analyses were performed using JASP software (Version 0.96.0, JASP Team). The normality of continuous variables was evaluated based on skewness (acceptable range ±1.5) and kurtosis (acceptable range ±2), and all variables met the assumptions of normal distribution. Descriptive statistics were presented as mean ± standard deviation (SD) for continuous variables and as frequencies with percentages for categorical variables. Baseline differences between the control and intervention groups were assessed using independent-samples t-tests for continuous variables and chi-square tests for categorical variables. The primary intervention effects were evaluated using Analysis of Covariance (ANCOVA), with post-intervention outcome scores as dependent variables, group allocation as the fixed factor, and corresponding baseline scores as covariates. Outcome measures included pain intensity (VAS), joint function (WOMAC), knee range of motion (ROM), and physical performance assessed using the Timed Up and Go (TUG) test. Effect sizes were reported as partial eta squared (η^2). All analyses were conducted using a per-protocol approach, and statistical significance was set at $p < 0.05$.

RESULTS

A total of 40 participants were enrolled and randomly allocated to the intervention group (n = 20) or control group (n = 20). No participants were lost to follow-up, and all participants completed the post-intervention assessments. Therefore, data from all 40 participants were included in the final analysis. Intervention adherence was monitored through attendance records. Participants attended all scheduled treatment sessions, resulting in 100% adherence. No adverse events related to the exercise or manual therapy interventions were reported during the study period.

Table 1. Baseline Characteristics of Study Participants

Characteristic	Control group (n = 20)	Intervention group (n = 20)	P between groups
Age (year ± SD)	58.10 ± 4.85	58.45 ± 5.02	0.781
Height (m ± SD)	1.61 ± 0.06	1.62 ± 0.07	0.654
Weight (kg ± SD)	89.45 ± 11.20	91.30 ± 10.75	0.592
BMI (kg/m² ± SD)	34.40 ± 3.15	35.10 ± 3.28	0.538
OA severity (K–L grade)	2.6 ± 0.50	2.7 ± 0.48	0.601
OA duration (months ± SD)	20.35 ± 8.90	21.10 ± 9.25	0.742

Abbreviations: SD, standard deviation; BMI, body mass index; OA, osteoarthritis; K–L grade, Kellgren–Lawrence classification. Data are expressed as mean ± SD. Between-group differences were analyzed using independent samples t-test.

Table 1 presents the baseline characteristics of participants in both the control and intervention groups. There were no statistically significant differences between groups in age, height, weight, body mass index (BMI), osteoarthritis severity (Kellgren–Lawrence grade), or osteoarthritis duration (all $p > 0.05$). These findings indicate that the two groups were comparable at baseline, confirming the effectiveness of the randomization process.

Table 2 presents comparisons of pre- and post-intervention outcomes within and between groups for pain (VAS), WOMAC, ROM, and the TUG test. Both the control and intervention groups demonstrated significant improvements in all outcome measures from pre- to post-intervention (all $p < 0.001$). Between-group comparisons revealed significantly greater improvements in pain (VAS), ROM, and TUG performance in the intervention group than in the control group ($p < 0.05$). In contrast, no significant difference was observed between groups for WOMAC scores

($p > 0.05$). Normality testing using Q–Q plots indicated that all variables were approximately normally distributed, as the data points closely followed the diagonal reference line, with no substantial deviations observed.

Table 2. Comparison of pre- and post-intervention outcomes within and between groups for pain (VAS), WOMAC, ROM, and TUG test

Outcomes	Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	p-value (within)	Effect size (η^2)	p-value (between)
VAS (pain score)	Control	7.29 ± 1.01	4.99 ± 1.20	<0.001	0.52	<0.001
	Intervention	7.59 ± 1.23	4.07 ± 1.21	<0.001		
WOMAC total	Control	61.30 ± 11.57	43.92 ± 12.68	<0.001	0.03	0.234
	Intervention	62.55 ± 10.15	39.63 ± 9.52	<0.001		
ROM (degree)	Control	106.75 ± 6.83	115.58 ± 6.72	<0.001	0.61	<0.001
	Intervention	105.45 ± 7.42	118.85 ± 8.34	<0.001		
TUG Test (seconds)	Control	14.99 ± 2.57	12.26 ± 2.79	<0.001	0.46	0.001
	Intervention	14.18 ± 2.38	10.34 ± 2.45	<0.001		

Abbreviations: C, control group; I, intervention group; SD, standard deviation; VAS, Visual Analogue Scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; ROM, range of motion; TUG, Timed Up and Go test. Data are presented as mean ± SD. Between-group intervention effects were analyzed using ANCOVA with baseline scores entered as covariates. Effect size is reported as partial eta squared (η^2).

All participants completed the intervention and post-intervention assessments. No participants were lost to follow-up or excluded from the final analysis. Adherence to the intervention protocol was 100% in both groups, and no adverse events related to the exercise or manual therapy interventions were reported during the study period.

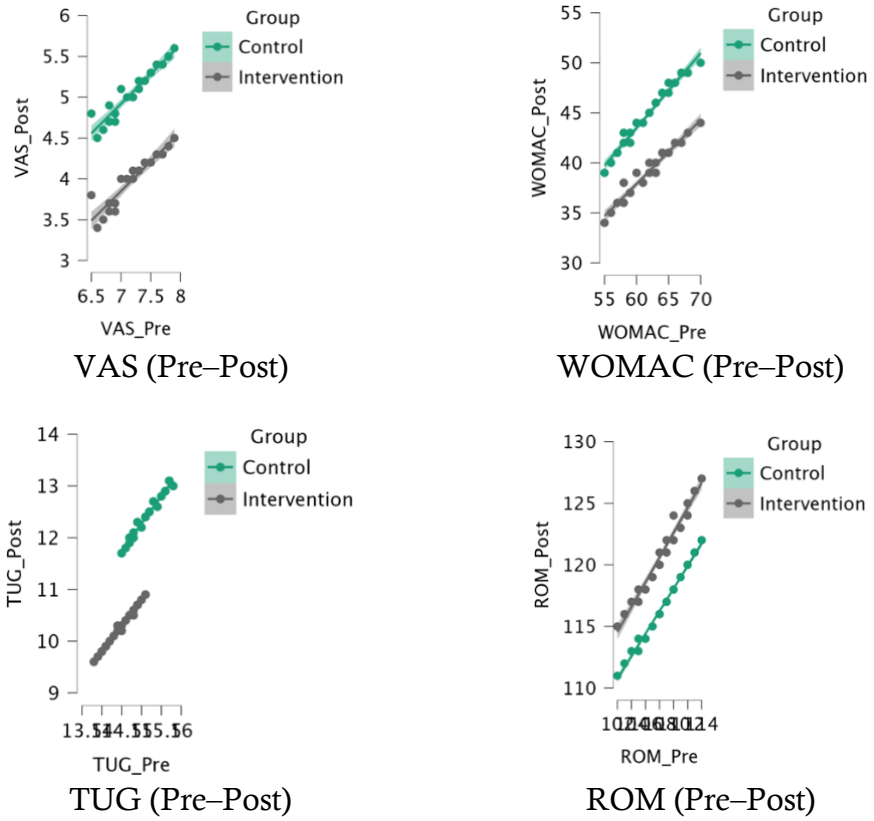

Figure 2. Scatter plots of pre- and post-test scores for VAS, WOMAC, TUG, and ROM in the control and intervention groups.

Figure 2 illustrates the scatter plots of pre- and post-test scores for VAS, WOMAC, TUG, and ROM across both groups. All outcomes demonstrate clear linear relationships between baseline and post-intervention values, indicating consistent changes following the intervention. The intervention group generally shows more favorable post-test outcomes than the control group, as reflected by lower VAS and TUG scores and higher ROM values. These visual patterns support the statistical findings and further highlight the effectiveness of the combined exercise and manual therapy program.

DISCUSSION

This study aimed to compare the effects of a combined exercise and manual therapy program with exercise alone on pain and functional outcomes in overweight older adults with knee osteoarthritis. The findings demonstrated that both interventions significantly improved pain, joint function, range of motion (ROM), and physical performance after 12 weeks. However, the combined intervention showed superior improvements in pain reduction (VAS), ROM, and functional mobility (TUG test) compared to exercise alone. At the same time, no significant between-group difference in WOMAC scores was observed.

Beyond statistical significance, the observed improvements are clinically meaningful. The intervention group demonstrated a reduction in VAS pain scores from 7.59 to 4.07, representing a mean improvement of 3.52 points. Previous studies have suggested that the minimally clinically important difference (MCID) for pain intensity in individuals with knee osteoarthritis is approximately 1.5–2.0 points on a 10-point scale. Therefore, the magnitude of pain reduction observed in the present study exceeded commonly accepted MCID thresholds, indicating that the benefits were not only statistically significant but also clinically relevant. Similar considerations may apply to improvements in functional mobility, as reflected in TUG performance, although MCID values can vary depending on patient characteristics and disease severity.

These findings are consistent with previous studies that have highlighted the effectiveness of exercise therapy in managing knee osteoarthritis. Exercise-based interventions have been widely reported to reduce pain and improve function by enhancing muscle strength and joint stability (Bennell et al., 2020). Furthermore, manual therapy provides additional benefits, particularly in reducing pain and improving joint mobility. Similar results were reported by Kandada & Heggannavar (2015), who found that combining manual therapy with exercise significantly improved pain and functional outcomes compared to exercise alone. In addition, systematic evidence suggests that multimodal physiotherapy approaches tend to yield better clinical outcomes than single-modality interventions (Abbott et al., 2013).

Although the findings generally align with previous reports supporting exercise-based rehabilitation and manual therapy for knee osteoarthritis, several alternative explanations should be considered. The additional benefits observed in the intervention group may not be attributable solely to the physiological effects of manual therapy. Increased therapist–participant interaction, enhanced treatment expectancy, and greater participant engagement could also have contributed to improved outcomes. Furthermore, the relatively short intervention period and the absence of long-term follow-up prevent conclusions regarding the durability of

treatment effects. Therefore, the present findings should be interpreted as evidence of short-term efficacy rather than definitive long-term effectiveness.

Several underlying mechanisms can explain the greater improvements observed in the intervention group. Exercise therapy improves muscle strength, particularly in the quadriceps, which play a critical role in knee joint stabilization and load distribution (DeVita et al., 2018). Stronger musculature reduces mechanical stress on the joint, thereby decreasing pain and improving function. Meanwhile, manual therapy contributes through neurophysiological and biomechanical mechanisms (Carvalho et al., 2025). Joint mobilization techniques can stimulate mechanoreceptors, leading to pain inhibition via central and peripheral pathways, while also enhancing synovial fluid movement and joint lubrication (Bialosky et al., 2009). Additionally, myofascial release may reduce muscle stiffness and improve tissue extensibility (Laimi et al., 2018), thereby further increasing ROM and functional performance. These combined effects explain why the intervention group demonstrated superior outcomes in VAS, ROM, and TUG.

Interestingly, no significant between-group difference in WOMAC scores was observed, despite improvements in both groups. This may be due to the multidimensional nature of WOMAC, which includes pain, stiffness, and functional components. While manual therapy may strongly influence pain and mobility, broader functional improvements, as measured by WOMAC, may require longer intervention durations or additional behavioral and lifestyle modifications, such as weight management and long-term adherence to physical activity (Young et al., 2023).

Despite the consistent improvements observed in the present study, previous research has reported heterogeneous findings regarding the added value of combining manual therapy with exercise in knee osteoarthritis. For instance, a study published in Osteoarthritis and Cartilage reported improvements in clinical symptoms following combined interventions, yet no significant superiority was observed in WOMAC outcomes compared to usual care. In contrast, a randomized controlled trial by Deyle et al. (2005) demonstrated substantially greater improvements in WOMAC scores when manual therapy was integrated with exercise compared to a home-based exercise program. Furthermore, a systematic review and meta-analysis by Runge et al. (2022) concluded that while combined interventions provide meaningful short-term benefits, their long-term superiority over exercise alone remains inconclusive.

Some studies reported clinically meaningful benefits of combined interventions, whereas others failed to demonstrate superiority over exercise alone. These discrepancies may be attributable to differences in participant characteristics, intervention dosage, therapist expertise, and outcome measures used across studies. Such methodological heterogeneity complicates direct comparison and highlights the need for population-specific investigations.

The findings of the present study align with this pattern of variability, particularly with respect to WOMAC outcomes, where no significant between-group difference was observed despite clear improvements in both groups. Such discrepancies across studies may be attributed to differences in study design, participant characteristics, intervention dosage, and adherence levels. In particular, the inclusion of overweight older adults in the current study introduces additional biomechanical and physiological considerations that may influence responsiveness to intervention. Increased joint loading, altered movement patterns, and reduced muscle efficiency in

this population may limit the extent to which improvements in pain and mobility translate into broader functional gains captured by multidimensional measures such as WOMAC.

From a clinical perspective, these findings suggest that physiotherapists should consider incorporating manual therapy into exercise-based rehabilitation programs for overweight older adults with knee osteoarthritis. A multimodal approach combining strengthening, flexibility, and manual techniques may optimize outcomes, particularly for pain reduction and mobility improvement. Additionally, interventions should be individualized based on patient tolerance, osteoarthritis severity, and functional limitations. Education on weight management and regular physical activity should also be emphasized to enhance long-term outcomes.

Limitations of the study

This study has several limitations. First, the relatively small sample size (n = 40) may limit the generalizability of the findings. Second, no formal a priori sample size calculation was performed, which may affect the statistical precision of the estimated treatment effects. Third, the intervention period was limited to 12 weeks, which may not have been sufficient to capture long-term functional adaptations, particularly for outcomes such as WOMAC. Fourth, the lack of long-term follow-up limits the ability to determine whether the observed improvements are sustained. In addition, allocation concealment procedures were not implemented, which may have introduced selection bias despite the use of random group assignment. Finally, although efforts were made to standardize procedures, the lack of full blinding may have introduced potential bias. Future randomized controlled trials should employ prospective power analyses, larger sample sizes, and longer follow-up periods to strengthen the robustness and generalizability of the findings.

Future research should consider larger sample sizes, longer intervention periods, and follow-up assessments to evaluate long-term effects. Additionally, exploring the combined effects of physiotherapy interventions with weight management programs may provide further insights into optimizing treatment outcomes for this population.

CONCLUSIONS

This randomized controlled trial demonstrated that adding manual therapy to an exercise-based rehabilitation program produced greater improvements in pain, knee range of motion, and functional mobility than exercise therapy alone in overweight older adults with knee osteoarthritis. Importantly, this study extends existing evidence by specifically focusing on an overweight older adult population, a subgroup characterized by increased biomechanical loading and elevated risk of functional decline that has been underrepresented in previous clinical trials.

The findings suggest that a multimodal rehabilitation approach combining therapeutic exercise and manual therapy may be particularly beneficial for addressing the complex clinical needs of overweight individuals with knee osteoarthritis. Given the substantial improvements observed in pain and mobility outcomes, clinicians should consider incorporating manual therapy as an adjunct to structured exercise programs when managing this population.

Future randomized controlled trials should include larger samples, prospective sample-size calculations, assessor blinding, and longer follow-up periods to assess the sustainability of treatment effects. In addition, future studies should investigate

whether combining physiotherapy interventions with weight-management strategies and lifestyle modification programs can further enhance functional outcomes and quality of life in overweight older adults with knee osteoarthritis.

AI DISCLOSURE STATEMENT

During the preparation of this manuscript, the authors used artificial intelligence (AI)-assisted tools, including Grammarly for language editing and grammar enhancement, DeepL Translate for translation support, and SciSpace for literature exploration and information retrieval. These tools were used solely to assist with language refinement, literature identification, and manuscript preparation. All outputs generated by these tools were carefully reviewed, verified, and revised by the authors. No AI tool was used to generate, analyze, interpret, or independently report the study data, results, or conclusions. The authors take full responsibility for the accuracy, originality, integrity, and final content of this manuscript.

DATA AVAILABILITY

The data supporting this study's findings are available on request from the corresponding author. The data are not publicly available because they contain information that could compromise the privacy of research participants

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CONFLICT OF INTEREST

The author hereby declares that this research is free from conflicts of interest with any party.

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REFERENCES

Abbott, J. H., Robertson, M. C., Chapple, C., Pinto, D., Wright, A. A., Leon de la Barra, S., Baxter, G. D., Theis, J.-C., & Campbell, A. J. (2013). Manual therapy, exercise therapy, or both, in addition to usual care, for osteoarthritis of the hip or knee: a randomized controlled trial. 1: clinical effectiveness. *Osteoarthritis and Cartilage*, *21*(4), 525–534. https://doi.org/10.1016/j.joca.2012.12.014

Bagheri Roochi, A., Mohammadi, F., Khorani, H., & Motalebi, S. A. (2021). Intrinsic Factors of Home Fall Among Older Adults in Qazvin City, Iran, 2018. *Iranian Rehabilitation Journal*, *2*(SpecialIssue), 29–36. https://doi.org/10.32598/irj.20.SpecialIssue.825.2

Bennell, K. L., Nelligan, R. K., Kimp, A. J., Schwartz, S., Kasza, J., Wrigley, T. V., Metcalf, B., Hodges, P. W., & Hinman, R. S. (2020). What type of exercise is most effective for people with knee osteoarthritis and co-morbid obesity?: The TARGET randomized controlled trial. *Osteoarthritis and Cartilage*, *28*(6), 755–765. https://doi.org/10.1016/j.joca.2020.02.838

Bialosky, J. E., Bishop, M. D., Price, D. D., Robinson, M. E., & George, S. Z. (2009). The mechanisms of manual therapy in the treatment of musculoskeletal pain: A comprehensive model. *Manual Therapy*, *14*(5), 531–538. https://doi.org/10.1016/j.math.2008.09.001

Bliddal, H., Leeds, A. R., & Christensen, R. (2014). Osteoarthritis, obesity and weight loss: evidence, hypotheses and horizons – a scoping review. *Obesity Reviews*, *15*(7), 578–586. https://doi.org/10.1111/obr.12173

Carvalho, G. F., Adamczyk, W. M., Ludes, C. S., Scharbach, R., Jung, A., Karstens, S., Luedtke, K., & Szikszay, T. M. (2025). Perceptions and beliefs of physical therapists regarding the mechanisms of manual therapy. *Brazilian Journal of Physical Therapy*, *29*(6), 101231. https://doi.org/10.1016/j.bjpt.2025.101231

DeVita, P., Aaboe, J., Bartholdy, C., Leonardis, J. M., Bliddal, H., & Henriksen, M. (2018). Quadriceps-strengthening exercise and quadriceps and knee biomechanics during walking in knee osteoarthritis: A two-centre randomized controlled trial. *Clinical Biomechanics*, *59*, 199–206. https://doi.org/10.1016/j.clinbiomech.2018.09.016

Deyle, G. D., Allison, S. C., Matekel, R. L., Ryder, M. G., Stang, J. M., Gohdes, D. D., Hutton, J. P., Henderson, N. E., & Garber, M. B. (2005). Physical Therapy Treatment Effectiveness for Osteoarthritis of the Knee: A Randomized Comparison of Supervised Clinical Exercise and Manual Therapy Procedures Versus a Home Exercise Program. *Physical Therapy*, *85*(12), 1301–1317. https://doi.org/10.1093/ptj/85.12.1301

Eftekhar-Sadat, B., Niknejad-Hosseyni, S. H., Babaei-Ghazani, A., Toopchizadeh, V., & Sadeghi, H. (2015). Reliability and validity of Persian version of Western Ontario and McMaster Universities Osteoarthritis index in knee osteoarthritis. *Journal of Analytical Research in Clinical Medicine*, *3*(3), 170–177. https://doi.org/10.15171/jarcm.2015.027

Espírito Santo, J., Moita, J., & Nunes, A. (2024). The Efficacy of Manual Therapy on Musculoskeletal Pain in Menopause: A Systematic Review. *Healthcare*, *12*(18), 1838. https://doi.org/10.3390/healthcare12181838

Eymir, M., Erduran, M., & Ünver, B. (2021). Active heel-slide exercise therapy facilitates the functional and proprioceptive enhancement following total knee arthroplasty compared to continuous passive motion. *Knee Surgery, Sports Traumatology, Arthroscopy*, *29*(10), 3352–3360. https://doi.org/10.1007/s00167-020-06181-4

Fransen, M., McConnell, S., Harmer, A. R., Van der Esch, M., Simic, M., & Bennell, K. L. (2015). Exercise for osteoarthritis of the knee: a Cochrane systematic review. *British Journal of Sports Medicine*, *49*(24), 1554–1557. https://doi.org/10.1136/bjsports-2015-095424

Genç, H., & Atılgan, E. (2024). Efficiency of a structured squat-based program in knee osteoarthritis rehabilitation. *Physiotherapy Practice and Research*, *45*(1), 59–66. https://doi.org/10.3233/PPR-240847

Hosseini, S. E., & Dudonienė, V. (2025). Effects of an 8-Week Exercise and Manual Therapy Programme Versus Exercise Alone on Knee Pain and Joint Function in Postmenopausal Women With Knee Osteoarthritis. *Reabilitacijos Mokslai: Slauga, Kineziterapija, Ergoterapija*, *1*(32), 100–112. https://doi.org/10.33607/rmske.v1i32.1605

Kandada, S., & Heggannavar, A. (2015). Effect of Mulligans MWM Versus Macquarie Injury Management Group (MIMG) Protocol on Pain And Function in Osteoarthritis of Knee: A Randomized Clinical Trial. *International Journal of Therapies and Rehabilitation Research*, *4*(4), 125. https://doi.org/10.5455/ijtrr.00000078

Laimi, K., Mäkilä, A., Bärlund, E., Katajapuu, N., Oksanen, A., Seikkula, V., Karppinen, J., & Saltychev, M. (2018). Effectiveness of myofascial release in treatment of chronic musculoskeletal pain: a systematic review. *Clinical Rehabilitation*, *32*(4), 440–450. https://doi.org/10.1177/0269215517732820

Nath, J. (2015). Knee osteoarthritis with special emphasis to physiotherapy treatment focusing various stimulation. *International Journal of Scientific and Research Publications*, *5*(3), 1–10.

Runge, N., Aina, A., & May, S. (2022). The Benefits of Adding Manual Therapy to Exercise Therapy for Improving Pain and Function in Patients With Knee or Hip Osteoarthritis: A Systematic Review With Meta-analysis. *Journal of Orthopaedic & Sports Physical Therapy*, *52*(10), 675-A13. https://doi.org/10.2519/jospt.2022.11062

Tsokanos, A., Livieratou, E., Billis, E., Tsekoura, M., Tatsios, P., Tsepis, E., & Fousekis, K. (2021). The efficacy of manual therapy in patients with knee osteoarthritis: a systematic review. *Medicina*, *57*(7), 696. https://doi.org/10.3390/medicina57070696

Wolf, D. F., Carvalho, C., Moreira Padovez, R. de F. C., Braz de Oliveira, M. P., & Mendes da Silva Serrão, P. R. (2024). Effects of physical exercise on muscle function of the knee, pain and quality of life in postmenopausal women with knee osteoarthritis: A systematic review with meta-analysis. *Musculoskeletal Science and Practice*, *71*, 102929. https://doi.org/10.1016/j.msksp.2024.102929

Young, J. J., Pedersen, J. R., & Bricca, A. (2023). Exercise Therapy for Knee and Hip Osteoarthritis: Is There An Ideal Prescription? *Current Treatment Options in Rheumatology*, *9*(3), 82–98. https://doi.org/10.1007/s40674-023-00205-z

Zhang, E. W., Jones, L. E., & Whitburn, L. Y. (2023). Tools for assessing labour pain: a comprehensive review of research literature. *Pain*, *164*(12), 2642–2652. https://doi.org/10.1097/j.pain.0000000000003004