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Resistance Training Versus Non-Weight Bearing Exercise for Knee Osteoarthritis Pain

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Abstract

Background: Knee osteoarthritis (OA) is a common degenerative joint disorder in older adults that causes pain, mobility limitations, and reduced quality of life. Exercise therapy is recommended as a core non-pharmacological intervention, with resistance training and non-weight bearing exercise frequently used in clinical practice.
Objective: To compare the effectiveness of resistance training and non-weight bearing exercise in reducing knee pain among older adults with knee OA.
Methods: A quasi-experimental, non-randomized pretest-posttest study was conducted among 30 older adults with grade I–II knee OA at RSIJ Pondok Kopi. Participants were allocated into a resistance training exercise group (n=15) and a non-weight bearing exercise group (n=15) using purposive sampling. Both interventions were performed three times weekly for four weeks under physiotherapist supervision. Pain was assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain subscale. Data were analyzed using paired and independent sample t-tests.
Results: WOMAC pain scores significantly decreased in both groups after the intervention ($p<0.001$). In the resistance training group, scores decreased from 10.27±4.57 to 8.87±4.05, while in the non-weight bearing exercise group scores decreased from 9.80±2.95 to 8.40±2.55. The mean reduction was 1.40 points in both groups. No significant between-group difference was observed ($p=0.709$).
Conclusion: Resistance training and non-weight bearing exercise were equally effective in reducing knee pain among older adults with grade I–II knee OA. Both interventions may be considered effective physiotherapy options for pain management.

Keywords
Aged; Exercise Therapy; Knee Osteoarthritis; Pain; Resistance Training

Introduction

Knee osteoarthritis (OA) is one of the most prevalent chronic musculoskeletal disorders among older adults and represents a major cause of pain, disability, and reduced quality of life worldwide. The condition is characterized by progressive degeneration of articular cartilage, subchondral bone remodeling, osteophyte formation, synovial inflammation, and changes in periarticular soft tissues, resulting in pain, joint stiffness, and functional limitations. Aging is recognized as one of the most important risk factors for knee OA because age-related changes in cartilage metabolism, muscle strength, neuromuscular control, and tissue repair capacity accelerate the degenerative process. Consequently, the global burden of knee OA continues to increase in parallel with population aging and longer life expectancy.[3–6]

The impact of knee OA extends beyond structural joint deterioration. Persistent knee pain frequently interferes with activities of daily living, including walking, stair negotiation, prolonged standing, and sit-to-stand movements.[1] As symptoms worsen, many individuals reduce their physical activity levels, leading to muscle weakness, decreased mobility, impaired balance, and loss of independence.[1] In Indonesia, musculoskeletal disorders remain highly prevalent among older adults and contribute substantially to disability and healthcare utilization.[7,8] Furthermore, several factors, including female sex, obesity, previous joint injury, biomechanical abnormalities, and physical inactivity, have been associated with the onset and progression of knee OA.[5,9–12]Women, particularly after menopause, demonstrate a higher prevalence of knee OA because hormonal changes may adversely affect cartilage metabolism and joint homeostasis.[5]

Pain associated with knee OA is multifactorial and involves both peripheral and central mechanisms. Structural degeneration within the joint stimulates nociceptive pathways through synovial inflammation, subchondral bone lesions, osteophyte formation, and increased mechanical stress during movement.[13,14] Chronic pain may subsequently contribute to arthrogenic muscle inhibition, particularly affecting the quadriceps muscle, thereby reducing knee stability and exacerbating functional impairment.[14] This interaction between pain, muscle weakness, and reduced physical activity creates a vicious cycle that accelerates functional decline and disease progression.[15]

Current clinical guidelines recommend exercise therapy as a core non-pharmacological intervention for individuals with knee OA because of its beneficial effects on pain, physical function, mobility, and quality of life.[1,16,17]Exercise interventions are considered safe, cost-effective, and adaptable to different clinical settings and patient characteristics. Consequently, exercise-based rehabilitation has become one of the most widely recommended strategies for managing knee OA symptoms while reducing dependence on pharmacological treatment.[1,16]

Among the available exercise approaches, resistance training has received considerable attention because of its ability to improve muscle strength and joint stability.[18] The quadriceps muscle plays a crucial role in shock absorption, dynamic stabilization, and load distribution across the knee joint during functional activities.[19] Improvements in muscle strength may reduce excessive joint loading, enhance movement efficiency, and improve functional performance, thereby contributing to pain reduction.[18] Several systematic reviews and meta-analyses have demonstrated that resistance training can significantly improve pain and physical function among individuals with knee OA.[18,20,21] These findings support the incorporation of strengthening exercises into rehabilitation programs for older adults with degenerative knee conditions.

Another intervention commonly prescribed in physiotherapy practice is non-weight bearing exercise.[22] Unlike conventional strengthening exercises performed under substantial joint loading, non-weight bearing exercise minimizes compressive forces across the knee joint while maintaining active muscle contraction and joint movement. This approach may improve circulation, facilitate neuromuscular activation, maintain joint mobility, and reduce pain without imposing excessive stress on degenerative articular structures.[22] Previous studies have reported that non-weight bearing exercise may improve pain, balance, and functional performance in individuals with knee OA, making it a suitable alternative for patients who experience discomfort during weight-bearing activities.[22,23]

Despite the growing body of evidence supporting exercise therapy for knee OA, several important knowledge gaps remain. First, many previous studies have evaluated the effectiveness of individual exercise modalities without directly comparing resistance training and non-weight bearing exercise within the same population.[18,20–23] Second, evidence regarding the comparative effectiveness of these interventions in Indonesian clinical settings remains limited. Third, because resistance training and non-weight bearing exercise are based on different physiological mechanisms, understanding their relative effectiveness may assist clinicians in selecting the most appropriate intervention according to patient characteristics, symptom severity, and rehabilitation goals.[1,18]

The clinical significance of comparing these interventions extends beyond determining statistical differences. If one intervention demonstrates superior effectiveness, clinicians may prioritize its use in routine rehabilitation programs. Conversely, if both interventions produce comparable outcomes, treatment selection may be individualized based on patient preferences, physical capacity, symptom presentation, and tolerance to joint loading. Therefore, direct comparison of these interventions has important implications for evidence-based physiotherapy practice and clinical decision-making.

Based on the identified research gap, this study aimed to compare the effectiveness of resistance training exercise and non-weight bearing exercise in reducing knee pain among older adults with grade I–II knee OA receiving physiotherapy services at RSIJ Pondok Kopi. It was hypothesized that both interventions would significantly reduce WOMAC pain scores, although differences in treatment effectiveness between the two exercise approaches might be observed due to their distinct therapeutic mechanisms.

Methods

This study employed a quasi-experimental, non-randomized pretest-posttest design to compare the effects of resistance training exercise (RTE) and non-weight bearing exercise (NWBE) on knee pain among older adults with knee osteoarthritis (OA). The study was conducted at the Physiotherapy Unit of RSIJ Pondok Kopi, Jakarta, Indonesia. The facility provides outpatient physiotherapy services for individuals with musculoskeletal disorders, including degenerative joint conditions. Ethical approval was obtained from the Health Research Ethics Committee of Politeknik Kesehatan Kemenkes Jakarta III (No. DP.04.03/F.XI.22/13402/2025), and all participants provided written informed consent prior to participation.

Participants were recruited using purposive sampling based on predefined eligibility criteria. Inclusion criteria were: (1) age 60–74 years; (2) physician-diagnosed grade I–II knee OA; (3) presence of knee pain during daily activities; (4) ability to follow verbal instructions and participate in exercise; and (5) willingness to participate in the study. Exclusion criteria included a history of knee fracture, previous knee replacement surgery, severe neurological disorders affecting mobility, uncontrolled cardiovascular disease, or other musculoskeletal conditions that could interfere with participation in the exercise program.

A total of 30 participants met the eligibility criteria and completed the study. Participants were allocated into either the RTE group (n = 15) or the NWBE group (n = 15). Allocation was performed using a non-randomized procedure based on participant eligibility and physiotherapy scheduling at the study site. Because random allocation was not performed, the possibility of selection bias cannot be completely excluded. To minimize this risk, identical inclusion and exclusion criteria were applied to both groups, and baseline pain scores were compared before intervention.

The primary outcome measure was knee pain assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain subscale. WOMAC is a widely used and validated instrument for evaluating symptoms in individuals with knee OA and consists of five items assessing pain during functional activities.[24–26] Higher scores indicate greater pain severity. WOMAC assessments were performed before the intervention and immediately after completion of the four-week exercise program.

The RTE group received a structured strengthening program targeting muscles involved in knee stabilization. The exercise protocol consisted of resistance-band hip abduction exercises, including spread knee 1, spread knee 2, and spread knee 3 movements. Each exercise was performed for two sets of eight repetitions with a five-second hold during each repetition. Sessions were conducted three times per week for four consecutive weeks under direct supervision of a physiotherapist. The resistance level of the elastic band and progression criteria were not formally documented in the original study and therefore could not be reported in detail.

The NWBE group received an exercise program designed to minimize compressive loading on the knee joint while maintaining muscle activation and joint mobility. The intervention consisted of straight leg raise exercises using a 1-kg ankle weight, static quadriceps exercises, and vastus medialis oblique strengthening exercises. Similar to the RTE group, each exercise was performed for two sets of eight repetitions with a five-second hold. Participants completed three supervised sessions per week for four weeks.

All exercise sessions were delivered individually under physiotherapist supervision. Prior to each session, participants were instructed regarding correct exercise performance and safety procedures. Attendance was monitored throughout the intervention period, and participants received verbal encouragement to complete the program. However, adherence rates were not quantitatively recorded, and no formal fidelity assessment was conducted. Likewise, no structured home exercise program was prescribed during the intervention period.

Participant safety was monitored throughout the intervention. Individuals were instructed to report discomfort, excessive fatigue, dizziness, or worsening symptoms during exercise sessions. No serious adverse events were documented during the intervention period. However, systematic adverse event recording was not incorporated into the original study protocol.

Data were analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics were used to summarize participant characteristics and WOMAC pain scores. Continuous variables were presented as mean ± standard deviation, whereas categorical variables were presented as frequencies and percentages. Normality testing was conducted before inferential analysis. Within-group differences between pre-intervention and post-intervention WOMAC pain scores were analyzed using paired sample t-tests. Between-group differences were analyzed using independent sample t-tests. Statistical significance was established at $p < 0.05$.

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A formal sample size calculation and power analysis were not performed prior to participant recruitment. In addition, effect size estimates and confidence intervals were not included in the original statistical analysis. These limitations should be considered when interpreting the findings because they restrict evaluation of the magnitude and precision of treatment effects.

Results

The participant flow is presented below according to the TREND recommendations for non-randomized intervention studies. The participant flow from eligibility assessment to final analysis is presented in Figure 1. Of the 100 participants assessed for eligibility, 70 were excluded, including 40 who did not meet the inclusion criteria and 30 who declined participation or were excluded for other reasons. The remaining 30 participants were allocated equally to the Resistance Training Exercise group (RTE; n = 15) and the Non-Weight Bearing Exercise group (NWBE; n = 15). All participants completed the intervention, and all 30 participants were included in the final analysis, with 15 participants analyzed in each group.

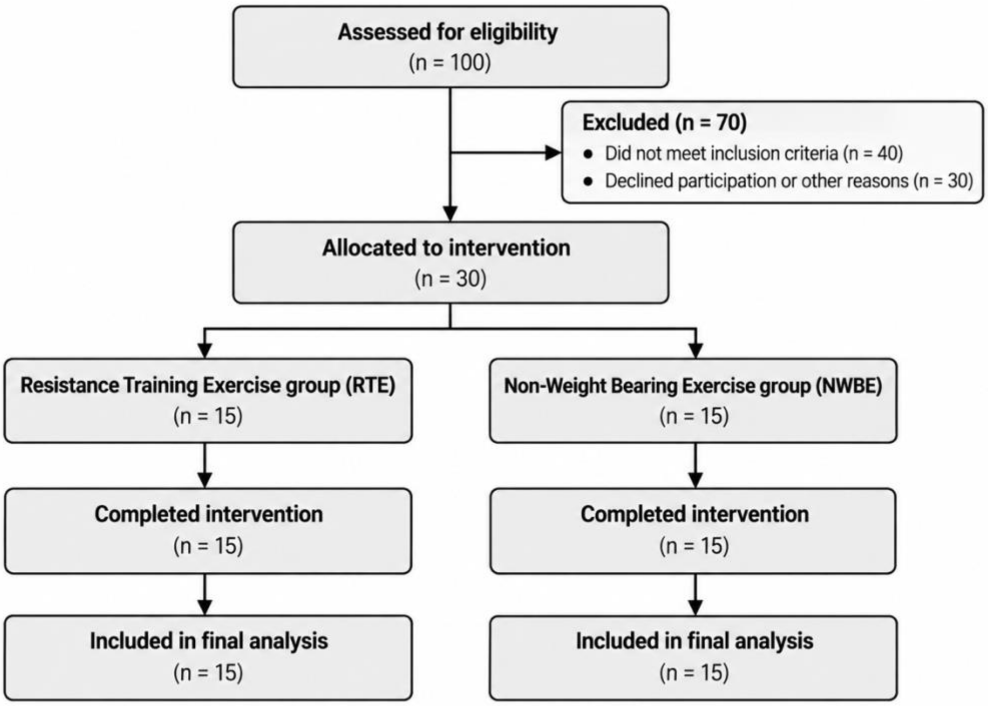

Figure 1. Participant Flow and Group Allocation

The participant flow demonstrates that all enrolled individuals completed the intervention and post-intervention assessment. Consequently, no attrition occurred during the study period, reducing the potential influence of attrition bias on the outcome assessment.

To provide an overview of the study population, demographic characteristics were analyzed before intervention. Understanding participant characteristics is important because age and sex are recognized risk factors for knee OA and may influence clinical presentation and treatment response.

Table 1. Sex Distribution of Participants

Sex	RTE (n=15)	%	NWBE (n=15)	%
Female	10	66.7	11	73.3
Male	5	33.3	4	26.7
Total	15	100	15	100

As shown in Table 1, female participants predominated in both groups, accounting for 70.0% of the total sample. This finding is consistent with the higher prevalence of knee OA among women reported in previous epidemiological studies.[5]

Participant age characteristics are presented in Table 2.

Table 2. Age Characteristics of Participants

Variable	RTE	NWBE
Mean ± SD (years)	64.73 ± 3.26	66.07 ± 4.94
Median	64.00	65.00
Minimum–Maximum	61–72	61–74

Table 2 indicates that participants in both groups were within the older adult age range, with relatively similar mean ages. These findings suggest that the age distribution between groups was generally comparable before intervention.

Before evaluating treatment effectiveness, baseline WOMAC pain scores were compared to determine whether the groups had similar pain severity prior to intervention. Establishing baseline comparability is important because substantial baseline differences could influence interpretation of treatment effects.

Table 3. Comparison of Baseline WOMAC Pain Scores Between Groups

Variable	RTE Mean ± SD	NWBE Mean ± SD	t	p-value
Pre-intervention WOMAC Pain	10.27 ± 4.57	9.80 ± 2.95	0.332	0.742

As shown in Table 3, no statistically significant difference was observed between groups at baseline (p = 0.742). This finding suggests that both groups started the intervention with comparable levels of knee pain, supporting the validity of subsequent between-group comparisons.

The primary objective of this study was to evaluate changes in WOMAC pain scores following four weeks of intervention. Descriptive statistics and within-group analyses are presented in Table 4.

Table 4. Changes in WOMAC Pain Scores Following Intervention

Group	Pre-test Mean ± SD	Post-test Mean ± SD	Mean Difference	% Change	t	p-value
RTE	10.27 ± 4.57	8.87 ± 4.05	1.40	13.63	5.50	<0.001
NWBE	9.80 ± 2.95	8.40 ± 2.55	1.40	14.29	4.58	<0.001

Table 4 demonstrates that both intervention groups experienced statistically significant reductions in WOMAC pain scores after four weeks of treatment. Participants in the RTE group showed a reduction from 10.27 ± 4.57 to 8.87 ± 4.05, corresponding to a 13.63% improvement. Similarly, participants in the NWBE group demonstrated a reduction from 9.80 ± 2.95 to 8.40 ± 2.55, representing a 14.29% improvement. These findings indicate that both exercise programs were effective in reducing knee pain among older adults with grade I–II knee OA.

To determine whether one intervention produced superior outcomes, post-intervention WOMAC pain scores were compared between groups. The results are presented in Table 5.

Table 5. Between-Group Comparison of WOMAC Pain Scores After Intervention

Variable	RTE Mean ± SD	NWBE Mean ± SD	t	p-value
Post-intervention WOMAC Pain	8.87 ± 4.05	8.40 ± 2.55	0.377	0.709

As presented in Table 5, no statistically significant difference was observed between the RTE and NWBE groups after completion of the intervention program (p = 0.709). Although both interventions significantly reduced WOMAC pain scores, neither intervention demonstrated superior effectiveness over the other within the four-week treatment period.

Overall, the results indicate that both resistance training exercise and non-weight bearing exercise produced meaningful reductions in knee pain. However, the absence of a significant between-group difference suggests that the two exercise approaches provided comparable benefits in this study population. Because effect sizes, confidence intervals, and MCID analyses were not included in the original study, interpretation of the magnitude and clinical significance of these improvements should be made cautiously.

Discussion

This study aimed to compare the effectiveness of resistance training exercise (RTE) and non-weight bearing exercise (NWBE) in reducing knee pain among older adults with grade I–II knee osteoarthritis (OA). The findings demonstrated that both interventions significantly reduced WOMAC pain scores after four weeks of treatment. However, no statistically significant difference was observed between groups, indicating that both exercise approaches produced comparable benefits for pain reduction in this study population. These findings support current recommendations that exercise therapy should be considered a core component of conservative OA management because of its ability to reduce pain and improve physical function.[1,2,16,17]

The predominance of female participants observed in this study is consistent with previous epidemiological evidence indicating that knee OA occurs more frequently among women, particularly after menopause. Hormonal alterations associated with estrogen deficiency have been linked to impaired cartilage homeostasis, increased inflammatory activity, and accelerated degenerative changes within articular tissues.[5,27] In addition, most participants were between 60 and 65 years of age, supporting existing evidence that aging is strongly associated with OA development and progression.[3,9,28] Age-related declines in muscle strength, neuromuscular control, and tissue regenerative capacity may contribute to both structural degeneration and chronic pain symptoms. Consequently, the demographic profile of the present sample is representative of the population most commonly affected by knee OA in clinical practice.

The significant reduction in WOMAC pain scores observed following RTE may be explained by several physiological mechanisms.[18] Muscle weakness, particularly involving the quadriceps muscle, is commonly observed in individuals with knee OA and contributes to impaired joint stability and increased mechanical stress during movement.[19] Resistance training improves muscular strength and neuromuscular control, thereby enhancing dynamic stabilization of the knee joint and reducing excessive loading of pain-sensitive structures.[18–21] Improved muscular support may also facilitate more efficient movement patterns and decrease abnormal joint stresses that contribute to pain generation. Consequently, strengthening interventions may reduce symptoms while simultaneously improving functional capacity.

In addition to biomechanical adaptations, resistance training may influence pain through neurophysiological mechanisms. Exercise has been shown to activate endogenous pain inhibitory pathways, improve central pain modulation, and reduce pain sensitivity in individuals with chronic musculoskeletal conditions.[13] These mechanisms may contribute to the observed reduction in WOMAC pain scores and help explain why strengthening exercises consistently demonstrate beneficial effects across different OA populations. The present findings are therefore consistent with previous systematic reviews and meta-analyses reporting significant improvements in pain and physical function following resistance-based interventions among individuals with knee OA.[18,20,21]

Similarly, NWBE produced a significant reduction in WOMAC pain scores. Unlike exercises performed under substantial joint loading, NWBE minimizes compressive forces acting across the knee while maintaining active muscle contraction and joint movement. Reduced loading may decrease mechanical irritation of degenerative structures and improve movement tolerance among individuals experiencing pain during weight-bearing activities.[22] Furthermore, repetitive unloaded movements may facilitate synovial fluid circulation, improve nutrient distribution within articular cartilage, reduce joint stiffness, and maintain neuromuscular activation.[29] These physiological effects may collectively contribute to symptom reduction and functional improvement. Therefore, the effectiveness of NWBE observed in this study is consistent with previous reports supporting its use in individuals with symptomatic knee OA.[22,23]

Although both interventions significantly reduced pain, no statistically significant difference was identified between groups. Several explanations may account for this finding. First, despite differences in exercise modality, both interventions target similar therapeutic goals, including improvement of muscle function, enhancement of movement tolerance, maintenance of joint mobility, and reduction of pain. Consequently, both approaches may produce comparable clinical outcomes through different physiological pathways. Second, both interventions were delivered with similar frequency, duration, and supervision, resulting in comparable treatment exposure. Third, the magnitude of pain reduction observed in both groups was nearly identical, suggesting that the therapeutic effects achieved during the four-week intervention period were largely equivalent.

The absence of a significant between-group difference should not be interpreted as evidence that one or both interventions lack efficacy. Rather, the findings suggest that clinicians may have flexibility in selecting exercise interventions according to patient-specific needs. Resistance training may be particularly appropriate for individuals presenting with substantial muscle weakness or impaired knee stability, whereas NWBE may be preferable for patients who experience pain during weight-bearing activities or demonstrate limited tolerance to mechanical loading.[2] Therefore, intervention selection may be individualized based on clinical presentation rather than assumptions regarding superiority of a specific exercise modality.

Several methodological considerations should be acknowledged when interpreting these findings. First, the study employed a quasi-experimental design without random allocation, introducing the possibility of selection bias. Although baseline WOMAC pain scores were comparable between groups, unmeasured participant characteristics may have influenced treatment allocation and outcomes. Second, purposive sampling may limit external validity and increase susceptibility to confounding. Third, the study was conducted in a single rehabilitation setting, potentially limiting generalizability to other populations and healthcare environments. These limitations should be considered when applying the findings to broader clinical contexts.

Another important consideration is the possibility of a type II error. The study included only 30 participants, and no formal sample size calculation or power analysis was conducted before recruitment. Consequently, the study may have lacked sufficient statistical power to detect small but clinically relevant differences between interventions. It is therefore possible that subtle treatment differences existed but were not identified because of the relatively small sample size. Future studies involving larger samples are necessary to confirm the present findings and improve the precision of treatment effect estimates.

The clinical significance of the observed improvement should also be interpreted cautiously. Although statistically significant reductions in WOMAC pain scores were observed, the average reduction was 1.40 points in both groups. Because minimal clinically important difference (MCID) analysis was not performed, it remains unclear whether the magnitude of improvement exceeded thresholds considered clinically meaningful from the patient perspective.[27] Future investigations should incorporate MCID analysis, effect size estimation, and confidence intervals to provide a more comprehensive assessment of treatment effectiveness and clinical relevance.

Despite these limitations, the present study contributes practical evidence regarding two commonly prescribed physiotherapy interventions for knee OA. Direct comparison of RTE and NWBE within the same clinical setting provides information that may assist physiotherapists in selecting appropriate interventions according to patient needs and functional limitations. Furthermore, the use of WOMAC, a validated and internationally recognized outcome measure, strengthens the credibility of the findings and facilitates comparison with previous studies.[24–26]

Overall, the findings support the growing body of evidence indicating that exercise therapy is an effective strategy for managing pain associated with knee OA. Both RTE and NWBE demonstrated beneficial effects, with neither intervention showing superior effectiveness during the four-week intervention period. Future randomized controlled trials involving larger samples, longer follow-up periods, and additional outcomes such as muscle strength, balance, physical function, and quality of life are required to further clarify the comparative effectiveness and long-term value of these interventions.

Conclusion

This study demonstrated that both resistance training exercise (RTE) and non-weight bearing exercise (NWBE) significantly reduced WOMAC pain scores among older adults with grade I–II knee osteoarthritis following a four-week intervention period. However, no statistically significant difference was observed between the two interventions, indicating that neither approach demonstrated superior effectiveness for pain reduction during the study period.

These findings suggest that both RTE and NWBE may be considered effective physiotherapy interventions for managing knee pain associated with mild to moderate knee osteoarthritis. The results further support the role of exercise therapy as a core component of conservative osteoarthritis management. Because both interventions produced comparable outcomes, intervention selection may be individualized according to patient characteristics, physical capacity, symptom presentation, and tolerance to joint loading.

The findings should be interpreted within the context of the study design and population. Therefore, generalization beyond older adults with grade I–II knee osteoarthritis and similar clinical settings should be undertaken cautiously. Future studies employing randomized controlled trial designs, larger sample sizes, longer follow-up periods, and more comprehensive outcome measures are recommended to further clarify the comparative effectiveness and long-term clinical benefits of these exercise interventions.

Clinical Implications

The present findings have several implications for physiotherapy practice. First, both RTE and NWBE may be incorporated into rehabilitation programs for older adults with knee osteoarthritis because both approaches demonstrated beneficial effects on pain reduction. Second, clinicians may select either intervention according to patient-specific characteristics rather than assuming superiority of one exercise modality over another.

For patients presenting with muscle weakness, reduced knee stability, or impaired functional performance, RTE may provide additional benefits through strengthening of muscles responsible for dynamic joint stabilization.[18] Conversely, NWBE may be particularly suitable for individuals who experience pain during weight-bearing activities or have limited tolerance to joint loading.[22] Therefore, individualized exercise prescription remains an important component of evidence-based physiotherapy management for knee osteoarthritis.

Study Limitations

Several limitations should be considered when interpreting the findings of this study. First, the quasi-experimental design without random allocation may increase the risk of selection bias and reduce internal validity. Although baseline WOMAC pain scores were comparable between groups, unmeasured confounding variables may have influenced treatment outcomes.

Second, purposive sampling and recruitment from a single clinical setting may limit the generalizability of the findings to broader populations. Third, the relatively small sample size may have reduced statistical power and increased the possibility of type II error, thereby limiting the ability to detect subtle differences between interventions.

Fourth, formal sample size calculation, effect size estimation, confidence interval reporting, and minimal clinically important difference (MCID) analysis were not included in the original study design. Consequently, interpretation of the magnitude and clinical relevance of treatment effects should be undertaken cautiously.

Finally, adherence rates, intervention fidelity, and detailed progression parameters were not quantitatively documented. Future studies should incorporate these methodological elements to improve reporting quality and strengthen the reproducibility of exercise-based interventions.

Author Contributions

Andy Martahan Andreas Hariandja: Conceptualization, Methodology, Investigation, Supervision, Validation, Writing, Review and Editing.
Dwi Agustina: Conceptualization, Methodology, Supervision, Validation, Writing, Review and Editing.
Muhammad Naufal Amru: Data Curation, Formal Analysis, Investigation, Project Administration, Visualization, Writing, Original Draft Preparation, Writing, Review and Editing.

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Conflict of Interest Statement

The authors declare that there are no conflicts of interest regarding the publication of this manuscript. The authors have no financial, professional, or personal relationships that could have influenced the conduct, analysis, interpretation, or reporting of the study findings.

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Ethics Statement

This study was approved by the Health Research Ethics Committee of Poltekkes Kemenkes Jakarta III, Indonesia (Approval No. DP.04.03/F.XI.22/13402/2025). Written informed consent was obtained from all participants prior to enrolment. All procedures were conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and applicable institutional regulations governing research involving human participants.

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