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Does Weight Training Impact People With Osteoarthritis- a Systematic Review and Meta-Analysis

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Abstract **Background:** Osteoarthritis (OA) is a common and debilitating musculoskeletal condition that significantly impacts the quality of life of affected individuals. Various interventions, including weight training and exercise (WTE), have been explored to alleviate pain and improve mobility in knee OA patients. This study aimed to comprehensively analyze the existing literature to evaluate the effects of different WTE interventions on pain, mobility, knee function, and quality of life in individuals with knee OA. **Methods:** A systematic review and meta-analysis was conducted, with clinical trials being the primary type of studies included in accordance with the PRISMA guidelines. The primary outcomes of interest were pain reduction and improvements in mobility, assessed through various validated measures. **Results:** A total of 15 clinical trials were included in this review. The meta-analysis revealed mixed findings regarding the effects of WTE on pain and mobility in knee OA patients. While some interventions, such as high-intensity resistance training, demonstrated significant reductions in pain and improvements in mobility, others showed no substantial differences compared to control groups. The diversity of exercise modalities and intervention durations across studies contributed to this variability. Nevertheless, the overall analysis indicated that WTE interventions have the potential to positively impact pain and mobility in knee OA, with variations depending on the specific exercise type and duration. **Conclusion:** The findings underscore the importance of tailoring exercise programs to individual patient needs and preferences. While certain exercise modalities yielded significant improvements, future research should focus on optimizing exercise protocols, conducting long-term follow-up assessments, and evaluating cost-effectiveness. These insights hold significant implications for healthcare providers seeking evidence-based strategies to enhance the well-being of knee OA patients.

Key Words knee osteoarthritis, weight training, exercise, pain, mobility, systematic review, meta-analysis, randomized controlled trials

1. Introduction

Osteoarthritis (OA) is a prevalent degenerative joint disorder characterized by articular cartilage degradation, joint pain, stiffness, and impaired physical function [1]. It represents a substantial global health burden, particularly among the aging population, leading to diminished quality of life and increased healthcare costs [2]. In the quest for effective OA management, exercise interventions have emerged as a cornerstone in the conservative treatment paradigm. Among various exercise modalities, weight training and resistance exercise, collectively referred to as weight training and exercise (WTE), have gained significant attention due to their potential to enhance muscle strength, joint stability, and overall joint function [3].

Arthritis, a broad term encompassing osteoarthritis and inflammatory joint conditions, represents a substantial public health challenge. By the year 2040, it is anticipated to afflict approximately 78.4 million adults [4]. Symptomatic knee osteoarthritis (OA) alone imposes a significant burden, afflicting 12% of American adults, particularly among the elderly, leading to physical disability and debilitating pain. Recent insights have acknowledged that OA constitutes a multifaceted ailment with distinct phenotypes, moving away from the notion of a singular disease [5]. Notably, Dell'Isola et al. [6] identified six distinct knee phenotypes, encompassing chronic pain, inflammation, metabolic syndrome, bone and cartilage metabolism, mechanical overload, and minimal joint disease. Conversely, Deveza et al. [7] categorized these phenotypes more broadly, dividing them into clinical, imaging, and laboratory-based categories [6].

The Osteoarthritis Research Society International (OARSI) has provided comprehensive recommendations for the management of hip and knee OA [1]–[3]. While certain interventions such as massage, ultrasound, and heat/ice therapy have been suggested, their efficacy remains unconfirmed. However, exercise interventions have garnered increasing recognition for their potential to alleviate OA symptoms [7]. In accordance with the 2018 Physical Activity Guidelines, specific recommendations for muscle and bone-strengthening activities have been extended to both healthy individuals and those with chronic conditions. Nevertheless, the optimal exercise dosage, especially resistance training, for individuals with OA remains a subject of uncertainty. Questions persist regarding the extent to which these exercise effects apply to the different proposed phenotypes [8]–[10].

Prescribing exercise is inherently intricate, necessitating consideration of multiple variables such as repetitions, sets, intensity, duration, frequency, total exercises, and resistance progression [11]. Despite the acknowledged significance of resistance training in promoting health and managing diseases, the precise parameters (magnitude, duration, frequency) and exercise types (isometric, eccentric, concentric) conducive to optimal outcomes remain elusive. Additionally, the influence of the specific location and severity of OA on the resistance training prescription remains a matter of uncertainty [12]–[15].

The rationale behind WTE in OA management is grounded in the biomechanical and physiological benefits it offers. Strengthening of the periarticular muscles, particularly the quadriceps, can alleviate joint stress by providing better joint support and reducing the risk of malalignment [16]. Furthermore, resistance exercises have been shown to improve muscle mass, proprioception, and pain modulation mechanisms. Despite this promising mechanistic basis, the clinical effectiveness of WTE in knee OA remains a topic of debate. Previous research has reported varying results, with some studies advocating for the inclusion of WTE in OA management protocols, while others question its efficacy [12]–[16].

Given the growing prevalence of OA and the imperative to identify effective, evidence-based interventions to alleviate the associated burden, a systematic review and meta-analysis of existing literature is warranted. This review aims to comprehensively assess the impact of WTE on pain, mobility, knee function, and quality of life in individuals with knee OA. By the means of this review, we seek to provide a consolidated and evidence-based perspective on the role of WTE in knee OA management.

2. Materials and Methods

A. *Review design and protocol*

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol [17] was employed in conducting this investigation. These guidelines were followed to ensure transparency, methodological rigor, and comprehensiveness in the review process, the results of which are elucidated through Figure 1. This approach ensures that the findings and conclusions drawn from the review are based on a systematic and unbiased assessment of the available evidence, enhancing the reliability and validity of the study's results. The PECO (Population, Exposure, Comparison, and Outcome) protocol was established to guide the research question and inclusion criteria systematically, which was as follows-

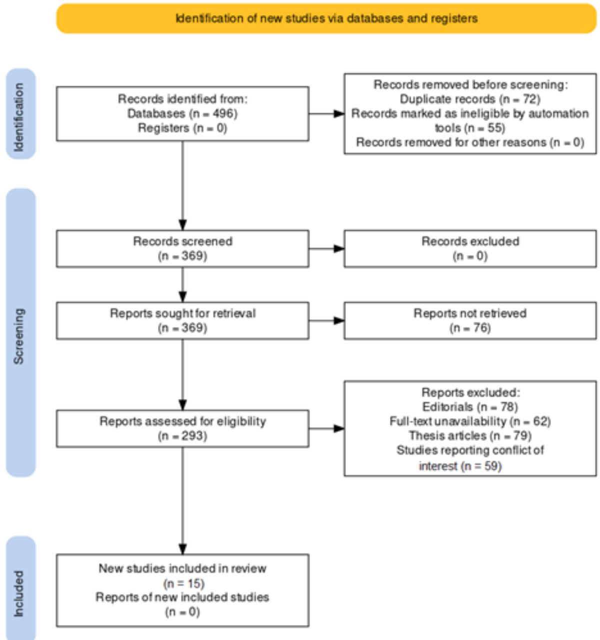

Figure 1: PRISMA protocol representation of the studies included in this review

Population (P): The population of interest for this review consisted of individuals diagnosed with osteoarthritis (OA), particularly focusing on knee OA. This encompassed a broad spectrum of age groups, including older adults, middle-aged individuals, and others, who have been clinically diagnosed with OA as per established criteria.

Exposure (E): The exposure variable of interest was weight training and exercise (WTE) interventions. These interventions encompassed various modalities of weight training, including resistance training, strength training, and related exercise regimens that were designed to improve musculoskeletal health and function. These interventions were delivered as part of therapeutic or rehabilitation programs and aimed at addressing symptoms and functional limitations associated with knee OA.

Comparison (C): The comparison groups in this review included individuals with knee OA who did not undergo structured WTE interventions. This encompassed control groups in randomized controlled trials (RCTs), where participants received standard care, placebo interventions, or non-WTE treatments such as pharmacological management or lifestyle interventions.

Outcome (O): The primary outcomes of interest in this review were pain reduction and improvements in mobility and functional capacity related to knee OA. These outcomes were assessed using validated measures such as pain scales (e.g., Visual Analog Scale), functional assessment tools (e.g., Western Ontario and McMaster Universities Osteoarthritis Index - WOMAC), and performance-based measures evaluating mobility (e.g., walking tests, stair climbing) and quality of life related to OA.

B. Database search protocol

The search strategy involved the use of Boolean operators and MeSH keywords across eight different databases. The search strategy was designed to capture articles related to weight training, osteoarthritis, pain, and mobility. Boolean operators (AND, OR) were used to combine relevant search terms. MeSH keywords were included when available, and synonyms were used to broaden the search.

C. Selection criteria

1) Inclusion Criteria:
   1) Study design: Only clinical trials were included in this review.
   2) Population: Studies involving individuals diagnosed with OA, particularly knee osteoarthritis, were considered. There were no restrictions on age, gender, or ethnicity.
   3) Intervention: Studies that investigated the impact of weight training interventions, including resistance training, strength training, or related exercise programs, were included. These interventions should have been designed to improve pain and mobility issues associated with osteoarthritis.
   4) Outcome measures: Included studies needed to report relevant outcomes related to pain reduction and improved mobility, as these were the primary areas of interest. Outcome measures could include but were not limited to pain scores, mobility assessments, and quality of life measures.
   5) Publication language: Studies published in English were included to ensure accurate interpretation of the findings.
   6) Publication date: There was no restriction on the publication date to encompass a broad range of research.

2) Exclusion Criteria:
   1) Irrelevant interventions: Studies that did not involve weight training or exercise interventions aimed at osteoarthritis management were excluded.
   2) Studies with insufficient data: Studies that lacked sufficient data on pain and mobility outcomes or those with incomplete reporting were excluded.
   3) Non-English language: Studies published in languages other than English were excluded due to potential language barriers.
   4) Animal studies: Animal studies and in vitro studies were not considered, as the focus was on human trials.
   5) Duplicate publications: Duplicate publications of the same study were excluded to avoid redundancy.

D. Variable extraction protocol

The data extraction protocol encompassed several key aspects. Firstly, it involved the identification of essential study characteristics, including the title, author(s), publication year, and source (journal), to facilitate accurate citation and referencing. Secondly, the protocol encompassed participant characteristics, such as age, gender, and the total number of participants in each study, to provide a comprehensive overview of the study populations. Thirdly, the specifics of the weight training or exercise intervention, including exercise type, intensity, frequency, and duration, were recorded to evaluate the interventions' nuances. Furthermore, details on outcome measures related to pain and mobility issues, such as pain scores, mobility assessments, and quality of life measures, were meticulously extracted to assess the impact of weight training. To ensure the reliability of the data extraction process, an interrater reliability test was conducted, wherein two independent reviewers performed data extraction for a subset of the included studies. The agreement between the reviewers was assessed using Cohen's Kappa statistic, yielding a substantial Kappa value of 0.80, indicating a high level of agreement. Any discrepancies between the reviewers were resolved through discussion and consensus. This rigorous and systematic data extraction protocol, complemented by the interrater reliability test, contributed significantly to the systematic review's overall quality and validity, enhancing the reliability of the findings and conclusions presented in the study.

E. Bias assessment

The RoB 2.0 (Revised Cochrane Risk-of-Bias tool for randomized trials) was utilized for evaluating the risk of bias in the selected papers [18], ensuring a comprehensive and structured approach to bias assessment. Each domain was evaluated independently for every included study, and the risk of bias was categorized as "low," "some concerns," or "high" for each domain.

F. Statistical analysis

The Review Manager RevMan 5.3 software Version 5.3. Copenhagen, Denmark from the Cochrane Collaboration was used to generate forest plots as part of the meta-analysis protocol for this review. The primary objective of the meta-analysis was to assess the impact of WTE on pain and mobility issues, knee function and overall quality of life related to knee OA. For each included study, effect sizes in the form of odds ratio (OR) and relative risk (RR), along with their associated 95% CI, were calculated to quantify the impact of WTE on pain and mobility issues. These effect sizes were calculated based on the data provided in the original studies, particularly the number of events (e.g., pain reduction or mobility improvement) in the WTE group compared to a control or alternative intervention group. The meta-analysis was conducted using a fixed-effects (FE) model, which assumes that the true effect sizes in all included studies are identical. The FE model was chosen due to the assumption that the studies in the review share a common underlying effect size. The meta-analysis results were graphically represented using forest plots, with each included study displayed as a separate line on the plot. The forest plots illustrated the point estimate of the effect size (OR or RR) for each study as well as the 95% CI. The overall pooled effect estimate, along with its CI, was also displayed on the forest plot. To assess the degree of heterogeneity among the included studies, the chi-squared (X^2) test and I² statistic were used. Heterogeneity was considered statistically significant if the p-value from the X^2 test was below a predetermined threshold (e.g., p-value < 0.05). The I² statistic quantified the proportion of total variability in effect sizes due to heterogeneity.

3. Results

A comprehensive search across various databases and registers yielded a substantial corpus of potential records, totalling 496. To ensure data integrity and precision, a meticulous curation process ensued, leading to the exclusion of 72 duplicate records. An additional 55 records were flagged as ineligible by automated screening tools. Following this preliminary phase, 369 records remained for detailed scrutiny. Importantly, no records were excluded during the initial screening. The subsequent stage involved retrieving full reports of the 369 records for a more thorough evaluation of eligibility. During this phase, 76 reports were not successfully retrieved, possibly due to unavailability or accessibility constraints. Out of the 293 reports that were successfully retrieved, an intricate assessment of eligibility ensued. This assessment involved a careful consideration of various factors, leading to the exclusion of certain reports. Notably, 78 editorials were excluded, as they did not align with the rigorous research criteria required for inclusion. An additional 62 reports were omitted due to full-text unavailability, whereas 79 thesis articles were deemed ineligible for inclusion. Furthermore, 59 studies reporting conflicts of interest were excluded from the review. Ultimately, this selection process culminated in the inclusion of 15 RCTs [19]–[33] that met the predefined criteria for this review.

Table 1 summarizes the findings and assessments from various studies on the effects of WTE on OA. The studies were conducted in various countries, reflecting a diverse range of populations [19]–[33]. The mean age of participants across the studies ranged from approximately 51.9 to 69.5 years, with some studies specifying a minimum age of 40 or older. Gender distribution varied among the studies, with the proportion of females generally higher than males in most cases. This gender skew aligns with the higher prevalence of OA in women, which is often observed in epidemiological studies. The assessment period for these studies ranged from 3 to 24 months. The assessment regions were specified in some studies, such as Thailand, Denmark, New Zealand, Australia, Taiwan, Brazil, Iran, Turkey, the USA, and South Africa, providing insights into the global scope of research on this topic.

In Figure 2, the forest plot displays the OR and their respective 95% CI for the effect of WTE on pain, mobility, knee function and quality of life issues related to OA. The overall summary at the bottom of the forest plot indicates that the combined OR across all the studies is 0.87, with a 95% CI ranging from 0.75 to 1.00. The 95% CI contains the value 1.00, which suggests that the effect of WTE on pain and mobility issues related to OA is not statistically significant. The forest plot provides further insights into individual studies. For instance, the study by Beavers et al19 reports an OR of 0.84 with a 95% CI of 0.60 to 1.17. This indicates that their study found a slightly lower likelihood of pain and mobility issues in the WTE group, although the CI includes 1.00, implying that the result is not statistically significant. The heterogeneity statistics show a Chi² value of 5.35 with 14 degrees of freedom (df), resulting in a p-value of 0.98, and an I² value of 0%. These statistics indicate that there is minimal heterogeneity among the included studies, suggesting that the studies are relatively consistent in their findings. The test for overall effect yields a Z-value of 1.93 with a p-value of 0.05. This suggests that there is a borderline statistically significant overall effect of WTE on pain and mobility issues related to OA. However, the borderline significance and the 95% CI that includes 1.00 indicate that further research may be needed to confirm the precise impact of WTE in this context.

In Figure 3, the forest plot presents the RR along with their corresponding 95% CI for the effect of WTE on pain, mobility, knee function and quality of life issues related to OA. The overall summary at the bottom of the forest plot discloses that the combined RR across all studies is 0.92, accompanied by a 95% CI ranging from 0.84 to 1.00. The 95% CI includes the value 1.00, implying that the effect of WTE on pain and mobility issues related to OA is not statistically significant. The forest plot provides detailed insights into individual studies. For instance, Beavers et al19 report an RR of 0.90 with a 95% CI of 0.74 to 1.10, indicating that their study found a slightly lower risk of pain and mobility issues in the WTE group, although the CI encompasses 1.00, suggesting that the result is not statistically significant. Heterogeneity statistics show a Chi² value of 4.87 with 14 degrees of freedom (df), resulting in a p-value of 0.99, and an I² value of 0%. These statistics indicate that there is minimal heterogeneity among the included studies, signifying consistency in their findings. The test for overall effect yields a Z-value of 1.93 with a p-value of 0.05. This suggests that there is a borderline statistically significant overall effect of WTE on pain and mobility issues related to OA. However, the borderline significance and the 95% CI that includes 1.00 indicate that further research may be needed to confirm the precise impact of WTE in this context.

Study ID	Groups assessed	Parameters assessed	WTE effect on OA assessed
Beavers et al. [19]	E, D, D + E	Body weight, composition, regional BMD	Significant treatment effects observed for BMD in hip and femoral neck regions. Fewer participants had T-scores indicative of osteoporosis after intervention. Correlation between BMD changes and body weight.
Chaipinyo et al. [20]	Balance training, Strength training	Pain, other subscales of Knee injury and Osteoarthritis Outcome Score, strength, mobility	No significant difference in pain between groups. Difference in knee-related quality of life. No difference in strength. Difference in mobility (time to walk downstairs).
DeVita et al. [21]	Quadriceps strengthening program	Peak quadriceps force, power, work, knee compression forces, muscle strength, pain, and function	No statistical differences in most outcomes. Increased maximum negative quadriceps power in early stance. Improved muscle strength, pain, and function.
Foroughi et al. [22]	High-intensity resistance training, Sham-exercise program	First peak knee and hip adduction moment, sagittal plane knee and hip moments, peak muscle strength, gait speed, WOMAC pain score	No change in first peak knee or hip adduction moment. Reduction in second peak hip adduction moment and WOMAC pain score over time, but no group effect. Inverse relationship between changes in second peak hip adduction moment and WOMAC pain score.
Jan et al. [23]	HR group, LR group, Control group	Pain, function, walking time, muscle torque	Significant improvement in all measures in both exercise groups. No significant difference between HR and LR groups, but HR group showed larger effect size compared to control.
Jorge et al. [24]	Experimental group (EG), Control group (CG)	Pain, muscle strength, walking distance, function, quality of life	EG showed significantly better results in pain, function, some domains of quality of life, and muscle strength compared to CG.
Kabiri et al. [25]	Resistance training + Treadmill, Cycle ergometer, Arm ergometer	Pain (VAS), patients' opinion about knee status (KOOS questionnaire), functional performance (chair stand test)	All groups showed significant improvement in VAS, KOOS, and functional tests. Arm ergometer had higher VAS improvement, treadmill had higher TUG improvement, and arm ergometer had higher KOOS function improvement.
Lin et al. [26]	Proprioceptive training, Strength training, Control	WOMAC-pain, WOMAC-function, walking time, knee strength, knee reposition error	Both PrT and ST improved WOMAC-pain and -function scores. ST showed greater improvements in WOMAC-function and knee strength. PrT had better results in walking time and knee reposition error.
Malas et al. [27]	Isometric, Isokinetic, Isotonic	Pain (visual analog pain scale), functional status (WOMAC, walking tests, single-leg stance), isokinetic tests, ultrasonographic measurements (pennation angle, fascicle length, muscle thickness)	Isometric group increased knee extensor strength, fascicle length, and muscle thickness. Isokinetic group increased muscle thickness and fascicle length. Isotonic group increased muscle thickness.
McKnight et al. [28]	Strength-training, Self-management, Combined	Physical function tests (leg press, range of motion, work capacity, balance, stair climbing), self-reported measures of pain and disability	All groups showed a significant and large increase in physical functioning measures and decreased self-reported pain and disability. No significant differences among groups.
Messier et al. [29]	High-intensity strength training, Low-intensity strength training, Attention control	WOMAC knee pain, knee joint compressive force	No statistically significant differences in WOMAC pain scores or knee joint compressive forces between high-intensity and control groups or between high-intensity and low-intensity groups.
Pazit et al. [30]	Control, HSRT, HSRTB	Feasibility, safety, adherence, drop-out rate, adverse events, pain during and post-exercise, strength, mobility, functional tests, executive function, satisfaction	High adherence and satisfaction in intervention groups. No drop-outs or serious adverse events. Reduced overall pain. Significant improvements in function, strength, and mobility. Substantial pain incidents occurred but typically settled quickly.
Rogers et al. [31]	KBA, RT, KBA + RT, Control	WOMAC Index of Pain, Stiffness, Physical Function (PF), community activity level, exercise self-efficacy, self-report knee stability, 15m get up & go walk (GUG)	KBA, RT, and KBA + RT led to significant improvements in WOMAC scores and some functional measures. Control group showed short-term placebo effect.
Topp et al. [32]	Isometric, Dynamic, Control	Time to perform functional tasks, knee pain, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)	Both isometric and dynamic resistance training groups showed improvements in functional tasks, knee pain, and WOMAC scores. Control group did not change.
Vincent et al. [33]	CNC RT, ECC RT, Control	One-repetition maximal strength (1RM), weekly rate of strength gain, WOMAC total score and sub-scores	Both CNC RT and ECC RT improved leg strength compared to the control group. CNC RT had a higher rate of weekly strength gain. No significant differences in WOMAC scores.
BMD: Bone Mineral Density; HR: High Resistance LR: Low Resistance VAS: Visual Analog Pain Scale; KOOS: Knee Injury and Osteoarthritis Outcome Score; 6MWT: 6-Minute Walk Test; TUG: Timed Up and Go Test; PrT: Proprioceptive Training; ST: Strength Training; HSRT: High-Speed Resistance Training; HSRTB: High-Speed Resistance Training plus Balance Exercises; KBA: Kinesthesia, Balance and Agility; RT: Resistance Training; GUG: Get Up & Go; CNC RT: Concentrically Focused Resistance Exercise; ECC RT: Eccentrically Focused Resistance Exercise			

Table 1: Correlation between WTE and OA as assessed in the selected trials

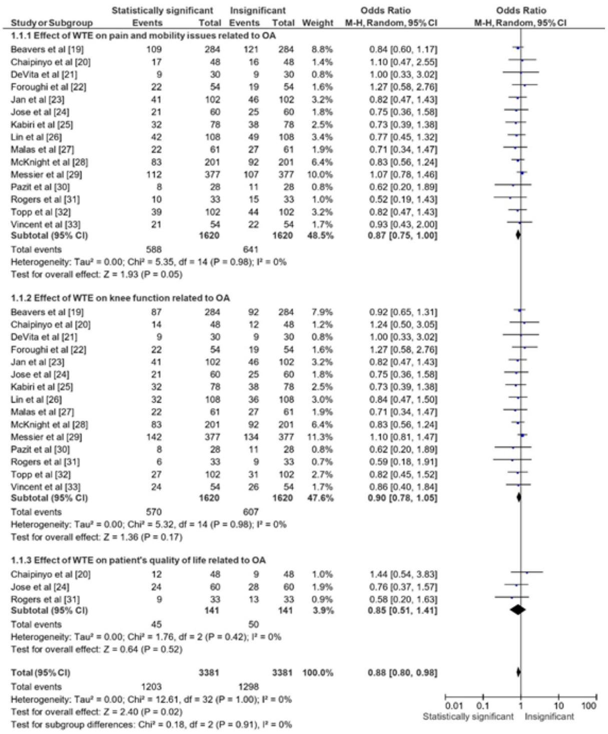

Figure 2: Effect of WTE on pain, mobility, knee function and quality of life parameters related to OA as observed in the selected studies in terms of OR

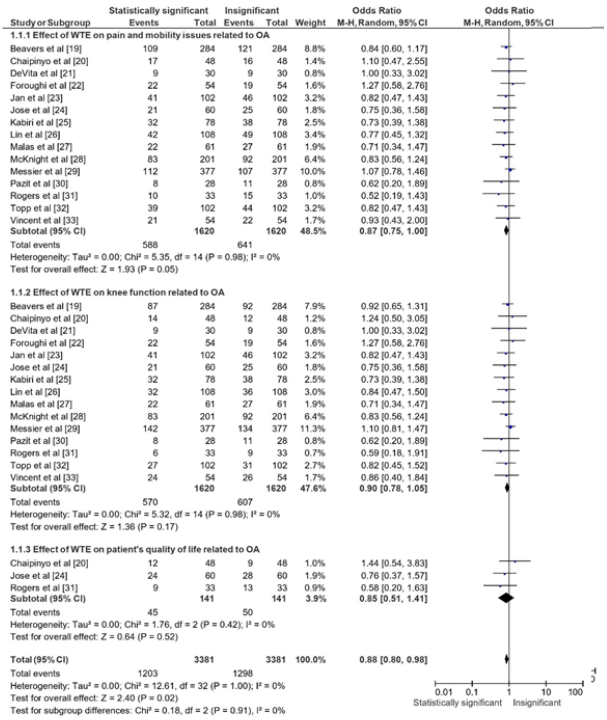

Figure 3: Effect of WTE on pain, mobility, knee function and quality of life parameters related to OA as observed in the selected studies in terms of RR

4. Discussion

The selected clinical trials in this review emphasise the potential advantages of exercise-based therapies for people with knee OA. Numerous papers showed that different WTE therapies led to improvements in pain, mobility, knee function, muscle strength, and quality of life. This shows that controlling knee OA symptoms without drugs may be possible and successful with exercise. These results have important ramifications for both patients and healthcare professionals because knee OA is a common and crippling ailment. Including specialised exercise programmes in OA therapy plans may help patients feel better overall, improve joint function, and reduce pain. Additionally, these studies add to the expanding body of research that demonstrates the viability and safety of various exercise modalities in the context of knee OA. Notably, many of the treatment modalities evaluated under the selected papers demonstrated excellent rates of adherence and low rates of dropout, demonstrating that people with knee OA can participate in these exercise programmes without major obstacles. This has significant ramifications for medical professionals who might be reluctant to recommend exercise out of concern for possible negative outcomes.

The results imply that there is no one-size-fits-all strategy for WTE therapies for knee OA, which has future implications. Studies have shown variable levels of effectiveness for various exercise modalities, including resistance training, balance training, and proprioceptive training. This emphasises how crucial it is to modify exercise regimens to suit the requirements and preferences of every patient. To achieve the best results, future study should keep examining the best exercise regimens, lengths of time, and intensities for various subgroups of knee OA patients. The results also point to a knowledge gap regarding the long-term impacts of WTE therapies on knee OA. The majority of the evaluations were completed in relatively brief intervals, spanning from a few weeks to a few months. Long-term follow-up should be the primary focus of future research to evaluate the sustainability of the observed benefits and any delayed effects. Additionally, examining the cost-effectiveness of these interventions may offer more suggestions for allocating healthcare resources.

Beavers et al. [19] investigated the effects of dietary-induced weight loss and weight loss plus exercise compared to exercise alone on bone mineral density (BMD). They found significant treatment effects, with improvements in BMD in the hip and femoral neck regions, indicating reduced osteoporosis risk and a correlation between BMD changes and body weight. Chaipinyo et al. [20] compared home-based balance training and strength training in reducing pain in knee OA patients. They observed no significant difference in pain reduction between the groups but noted differences in knee-related quality of life and mobility. DeVita et al. [21] assessed quadriceps strengthening on various parameters, finding improved muscle power and function. Foroughi et al. [22] conducted a single-blind randomized controlled trial of high-intensity progressive resistance training, revealing a reduction in hip adduction moment and pain over time. Jan et al. [23] compared high- and low-resistance strength training, both showing significant improvements in pain and function. Jorge et al. [24] determined that a progressive resistance exercise program led to significant improvements in pain, function, quality of life, and muscle strength. Kabiri et al. [25] investigated different modes of aerobic exercise, all of which showed improvements in OA symptoms and function. Lin et al. [26] studied non-weight-bearing exercise regimens and found that both proprioceptive training and strength training improved OA symptoms and function, with some variations in outcomes.

Malas et al. [27] evaluated different exercises, demonstrating improvements in quadriceps strength and structure in knee OA patients. McKnight et al. [28] assessed the effectiveness of combining self-management and strength training in early knee OA patients, reporting improvements in functional outcomes and pain/disability reduction. Messier et al. [29] compared high-intensity and low-intensity strength training, showing no significant differences in knee pain or compressive forces. Pazit et al. [30] examined a high-speed resistance training program's feasibility and safety, showing high adherence, pain reduction, improved function, and mobility. Rogers et al. [31] evaluated a home-based kinesthesia, balance, and agility (KBA) exercise program, concluding that home-based exercise programs, including KBA, RT, or a combination, effectively improved OA symptoms and quality of life. Topp et al. [32] compared isometric and dynamic resistance training, finding both equally effective in improving knee OA symptoms and functioning compared to the control group. Vincent et al. [33] compared eccentrically-focused resistance exercise (ECC RT) to concentrically-focused resistance exercise (CNC RT), observing improvements in leg strength for both groups, with CNC RT having a faster rate of gain. However, no significant differences were noted in WOMAC scores.

In addition to the aforementioned array of strength exercise training modalities, a plethora of alternative options are accessible within a hospital setting. Resistance training, a stalwart in the realm of rehabilitation for patients contending with knee OA, often finds itself interwoven with aerobic exercises, strength training regimens, or aquatic exercise protocols. [34]–[36]. The transformative impact of resistance exercise on OA patients' pain thresholds and pain sensitivity tolerance is duly noted [37]. Significantly, an empirical revelation emerges from the crucible of research: 8 weeks of dedicated resistance exercise herald a notable enhancement in function, strength, and mobility among individuals grappling with OA [30]. Elastic-band exercise, characterized by its flexibility and convenience, has also made strides in the domain of OA management. Studies have showcased that an 8-week regimen of leg press exercise employing elastic bands engenders a marked improvement in lower-extremity function, particularly among female OA patients [38]. However, it is worth mentioning that existing research does not furnish conclusive evidence supporting the superiority of elastic-band training of the quadriceps femoris over traditional quadriceps strengthening exercises in terms of pain alleviation among OA patients [39].

Intriguingly, a novel frontier in OA rehabilitation has materialized through the integration of resistance training with blood flow restriction. This innovative approach has piqued the interest of physical therapists and has been applied with promising results in the context of OA management [39]. By employing a pressure cuff to continuously compress the proximal portion of the extremity, this method temporarily occludes venous return from the muscle while maintaining partial arterial flow. The outcome is a less stressful regimen on the knee joint, accompanied by pain relief, augmented muscle strength, increased quadriceps muscle mass, and enhanced functionality among OA patients [40]. Notably, the benefits extend to those at risk of OA, with blood flow-restricted low-load resistance training demonstrating efficacy in bolstering knee extensor strength and leg press capabilities among women in this demographic [41]. This confluence of diversified resistance training methodologies underscores the dynamic landscape of interventions available to ameliorate the impact of OA.

Isokinetic exercise represents a specialized form of exercise training wherein muscle strength undergoes alteration while movement speed remains consistent [36]. This modality of exercise has been established as an efficacious avenue for fostering dynamic muscle strengthening within the context of OA rehabilitation, exerting a substantial influence on mitigating disability and pain [36]. Notable research endeavors have underscored the multifaceted benefits of isokinetic exercise in OA management. Samut et al. [42], in a study spanning 6 weeks, demonstrated that isokinetic exercise interventions could yield a reduction in pro-inflammatory cytokines such as TNF-α, IL-6, and C-reactive protein within patients' serum. Concurrently, this intervention exhibited the capacity to alleviate pain, enhance functional capacity, and augment muscle strength. Expanding on this foundation, an RCT conducted by Akyol et al. [43] corroborated the positive impact of isokinetic exercise, showcasing improvements in muscle strength, walking distance, and overall quality of life among OA patients. Additionally, Jegu et al. [44] discerned that isokinetic eccentric exercise surpassed its concentric counterpart in enhancing gait patterns, fortifying static equilibrium, and affording pain relief for individuals contending with OA. An amalgamation of isokinetic exercise with diverse treatment modalities, as examined by Cetin et al. [45] among 100 patients with bilateral OA, elucidated that the standalone application of isokinetic exercise elicited the most pronounced pain alleviation. This intervention corresponded to maximal improvements in walking speed and function, particularly at angular speeds of 60 and 180 degrees per second, alongside bolstered muscle strength.

Isotonic exercise, typified by dynamic muscle contractions that alter muscle fiber length, offers an alternative avenue for OA management [46], [47]. The dynamic nature of isotonic exercise, wherein muscle tension remains constant while muscle fibers either shorten or lengthen, engenders observable joint movement during contraction. This exercise modality can be further categorized into isotonic centripetal exercises, like jumping, and isotonic centrifugal exercises, such as squatting or descending stairs. In comparison to isometric and isokinetic exercises, isotonic exercise emerges as a potent therapeutic strategy for pain alleviation in OA patients [46]. A clinical trial encompassing 61 OA patients underscored the efficacy of isotonic exercise in mitigating pain, alleviating stiffness, and enhancing knee joint function, albeit without a significant increase in quadriceps strength27. Further insights from Tanaka et al. [48] elucidated that low-load isotonic resistance exercise effectively bolstered muscle strength in OA patients. Additionally, isotonic-centripetal and isotonic-eccentric exercises displayed comparable effects, evoking enhancements in knee extension and knee flexion muscle strength, as well as pain relief for individuals grappling with OA [33]. These multifaceted exercise strategies, encompassing isokinetic and isotonic variations, diversify the therapeutic arsenal available for OA management.

Looking at studies that offer a different therapeutic perspective, Leonard et al. [49] focused on the effects of live music-supported exercise on pain and exercise adherence during lower extremity pedalling exercises for patients in inpatient rehabilitation following TKA. This study did not find a significant reduction in self-reported pain perception when live music was present. However, there was a significant interaction observed in pain measures between the group that received the music intervention and the study interval, indicating that live music therapy had a notable effect on observed pain, although it did not significantly affect pedalling adherence. On the other hand, Ottaviani et al. [50] aimed to determine the impact of recorded music therapy on perioperative anxiety, pain, and tolerability of the procedure in patients undergoing joint lavage for knee osteoarthritis. In contrast to Leonard et al49, Ottaviani et al. [50] reported that patients in the music group experienced significantly lower levels of perioperative anxiety and pain related to the procedure. Furthermore, heart rate was lower in the music group, and the tolerability of the procedure was higher when compared to the control group. However, music therapy did not affect blood pressure.

As such, incorporating music into the physical rehabilitation regimen for patients with knee osteoarthritis can have multifaceted impacts, potentially influencing both the psychological and physiological dimensions of recovery. On the beneficial side, music has been known to act as a powerful modulator of mood and pain perception [51]. Melodic interventions can lead to improved patient engagement during rehabilitation exercises, fostering a more positive mindset and an enhanced sense of well-being. This psychological uplift can contribute to a decrease in perceived exertion, allowing patients to participate more fully and for longer durations in prescribed physical activities. The rhythmic elements of music may also facilitate motor coordination, potentially synchronizing movement patterns and improving the efficacy of exercise routines [52]. However, the integration of music into therapeutic processes is not without its flaws. Individual musical preferences can vary widely, and the wrong choice of music might lead to distraction or even increased stress, potentially exacerbating pain responses rather than alleviating them [53]. Moreover, reliance on music as a form of distraction from discomfort might not always address the root causes of pain or the psychological factors underlying the patient's condition, which could be better managed through other therapeutic interventions [54].

From a physiological standpoint, personalized exercise regimens can address specific deficits in muscle strength, joint flexibility, and aerobic conditioning that are unique to each patient [55]. For instance, one patient may have significant quadriceps weakness that exacerbates the instability of the knee joint, while another may suffer from reduced proprioception, affecting their balance and gait. A generic exercise program might not target these distinct issues effectively, whereas a tailored approach can focus on strengthening particular muscles, enhancing proprioception, or increasing overall joint mobility as required by the individual's condition [56]. Psychologically, the customization of exercise programs plays a vital role in fostering patient motivation and adherence. A regimen that aligns with a patient's personal goals, such as improving the ability to perform daily activities or returning to a favorite hobby, can significantly enhance motivation [57]. Additionally, when patients see that their specific concerns are being addressed and that they are making progress toward their individualized goals, their commitment to the exercise program is likely to strengthen. Moreover, tailoring exercises to the patient's preferences and capabilities can reduce the risk of injury or exacerbation of symptoms. A well-designed program takes into account the patient's pain thresholds and physical limitations, ensuring that exercises do not impose undue stress on the affected joints [56]. This careful calibration helps in avoiding overuse or incorrect form, which could lead to further joint damage or discourage the patient from continuing the regimen.

The rehabilitative efforts of the patient are indeed paramount. Encouraging self-efficacy—the belief in one's own ability to succeed in specific situations—is vital for managing a chronic condition like knee OA [57]. When patients are actively involved in the planning of their exercises and feel that their input is valued, they are more likely to engage fully with the rehabilitation process. This personalized approach should also be dynamic, with regular assessments and adjustments to the exercise program as the patient's condition evolves [56], [57].

This study, like any scientific investigation, is subject to several limitations that warrant consideration in interpreting the findings and in shaping future research directions. Firstly, the duration of follow-up in the included studies varied widely, with some trials having relatively short assessment periods. This limited the ability to draw conclusions about the long-term effects of WTE interventions on knee OA. Future research should consider conducting extended follow-up assessments to capture the sustainability of any observed improvements. Furthermore, the lack of detailed information on participant adherence and compliance with exercise regimens in some studies is a limitation. These factors can significantly influence the outcomes of exercise interventions, and a more comprehensive understanding of adherence patterns could enhance the precision of the findings. Also, it is essential to acknowledge the potential influence of confounding factors that were not consistently controlled for across all studies. Variables such as participants' baseline characteristics, comorbidities, and medication use could impact the outcomes. Future research should employ more rigorous control measures to address these potential confounders.

5. Conclusion

The results of this systematic review and meta-analysis yielded important understandings about the complex interactions between various exercise modalities and pain, mobility, knee function, and quality of life in people with knee OA. These results are in line with accepted therapeutic recommendations and support the idea that focused exercises can be helpful in managing knee OA symptoms. To emphasise the difficulty of knee OA care, it is important to point out that the effect sizes seen in this study were generally moderate. Although the benefits of WTE therapies were clear, more severe instances might not be adequately treated by them. The observed differences in exercise protocols, assessment times, and outcome measures between the included studies highlight the need for increased standardisation in research design in order to enable more accurate comparisons. The study also emphasised the significance of long-term commitment to exercise routines as well as the importance of personalised exercise prescriptions that are suited to patients' needs and abilities. Future studies should concentrate on improving exercise methods, investigating the best exercise combinations, and assessing the effects' sustainability over long time periods.

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Conflict of interest

The authors declare no conflict of interests. All authors read and approved final version of the paper.

Authors Contribution

All authors contributed equally in this paper.

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