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ORIGINAL ARTICLE

Combined Effects of Turmeric Supplementation and Strengthening Exercises on Knee Pain, Physical Function, and Quality of Life among Knee Osteoarthritis Patients

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ABSTRACT
Background. Strengthening exercises have been reported to enhance individuals' physical function and quality of life (QoL). Additionally, turmeric supplementation has demonstrated analgesic qualities, which may indirectly improve physical function and QoL. **Objectives.** This study examines the combined effects of turmeric supplementation and strengthening exercises on knee pain, physical function, and QoL in knee osteoarthritis patients versus knee-strengthening exercises alone. **Methods.** Thirty-five knee osteoarthritis patients (mean age 59.0 ± 11.4 years) were recruited and randomly assigned to the PE group (n=17) or the TE group (n=18). All participants performed strengthening exercises three times per week for 12 weeks. Participants in group TE took one turmeric supplement daily containing 697 mg/tablet of curcumin for 12 weeks. Measurements were conducted at pre-test, mid-test, and post-test, including anthropometric assessments, the 6-minute walk test (6MWT), and the administration of the Visual Analogue Scale (VAS), the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and the Quality of Life Questionnaire-Malay version. **Results.** The VAS-pain score, walking distance during the 6MWT, WOMAC scores, and QoL levels for physical, psychological, and social health showed significant improvements ($p<0.05$) in the TE group. However, the prescribed intervention did not significantly affect QoL related to environmental health ($p>0.05$). **Conclusion.** Combining turmeric supplementation and strengthening exercises enhanced pain reduction, physical function, and overall quality of life compared to strengthening exercises alone.

INTRODUCTION

Knee osteoarthritis (OA) is a prevalent illness impacting the community. The predominant symptom of knee OA is pain. Evidence suggests that pain is associated with an individual's quality of life (QoL) (1). Research demonstrates that regular knee strengthening exercises alleviate pain and enhance the quality of life for those with knee osteoarthritis (2). The discomfort must be managed to prevent future joint limitations that could result in impairments.

Turmeric is a plant in the ginger family, is native to Southeast Asia, and is grown commercially in that region, primarily in India (3). It contains curcumin as the active component, comprising around 3% to 10% of its overall composition. This active ingredient possesses potent anti-inflammatory characteristics akin to non-steroidal drugs. Numerous studies demonstrate the efficacy of turmeric in alleviating pain for people with knee osteoarthritis by inhibiting inflammatory processes in the joints. Curcumin is a natural supplement that has been shown in recent research to have anti-inflammatory (4), anti-oxidative (5), and pain-relieving (6) effects. It is claimed that curcumin's anti-inflammatory qualities even rival those of NSAIDs. Turmeric's curcumin extract limits the upregulation of matrix metalloproteinase MMP-3 (stromelysin) and MMP-1 (interstitial collagenase) enzymes caused by macrophage inhibitory factors. This is because turmeric's active ingredients affect NF kappa beta activity (4) by altering the signaling of pro-inflammatory cytokines, including COX-2, phospholipase A2, 5-lipoxygenase enzyme, and interleukins. Ultimately, all these actions and modifications will hasten the articular cartilage's catabolic alterations, reducing the development of knee OA.

In addition, research indicates that curcumin and diclofenac exhibit comparable efficacy; however, curcumin supplements demonstrate superior patient tolerance (7).

A key factor contributing to pain and functional impairment in individuals with knee OA is reduced muscle strength, particularly in the quadriceps (8). Most individuals with knee OA exhibit significantly poorer musculature than those without the condition, exacerbating joint stress and further impairing movement. It was reported that the maximal torque of the quadriceps muscle in individuals with knee OA was approximately 26% lower than in age-matched individuals without the condition (9). This decline in quadriceps strength underscores the importance of targeted strengthening programs, as improving muscle function can help mitigate the mechanical load on the knee joint, reduce pain, and enhance QoL (10, 11).

Strengthening exercises have been widely reported to reduce discomfort, improve joint stability, enhance mobility, and restore overall functionality. These benefits make strengthening exercises a cornerstone of non-pharmacological management strategies for osteoarthritis (OA) (12). By targeting the muscles surrounding the affected joint, particularly the quadriceps in knee OA, these exercises reduce the mechanical strain on the joint, thereby alleviating symptoms and slowing the condition's progression.

Furthermore, engaging in regular strengthening activities has been strongly correlated with significant pain reduction in patients with knee OA (13). During daily activities, these exercises improve muscular strength, endurance, and neuromuscular control, improving shock absorption and joint alignment. Consistent participation in strengthening programs decreases pain and enhances functional performance, such as walking, climbing stairs, and maintaining balance (14). As a result, strengthening exercises effectively reduce physical symptoms and play a vital role in improving the overall quality of life for individuals with OA (15).

A complementary approach is essential in contemporary clinical practice to ensure effective patient treatment. This involves not only addressing the primary condition but also considering all contributing factors that may influence the condition, thereby enabling comprehensive care as recommended in the American College of Rheumatology/Arthritis Foundation Guideline for the Management of Osteoarthritis of the Hand, Hip, and Knee (16). No studies have examined the combined efficacy of turmeric supplements and strengthening exercises as a treatment for knee osteoarthritis. This research aims to fill this gap by contributing new knowledge, as highlighted by Paultre et al. (17), who emphasized the need for studies linking turmeric supplementation and physical therapy in this context.

MATERIALS AND METHODS

Experimental Design. This is a double-blind, placebo-controlled, randomized trial with pre-, mid-, and post-test measurements. Ethical approval for this work was obtained from the Human Research Ethics Committee USM (Approval code: USM/JEPeM/22060360). The research protocol was executed in compliance with the Declaration of Helsinki. The CONSORT flow diagram of the progress through the phases of both groups in this study is as in Figure 1.

Participants. A total of 36 knee OA grade II and III patients were recruited using a convenient sampling method and randomly allocated into two groups (matched by gender, age, and BMI): the PE group (n=18) and the TE group (n=18). Participants in the PE group engaged in strengthening exercises three times weekly for 12 weeks, accompanied by a daily placebo capsule ingestion for the same duration. In contrast, participants in the TE group undertook identical strengthening exercises while receiving turmeric supplementation, one capsule daily for 12 weeks. Both male and female participants aged between 40-60 years old, with symptomatic knee OA with Kellgren-Lawrence grades of II or III upon radiographic classification and have an active full range of knee movement and BMI range between 18.5–29.9 kg/m^2 were included in this study. Whereas participants who are allergic to turmeric supplements or herbal medications, who have secondary OA, who had intra-articular steroid injection done within three months prior to the study, using corticosteroids, have heart, liver, and/or renal failure, candidates for surgical procedures and smokers were excluded from this study.

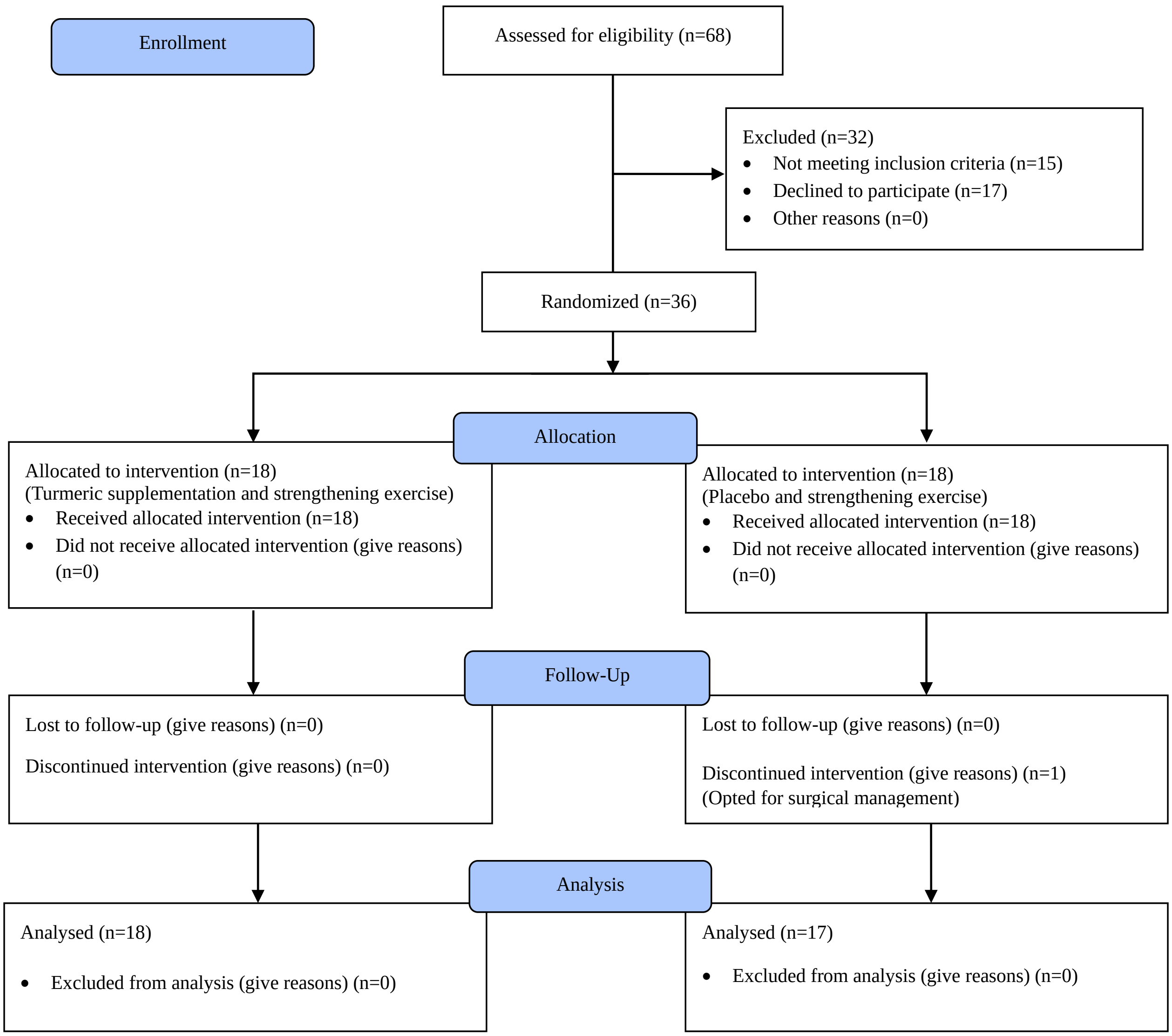

Figure 1. CONSORT diagram showing the flow of participants through each stage of a randomized trial.

Study Procedures. Upon obtaining participants' informed consent, data collection was started with pre-test measurements, which included anthropometric measurements, a 6-minute walk test, and administration of the Malay version quality of life (QoL) questionnaire (WHOQOL-BREF), the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and the Visual Analogue Scale (VAS). Then, they were randomly allocated into either PE or TE groups.

Throughout the 12-week intervention period, participants in both groups performed strengthening exercises 3 times weekly for approximately 30 minutes per session. In addition, participants in the PE group consumed one capsule of placebo daily for 12 weeks, whereas the TE group consumed one capsule of turmeric daily for 12 weeks. Mid-test and post-test measurements were carried out at the end of Week 6 and Week 12, and the procedures were similar to the pre-test measurement.

This study was double-blind, and neither the researchers nor the participants knew what supplement they consumed. A lab technologist carried out double-blind procedures. He helped label the supplement's bottles with A, B, C, or D and assigned each participant accordingly. Unblinding was done after finishing the data collection.

Strengthening Exercise. All participants performed strengthening exercises thrice weekly for 12 weeks. It comprises six types of exercise designed to strengthen the knee flexors, extensors, hip flexors, and hip extensors, which include inner-range quadriceps (IRQ), straight leg raises (SLR), knee extension with an elastic band, hamstring curls using a resistance band, static low-angle squats (SLAS), and sit-to-stand exercises. The participants were broken down into small groups during exercise sessions to allow for in-depth supervision whilst performing strengthening exercises.

Each exercise lasts approximately 30 minutes, comprising 5 minutes of warm-up and cool-down. Progressive loading was employed where the number of repetitions for each exercise was increased: Week 1 to 3 (4 repetitions), Week 4 to 6 (6 repetitions), Week 7 to 9 (8 repetitions), and Week 10 to 12 (10 repetitions). The researcher monitored participants throughout all exercise sessions. This was crucial to guarantee the proper execution of workouts and to ensure their adherence to the training routine. Participants were instructed to adhere to the prescribed workout regimen.

Turmeric Supplementation and Placebo. Participants in the TE group consumed one turmeric supplement daily containing 697 mg/capsule of curcumin for 12 weeks. The dosage prescribed to the patients is based on the dosage recommended by the supplement manufacturer. There is no optimal dosage recommended thus far. However, according to a recent review on low (<1000 mg) dosage and high dosage (>1000 mg) of curcumin intake, similar pain reduction was reported among knee osteoarthritis patients (18). In addition, a systematic review and meta-analysis on the efficacy and safety of turmeric supplementation for arthritis has found that dosages between 120 mg to 1500 mg administered for a period of four to thirty-six weeks were effective in reducing the degree of inflammation and discomfort in the arthritis patients and generally demonstrated safety in all investigations (19). The turmeric supplement used in this study is from 21st Century HealthCare Inc. It is manufactured in Malaysia, registered under The National Pharmaceutical Regulatory Agency, and is certified Halal. The supplement is available online and can be purchased from anywhere in Malaysia. On the other hand, participants in the PE group consumed one capsule of placebo containing 300 mg of maltodextrin daily for 12 weeks. Maltodextrin is a polysaccharide food additive commonly used as a placebo in past studies to investigate treatments/interventions in humans (20).

Both turmeric and placebo capsules were similar in shape, size, and color to facilitate double-blind procedures. Participants cannot take any other turmeric supplement or food throughout the study to ensure definitive evidence on strengthening exercises and turmeric supplements alone. Participants can take painkillers/medications at any time during the study period. The medication's type, dosage, and time taken were noted in the logbook provided. The participants were also given A supplementation compliance log to record their compliance with the supplementation regimen.

Statistical Analysis. Statistical analysis was performed using the Statistical Package for Social Science (SPSS) version 28.0. The Shapiro-Wilk Test determined the normality of the data. The data was analyzed using descriptive statistics and mixed ANOVA (General Linear Model-Repeated Measures). The statistical significance was accepted at $p<0.05$. The results were reported as mean ± SD.

RESULTS

Participants. Thirty-six subjects were assigned to this study, with 18 participants in each group. One participant did not complete the intervention due to opting for total knee replacement surgery. The participant from group PE was dropped from this study per the exclusion criteria protocol, whereby the participants opted for surgical management. Therefore, the total number of participants who completed this study in the TE and PE groups was 18 and 17, respectively. The mean age, body height, body weight, and body mass index (BMI) of the participants in the study are shown in Table 1. There was no significant difference in the main effect of time, group, and interaction ($F(1, 32) = 0.161$; $p>0.05$) on body weight after 12 weeks of intervention. Similarly, no significant main effect of time, group, and interaction ($F(1, 32) = 3.730$; $p>0.05$) on BMI.

Table 1. Physiological characteristics of the participants.

Variables		Groups		p-value (between groups)
		PE (n=17)	TE (n=18)	
Age (years)		59.0 ± 1.0	55.0 ± 2.0	
Body height (cm)		152.8 ± 8.2	158.2 ± 6.0	0.339
Body weight (kg)	Pre-test	59.6 ± 5.8	63.6 ± 7.3	0.061
	Mid-test	59.1 ± 5.7	63.5 ± 7.2	0.061
	Post-test	58.9 ± 5.8	68.0 ± 3.6	0.302
Body mass index (BMI) (kg/m^2)	Pre-test	25.7 ± 3.2	26.1 ± 2.7	0.95
	Mid-test	25.5 ± 3.4	25.4 ± 2.6	0.85
	Post-test	25.4 ± 3.4	26.5 ± 1.7	0.77

#: Significantly different between groups ($p<0.05$); Values are expressed as mean ± standard deviation (SD).

Throughout the 12-week intervention period, all participants showed commendable attendance and engagement during the exercise sessions, achieving a 97% attendance rate. Moreover, compliance with the supplements and placebo was satisfactory (>85%), with all intakes recorded in the supplied logbook.

Pain Score. The Visual Analogue Scale (VAS) was used to evaluate participants' pain levels. A significant main effect of time was seen for pain score ($F(1, 33) = 419.317$; $p=0.011$). Additionally, significant group effects were observed ($F(1, 33) = 0.012$; $p=0.021$), together with a significant interaction effect ($F(2, 32) = 419.317$; $p<0.001$). Post-hoc analysis revealed a significant decrease in VAS scores for both groups at the post-test ($F(1, 33) = 0.912$; $p<0.05$). The pain score in the TE group was considerably lower at the post-test than in the PE group ($p=0.012$) (Figure 2).

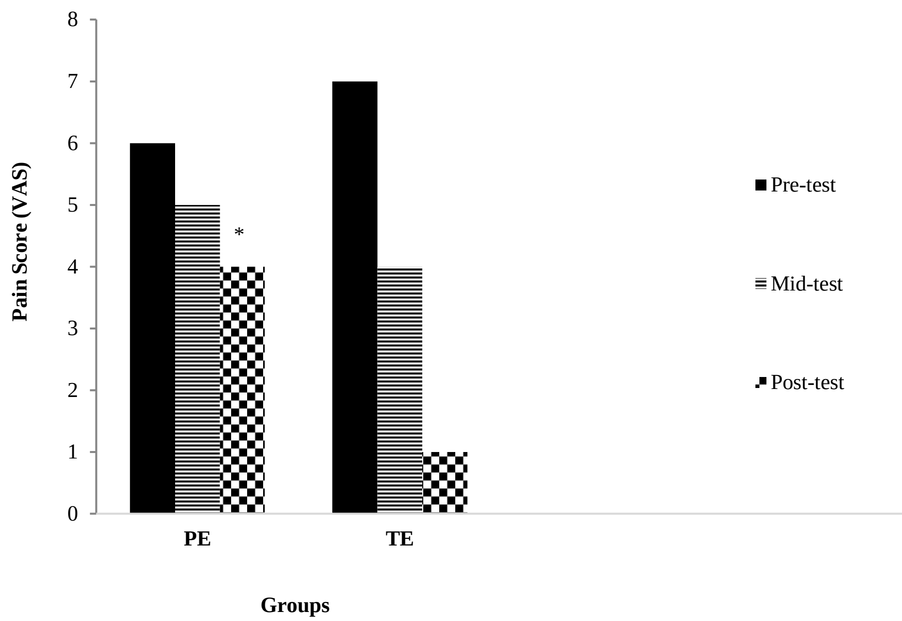

Figure 2. Mean pain score (VAS) at pre-, mid, and post-test in all groups. PE: Placebo and strengthening exercise; TE: Turmeric supplementation and strengthening exercise; *: Significantly different compared to the respective pre-test ($p<0.05$); #: Significantly different between groups ($p<0.05$).

Six-Minute Walk Test. The six-minute walk test (6MWT) was used to evaluate the participants' physical functional capacity. Analysis revealed a significant main effect of time ($F(2, 32) = 67.063$; $p=0.025$), a significant interaction effect ($F(2, 32) = 88.126$; $p=0.013$), and a significant group effect ($F(2, 32) = 42.486$; $p=0.002$) for the walking distance covered by the participants during the test. Post-hoc analysis indicated a significant increase ($p<0.001$) in the walking distance recorded from the pre-test to mid-test and post-test in the TE group; however, no such increase was observed in the PE group. The walking distance in the TE group was considerably greater at both the mid and post-test compared to the PE group ($p=0.012$) (Figure 3).

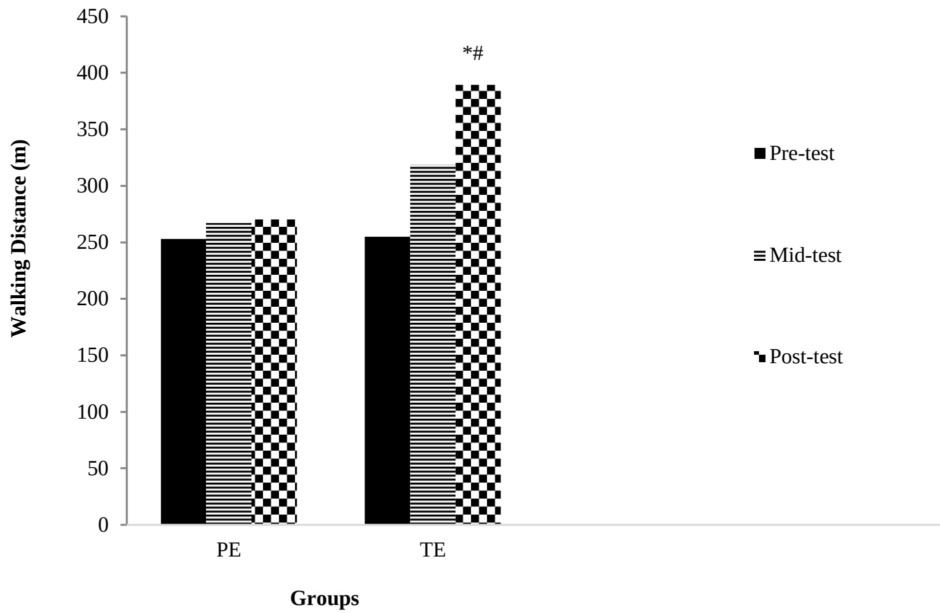

Figure 3. Mean walking distance (m) in the 6MWT for both groups at pre, mid and post-test. PE: Placebo and strengthening exercise; TE: Turmeric supplementation and strengthening exercise; *: Significantly different compared to the respective pre-test ($p<0.05$); #: Significantly different between groups ($p<0.05$).

Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC).

WOMAC - Pain Score. There was a significant main effect of time ($F(2, 32) = 198.679$; $p=0.004$), significant interaction effect ($F(2, 32) = 59.531$; $p=0.015$) and significant group effect ($F(1, 33) = 0.243$; $p=0.001$) on the WOMAC-pain score. Subsequent analysis revealed a significant reduction in the mean WOMAC-pain score in the TE group from the pre-test to the post-test ($p<0.05$). The comparison between groups indicated that the WOMAC pain score in the TE group was considerably lower at the post-test than in the PE group ($p=0.026$) (Figure 4).

WOMAC - Stiffness Score. There was a significant main effect of time ($F(2, 32) = 108.650$; $p=0.018$), significant group effect ($F(2, 32) = 53.980$; $p=0.002$), and significant interaction effect ($F=0.990$; $df=33$; $p=0.042$) on the WOMAC-stiffness score. Subsequent analysis revealed a substantial decrease in scores for both PE and TE groups from the pre-test to the post-test ($p<0.05$). The stiffness score in the TE group was considerably reduced at the post-test compared to the PE group ($p=0.011$) (Figure 4).

WOMAC - Difficulty in Physical Function Score. There was a significant main effect of time ($F(2, 32) = 108.650$; $p=0.011$), a significant group effect ($F(2, 32) = 53.980$; $p=0.005$), and a significant interaction effect ($F(1, 33) = 0.990$; $p=0.006$) on the difficulty in physical function score. Post-hoc analysis indicated a substantial reduction in the scores for the TE group from the pre-test to the post-test ($p<0.01$). The score was considerably lower in the TE group at the post-test compared to the PE group ($p=0.006$) (Figure 4).

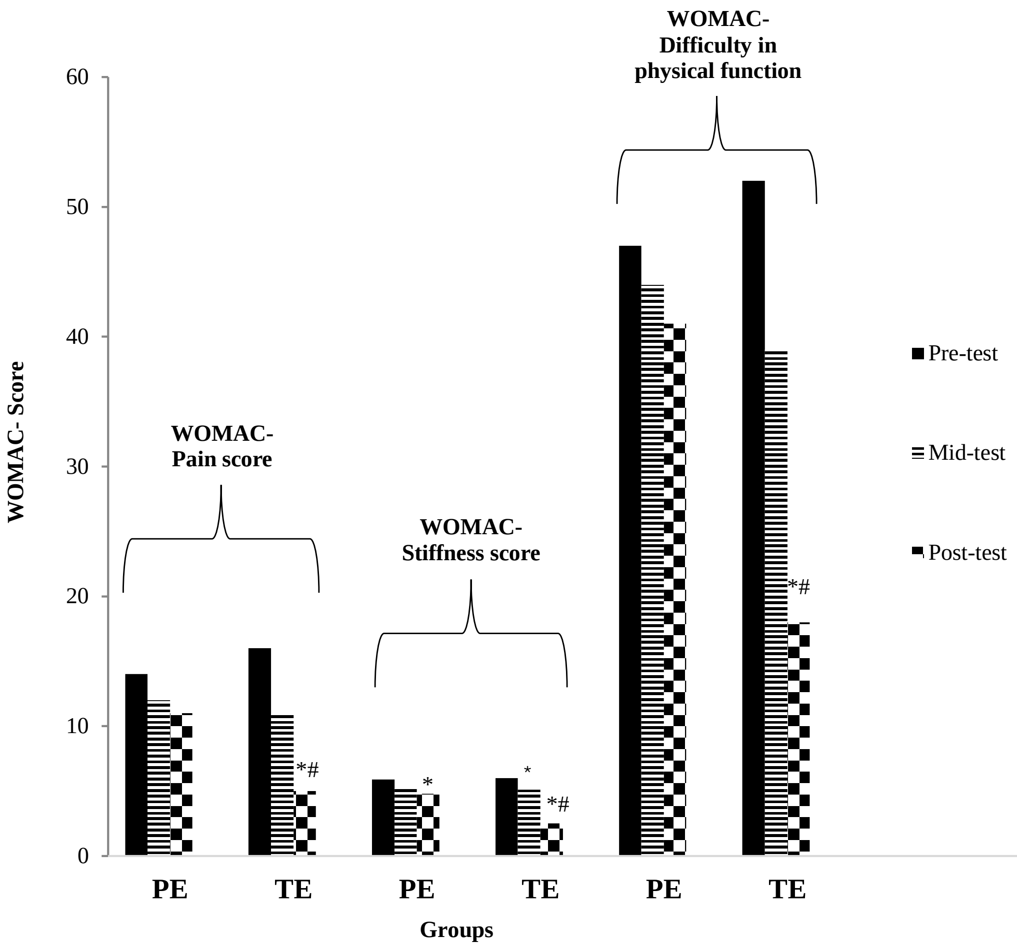

Figure 4. WOMAC-pain, stiffness, and difficulty in physical function scores. PE: Placebo and strengthening exercise; TE: Turmeric supplementation and strengthening exercise; *: Significantly different compared to the respective pre-test (p<0.05); #: Significantly different between groups (p<0.05).

Quality of Life (WHOQOL-BREF).

Physical Health Score. There was a significant main effect of time (F(2, 32) = 254.107; p=0.007), significant group effect (F(2, 32) = 175.589; p=0.014), and significant interaction effect (F(2, 32) = 175.8; p=0.017) for the physical health score. Post-hoc analysis demonstrated a substantial increase in physical health scores from pre-test to post-test in the TE (p=0.013) and PE groups (p=0.011). The TE group exhibited a considerably higher score (p<0.05) at both the mid and post-test compared to the PE group (Figure 5).

Psychological Health Score. There was a significant main effect of time (F(2, 32) = 68.819; p=0.028), significant group effect (F(2, 32) = 19.161; p=0.016), and significant interaction effect (F(2, 32) = 49.63; p=0.002) for the psychological health score. Post-hoc analysis revealed a significant improvement in psychological health scores from the pre-test to the post-test in both groups (p<0.05). The score was considerably elevated in the TE group at post-test relative to the PE group (p=0.003) (Figure 5).

Social Health Score. There was a significant main effect of time (F(2, 32) = 10.441; p=0.021), but no significant group effect (F(2, 32) = 10.441; p=0.053) and no interaction effect (F(2, 32) = 10.441; p=0.074) observed on the social health score. Post-hoc analysis indicated a substantial increase in the scores from pre-test to post-test in the TE group (p=0.003) (Figure 5).

Environment Health Score. There was no significant main effect of time (F(1, 34) = 0.388; p=0.082), nor was there a significant group effect (F(2, 32) = 0.499; p=0.140), and interaction effect (F(1, 34) = 0.388; p=0.142) for the environment health score (Figure 5). Consequently, further analysis was not performed.

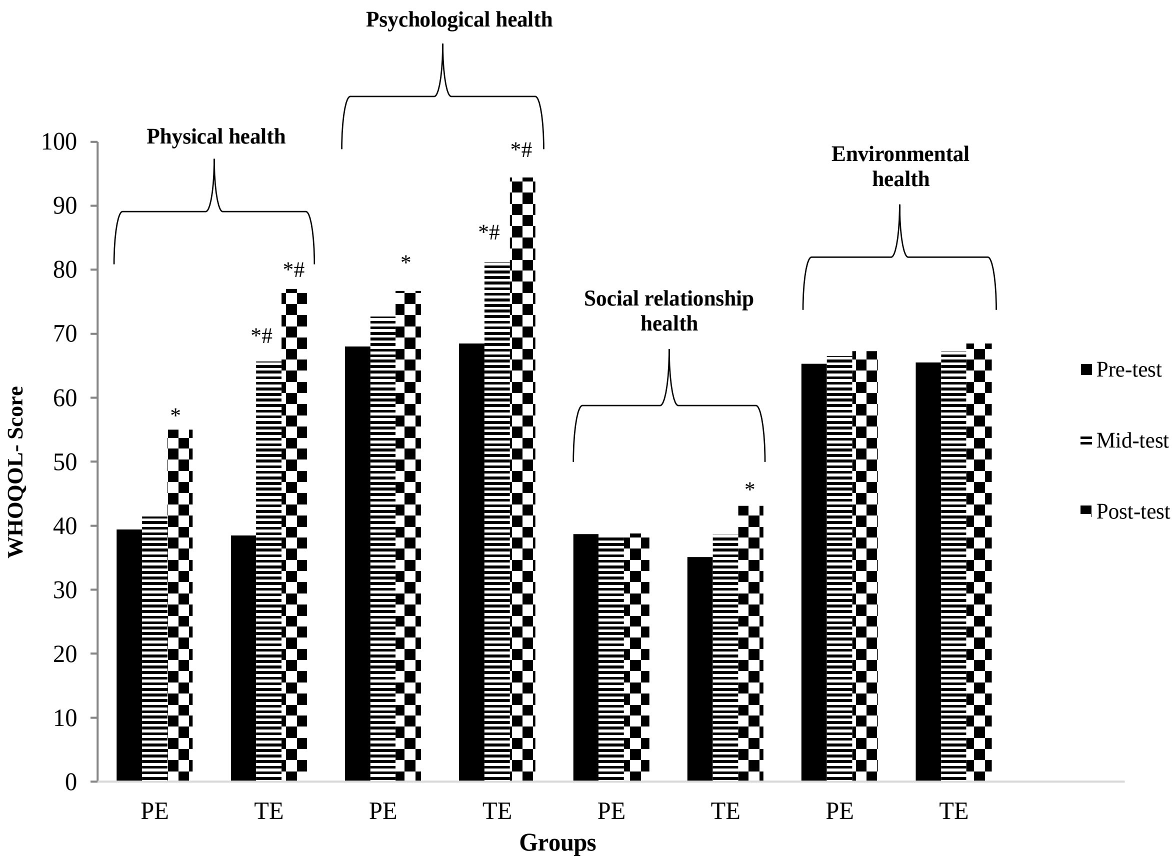

Figure 5. Mean physical health, psychological health, social relationship and environmental health scores (WHOQOL-BREF). PE: Placebo and strengthening exercise; TE: Turmeric supplementation and strengthening exercise; *: Significantly different compared to the respective pre-test ($p<0.05$); #: Significantly different between groups ($p<0.05$).

DISCUSSION

In this study, 35 individuals completed the intervention and all pre-, mid-, and post-test assessments. The average age of participants in the PE and TE groups was 59.0 ± 1.5 years and 55.0 ± 2.0 years, respectively. All participants were knee osteoarthritis patients classified as grade II or III attending a clinic. Overall, patient attendance during the intervention was satisfactory, and supplement adherence, as recorded in the logbook, was commendable. The curcumin and placebo groups reported no adverse effects, and curcumin was well tolerated. Moreover, no significant detrimental effects were documented. The participants in group TE were noted to have abstained from painkillers throughout the experimental period. However, PE group participants were noted to have consumed painkillers (15 participants noted they consumed 1000 mg of Paracetamol twice a day on a PRN basis, and three participants took 50 mg of diclofenac once per day on a PRN basis).

The findings of this study indicate that resistance training combined with curcumin supplementation is superior in reducing knee pain compared to resistance exercise alone. Similarly, previous research supports these results, demonstrating that combining supplements and strengthening exercises provides greater pain relief for knee osteoarthritis patients (21). In that study, patients in Group A consumed 500 mg of curcuminoids twice daily for six weeks without additional intervention, while those in Group B followed the same supplementation regimen alongside a six-week strengthening exercise program. The WOMAC pain score in Group B (11.0 ± 3.0) was significantly lower ($p<0.05$) than in Group A (27.1 ± 16.1).

Curcumin, the primary active component of turmeric, is believed to alleviate pain due to its anti-inflammatory and antioxidant properties. It inhibits the activity of inflammatory mediators such as cyclooxygenase-2 (COX-2), tumor necrosis factor-alpha (TNF-α), and interleukin-6

(IL-6), which play key roles in osteoarthritis-related inflammation and pain (22). Additionally, curcumin reduces oxidative stress in the joints, protecting cartilage from further damage and improving joint function. Strengthening exercises further alleviate pain by enhancing the stability of the knee joint, reducing stress on the joint, and increasing muscle strength (23). These exercises may also improve the range of motion and stimulate the release of anti-inflammatory compounds, further mitigating pain (24, 25). These mechanisms explain why the present study found superior outcomes with the combination of exercise and curcumin compared to exercise alone.

Physical function was assessed using the 6MWT and WOMAC. Participants in the TE group exhibited significantly better physical function than those in the PE group. Physical function is critical for individuals with knee osteoarthritis, as it directly impacts mobility, independence, and quality of life. Maintaining or improving physical function enables patients to perform daily activities such as walking, climbing stairs, and rising from a seated position. Impaired function can lead to reduced mobility, muscle weakness, joint instability, and an increased risk of falls (26). Regular physical activity, particularly resistance and aerobic exercises, improves joint flexibility, reduces pain, and prevents further functional decline. Furthermore, enhanced physical function can alleviate the psychological burden of osteoarthritis by promoting independence and reducing disability (27).

Curcumin has been reported to reduce inflammation, alleviate pain and swelling, and exhibit antioxidant properties that neutralize free radicals, mitigating oxidative stress and protecting joint tissues from further deterioration, ultimately improving mobility (25). Combining curcumin's anti-inflammatory and antioxidant effects contributes to enhanced physical functionality. Strengthening exercises further support knee joint and muscle function, improving physical performance. Patients experiencing less pain are more likely to engage in physical activity, enhancing their overall mobility.

This study assessed patients' quality of life using the WHOQOL-BREF questionnaire, which comprises four domains: physical health, psychological well-being, social relationships, and environmental health. The results showed improvements in physical and psychological health scores in both groups, with significantly greater improvements in the TE group compared to the PE group. Social relationship scores improved only in the TE group, whereas environmental scores showed no significant changes between or within the groups.

Chronic pain significantly impacts the quality of life of knee osteoarthritis patients (28). It disrupts daily activities, sleep quality, and physical function, limiting patients' ability to perform tasks necessary for independent living. Chronic pain is also associated with mood disorders, such as anxiety and depression, further diminishing quality of life (29). Restricted mobility due to joint discomfort, stiffness, and swelling exacerbates these challenges, limiting individuals' ability to walk, climb stairs, or maintain an upright position (30). As physical function declines, patients often reduce their activity levels, leading to muscle weakness and worsening symptoms, creating a cycle of decreased mobility and increased impairment.

The psychological impact of osteoarthritis can result in feelings of frustration, helplessness, and social isolation (31). Many patients find themselves unable to participate in previously enjoyed social activities or hobbies, leading to emotional distress and reduced life satisfaction. Social participation, a key quality of life, is often compromised due to pain and mobility limitations, leading to decreased engagement in family gatherings, work responsibilities, and recreational activities (32). Additionally, knee osteoarthritis can reduce productivity among working-age individuals, potentially resulting in premature retirement or job loss due to physical impairment. The financial burden of treatment, including medication, physical therapy, and sometimes surgery, further diminishes the quality of life (33).

As demonstrated in this study, exercise and curcumin supplementation improve knee pain and physical function, ultimately enhancing the quality of life. Exercise has been shown to promote psychological well-being, strengthen muscles, improve posture, and enhance cardiorespiratory efficiency (34). Furthermore, curcumin supplementation helps alleviate pain, allowing individuals with knee osteoarthritis to engage in physical activities more confidently, thereby improving their quality of life (35).

The environmental health score remained unchanged, regardless of the intervention. This may be due to environmental health factors, including personal freedom, physical safety, home environment, financial stability, access to healthcare, and transportation. These factors are generally unaffected by medical treatment and may remain stable throughout the study period. Previous research has not extensively explored the environmental health aspects of knee osteoarthritis patients. This study contributes to the discussion by examining how a multimodal intervention, combining strengthening exercises with curcumin supplementation, may influence various quality of life among knee osteoarthritis patients. One of the study's shortcomings is that it failed to test antioxidant parameters or pro- and anti-inflammatory cytokines, which would have offered scientific proof of curcumin's anti-inflammatory and antioxidant qualities. The capacity to completely comprehend the biochemical processes behind curcumin's actions in people with osteoarthritis in their knees is limited by this omission. Besides, this study was conducted for 3 months; a long study period should be designed to yield the long-term effect of turmeric supplementation. The placebo effects have not been thoroughly investigated, which is a shortcoming of the research. Furthermore, the small sample size mainly affects the findings' statistical power and generalizability. It may be challenging to confidently extrapolate the results from a small sample size since it may not represent the larger population fairly. In addition, the dietary intake of the participants in this study was not controlled, which may interfere with the absorption of the turmeric supplement. Its therapeutic potential is jeopardized, nonetheless, by a poor pharmacokinetic profile. Oral bioavailability is significantly reduced by the combination of the liver's considerable reductive and conjugative metabolism and the small intestine's poor absorption (36, 37).

CONCLUSION

In conclusion, this study found that combining turmeric supplementation and strengthening exercises significantly improves knee pain, physical function, and quality of life in patients with knee osteoarthritis. Turmeric supplementation, with its anti-inflammatory properties, enhances the pain-relief effects of strengthening exercises, resulting in greater reductions in pain scores and improved physical function compared to exercise alone. The findings suggest that turmeric supplementation can be a complementary treatment to physiotherapy exercises, offering a complementary approach to managing knee OA by reducing pain and enhancing the patient's overall quality of life.

APPLICABLE REMARKS

- Combining turmeric supplementation with strengthening exercises promotes better effective pain management among knee osteoarthritis patients compared to exercise alone.
- Consequently, patients' quality of life and physical function improved in the combined group compared to exercise alone.

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AUTHORS’ CONTRIBUTIONS

Study concept and design: Bawani Ramakrishnan, Ayu Suzailiana Muhamad, Garry Kuan. Acquisition of data: Bawani Ramakrishnan. Analysis and interpretation of data: Bawani Ramakrishnan, Ayu Suzailiana Muhamad. Drafting the manuscript: Bawani Ramakrishnan, Ayu Suzailiana Muhamad. Critical revision of the manuscript for important intellectual content: Bawani Ramakrishnan, Ayu Suzailiana Muhamad. Statistical analysis: Bawani Ramakrishnan, Ayu Suzailiana Muhamad, Garry Kuan. Administrative, technical, and material support: Bawani Ramakrishnan, Ayu Suzailiana Muhamad. Study supervision: Ayu Suzailiana Muhamad, Garry Kuan.

CONFLICT OF INTEREST

The authors confirm no conflict of interest in this study.

FINANCIAL DISCLOSURE

There are no financial interests related to the material in the manuscript.

FUNDING/SUPPORT

No funding supports this research.

ETHICAL CONSIDERATION

Ethical approval for this work was obtained from the Human Research Ethics Committee USM (Approval code: USM/JEPeM/22060360). The research protocol was executed in compliance with the Declaration of Helsinki. This protocol was registered at thaiclinicaltrial.org (registration number: TCTR20230615003). Recruitment of the participants commenced on Mar 20, 2023, and was completed on Jun 2, 2023.

ROLE OF THE SPONSOR

Not Applicable.

ARTIFICIAL INTELLIGENCE (AI) USE

No specific AI and AI-assisted technologies were used in the research and manuscript to be disclosed.

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