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Comparison of Pilates Based Core Strengthening Exercises and Closed Kinematic Chain Exercise on Pain Pressure Threshold, Range of Motion in Knee Osteoarthritis Post Menopausal Women: A Randomized Controlled Trial

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ABSTRACT

Knee osteoarthritis is a prevalent degenerative joint disorder, especially among post - menopausal women due to hormonal changes. It leads to pain, reduced range of motion (ROM), and functional limitations. Exercise therapy plays a key role in its management. To compare the effects of Pilates - based core strengthening exercises and closed kinematic chain exercises on pain pressure threshold (PPT), knee range of motion, and functional outcomes in post-menopausal women with knee osteoarthritis. A study was conducted on 40 participants aged 50 to 70 years with Grade 1 and 2 knee osteoarthritis. Participants were randomly divided into two groups: Group A received Pilates - based core strengthening exercises, and Group B received closed kinematic chain exercises. Both groups underwent a structured 4 - week intervention program. Outcome measures included pain pressure threshold (PPT), knee ROM assessed using goniometry, and functional status measured by the WOMAC index. Both groups showed statistically significant improvements in PPT, ROM, and functional outcomes ($p< 0.0001$).

However, Group A demonstrated greater improvement in pain reduction, knee flexion - extension range, and overall functional performance compared to Group B. Pilates - based core strengthening exercises are more effective than closed kinematic chain exercises in reducing pain, improving knee ROM, and enhancing functional ability in post - menopausal women with knee osteoarthritis.

INTRODUCTION:

Osteoarthritis is a commonly slowly progressing joint disease typically observed in middle-aged to elderly individuals, most often affecting those over 50 years of age. Knee osteoarthritis is a prevalent musculoskeletal condition that progresses in a non-random manner, closely linked to asymmetric dynamic loading of the affected joint. It is particularly common among post-menopausal women, likely due to decreased estrogen and calcium levels. Pilates exercises may help by enhancing neurological coordination, improving muscle fiber recruitment, and stimulating proprioception.[1]

PATHOLOGY:

Osteoarthritis is characterized by the progressive erosion and loss of articular cartilage, hypertrophy of bone at the joint margins, osteophytic lipping, subchondral sclerosis, and various biomechanical and morphological changes in the synovial membrane and joint capsule.[2]

SYMPTOMS:

Patients typically report pain that worsens by the end of the day and after physical activity. They often experience several minutes of stiffness or pain upon waking or after periods of inactivity, a symptom known as gelling. Soft tissue swelling is uncommon, whereas bony deformities are more frequently observed. Large joint effusions may also occur.

MANAGEMENT:

Currently, knee osteoarthritis is incurable, as the exact mechanisms underlying its onset and progression are not fully understood. Therefore, treatment aims to alleviate symptoms and, if possible, slow disease progression. Management strategies range from general measures and physiotherapy to orthopedic aids, pharmacotherapy, and, in advanced cases, surgery and rehabilitation.[3] Closed Kinematic Chain (CKC) exercises have been argued to be more functional as they effectively stimulate the role of lower limb muscles during daily activities. Knee-related musculoskeletal disorders such as osteoarthritis (OA) and patellofemoral pain syndrome (PFPS) significantly contribute to pain and disability throughout the

lifespan. Osteoarthritis predominantly affects postmenopausal women due to hormonal and metabolic factors, whereas PFPS is more common among physically active adolescents. Both conditions involve muscular imbalances, altered knee joint loading, and compromised functional capacity. Traditional physiotherapy focuses on pain relief and targeted muscle strengthening; however, Pilates-based core training has recently gained attention for its benefits in improving strength, alignment, and neuromuscular coordination through controlled movements, breath regulation, and mental focus. This integrated analysis aims to investigate the comparative effects of Pilates-based core strengthening on these two clinical populations.[4,5]

NEED OF THE STUDY: Recently, Pilates exercises and Closed Kinematic Chain exercises have garnered considerable attention in the management of knee osteoarthritis. Pilates-based core strengthening is a novel concept wherein strengthening the core muscles may help manage mobility symptoms effectively.

AIMS AND OBJECTIVES: To compare the effects of Pilates-based core strengthening exercises and Closed Kinematic Chain exercises on pain pressure threshold and range of motion in postmenopausal women with knee osteoarthritis.

MATERIALS AND METHODS:

1. **Study design:** Randomized controlled trial (Comparative).
2. **Informed consent:** The purpose of the study was thoroughly explained to participants, who were provided with an information sheet. Written informed consent was obtained from all participants, ensuring their rights were protected.
3. **Study setting:** Physiotherapy centers in Ahmedabad, Gujarat.
4. **Study duration:** Conducted between July 2024 to January 2025.
5. **Sampling technique:** Simple Random sampling.
6. **Intervention**: 6 weeks of training program which includes Pilates based core strengthening Exercise and Closed Kinematic Chain Exercise.
7. **Sample size:** A total of 60 subjects were screened, of which 40 (20 subjects per group) were recruited based on willingness to participate. Participants were briefed on the study's purpose and

relevance. Demographic data including name, age, height, weight, and body mass index were recorded. Participants meeting inclusion and exclusion criteria were randomly assigned to Group A (Pilates-based core strengthening exercises) or Group B (Closed Kinematic Chain exercises), with 20 participants in each. The sample size was calculated using the OpenEpi app.

8. **Inclusion criteria:**
    - Age between 50-70 years, both genders.
    - Sub-acute and chronic knee osteoarthritis.
    - Grade 1 and 2 knee osteoarthritis.
    - Moderate BMI.
    - Pain, limitation of range of motion (ROM), knee stiffness.
9. **Exclusion criteria:**
    a. Severe knee deformity.
    b. Recent surgery.
    c. Infection or malignant tumor.
    d. Severe sensory disturbances.
    e. Participation in regular physical activity in the past 3 months.
    f. Limb length discrepancy.
10. Pain intensity, range of motion, and knee function were measured pre-intervention and post 4 weeks of intervention.

OUTCOME MEASURES: An independent researcher who was unaware about the group interventions measured Primary outcome measures Knee Range of motion (ROM) and Pain pressure threshold (PPT) and Secondary outcome measure WOMAC pre and post intervention.

PRIMARY OUTCOME MEASURES:

1. **Knee pain using pain pressure threshold (PPT**) - Used to measure deep muscular tissue sensitivity. The test determines the amount of pressure over a given area in which a steadily increasing non-painful pressure stimulus turns into a painful pressure sensation. A varying pressure is applied from 0.5 to 1 kg/sec in a perpendicular direction relative to the muscle. PPT has no standard protocol on administration and placement. Equipment used varies with many handheld electric algometers[3,4].

2. **Knee range of motion (ROM) using Goniometry:** A half circle long-arm metallic goniometer, ranging from 0 to 180°, with 1° interval marking was used. It had a central fulcrum, a stationary or fixed arm, and a pivoting or moving arm. Both arms were 30 cm long. The active ROM of knee joint was measured. Participants carried out the motion by using muscle strength to increase the angle. The examiner did not provide support or apply any kind of force for the completion of the joint motion. Measurements of knee flexion and extension were obtained with subjects lying supine on an examination table. Central fulcrum of goniometer was placed over lateral epicondyle of femur, stationary arm was aligned proximally with lateral midline of thigh along length of femur, using greater trochanter as reference, moving arm was aligned distally with lateral midline of leg along length of fibula, using lateral malleolus as reference. For well demarcation, cross marks were given over the reference points by a temporary marker (when needed). A towel roll or small pillow was placed under ankle. Normal extended knee was in the 0° position. A positive ROM score for extension is used for hyperextension. A negative ROM score for extension mean a patient was unable to reach the 0° position. Patient was asked to actively flex knee. At the end of knee flexion, examiner used 1 hand to hold stationary arm, while other hand was used to align the moving arm of goniometer with lateral midline of leg. Examiner kneeled or sat on a stool to see the measurements of goniometer on eye level6. The degree of maximum flexion, extension, hyperextension (if present) was recorded. The summation of maximum flexion and maximum extension (extension + hyperextension) was described as the total excursion range. It resembled the available ROM in sagittal plane in knee. Internal and external rotation of the tibia were measured in a seated position, with the hip and knee flexed in 90°. Tibiofemoral and ankle joints were aligned in the same line, and the fulcrum of the goniometer was positioned just above the tibiofemoral joint. Stationary or fixed arm of the goniometer was placed along the long axis of the thigh, and the moving arm was placed on parallel to the long axis of the foot, which rotated internally or externally. The foot was kept on the floor to restrict eversion and inversion during rotations. Patient was asked to move leg actively in medial and

lateral direction to measure internal and external rotation of tibia, respectively7 All the knee ROMs were measured only by researcher.

SECONDARY OUTCOME MEASURES:

1. **Knee functions** by using WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) - The WOMAC questionnaire, introduced in 1988, is a widely used tool to assess the health status of patients with osteoarthritis. It consists of 33 items evaluating various aspects of the patient's health and function, including:

   Clinical symptoms (5 questions).

   Severity of joint stiffness (2 questions).

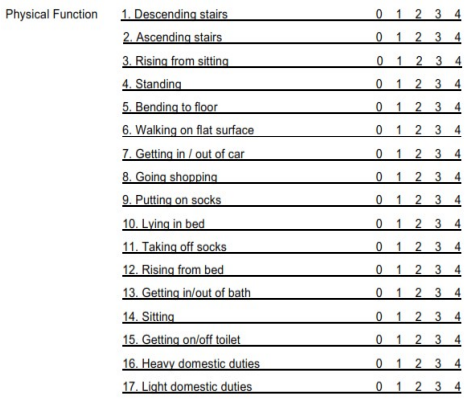
   Degree of pain (9 questions).

   Activities of daily living (17 questions).

Each question is scored on a five-point scale, ranging from the best condition - labeled as "never" or "none" to the worst condition, labeled as "extreme" or "always." Higher total scores indicate better health status and less pain.

STUDY PROTOCOL:

An independent researcher, blinded to the treatment allocation, conducted the assessments.



Physical Function						
	1. Descending stairs	0	1	2	3	4
	2. Ascending stairs	0	1	2	3	4
	3. Rising from sitting	0	1	2	3	4
	4. Standing	0	1	2	3	4
	5. Bending to floor	0	1	2	3	4
	6. Walking on flat surface	0	1	2	3	4
	7. Getting in / out of car	0	1	2	3	4
	8. Going shopping	0	1	2	3	4
	9. Putting on socks	0	1	2	3	4
	10. Lying in bed	0	1	2	3	4
	11. Taking off socks	0	1	2	3	4
	12. Rising from bed	0	1	2	3	4
	13. Getting in/out of bath	0	1	2	3	4
	14. Sitting	0	1	2	3	4
	15. Getting on/off toilet	0	1	2	3	4
	16. Heavy domestic duties	0	1	2	3	4
	17. Light domestic duties	0	1	2	3	4

- **Group A (Pilates - Based Core Strengthening):** Participants performed Pilates exercises on a mat using resistance bands and a ball for 30 minutes, three times per week.
- **Group B (Closed Kinematic Chain Exercise):** Participants received moist heat therapy followed by Closed Kinematic Chain exercises and stretching for 30 minutes, three times per week.

INTERVENTION:

Group A: Pilates-Based Core Strengthening Exercises: The exercise program was conducted over 4 weeks using a mat, resistance band, and Pilates ball. Participants performed each exercise with 5 repetitions and 3 sets during the first 2 weeks. After 2 weeks, the program progressed to 10 repetitions and 3 sets per exercise.

1. **Hundred Exercise on Mat:** Participants lay supine with hips and knees flexed to 90 degrees. They were instructed to take a deep breath, contract their core muscles, then exhale while raising their head and curling their shoulders off the floor. Arms moved in a controlled up-and-down manner for a count of 100.

2. **Plank on Mat**: Participants have to position their upper arms parallel with elbows and shoulders aligned at shoulder width. Both knees were fully extended, with toes pointed in plantar flexion. They maintained a straight line from head to lower limbs, then breathed in and out while abducting the hips to 30 degrees.

3. **Hip Twist with Pilates Band:** In a supine position with knees bent and an elastic band around the knees, participants inhaled deeply, lifting their feet so hips and knees formed right angles. They then exhaled while abducting both lower limbs against the band resistance.

4. **Squat with Pilates Band:** Standing with hips flexed approximately 45 degrees, an elastic resistance band was placed around the upper legs to promote abduction and external rotation. Participants slowly lowered into a squat position, then returned to standing, repeating the sequence on the left side.

5. **Swimming with Stabilizing Ball:** Participants lay prone, holding a Pilates ball with outstretched hands and legs slightly abducted. While inhaling, they lifted both upper limbs and moved their lower limbs up and down reciprocally. They exhaled while lowering the upper limbs, maintaining reciprocal lower limb movement.

6. **Wall Squat Rolls with Pilates Ball:** Standing against a wall with a Pilates ball placed between the lower back and the wall, feet positioned about one foot away from the wall, participants slowly lowered into a squat position, ensuring knees did not pass the ankles. They then rolled back up slowly to recover balance. Each squat roll counted as one repetition.

Group B: Closed Kinematic Chain Exercises:

All exercises were given for 4 weeks on hard ground and soft ground mat with 10 Repetitions and 3 sets each. After 2 weeks, progression was given with 15 Repetitions and 3 sets.

1. Standing with feet together in eyes-closed and training balance time without sway.
2. Retro walking (25 m).
3. Walking on heels (25 m).
4. Walking on toes (25 m).
5. Walking with eyes closed (25 m).
6. Stair-up and down a regular 3 steps staircase (17 cm high and 23 cm wide).
7. Lift both heels off the floor and try to hold the position for 10 seconds.
8. Sitting down and standing up from a low chair slowly.
9. Walking quickly.

STATISTICAL ANALYSIS:

All statistical analyses were performed using SPSS software version 21.0 and Microsoft Excel 2007. Descriptive data are presented as Mean ± Standard Deviation (SD), and mean difference percentages were calculated and reported.

For within-group comparisons (pre- and post-intervention), the Wilcoxon signed-rank test was used for each

TEST BETWEEN	STATISTICAL ANALYSIS
Each Parameter Pre and Post Within group	Wilcoxon Test
Between 2 groups	Mann Whitney U Test

parameter. Between-group comparisons were conducted using the Mann - Whitney U test.

RESULTS:

The aim of this study was to evaluate the effectiveness of Pilates-based core strengthening exercises and Closed Kinematic Chain (CKC) exercises on pain pressure threshold (PPT), range of motion (ROM), and knee function in postmenopausal women with knee osteoarthritis. Subjects were assessed for knee pain, knee range of motion, and knee function using PPT and the WOMAC index, respectively. Participants underwent either Pilates-based core strengthening or CKC exercises for four weeks, with assessments conducted before and after the exercise training[1].

AGE	Group A (20 Subjects)	Group B (20 Subjects)
MEAN & SD	57.8 (3.4)	60.3 (2.3)

STUDY FINDINGS AND DISCUSSION:

- **Pain Pressure Threshold (PPT):** PPT was used to assess the intensity of knee pain due to its established reliability and validity. Results showed a highly significant improvement within both groups from pre-test to post-test ($p < 0.0001$). In Group A (Pilates), the mean PPT decreased from 8.5 (±2.3) to 4.3 (±1.3), while in Group B (CKC), it decreased from 7.5 (±1.3) to 5.3 (±2.3). The reduction in pain may be explained by stimulation of mechanoreceptors (myelinated alpha-beta and alpha-delta fibers) at spinal and higher centers, leading to endorphin release. These findings align with Kaur Rajinder et al., who reported significant pain improvement with Pilates-based core strengthening. Similarly, CKC exercises showed significant pain reduction, likely due to quadriceps strengthening improving knee joint stability, activating the beta-endorphin pain suppression system, modulating sensory input via the gate control mechanism, and enhancing blood flow and cartilage nutrition.[1]

- **Range of Motion (ROM):** Pilates-based core strengthening exercises produced highly significant improvements in knee flexion and extension ($p < 0.0002$) within Group A. Pre-intervention mean knee flexion was 100° (±5.6) and extension was -10° (±1.5); post-intervention, flexion improved to

110° (±3.6) and extension to -12° (±11.6). Phrompaet et al. noted that Pilates training aims to improve flexibility, activate specific muscle groups, and includes isometric components (e.g., Hundred and Single Leg Circles) that strengthen muscles around the knee without exacerbating pain. Strengthened quadriceps can better absorb joint shock, reducing muscle guarding.[1]

- **Functional Outcomes:** CKC exercises demonstrated superiority in improving physical function in the short term by engaging weight-bearing, multi-joint movements that mimic daily activities. Both Pilates and CKC exercises reduce pain and enhance joint stability by promoting muscle co-contraction, which is particularly beneficial in knee osteoarthritis rehabilitation. Pilates emphasizes core and spinal stabilization, providing a stable base for limb movements. It has been shown to effectively reduce pain and improve functional performance, often complementing traditional physiotherapy.[6]

- **Mechanisms and Benefits of Pilates:** The use of Pilates balls and therabands offers extensive sensory stimulation, providing comprehensive feedback that enhances performance. Pain relief observed in this study is consistent with findings by Wells et al. for back pain patients, where stress reduction and improved circulation lowered pain levels. Segal et al. demonstrated that Pilates increases flexibility, enhancing physical performance and reducing the energy cost of joint movement by decreasing muscle tension and soreness during exercise. The multi-sensory feedback from controlled Pilates movements combined with breathing and posture awareness likely enhances pain modulation and neuromuscular control. Pilates strengthens the kinetic chain, optimizes joint mechanics, and promotes functional symmetry across age groups. Additionally, Pilates equipment may amplify proprioceptive feedback, contributing to higher adherence and patient satisfaction.[7]

CONCLUSION: Pilates-based core strengthening exercises are more effective than Closed Kinematic Chain exercises in reducing knee pain, improving knee range of motion, and enhancing knee function in postmenopausal women with knee osteoarthritis.

LIMITATIONS:

- Long-term follow-up was not conducted.
- The study was limited by a relatively small sample size.

RECOMMENDATIONS FOR FURTHER RESEARCH:

- Future studies should include a larger sample size.
- The duration of the intervention could be extended to 8 to 12 weeks.
- Incorporation of a follow-up protocol to assess long-term effects is recommended.

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