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Effect of Multimodal Physiotherapy on Side-to-Side Differences in Knee Range of Motion and Strength in Postmenopausal Women with Bilateral Knee Osteoarthritis

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Abstract: **Background: Knee osteoarthritis is a degenerative disorder affecting postmenopausal women, frequently resulting in pain, reduced muscle strength, stiffness and limitation in joint range of motion. Bilateral knee osteoarthritis presents with asymmetrical involvement between the left and right knee, leading to functional imbalance and altered gait mechanics. Multimodal physiotherapy interventions including manual therapy and therapeutic exercises are commonly used in the management. However, limited studies have investigated side-to-side differences in knee range of motion and muscle strength following multimodal physiotherapy interventions in postmenopausal women with bilateral knee osteoarthritis.**

Objective: To compare the effectiveness of Maitland Mobilisation combined with Isometric exercises and Dynamic Quadriceps and Maitland Mobilisation combined with Multiple-Angle Isometrics and Mini-squats on left and right knee range of motion and muscle strength in postmenopausal women with bilateral knee osteoarthritis.

Methods: Sixty postmenopausal women aged 40-60 years diagnosed with bilateral knee osteoarthritis (Kellgren Lawrence grade II-III) were randomly allocated into two groups. Group A received Maitland Mobilisation with Isometric exercises and Dynamic Quadriceps whereas Group B received Maitland Mobilisation with Multiple-Angle Isometrics and Mini-squats. Interventions were administered for three sessions per week for four weeks. Outcome measures included Range of Motion (Active and Passive) and Manual Muscle Testing (MMT).

Results: Both groups showed significant improvements in, increase in range of motion and muscle strength. However, the interventions used in Group B demonstrated comparatively greater improvement in both the outcome measures. Although improvements were observed bilaterally, the right knee demonstrated slightly better outcome in range of motion parameter as well as muscle strength improvements.

Conclusion: The study provides evidence regarding the effectiveness of multimodal physiotherapy interventions in improving side-specific knee range of motion and muscle strength in postmenopausal women with bilateral knee osteoarthritis. The findings guide clinicians to design targeted protocols for patients presenting with asymmetrical and bilateral involvement.

Keywords: **Knee osteoarthritis, Postmenopausal Women, Maitland Mobilisation, Isometric Exercise, Multiple-Angle Isometrics.**

I. INTRODUCTION

Knee Osteoarthritis (KOA) is among the most prevalent degenerative musculoskeletal condition, commonly associated with pain, restricted mobility and diminished quality of life.[1] According to the Osteoarthritis Research Society International, Osteoarthritis (OA) initially develops through molecular-level changes and gradually advances to structural and functional alterations, including cartilage breakdown, bone remodelling, osteophyte development, joint inflammation and compromised joint function. [2],[3]

A reduction in estrogen levels has been linked with a higher susceptibility to arthritis, especially among postmenopausal women. Estrogen is believed to play a protective role by reducing inflammation, limiting degenerative changes in chondrocytes and delaying the progression of OA. [4,5] Furthermore, factors such as anatomical differences, ageing-related loss of muscle mass and altered biomechanics may further accelerate the progression of OA.[6]

OA imposes a substantial physical as well as psychological burden, leading to pain, stiffness, restricted mobility, functional disability and emotional distress. Limitations in mobility may be associated with decreased knee range of motion as most activities of daily living require complete knee extension and nearly 110° of knee flexion. Furthermore, functional impairments in individuals with KOA are often related to muscle weakness, particularly involving the knee flexors and extensors. [7]

Physiotherapy plays a vital role in the conservative treatment of KOA. It encompasses interventions such as manual therapy and therapeutic exercises aimed at alleviating pain, increasing joint mobility and improving functional performance. Individually tailored physiotherapy programs have also been found to enhance range of motion and muscle strength.[8]

Maitland Mobilisation is a widely used manual therapy approach that involves the application of passive oscillatory movements to synovial joints through a graded system of mobilisation. This technique enables the physiotherapist to carefully regulate the amplitude, speed and rhythm of movement according to the patient's symptoms and the severity of joint dysfunction. The mobilisation grades are selected based on the presence of pain, stiffness and movement restriction, allowing treatment to be individualized for each patient. Through its neurophysiological and mechanical effects, Maitland Mobilisation helps to decrease pain, reduce joint stiffness, improve mobility and enhance overall functional performance. [9]

Isometric exercise is a static strengthening technique in which muscle contraction contributes to improved muscle performance by increasing motor unit recruitment, enhancing firing frequency and facilitating activation of inhibited quadriceps muscles. [9],[10] Multiple-Angle isometrics further improves muscle fibre recruitment by producing muscular tension at different joint angles, thereby promoting strength gains across a broader and more functional range of motion. This approach is particularly beneficial in individuals with KOA, where pain and weakness often limit dynamic movement. [11]

Dynamic Quadriceps is a controlled non-weight-bearing open kinetic chain exercise designed to selectively activate the quadriceps muscle group. This exercise is especially effective during terminal knee extension, leading to enhanced activation of the vastus medialis oblique (VMO) which further helps to improve patellar tracking, knee stability and functional performance while minimizing excessive joint loading. [12] Mini Squats is a closed kinetic chain exercise during which the quadriceps muscles generate an internal extension moment to oppose the external flexion moment produced by gravity and ground reaction forces. This exercise promotes coordinated activity of the hip, knee and ankle joints, thereby improving lower limb stability, neuromuscular control and functional strength. In addition, it also facilitates co-contraction of surrounding musculature, enhance proprioception and simulate functional daily activities such as sitting, standing and stair climbing. [13]

II. METHODOLOGY

Study Design: Randomized controlled trial (RCT)

Study Setting: OPD of Department of Physiotherapy, Khalsa University, Amritsar

Study Population: Postmenopausal women radiologically diagnosed with bilateral knee osteoarthritis (Kellgren-Lawrence grade II-III)

Sampling Method: Simple Random Sampling

Sample Size: The sample size for this study was calculated using G*Power 3.1.9.7 software. Based on an effect size of 0.74, α= 0.05 and power =0.80, the analysis indicated a required sample size of 30 participants per group, resulting in a total sample of 60 participants for the trial.[17]

Inclusion criteria:

- Postmenopausal women aged 40-60 years [14]
- Radiologically diagnosed bilateral knee osteoarthritis (Kellgren-Lawrence grade II-III) (radiograph obtained within six months of the outset of the study) [2],[15]
- Persistent knee pain $\geq$ 3 months [14]

Exclusion criteria:

- History of knee surgery or intra-articular injection within the last 6 months.[16]
- Advanced Knee osteoarthritis (Kellgren-Lawrence grade IV) [14]
- Neurological disorders affecting gait or balance [14]
- Systemic inflammatory disease [16]
- Acute trauma, fracture or ligamentous injury of the lower limb [16]
- Concurrent participation in another physiotherapy or exercise trial [16]

Variables:

Independent Variables	Dependent Variables
Maitland Mobilisation	Range of Motion
Isometric Exercises	Muscle Strength
Multiple-Angle Isometrics	
Dynamic Quads	
Mini-Squats	

Instruments and tools:

Universal Goniometer: It is a commonly used clinical instrument for assessing knee joint range of motion, including flexion and extension, measured in degrees. The device consists of a central body, also known as the fulcrum, along with two extensions referred to as arms. One arm remains stationary while the other moves in accordance with joint motion, allowing accurate measurement of angular displacement. It is termed "universal" because of its versatility and ability to measure the range of motion of multiple joints throughout the body. [22]

Manual Muscle Testing: Muscle strength grading, commonly known as Manual Muscle Testing (MMT), is an essential clinical evaluation technique used to assess the strength and functional capacity of individual muscles or muscle groups. The assessment is performed by applying manual resistance against a voluntary muscle contraction to determine the patient's ability to generate and sustain force. Muscle strength is graded using a standardized scale ranging from 0 to 5, where grade 0 indicates no visible or palpable muscle contraction and grade 5 represents normal muscle strength against maximal resistance. MMT is widely utilized in physiotherapy to identify muscle weakness. [23],[24]

Outcome measures:

- Knee Joint Range of Motion – measured with Universal Goniometer
- Muscle strength – assessed using Manual Muscle Testing

Procedure:

Informed consent of all the participants was taken. Baseline assessment was carried out. The participants were randomly allocated into two groups:

Group A: Participants received Maitland Mobilisation, Isometric exercise and Dynamic Quadriceps. (n=30)

Group B: Participants received Maitland Mobilisation, Multiple-Angle Isometrics and Mini-squats. (n=30)

Protocol: A total of 12 treatment sessions were administered three times per week over a period of four weeks in both groups.

Group A:

1. Maitland Mobilisation:

Patient Position – The patient was positioned in supine lying. For tibiofemoral mobilisation, the knee was maintained in slight flexion with a towel roll placed beneath the knee. For patellofemoral mobilisation, the knee was maintained in an extended or slightly flexed position.

Therapist Position: The therapist stood beside the treatment table. stabilizing the proximal segment with one hand while the other hand applied the mobilizing force to the tibia or patella according to the glide performed.

Procedure: Grade II and Grade III oscillatory glides were applied. Anteroposterior (AP) and posteroanterior (PA) glides were performed for the tibiofemoral joint, while inferior (caudal) and superior (cephalic) patellar glides were applied for the patellofemoral joint.

Frequency and Dosage: Mobilisation was performed at a rate of approximately two oscillations per second. Each glide was given for two minutes.

2. Isometric exercises: Participants performed three different isometric exercises:

Exercise	Position	Description	Hold	Rest Period	Reps per set
Supine Straight Leg Raise (Isometric Hold)	Supine lying	The affected lower limb was elevated approximately 10 cm above the treatment table while maintaining knee extension and ankle dorsiflexion. The opposite limb was positioned with the hip and knee flexed to provide stability and support.	10 seconds	2 seconds	10
Side-Lying Leg Raise	Side lying	The affected limb was raised nearly 10 cm above the resting surface from a starting position in which the hip and knee were maintained at 90° flexion while the limb rested on the table.	10 seconds	2 seconds	10
Ball Squeeze Exercise	Sitting on treatment table	A ball was positioned between the knees with the knees flexed to approximately 30°. The participant was then instructed to gently compress the ball by squeezing the knees together.	10 seconds	2 seconds	20

3. Dynamic Quadriceps: The participant was positioned in high sitting on the treatment table both the hip and knee maintained at approximately 90° flexion. From this position, the participant was instructed to actively straighten the knee until full extension was achieved. The terminal extended position was maintained briefly, after which the limb was slowly lowered back to the initial starting position in a controlled manner. Progression Protocol of Dynamic Quadriceps:

Week	Protocol	Reps
Week 1	Dynamic Quadriceps	5
Week 2	Dynamic Quadriceps	10
Week 3	Resisted Dynamic Quadriceps using 50%,75% and 100% of 10 RM weight	10
Week 4	Resisted Dynamic Quadriceps using 50%,75% and 100% of progressed 10 RM weight	10

Group B:

1. Maitland Mobilisation:

Patient Position – The patient was positioned in supine lying. For tibiofemoral mobilisation, the knee was maintained in slight flexion with a towel roll placed beneath the knee. For patellofemoral mobilisation, the knee was maintained in an extended or slightly flexed position.

Therapist Position: The therapist stood beside the treatment table. stabilizing the proximal segment with one hand while the other hand applied the mobilizing force to the tibia or patella according to the glide performed.

Procedure: Grade II and Grade III oscillatory glides were applied. Anteroposterior (AP) and posteroanterior (PA) glides were performed for the tibiofemoral joint, while inferior (caudal) and superior (cephalic) patellar glides were applied for the patellofemoral joint.

Frequency and Dosage: Mobilisation was performed at a rate of approximately two oscillations per second. Each glide was given for two minutes.

2. Multiple-angle Isometrics: The participant was positioned in sitting on the treatment table with the hip and knee maintained at 90° flexion. The participant was then instructed to extend the knee as far as possible against the resistance provided by the resistance band at predetermined joint angles.

Angle	Hold	Reps	Sets
30° of knee flexion	6 seconds	10	3
60° of knee flexion	6 seconds	10	3
90° of knee flexion	6 seconds	10	3

3. Mini-Squats: The participant was positioned in standing with the feet placed shoulder-width apart and the trunk maintained upright. From this position, the participant was instructed to slowly bend the knees while keeping the feet flat on the floor and the trunk erect, followed by a controlled return to the initial standing position.

Progression Protocol of Mini Squats:

Week	Exercise Protocol
Week 1	Up to 30° knee flexion for 5 reps
Week 2	Up to 45° knee flexion for 10 reps
Week 3	Resisted mini squats using 50%,75% and 100% of 10 RM weight held in both hands with 45° knee flexion for 5 reps
Week 4	Resisted mini squats using 50%,75% and 100% of 10 RM weight held in both hands with 45° knee flexion for 10 reps

III. STATISTICAL ANALYSIS

Data analysis was performed using IBM SPSS Statistics. Both descriptive and inferential statistical methods were employed for data evaluation. Descriptive statistics, including mean and standard deviation, were used to summarize the baseline characteristics and outcome measures of participants in both groups. The paired t-test was utilized to compare pre-intervention and post-intervention values within each group, while the independent t-test was applied to assess differences in post-intervention outcomes between Group A and Group B. Statistical significance was established at $p \leq 0.05$.

IV. RESULTS

Table 1: Baseline characteristics of participants in Group A and Group B

Variable	Group A Mean ± SD	Group B Mean ± SD	t value	p value
Age (years)	50.47 ± 1.93	50.93 ± 2.02	-0.91	0.363
Height (m)	1.57 ± 0.02	1.60 ± 0.03	-0.98	0.327
Weight (kg)	70.27 ± 4.02	70.01 ± 4.29	0.24	0.814
BMI (kg/m²)	28.37 ± 1.77	28.22 ± 1.99	0.31	0.754

Data are expressed as mean ± standard deviation (SD). Table 1 presents the descriptive analysis of baseline characteristics of the participants in Group A and Group B. The mean age of participants in Group A was 50.47 ± 1.93 years, whereas in Group B it was 50.93 ± 2.02 years. The mean height of participants was 1.57 ± 0.02 m in Group A and 1.60 ± 0.03 m in Group B. The mean body weight was 70.27 ± 4.02 kg in Group A and 70.01 ± 4.29 kg in Group B. The mean BMI was 28.37 ± 1.77 kg/m² in Group A and 28.22 ± 1.99 kg/m² in Group B. Statistical analysis using the independent samples t-test demonstrated no statistically significant differences between the two groups in any of the baseline variables ($p > 0.05$). These findings indicate that both groups were comparable and homogeneous prior to the intervention.

Table 2: Analysis of baseline and post intervention values within Group A:

Variable	Pre Mean ± SD	Post Mean ± SD	t value	p value
AROM Flexion (Lt) (°)	103.60 ± 7.28	114.10 ± 5.61	11.35	<0.001*
AROM Extension (Lt) (°)	-3.93 ± 1.34	-1.60 ± 0.50	10.1	<0.001*
AROM Flexion (Rt) (°)	103.73 ± 7.33	114.44 ± 5.65	11.49	<0.001*
AROM Extension (Rt) (°)	-3.96 ± 1.36	-1.50 ± 0.51	11.2	<0.001*

PROM Flexion (Lt) (°)	109.55 ± 6.30	120.20 ± 4.88	12.46	<0.001*
PROM Extension (Lt) (°)	-2.50 ± 0.50	-1.33 ± 0.48	13.1	<0.001*
PROM Flexion (Rt) (°)	109.65 ± 6.34	120.46 ± 4.92	12.60	<0.001*
PROM Extension (Rt) (°)	-2.50 ± 0.50	-1.23 ± 0.43	14.8	<0.001*
MMT(Lt)	3.43 ± 0.50	4.33 ± 0.49	9.86	<0.001*
MMT (Rt)	3.43 ± 0.50	4.53 ± 0.51	11.24	<0.001*

(Note: * mark indicates that p<0.05)

Table 2 presents the within-group comparison of outcome measures before and after the intervention in Group A. Statistical analysis using the paired t-test demonstrated statistically significant improvements in all outcome measures following intervention ($p < 0.001$).

Both active and passive knee range of motion showed bilateral improvement. However, comparison between sides revealed slightly greater improvement in the right knee as compared to the left knee following intervention. In active range of motion, the right knee demonstrated higher gains in flexion and greater reduction in extension deficit than the left knee. Similarly, passive range of motion findings indicated comparatively better improvement on the right side.

Muscle strength assessed using Manual Muscle Testing also improved significantly in both knees after treatment. Nevertheless, the right knee demonstrated comparatively greater improvement in muscle strength than the left side at post-intervention assessment. These findings suggest the presence of side-to-side differences, with the right knee showing superior functional recovery and strength gains compared to the left knee.

Table 3: Analysis of baseline and post intervention values within Group B:

Variable	Pre Mean ± SD	Post Mean ± SD	t value	p value
AROM Flexion (Lt) (°)	103.30 ± 7.88	118.90 ± 5.60	13.60	<0.001*
AROM Extension (Lt) (°)	-4.15 ± 1.56	0.00 ± 0.00	14.40	<0.001*
AROM Flexion (Rt) (°)	103.36 ± 7.94	119.10 ± 5.66	13.82	<0.001*
AROM Extension (Rt) (°)	-4.25 ± 1.60	0.00 ± 0.00	14.74	<0.001*
PROM Flexion (Lt) (°)	109.45 ± 7.68	124.90 ± 4.88	15.12	<0.001*
PROM Extension (Lt) (°)	-2.67 ± 0.47	-0.20 ± 0.41	29.40	<0.001*
PROM Flexion (Rt) (°)	109.55 ± 7.72	125.10 ± 4.94	15.39	<0.001
PROM Extension (Rt) (°)	-2.67 ± 0.47	0.00 ± 0.00	44.0	<0.001*
MMT(Lt)	3.37 ± 0.49	4.83 ± 0.38	17.96	<0.001*
MMT (Rt)	3.37 ± 0.49	4.97 ± 0.18	19.83	<0.001

(Note: * mark indicates that p<0.05)

Table 3 presents the within-group comparison of baseline and post-intervention values in Group B. Statistical analysis using the paired t-test demonstrated statistically significant improvement in all outcome measures following intervention ($p < 0.001$).

Both active and passive knee range of motion improved considerably in the left and right knee. Active knee flexion increased markedly on both sides, while extension deficits showed substantial reduction following treatment. Passive flexion range also demonstrated significant improvement bilaterally. Comparison of side-to-side outcomes revealed comparatively greater improvement in the right knee than the left knee following intervention. The right knee demonstrated slightly superior gains in both active and passive flexion range. In passive extension, the right knee achieved complete restoration of extension post-intervention, whereas the left knee showed minimal residual extension deficit.

Muscle strength assessed using Manual Muscle Testing improved significantly in both knees after intervention. However, the right knee demonstrated comparatively greater improvement in muscle strength, achieving near-normal strength values at post-intervention assessment when compared with the left side. Overall, the findings indicate that the intervention was effective in improving knee mobility and muscle strength.

Table 4: Analysis of baseline and post intervention values between Group A & Group B:

Variable	Group A Mean ± SD	Group B Mean ± SD	t value	p value
Pre-AROM Flexion (Lt) (°)	103.60 ± 7.28	103.30 ± 7.88	0.18	0.860
Post-AROM Flexion (Lt) (°)	114.10 ± 5.61	118.90 ± 5.60	-3.32	<0.001*
Pre-AROM Extension (Lt) (°)	-3.93 ± 1.34	-4.15 ± 1.56	0.83	0.41
Post-AROM Extension (Lt) (°)	-1.60 ± 0.50	0.00 ± 0.00	-17.5	<0.001*
Pre-AROM Flexion (Rt) (°)	103.73 ± 7.33	103.36 ± 7.94	0.19	0.852
Post-AROM Flexion (Rt) (°)	114.44 ± 5.65	119.10 ± 5.66	-3.21	<0.001*
Pre-AROM Extension (Rt) (°)	-3.96 ± 1.36	-4.25 ± 1.60	1.07	0.29
Post-AROM Extension (Rt) (°)	-1.50 ± 0.51	0.00 ± 0.00	-16.1	<0.001*
Pre-PROM Flexion (Lt) (°)	109.55 ± 6.30	109.45 ± 7.68	0.06	0.956
Post-PROM Flexion (Lt) (°)	120.20 ± 4.88	124.90 ± 4.88	-3.73	<0.001*
Pre-PROM Extension (Lt) (°)	-2.50 ± 0.50	-2.67 ± 0.47	1.33	0.19
Post-PROM Extension (Lt) (°)	-1.33 ± 0.48	-0.20 ± 0.41	-9.98	<0.001*
Pre-PROM Flexion (Rt) (°)	109.65 ± 6.34	109.55 ± 7.72	0.06	0.956
Post-PROM Flexion (Rt) (°)	120.46 ± 4.92	125.10 ± 4.94	-3.65	<0.001*
Pre-PROM Extension (Rt) (°)	-2.50 ± 0.50	--2.67 ± 0.47	1.33	0.19
Post-PROM Extension (Rt) (°)	-1.23 ± 0.43	0.00 ± 0.00	-15.6	<0.001*
Pre-MMT (Lt)	3.43 ± 0.50	3.37 ± 0.49	0.47	0.640
Post-MMT (Lt)	4.33 ± 0.49	4.83 ± 0.38	-4.82	<0.001*
Pre-MMT (Rt)	3.43 ± 0.50	3.37 ± 0.49	0.47	0.640
Post-MMT (Rt)	4.53 ± 0.51	4.97 ± 0.18	-4.87	<0.001*

(Note: * mark indicates that $p<0.05$)

Table 4 presents the comparison of baseline and post-intervention values between Group A and Group B. Statistical analysis using the independent t-test demonstrated no statistically significant differences between Group A and Group B in any of the pre-intervention variables ($p > 0.05$), indicating that both groups were comparable and homogeneous at baseline.

Post-intervention analysis revealed statistically significant differences between the two groups in all active and passive range of motion variables as well as muscle strength measurements ($p < 0.001$), with Group B demonstrating comparatively greater improvement than Group A. Both left and right knees showed marked improvement in active and passive flexion ranges following intervention. However, the right side demonstrated slightly superior gains compared to the left side in both groups. For active and passive extension, Group B achieved complete restoration of knee extension post-intervention, whereas Group A demonstrated residual extension deficits bilaterally.

Similarly, Manual Muscle Testing scores improved significantly in both groups, with Group B showing greater enhancement in muscle strength compared to Group A. Side-to-side comparison further indicated slightly better muscle strength recovery in the right knee than the left knee.

Overall, the findings suggest that although both interventions were effective in improving knee joint mobility and muscle strength in participants with Knee Osteoarthritis, Group B demonstrated superior outcomes, with minimal side-to-side differences favouring the right side.

V. DISCUSSION

The present study was conducted to compare the effectiveness of Maitland Mobilisation combined with Isometric exercises and Dynamic Quadriceps exercise versus Maitland Mobilisation combined with Multiple-Angle Isometrics and Mini-Squats on side-to-side differences in knee range of motion and muscle strength among postmenopausal women with bilateral Knee Osteoarthritis. The findings of the study demonstrated that both intervention protocols produced statistically significant improvements in active and passive knee range of motion as well as muscle strength. However, Group B showed comparatively greater improvement than Group A in all post-intervention outcome measures.

Knee Osteoarthritis is among the most common musculoskeletal disorders affecting older adults, with a particularly high prevalence in postmenopausal women. Liu Y-P et al. (2018) reported that menopause is associated with reduced ovarian function, leading to decreased estrogen secretion and gradual decline in ovarian activity, which subsequently affects the

body's inflammatory mechanisms. Their study suggested that osteoarthritis is linked with reduced serum estradiol (E2) levels, and the decline in estrogen may contribute to an increased risk of osteoarthritis among postmenopausal women. Furthermore, the authors emphasized the important role of interleukin-1 (IL-1) in the initiation and progression of osteoarthritis. IL-1 alters the articular cartilage environment by promoting synovial inflammation, suppressing cartilage matrix synthesis, accelerating cartilage degeneration and reducing the repair capacity of cartilage tissue, thereby contributing to progressive joint deterioration in osteoarthritis.[20]

Opara Zupančič M, Šarabon N. (2026) stated deficits in knee Range of Motion in individuals with Knee Osteoarthritis may result from pain, fear of movement and structural joint changes such as osteophyte formation and reduced joint space. Soft tissue tightness, muscle shortening, joint effusion and excess body fat may also contribute to restricted knee mobility. These factors may further create a cycle of reduced joint use and progressive tissue changes, leading to additional limitation in knee range of motion. They also reported that sedentary behaviour may lead to reduced muscle mass and decreased muscle cross-sectional area, ultimately lowering the muscle's force-generating capacity. In individuals with Knee Osteoarthritis, pain can further inhibit muscle strength by altering reflex pathways and reducing maximal voluntary muscle activation. Factors such as joint swelling, inflammation, laxity and sensory receptor damage may also contribute to muscle inhibition. Evidence suggests that many individuals with KOA are unable to fully activate the quadriceps muscle, resulting in deficits in both isometric and concentric knee extensor strength irrespective of knee flexion angle or movement velocity. [7]

Maitland Mobilisation is widely recognized as an effective manual therapy approach for the management of joint pain and stiffness. Joel E. Bialosky et al. (2009) reported that oscillatory joint mobilisation stimulates joint mechanoreceptors, which help modulate pain through spinal inhibitory pathways, thereby contributing to pain relief, tissue relaxation and improved joint mobility. The authors further suggested that mobilisation promotes synovial fluid movement within the joint, enhancing cartilage nutrition and reducing mechanical stress on articular structures. These findings are consistent with earlier studies that have demonstrated the beneficial effects of manual therapy interventions in individuals with Knee Osteoarthritis. [21]

Isometric Exercise allows muscle contraction without producing visible joint movement, making it particularly suitable for individuals who experience pain during dynamic activities. These exercises facilitate neuromuscular activation by improving motor unit recruitment, increasing muscle fibre activation and enhancing muscular endurance while minimizing excessive stress on joint structures. [22],[23] The findings of the present study are in agreement with those of Huang et al. (2018), who reported that isometric exercises significantly reduced pain and improved knee joint function in individuals with Knee Osteoarthritis. The authors concluded that isometric strengthening enhances joint stability and functional mobility, thereby contributing to improved clinical outcomes.[24]

Dynamic Quadriceps Exercise, an open kinetic chain exercise selectively targeting the quadriceps muscle group, is particularly beneficial for individuals with increased body mass index or severe pain during weight-bearing activities.[12] The results of the present study are supported by the findings of Desai et al. (2022), who demonstrated that open kinetic chain strengthening exercises significantly improved quadriceps strength and functional outcomes in individuals with knee osteoarthritis. The authors suggested that these exercises permit controlled knee joint movement and facilitate selective strengthening of the quadriceps musculature, especially the vastus medialis oblique, which plays a critical role in patellar stabilization.[25]

Multiple-Angle Isometrics enables muscle activation at different joint angles, thereby promoting strength gains across a wider functional range of motion and improving joint stability.[11] Parveen et al. (2024) demonstrated that multiple-angle isometric exercises produced greater improvements in pain reduction and functional performance compared with conventional isometric exercises in individuals with knee osteoarthritis. These findings support the inclusion of multi-angle strengthening approaches within rehabilitation protocols for enhancing muscle performance and functional recovery.[26]

Closed Kinetic Chain Exercise involves weight-bearing movements in which multiple joints and muscle groups function together to generate coordinated movement patterns.[11] The findings of the present study are consistent with those reported by Desai et al. (2022), who found that closed kinetic chain exercises such as mini-squats resulted in greater improvements in functional performance, dynamic balance and WOMAC scores among individuals with knee osteoarthritis. The authors explained that such exercises enhance proprioception, improve joint stability and facilitate coordinated muscle activation, collectively contributing to superior functional outcomes.[25]

The present study had certain limitations. The intervention period was limited to four weeks; therefore, the long-term effectiveness of the treatment protocols could not be determined. The sample size was relatively small and included only postmenopausal women, which may limit the generalizability of the findings to other populations. Additionally, functional outcome measures such as pain intensity, gait analysis, balance and quality of life were not evaluated in the present study.

Muscle strength assessment was performed using Manual Muscle Testing, which may be less sensitive compared to instrument-based methods such as dynamometry.

Future studies may include larger sample sizes and longer follow-up durations to evaluate the long-term effectiveness of multimodal physiotherapy interventions in individuals with Knee Osteoarthritis. Incorporating additional outcome measures such as pain, gait parameters, balance, functional disability and quality of life may provide a more comprehensive understanding of treatment effects. In addition, the use of advanced assessment tools such as handheld dynamometry, electromyography and motion analysis systems may provide more objective evaluation of muscle performance and movement patterns.

Overall, the findings of the present study demonstrate the effectiveness of multimodal Physiotherapy interventions in the management of Knee Osteoarthritis among postmenopausal women. The results further emphasize the important role of physiotherapy in the conservative treatment of knee osteoarthritis and support the implementation of comprehensive multimodal rehabilitation approaches for achieving improved clinical outcomes in this population.

VI. CONCLUSION

The present study concluded that both multimodal physiotherapy interventions were effective in improving knee joint range of motion and muscle strength in postmenopausal women with bilateral Knee Osteoarthritis. However, Maitland Mobilisation combined with Multiple-Angle Isometrics and Mini-Squats demonstrated comparatively superior improvement when compared to Maitland Mobilisation combined with Isometric exercises and Dynamic Quadriceps exercise. The study also identified minimal yet notable side-to-side differences, with the right knee showing slightly greater improvement in range of motion and muscle strength. These findings highlight the importance of incorporating functional strengthening and side-specific rehabilitation strategies in the physiotherapy management of bilateral knee osteoarthritis.

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