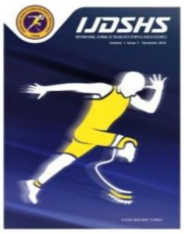

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RESEARCH ARTICLE

Effect of Spinal and Lower limb Re-alignment Protocol on Bilateral Medial Compartment Osteoarthritis of Knee in Postmenopausal Women

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Abstract
The alignment of spine-pelvis-lower extremity axis is significantly influenced by knee osteoarthritis. Joint alignment is the main bio-mechanical risk factor for progression of knee osteoarthritis. The purpose of this study was to find out the effect of spinal and lower limb realignment protocol on bilateral medial compartment knee osteoarthritis in postmenopausal women and to compare it with the conventional method of treatment for osteoarthritis of knee. A study sample of 128 post-menopausal subjects within age group 50-70 and BMI between 25-35 kg/m^2 having bilateral knee osteoarthritis with medial compartment involvement were selected and equally divided into two groups as the control group and the experimental group. Assessment of pain, knee range of motion, quadriceps and hip abductor strength, and posture for spinal and lower limb malalignment was taken before and after giving the treatment regime to both the groups. Comparison was carried out between the results of the two groups.The results showed how significantly the mal-aligned structures were re-aligned after giving 8 weeks of realignment protocol and how significantly this resulted in better reduction of pain intensity and improvement in knee range of motion and strength of quadriceps and hip abductor muscles in experimental group as compared to the control group. Re-aligning the spinal and lower limb malalignment present in postmenopausal women with bilateral medial compartment knee osteoarthritis results in pain reduction associated with knee joint and improved knee range of motion and strength of quadriceps and hip abductor muscles in these individuals as compared to the ones receiving conventional physiotherapy.

Keywords
Knee-Hip-Spine Syndrome, Genu Varum Malalignment, Realignment Exercises

INTRODUCTION

Osteoarthritis is a progressive degenerative joint disorder that causes destruction of the articular cartilage and results in the development of bony spurs and cysts at the margins of the joint. It is one of the leading causes of disability. Knee osteoarthritis (OA) is the most commonly encountered type leading to pain of muscle-skeleton and disability in the elderly. Patients generally complain about pain, muscle weakness, joint stiffness, instability and decrease in physical functions (Yilmaz et al., 2013).

Knee osteoarthritis is one of the most prevalent forms of this disease,with the medial compartment most commonly affected with lateral compartment and patello-femoral joint being relatively spared. This is because medial compartment experiences greater force during bipedal activities such as walking and running. A study shows prevalence of medial compartment involvement was 91.7% while that of lateral compartment and patellofemoral joint was 32.1% and 33.9% respectively (Wang et al., 2018).

Prevalence of knee osteoarthritis is higher in women as compared to men. Evidence suggests that

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women's susceptibility to osteoarthritis may be related to increased hormone levels during certain stages of the menstrual cycle which may increase joint laxity, which is associated with joint instability and injury (Chidi-Ogbolu & Baar, 2019; Jin et al., 2017; Shultz et al., 2005). Both joint instability and injury contributes to the development of osteoarthritis. Incidence of knee osteoarthritis increases in menopause with reduction in oestrogen levels being the main cause (Fenton & Panay, 2016). Oestrogen has an anti-inflammatory effect at high concentrations and plays a chondroprotective role (Martin-Millan & Castaneda, 2013). At the same time, those women who undergo hormone replacement therapy after their menopause have a lower possibility of developing osteoarthritis.

The sagittal alignment of spine-pelvis-lower extremity axis is significantly influenced by knee osteoarthritis (Wang et al., 2016). Study shows that individuals over 50 years of age with knee osteoarthritis had poor spino-pelvic sagittal alignment. Moreover, the progression of knee osteoarthritis had stronger relationship with spino-pelvic malalignment more in women than in men (Yasuda et al., 2020). The increased spinal inclination angle is the most important factor associated with knee osteoarthritis, followed by decreased spinal range of motion (Tauchi et al., 2015). Decreased lumbar lordosis and lumbar range of motion is related to increased spinal inclination angle. There is reduction in hip, knee and ankle range of motion, and increased hip adduction and knee adduction moment. Weakness of quadriceps and hip abductors is common. In severe cases varus deformity sets in at the knee joint. The main bio-mechanical risk factor for progression of knee osteoarthritis is joint malalignment.

Osteoarthritis is a progressive and degenerative condition with unlikely regression and restoration of damaged structures seen.

Studies show that almost all clinical practice guidelines focus on non-pharmacological conservative treatment approaches particularly exercise therapy for the management of knee osteoarthritis (Bannuru et al., 2019; Fernandes et al., 2013; McGrory et al., 2016).

The current management focuses on reducing pain intensity, improving range of motion, strengthening the weakened structures and improving quality of life. To achieve this, various electrotherapeutic modalities like transcutaneous electrical nerve stimulation and ultrasound are used, along with this aerobic training, strength training, stretching and balance training is given to the patients. A study was done that shows effectiveness of quadriceps strengthening for treatment of knee osteoarthritis (Bennell et al., 2010). Another study found that hip abductor exercises combined with quadriceps exercises reduces pain and improves function (Yuenyongviwat et al., 2020). Aquatic therapy that is water-based treatment is an alternative approach for patients who find it difficult to perform land-based exercises given the lesser joint impact.

There has been no focus done on managing the biomechanical factors such as malalignment that affects osteoarthritis and its progression. Hence, re-alignment of spinal and lower limb mal-aligned structures by setting appropriate treatment protocol is essential and may help in delaying the progression of bilateral medial compartment osteoarthritis in postmenopausal females.

MATERIALS AND METHODS

Study Group

All postmenopausal females within age group 50-70 and BMI between 25-35 kg/m^2 with bilateral knee osteoarthritis involving the medial compartment were called to participate in the study. They were then assessed for the presence of spinal and lower limb malalignment. Then females who had spinal and/or lower limb malalignment were selected as the study sample. Inclusion criteria were as follows: 1. Postmenopausal females; 2. Bilateral knee osteoarthritis; 3. Involvement of medial compartment of knee; 4. Presence of spinal and lower limb malalignment. Volunteers who met the following criteria were excluded form the study: 1. Unilateral knee osteoarthritis; 2.Involvement of compartment other than medial compartment.

Subjects were then randomly assigned into two groups that is experimental group (n=64) and control group (n=64). While the control group received conventional treatment protocol for management of bilateral medial compartment knee osteoarthritis the experimental group received spinal and lower limb re-alignment protocol based on the malalignment present in subjects along with the conventional treatment.

Ethics Statement

This interventional study was accepted by Institutional Human Ethics Committee of

Krishna Institute of Medical Sciences, "Deemed to be University," Karad (Protocol number-296/2022-2023).

Data Collection Tools

Numerical Pain Rating Scale (NPRS)

It is one of the most common and most sensitive methods of pain measurement was used. Reliability of this scale for patients who experience pain from a musculoskeletal disorder has been proven excellent (Seidi et al., 2014)

Goniometer.

Goniometer can help in clinical decision making regarding the management, outcome analysis after a particular intervention has been applied, and compare the efficacies of different treatments. According to a study measuring a joint angle with a universal goniometer has moderate to excellent reliability (Norkin &White , 2016)

Manual Muscle Testing(MMT)

Manual Muscle Testing is most commonly used method for documenting impairments in muscle strength.On 5 point scale,the examiner rates the studied muscle as subjectively "weak"or"strong"when exerting force against the subject's resistance

Observational Posture Analysis

It provides valuable insights into spinal alignment, pelvic position, and other body segments,it also allows to identify postural deviations and develop targeted treatment plans.

Experimental design

The screening process of the subjects as per the inclusion and exclusion criteria was done and The subjects were divided into 2 groups i.e the control and experimental group. Prior to the initiation of the study the participants were briefed about the nature of the study and the intervention as well as the testing procedures . The informed consent was obtained from the participants who are willing to participate and were recruited for the study. All the subjects were assessed pre and post treatment . For degree of pain, Numerical Pain Rating Scale (NPRS) was used. Range of motion for knee was assessed using a goniometer. Manual Muscle Testing was used to assess the strength of quadricep muscles and hip abductors. This was followed by assessment of posture in all the three views that is the anterior view, posterior view and the lateral view. From this presence of spinal and lower limb malalignment like thoracic kyphosis, lumbar lordosis, anterior pelvic tilt, level of PSIS (Posterior Superior Illiac Spine), pronated foot, genu varum, hyperextended knee, tibial rotation and femoral torsion were noted in the selected subjects.Rehabilitation exercise program was administered for 12 weeks and during the withdrawal phase of the program the participants were given a brief instruction about the maintenance program of the home exercises. Both the groups were treated with Hot Moist pack before the treatment.

Group A: Spinal and lower limb re-alignment protocol

Group B: Conventional Physiotherapy

Spinal And Lower Limb Re-Alignment Protocol

The exercise program for each alignment changes were designed according to the condition; the exercise program was carried out for 12 weeks.

During the 12-week intervention period, participants were prescribed a comprehensive exercise protocol aimed at re-alignment of spinal and lower limb mal-aligned structures, delaying the progression of unilateral medial compartment osteoarthritis as well as improving knee function. As part of the intervention, participants were advised to utilize a knee unloading brace and lateral wedge insole (Page et al., 2011). The knee unloading brace, designed change the force around the knee joint to alleviate knee joint stress and pain, was custom-fitted to each participant and recommended to be worn during exercise sessions and daily activities. Additionally, participants were provided with lateral wedge insoles, intended to modify biomechanics and reduce knee discomfort; these insoles were recommended for wear in participants' footwear throughout the intervention period. Detailed instructions regarding the correct usage, duration, and maintenance of both the knee unloading brace and lateral wedge insole were provided to ensure proper implementation. Compliance with the intervention strategies was monitored through regular check-ins and participant feedback.

The intervention is discussed in detail in the folllowing tables.

Table 1. Thoracic Kyphosis (Oshima et al., 2019, Brotzman & Manske , 2011)

Exercises	Intensity/Sets
Session 1-	
Day 1- Day 5	
Flexibility-Pectoral major stretch,Thoracic extension exercise	3 sets-15 repetitions-10 seconds hold
Strength-Shoulder Shrugs	10 repetitions-10 sets
Mobility-Chin Tucks	10 repetitions -5 seconds hold
Day 6-Day 10	
Flexibility-Foam roll stretch(touchdown), Foam roll stretch(pectoralis major and subscapularis)	10 repetitions-10 seconds hold
Mobility-Arm circles,shoulder blade squeeze	10 repetitions-10 sets
Session 2-	
Week 3-5	
Strength-Seated Rowing,Pushups,Lateral pulldown	10 repetitions-3 sets
Mobility-Prone Y,T,W exercises	10 repetitions-2sets
Week 9-12	
Strength-Dumbell Rowing	10 repetitions-3 sets
Flexibility-Face pull with theratube,Dyanamic thoracic extension exercises with lunges	10 repetitions-3 sets
Endurance-Planks,Deadbug exercise	3sets-5 repetitions-30 seconds hold
Progression criteria:- - Decreased pain levels during activities of daily living. - Improved thoracic mobility and range of motion. - Increased strength in thoracic extensors and scapular stabilizers. - Enhanced posture awareness and maintenance. - Gradual reduction in thoracic kyphosis angle through postural assessments	

Table 2. Lumbar Lordosis (Javid et al., 2014 ; McGill, 2015 ; Kisner et al., 2017)

Exercises	Intensity/Sets
Session 1-	
Day 1- Day 5	
Flexibility-Seated lumbar flexion -extension	10 repetitions -5 seconds hold
Strength-Pelvic tilt,Drawing in maneuver,Lumbar isometrics	10 repetitions -5 seconds hold
Week 2	
Flexibility-Cat-Cow stretch,Child pose	10 repetitions-5sets-10 seconds hold
Mobility-Single Knee to chest	hold for 5-10 seconds-3 Sets
Strength-Drawing in maneuver	10 repetitions -5 seconds hold
Session 2	
Week3-4	
Flexibility-Hip flexor stretch,Hamstring stretch	5 to 10 seconds holds-10 repetitions
Strength-Double knee to chest,Partial sit-up,Bridging exercise,Dead Bug exercises	10 repetitions-5 sets
Week 5-6	
Flexibility-Pigeon pose stretch	5 to 10 seconds holds-10 repetitions
Strength-Modified plank with variations,Dead-bug with ball squeeze,Standing quadriceps stretch with hip extension	5 to 10 seconds holds-10 repetitions
Session 3-	
Week 7-8	
Strength-Swiss ball roll outs,Squats,Lunges with controlled lumbar posture	10 repetitions-5 sets
Mobility-Bird Dog exercises	15 seconds hold-10 repetitions
Endurance-Modified curl-up,Seated Russian twists with medicine ball	10 repetitions-5sets
Week 9-12	
Flexibility-Standing trunk rotations with resistance band	10 repetitions-5sets

Strength-Side plank with with lateral hip abduction,Bosu ball squats with overhead reach	20 seconds hold-10 repetitions
Balance-Weight shifts to multiple direction on single leg standing,Single leg standing on balance board	10 repetitions-5sets
Progression criteria- - Decreased pain levels during activities of daily living. - Improved lumbar mobility and range of motion. - Enhanced core strength and stability. - Enhanced awareness of posture and its impact on lumbar lordosis. - Gradual reduction in excessive lumbar lordotic curve through postural assessments.	

Table 3. Anterior Pelvic Tilt (Sahrmann 2002; Selkowitz et al., 2013;Kuszewski et al., 2018; Kadav et al. 2023)

Exercises	Intensity / sets
Session 1-	
Week 1-2	
Flexibility-Iliotibial stretch,Tensor fascia lata stretch,Hip flexor stretch,Hamstring stretch,Hip adductor stretch,Quadriceps stretch	10-20 seconds hold-3 repetitions
Strength-Drawing in maneuver	10 repetitions-3 sets
Endurance-Gluteus bridging	10 repetitions-3 sets
Session 2-	
Week 3-4 (Continue with all the stretches**)**	
Strength-Clamshell exercise,Single leg gluteus bridging,Dead bug	10 repetitions-3 sets
Mobility-Bird dog exercise,Cat cow exercise	10 repetitions-3 sets
Week 5-6	
Strength-Quadruped hip extension,Resistance band lateral walk,Bent knee fallout	10 repetitions-3 sets
Endurance-Plank with alternate leg lift	10 repetitions-3 sets
Session 3-	
Week 7-12	
Strength-Step-ups,Resistance band around ankle walk ,Supine Bridging exercise(progression ladder pattern),Seated Russian twists ,Lateral lunges with rotation	10 repetitions-3 sets
Progression criteria: - -Improved pelvic alignment and reduced anterior pelvic tilt. -Enhanced hip flexibility and hamstring length. -Increased gluteus and core muscle strength. -Decreased discomfort or pain associated with anterior pelvic tilt. -Enhanced awareness of pelvic alignment during functional tasks.	

Table 4. Pronated Foot (Anderson et al., 2004 ; Moon et al., 2014; Pabón-Carrasco et al. 2020; Sawant & Shinde, 2021)

Exercises	Intensity/Sets
Session 1-	
Week 1-2	
Flexibility-Eccenteric calf stretch,Short foot exercises with toe spread	15repetitions-3 sets
Strength-Calf raise	15repetitions-3 sets
Mobility-Foot mobility exercises	15repetitions-3 sets
Session 2-	
Week 3-4	
Strength-Toe spreading and gripping exercise ,Seated Arch lifts	15repetitions-3 sets
Mobility-Ankle Alphabet,Marble pickup	15repetitions-3 sets
Week 5-6	
Flexibility-Towel scrunch	10 repetitions-3 sets
Strength-Resistance foot flexion and extension,Toe curls with resistance bands	10 repetitions-3 sets

Mobility-Tripod push	10 repetitions-3 sets
Session 3-	
Week 7-8	
Balance and stability-Single-leg balance with eyes closed	10 repetitions-3 sets
Strength-Resistance band ankle exercise,Calf raises with eccentric control	10 repetitions-3 sets
Mobility-Dynamic foot workouts	10 repetitions-3 sets
Week 9-12	
Balance and stability-Balance board exercises	10 repetitions-3 sets
Strength-Intrinsic foot muscle activation during squats,Calf raises on unstable surface,Ankle resistance bands inversion and eversion	10 repetitions-3 sets
Progression criteria- -Improved foot alignment and reduced pronation during static and dynamic activities. -Increased intrinsic foot muscle strength and arch support. -Enhanced ankle stability and proprioception. -Decreased discomfort or pain associated with pronation. -Enhanced ability to perform functional movements with proper foot control.	

Table 5. Genu Varum (Kang et al., 2009; Han et al., 2011; Kwon et al., 2013; Moon et al., 2022)

Exercises	Intensity/Sets
Session 1-	
Week 1-4	
Flexibility-Hamstring stretch,Quadriceps stretch,Iliotibial band stretch,Wall calf stretch with knee alignment awareness	1 min hold/2 set
Strength-Isometrics -quadriceps,Seated hip abduction with resistance band	10 repetitions-3 sets
Mobility-Joint rotation exercises	10 minutes
Session 2-	
Week 5-Week 8	
Flexibility-Foam roller- Tibialis anterior,Anterior capsular ligament Stretch,Tensor fascia latae Stretch,Illiopsoas Stretch,Hamstring Stretch with progression,Adductor stretch with progression	1 min hold/2 set
Strength-Pelvic stretch,Squats,Abductor/External rotator,Kick back exercise	15 times-3 sets
Mobility-Joint rotation exercises	10 minutes
Session 3	
Week 9-12	
Strength-Side-Lying Leg Lifts with Hip Abduction,Calf Raises with Resistance Band,Leg extension quadriceps,Wall bar squat.	3sets 15reps
Endurance-Wall Squats with Ball Squeeze,Forward and backward stepping,Step ups and step down	3sets 20reps
Balance and stability-Balance board exercise	3sets 20reps
Progression criteria -Improved knee alignment and reduced genu varum during static and dynamic activities. -Increased strength in hip abductors, quadriceps, and calf muscles. -Enhanced stability and proprioception of the lower extremities. -Decreased discomfort or pain associated with genu varum. -Enhanced ability to perform functional movements with proper knee alignment.	

Table 6. Hyperextended Knee (Hubley-Kozey et al., 2006 ; Shelborne et al., 2007)

Exercises	Intensity/Sets
Session 1-	
Week 1-Week 4	
Flexibility-Quadriceps stretch,Hamstring Stretch with Knee Slight Bend,Hip abductor stretch,Hip adductor stretch,Calf stretch	10 seconds hold-3 repetition
Strength-Static quadriceps activation.,Seated knee rotation with ball squeeze	10 repitions-3 sets
Session 2-	
Week 5-Week 8	
Strength-Step-up with controlled descent,Prone hamstring curls,Terminal Knee Extension with Resistance Band,Prone Hamstring Curl with Resistance Band,Step-Up and Knee Raise	10 repitions-3 sets
Session 3	
Week 9-Week 12	
Strength-Wall Sit with Ball Squeeze	10 repetitions-3 sets
Balance and stability-Bosu Ball Squats	10 repetitions-3 sets
Endurance-Box Jumps with Controlled Landing	10 repetitions-3 sets
Progression Criteria: - Reduced knee hyperextension during static and dynamic activities. Improved muscle activation patterns for knee stability. Increased strength in quadriceps and hamstring muscles. Enhanced knee control during functional movements. Decreased discomfort or pain associated with knee hyperextension.	

Table 7. Tıbial Rotation (Homan et al., 2013 ; Kenji et al. 2018)

Exercises	Intensity/Sets
Session 1-	
Week 1-Week 4	
Flexibility- Tensor fascia latae stretch, seated hip internal rotation stretch, supine hip external rotation stretch, seated ankle rotation,internal tibial rotation with towel	10 seconds hold-3 repetitions
Strength- Internal tibial rotation with towel	10 repetitions 3 sets
Session 2-	
Week 4-Week 8	
Strength- Strength-Side lying leg lift with resistance band, resistance band stepouts, seated hip internal rotation with ball Squeeze Resistance- Active tibial rotation with resistance band, leg press With internal rotation of tibia	10 repetitions 3 sets
Session 3-	
Week 9-Week 12.	
Flexibility-Single leg squats, step ups,	10 repetitions 3 sets
Balance and stability- single leg balance with External pertubations, single leg balance with med ball throws.	10 repetitions 3 sets
Resistance – leg press with internal rotation of tibi	10 repetitions 3 sets
Progression Criteria: Improved tibial alignment during static and dynamic activities. Enhanced muscle activation patterns for knee stability and alignment. Increased strength in hip external and internal rotators. Enhanced tibial control during functional movements. Decreased discomfort or deviations related to tibial rotation	

Table 8. Femoral Torsion (Gaudreault et al., 2011)

Exercises	Intensity/Sets
Session 1-	
Week 1-Week 4	
Flexibility-Stretching of iliotibial band,Piriformis Stretch	10 seconds hold-3 repetitions
Strength-Isometric quadriceps contraction,Short Arc Quadriceps Contraction,Supine Hip External Rotation	10 repetitions 3 sets
Session 2-	
Week 4-Week 8	
Strength-Clamshell Exercise ,Isometric Hip External Rotation with Ball Squeeze,Side-Lying Leg Lift with Increased Resistance,Bridging with Hip External Rotation and Leg Lift	10 repetitions 3 sets
Session 3-	
Week 9-Week 12.	
Strength-Multi-Directional Cone Drills,Single-Leg Stability Ball Exercises.	10 repetitions 3 sets
Balance and stability-Single-Leg Bosu Ball Squats,	10 repetitions 3 sets
Endurance-Resisted Lateral Bounds	10 repetitions 3 sets
Progression Criteria: Improved femoral alignment during static and dynamic activities. Enhanced muscle activation patterns for knee stability and alignment. Increased strength in hip external rotators. Enhanced femoral control during functional movements. Decreased discomfort or deviations related to femoral torsion.	

RESULTS

Paired t-test was used to analyse the effect of re-alignment protocol on bilateral medial compartment knee osteoarthritis in postmenopausal females. Statistical analyses were performed using SPSS Software 23.0.Arithmetic mean, standard deviation, p value were calculated from the data. Table 1 Demonstrates the effectiveness of physiotherapy intervention on spinal and lower limb realignment.

Thoracic kyphosis :

The mean value from the experimental group show a decrease from pre-interventional assessment (0.4694) to post interventional assessment (0.2041),indicating improvement in thoracic kyphosis. The p-value (0.0004) indicates a statistically significant difference between pre and post-interventional assessments,demonstrating the effectiveness of the exercises in reducing thoracic kyphosis.

Lumbar lordosis. The p-value(0.0008) suggests a statistically significant difference between pre and post-interventional assessments,indicating that the exercises had a positive impact on lumbar lordosis

Anterior Pelvic Tilt. The obtained p-value of 0.0019 indicates a statistically significant distinction between the pre- and post-interventional assessments. This demonstrates strong evidence that the exercises had a beneficial impact in reducing anterior pelvic tilt. Pronated foot. The p-value (<0.0001) suggests a statistically significant difference between pre- and post-interventional assessments, indicating the effectiveness of the exercises in reducing pronated foot.

Genu varum:

The p-value (0.011) suggests a statistically significant difference between pre- and post-interventional assessments, indicating that the exercises had a positive effect on genu varum.

Hyperextended knee:The p-value (0.0016) suggests a statistically significant difference between pre- and post-interventional assessments, indicating that the exercises were effective in reducing hyperextended knee.

Tibial rotation:

The p-value (0.0068) suggests a statistically significant difference between pre- and post-interventional assessments, indicating the impact of the exercises on tibial rotation.

Femoral torsion:

The p-value (0.0324) suggests a statistically significant difference between pre- and post-interventional assessments, indicating that the exercises had a positive impact on femoral torsion. Based on the results, the exercises targeting spinal and lower limb alignment showed positive effects in reducing thoracic kyphosis, lumbar lordosis, scoliosis, anterior pelvic tilt,pronated foot, genu varum, hyperextended knee, tibial rotation, and femoral torsion in the experimental group compared to the control group. Regarding hip abductors strength, the obtained p-value of 0.0068 signifies a statistically significant difference between the pre- and post-interventional assessments. This suggests that the exercises had a notable positive effect on enhancing hip abductors strength in both the experimental and control group.

Table 2 demonstrates results of paired t-test in experimental group .The obtained p-value of less than 0.0001 indicates a highly statistically significant distinction between the pre- and post-interventional assessments for pain levels. This strong evidence suggests that the exercises were remarkably effective in reducing pain in both the experimental and control groups.Similarly, for range of motion, the obtained p-value of less than 0.0001 reveals a highly statistically significant difference between the pre- and post-interventional assessments. This significant finding indicates that the exercises had a substantial positive impact on improving the range of motion in both groups.For quadriceps strength, the obtained p-value of 0.0019 signifies a statistically significant difference between the pre and post interventional assessments. This suggests that the exercises yielded a noteworthy improvement in quadriceps strength for both the experimental and control groups.

Table 1. Effect of exercises of spinal and lower limb alignment pre and post of both experimental and control group (paired t test was used.)

	Control Group		**Experimental Group**	
	Pre interventional assessment	Post-interventional assessment	Pre - interventional assessment	Post-interventional assessment
THORACIC KYPHOSIS				
Mean (M) ± Standard Deviation(SD)	0.3878 ± 0.4923	0.3469± 0.4809	0.4694± 0.5042	0.2041± 0.4072
p value =		0.6594		0.0004
LUMBAR LORDOSIS				
M ± SD	0.449 ± 0.5025	0.3878 ± 0.4923	0.5306 ± 0.5042	0.2857 ± 0.4564
p value =		0.4725		0.0008
ANTERIOR PELVIC TILT				
M ± SD	0.3265 ±0.4738	0.2857±0.4564	0.4286±0.5	0.2449±0.4345
p value =		0.6594		0.0019
PRONATED FOOT				
M ± SD	0.3878±0.4923	0.3673±0.4871	0.4694±0.5042	0.1429±0.3536
p value =	0.8298			<0.0001
GENU VARUM				
M ± SD	0.3469±0.4809	0.3265±0.4738	0.4286±0.5	0.2449±0.4345
p value =		0.8112		0.011
HYPEREXTENDED KNEE				
M ± SD	0.5714±	0.5918±	0.449±	0.2245±
p value =		0.8212		0.0016
TIBIAL ROTATION				
M ± SD	0.4082	0.3878	0.5102	0.3673
p value =		0.3223		0.0068
FEMORAL TORSION				
M ± SD	0.3878	0.3673	0.4694	0.3469
p VALUE =	0.7993		0.0324	

Table 2. Effect of exercises on the coutcome measures pre and post of both the interventional and control group. (paired t test was used.)

	CONTROL GROUP		EXPERIMENTAL GROUP	
	Pre-interventional assessment	Post-interventional assessment	Pre-interventional assessment	Post-interventional assessment
PAIN				
M ± SD	8.122±1.201	4.735±1.151	7.939± 1.248	2.714± 1.173
p VALUE	<0.0001		<0.0001	
RANGE OF MOTION				
M ± SD	92.735± 9.617	108.43± 8.147	90.918± 9.893	135.27± 8.482
p VALUE	< 0.0001		<0.0001	
QUADRICEPS STRENGTH				
M ± SD	3.592±0.4966	3.776±0.4216	3.49±0.5051	4.531±0.5042
P VALUE	0.0019		<0.0001	
HIP ABDUCTORS STRENGTH				
M ± SD	3.531±0.5042	3.673±0.4738	3.633±0.6355	4.061±0.5919
p VALUE	0.0068		0.0011	

DISCUSSION

This study was conducted to evaluate the effectiveness of re-aligning the spinal and lower limb mal-alignment present in bilateral medial compartment knee osteoarthritic females, in reducing symptoms of knee osteoarthritis. 128 participants were included based on the inclusion criteria and the outcome measures ie: pain, range of motion, quadriceps strength, hip abductors and postural analysis was assessed pre and post intervention and spinal realignment exercises. The results show that 8 weeks of realignment protocol was not only effective in correcting the malalignment but also was very effective in reducing pain symptom. Pain reduction in experimental group was much better than control group. There was also greater improvement seen in knee range of motion and strength of quadricep and hip abductor muscles in experimental group individuals than control group individuals who received only conventional treatment.
According to Norkin, musculoskeletal structures are interconnected. Knee-hip-spine syndrome is referred to as pathologies of these structures. Thus, when any of these structure is treated its effect is seen on the entire body (Norkin & White , 2016).

Another study conducted in Nanjing University Medical School, Nanjing, China shows that severe knee osteoarthritis have a significant influence on sagittal alignment of spine-pelvis-lower extremity axis (Wang et al., 2016). A study also demonstrated relationship between total spinal factors and occurrence of radiographic knee osteoarthritis in elderly subjects (Tauchi et al., 2015). There had been various studies done,that show how spine and lower limb alignment affects osteoarthritis of the knee joint, but there is no study done that demonstrates the effectiveness of treating those malalignments on knee osteoarthritis, hence this study was carried out. Various studies have been done on truncal alterations in people with severe osteoarthritis of the knee. According to Weng J, individuals with severe knee osteoarthritis had a more forward inclination of the global spine and increased hip and knee flexion. In individuals with minimal knee flexion (Fi < 10°), the lumbar spine appeared to be the main source of compensation for sagittal alignment issues. However, the spine, pelvis, and hip joint were all implicated in compensating in individuals with excessive knee flexion (Fi > 10°), resulting in a forward-inclined spine and pelvis and a flexed hip joint (Weng et al., 2015).

A study done by Bhore; P stated that multicomponent exercise program had a beneficial impact on alleviating pain. This was achieved by incorporating isometric exercises that targeted muscles crucial for the knee joint (quadriceps, hamstrings, and adductors) and core muscles (abdominals and lower back). These exercises activated the muscles and influenced the Golgi tendon reflex mechanism. When muscles contract, sensory nerves transmit impulses to an excitatory synapse. Subsequently, an inhibitory synapse is activated through an inhibitory interneuron. This leads to an impulse being relayed back to the muscle through a motor nerve as the muscle relaxes. In simpler terms, these exercises helped activate and relax muscles, contributing to pain reduction (Bhore & Shinde, 2023). The exercise protocol used in this study for improving lordosis (Table 2) showed positive results, In few other studies improvement of back flexion strengthening with flexion exercises is advised as the efficient technique to revise individuals with spinal abnormalities since the primary supporting muscles of the spine are flexors (Walker et al., 1987 ; Li et. al., 1996). According to Woon Gyu Yoo individual strengthening exercise for anterior pelvic tilt resulted in recovery of pelvic tilt to a normal range (Yoo, 2013) and previous studies supports the theory of effectiveness of core muscle coordination training which increased the anterior pelvic tilt who had passive hamstring stiffness (Kuszewski et al., 2018) and similar results were observed in the experimental group (Table 3) of present study

The osteoarthritic knee joint deformity causes altered gaits and weak hip muscles. As a result, individuals with knee OA experience maladaptive kinematic stresses and loads during posture and walking, which leads to morphological alterations in the trunk in the sagittal, frontal, and transverse planes in addition to the lower extremities (Weng et al., 2015). The contracture and varus-valgus deformity of the osteoarthritic knee leading to compensatory mechanism may be the cause of the findings of increased scoliosis, apical deviation of the spine, and greater obliquity of the pelvis (Murray& Azari , 2015).

Genu varum, a common lower-extremity malalignment, can present challenges, especially in middle-aged postmenopausal women. This specific demographic, often characterized by muscle weakness and reduced bone density, may experience a rapid progression of genu varum. This progression can result in various issues, such as pain, diminished functionality, and an overall reduction in the quality of life (Lee & Park , 2016) It is crucial to address these concerns promptly and implement appropriate interventions to improve the overall well-being and mobility of affected individuals. Study done by Hyung-Hoon, Moon addressed muscle imbalance resulting from genu varum through a variety of exercises. They hypothesized that these exercises enhanced static stability and strength in the pelvis and lower extremities, ameliorated muscle imbalances, possibly by strengthening major lower extremity muscles (quadriceps femoris and rectus femoris) with resistance training, and notably reduced knee pain during body movements by balancing dynamic load within the knee joint.Genu varum malalignment of the knee may lead to compensatory foot pronation to enable the foot to be plantigrade when weightbearing.

Genu varum malalignment, can cause compensatory foot pronation as a means to achieve a plantigrade foot position during weightbearing (Riegger-Krugh & Keysor ,1996) short foot exercises increased the muscle activity of the abductor hallucis and the medial longitudinal arch angle during toe curl and short foot exercises. In this study tailor made protocol was given for Genu varum (Table 5) as well as pronated foot (Table 4) and improvement was observed in the results.

The clinical application of the designed spinal and lower limb realignment protocol presented in this research article holds significant promise for the management of bilateral medial compartment knee osteoarthritis in postmenopausal women. The study's findings suggest that the intervention, which focuses on correcting malalignments and improving alignment-related parameters, has the potential to alleviate pain, enhance knee range of motion, increase quadriceps and hip abductor strength, and enhancement of overall postural alignment. Collectively enhancing the functional capacity and overall quality of life of individuals suffering from osteoarthritis. The observed improvements in thoracic kyphosis (Table 1), lumbar lordosis,anterior pelvic tilt, pronated foot, genu varum, hyperextended knee (Table 6), tibial rotation (Table 7), and femoral torsion (Table 8) are indicative of the effectiveness of the realignment exercises in addressing various structural deviations associated with knee osteoarthritis. These changes are important not only for the immediate symptom relief but also for potentially slowing down the progression of the condition by minimizing aberrant biomechanical forces on the knee joint.

Furthermore, the significant reduction in pain levels, improved knee range of motion, and increased quadriceps and hip abductor strength observed in the experimental group compared to the control group underscore the clinical relevance of the intervention. The comprehensive nature of the realignment protocol, addressing both the spinal and lower limb components, appears to have a positive impact on various aspects of knee osteoarthritis management. These findings highlight the potential for a holistic approach in the treatment of knee osteoarthritis, one that not only focuses on symptomatic relief but also aims to address underlying structural factors contributing to the disease. The study's emphasis on utilizing exercise-based interventions, such as the realignment protocol, presents a non-pharmacological and conservative option for managing knee osteoarthritis, aligning with current clinical guidelines that promote exercise therapy as a central component of treatment.

There were several limitations, first the number of subjects were relatively less. Second, radiographic evaluation of knee joint pre and post treatment was not performed in all the subjects. However, pre and post treatment results were calculated including outcome measures such as pain, range of motion and strength which are the main components that gets affected with development of osteoarthritis of knee and improvement in these components helps in controlling the progression of knee osteoarthritis. Thus, this may be sufficient as being the first study that shows better improvement in these outcomes by using re-alignment protocol than the conventional method in postmenopausal females having one or more than one spinal and lower limb malalignment.

Conclusion

The spinal and lower limb realignment protocol, has shown promising results in improving malalignment and reducing symptoms in postmenopausal females with bilateral medial compartment knee osteoarthritis. By addressing structural deviations and promoting improved alignment, this intervention has the potential to positively impact pain, functional outcomes, and overall quality of life in individuals with knee osteoarthritis. Further research and validation are needed to solidify the clinical application of this approach and its long-term effects on disease progression.

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Conflict of interest

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Ethics Committee-

The study was approved by Institutional Human Ethics Committee of Krishna Institute of Medical Sciences, “Deemed to be University,” Karad (Protocol number-296/2022-2023).

Author Contribution Statement:

KA conducted literature review for this manuscript, developed the introduction section of the manuscript,collected data.SM conducted the discussion of the study and analyzed the data. SS provided a description of the background information, collected data and analyzed the data, and participated in the prescription of the manuscript. All the authors read and approved the final manuscript.

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