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Original Article

Physiotherapy Section

Efficacy of Open versus Closed Kinetic Chain Exercises on Dynamic Balance and Health Status in Individuals with Osteoarthritis of Knee Joint: A Quasi-experimental Study

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ABSTRACT

Introduction: Osteoarthritis is an inflammatory disorder characterised by changes in the biomechanics, biochemistry and genetic background of joint cartilage and subchondral bone. When distal parts move freely throughout exercises in a weight-bearing position, the phrase open kinetic exercises is employed. Closed kinetic exercises are employed in a weight-bearing position when the body travels through a hard and quick distal phase.

Aim: To compare the efficacy of Open Kinetic Chain (OKC) and Closed Kinetic Chain (CKC) exercises on dynamic balance and health status in individuals with osteoarthritis of knee joint.

Materials and Methods: A single-blinded experimental study was conducted from April 2020 to May 2021 at Dr D.Y. Patil College of Physiotherapy, Pimpri-Chinchwad area, Pune, Maharashtra, India. A sample of 30 subjects with unilateral osteoarthritis of knee joint, between the age of 40-60 years of both genders, were recruited. They were divided into open kinetic group (Group A) and closed kinetic group (Group B) using convenient sampling method. Y-balance and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (Pune CRD version) were used as outcome measures-preintervention, post two weeks and post four weeks of intervention. Data normality was tested by Shapiro-Wilk test. Significance was tested using paired t-test within the groups for WOMAC and Y-balance test. Unpaired t-test was used between the groups.

Results: Among 30 subjects, 17 were males and 13 females. There was a significant improvement in dynamic balance (p=0.001) and WOMAC (p=0.001) in both the groups. In group A, preintervention mean values for WOMAC was 41.2±10.53, and post four weeks of intervention, it was 34.53±10.12 (p=0.001). Preintervention mean for Y-balance test was 0.554±14.6 and after four weeks of intervention mean was 0.586±13.8 (p<0.001). In group B, preintervention mean for WOMAC was 40.87±8.33, and after four weeks of intervention, mean was 30.47±7.22 (p=0.001); while preintervention mean for Y-balance test was 0.583±7.8 and after four weeks of intervention, mean was 0.645±7.0 (p=0.001). Between groups, analysis showed p=0.051 for both groups post four weeks of intervention.

Conclusion: The study concluded that CKC exercises are more effective than OKC exercises in improving dynamic balance and decrease in pain, stiffness, and improving physical function in knee osteoarthritis.

Keywords: American college of rheumatology criteria, Fall prevention, Western ontario and McMaster universities index of osteoarthritis, Y-balance test

INTRODUCTION

Osteoarthritis is a degenerative disease that affects the articular cartilage, resulting in a painful joint and reduced joint activities [1]. Pain has an inhibitory impact, resulting in decreased voluntary activation, atrophy of type II muscle fibres, and defensive reflexes. Muscular deficiencies caused by osteoarthritis of the knee might result in muscle weakness and strength [2].

In people aged 40 and above, the global prevalence of knee osteoarthritis was determined to be 22.9%. Also, the global incidence was found to be 203 per 1000 individuals [3]. In people aged 65 and up, the prevalence rate of osteoarthritic knee ranges from 22-39%, with the rate continuously increasing with age [4]. According to the Kellgren and Lawrence scale [5], the prevalence of osteoarthritis of the knee joint in India is 28.7%, whereas according to the American College of Rheumatology (ACR) criteria, the prevalence is 41.1% [6].

Clinical features of knee osteoarthritis are pain, joint stiffness, bone enlargement, and swelling. All these factors lead to decreased active as well as passive range of motion in osteoarthritic individuals. Prolonged movement impairment in larger joints like hips, knees or elbows results in fixed flexion deformity [7]. Initially, the pain becomes worse with weight bearing and ambulation. Progression of the disease leads to pain, day and night as loss of cartilage leads to bone-to-bone contact [8]. Risk factors are ageing, joint injury and trauma, obesity, genetics, anatomical aspects, and postmenopausal women [7].

Balance is an essential component of all these activities including other activities of daily life [9]. It has been observed in individuals with osteoarthritis that muscles controlling the hip and knee get atrophied and there is reduced ankle strength. Thus, the biomechanics gets altered during activities such as walking. For proper walking function, plantar flexion power of an ankle is very important [10]. Dynamic balance is the ability of the motor system to quickly adjust the sections of the body according to the activities performed that put pressure on the knee joint. The body has its own capacity to maintain upright position due to its dynamic strength [11]. Takacs J et al., found that the potential factors that are responsible for dynamic balance impairment in knee osteoarthritic individuals are muscle strength and knee range of motion according to the Community Balance and Mobility Scale (CB&M), which may lead to falls in future [12]. A study conducted in Malaysia concluded that individuals with mild and moderate knee osteoarthritis have

impaired static as well as dynamic balance, which increases the risk of fall [13].

Various treatment approaches for knee osteoarthritis are aerobic exercises, resistance training, balance and proprioception, stretching, aquatic therapy, and pilates [14,15]. The term "open kinetic exercises" refers to workouts performed in a weight-bearing stance with distal portions moving freely throughout. Closed kinetic exercises are performed in a weight-bearing position as the body moves through a hard and quick distal phase. Cho T et al., proved in their study that after Closed Kinetic Chain (CKC) exercises, improvement was seen in electromagnetic activities of all components of quadriceps femoris muscle, whereas, Open Kinetic Chain (OKC) exercises did not show significant improvement on vastus lateralis muscle [16].

Also, CKC exercises help in co-contraction of other groups and body weight provides additional resistance, whereas OKC are very effective for isolated strengthening of quadriceps [17]. There are many research studies that compare OKC exercises and CKC exercises to improve strength [18], but very few of these studies have focused on improving dynamic balance. Hence, the purpose of this study was to find the efficacy of OKC exercises and closed kinetic chain exercises on dynamic balance and health status and also to see the effect on individual components of WOMAC in osteoarthritis of knee joint. Primary outcome was Y-balance test and secondary outcome was WOMAC.

MATERIALS AND METHODS

A single-blinded experimental study was conducted from April 2020 to May 2021 at Dr D.Y. Patil College of Physiotherapy, Pimpri-Chinchwad, Pune, Maharashtra, India. Ethical clearance was obtained from Institutional Ethics Committee with ref. no. DYPCPT/IEC/08/2020. The trial was registered with the Clinical Trial Registry no. CTRI/2021/01/030389. The sample size was estimated to be 30 with α error of 0.02 and 80% of power with reference to a previous study [18].

Inclusion criteria: Subjects with unilateral osteoarthritis of knee joint, age ranging between 40-60 years of both genders, subjects with tibiofemoral and patellofemoral osteoarthritis, having primary osteoarthritis of knee joint according to ACR criteria were included.

Exclusion criteria: Subjects with acute knee synovitis, advised for total knee replacement, secondary osteoarthritis, lower extremity amputations, received any intra-articular injections were excluded.

Procedure

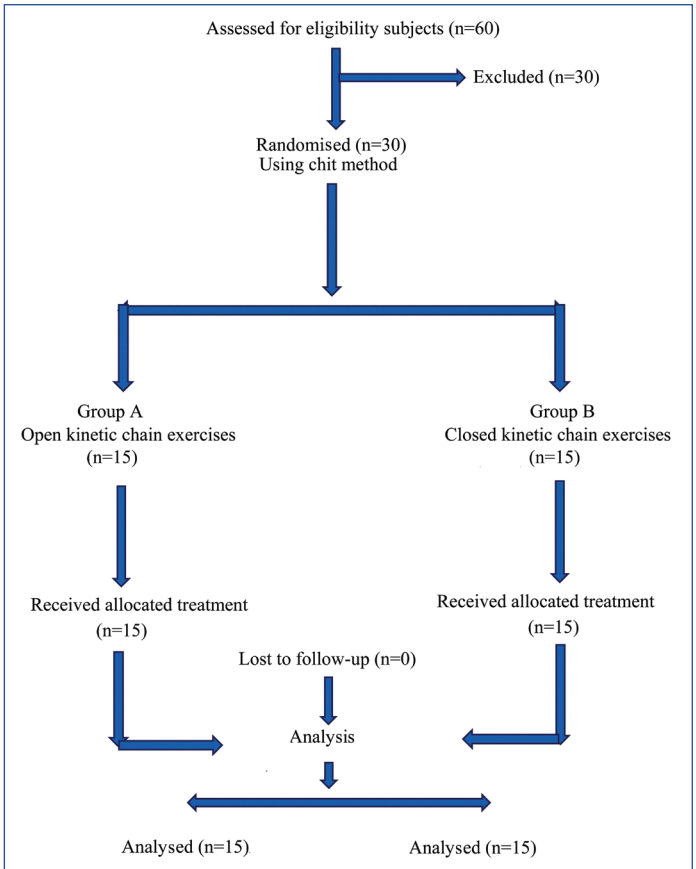
Subjects were assigned using chit method into

- Group A- OKC exercises which consisted of dynamic quads, short arc terminal extension, straight leg raise and hamstring curls.
- Group B- CKC exercises which consisted of mini-squats, step-ups and step-down (forward and backward), lunges and standing wall slides.

All the necessary Coronavirus Disease (COVID-19) precautions were taken, like wearing mask, maintaining social distancing, avoidance of overcrowding, presanitising and postsanitising of hands as well as equipment used in the study. At the end of each treatment session, hot-pack was given to all the subjects [Table/Fig-1-3].

Progression of exercises:

- OKC exercises
- CKC exercises



[Table/Fig-1]: Flowchart of procedure.

Exercises	Week 1	Week 2	Week 3	Week 4
Dynamic quadriceps	5 repetitions	10 repetitions	Resisted dynamic quadriceps with 50%, 75% and 100% of 10RM weight × 10 repetitions	Resisted dynamic quadriceps with 50%, 75% and 100% of progressed 10RM weight × 10 repetitions
Short arc terminal extension	5 repetitions with 5 degrees of knee flexion	10 repetitions with 10 degrees of knee flexion	50%, 75% and 100% of 10RM weight added at the ankle × 10 repetitions with 15 degrees of knee flexion	50%, 75% and 100% of progressed 10 RM weight added at the ankle × 10 repetitions with 20 degrees of knee flexion
Straight leg raise	45 degrees of hip flexion with knee extension with 10 seconds hold × 5 repetitions	30 degrees of hip flexion with knee extension with 10 seconds hold × 10 repetitions	15 degrees of hip flexion with knee extension with 10 seconds hold × 10 repetitions	50%, 75% and 100% of 10RM weight added at the ankle × 10 repetitions
Hamstring curls	Up to 90 degrees of knee flexion × 5 repetitions	Up to 90 degrees of knee flexion × 10 repetitions	50%, 75% and 100% of 10RM weight added at the ankle × 10 repetitions	50%, 75% and 100% of progressed 10RM weight added at the ankle × 10 repetitions

[Table/Fig-2]: Open kinetic chain exercises progression.

The outcome measures used were Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC Pune CRD version) [19] and Y-balance test [20]. All subjects were assessed before, post two weeks and post four weeks of intervention.

STATISTICAL ANALYSIS

The data collected were analysed for demographic variables and significance by using Winpepi version 4.0 and Primer of biostatistics version 7.0 software. Data normality was tested by Shapiro-Wilk test and data were found to be normally distributed. Significance

Exercises	Week 1	Week 2	Week 3	Week 4
Mini squats	30 degrees knee flexion × 5 repetitions	45 degrees knee flexion × 10 repetitions	50%, 75% and 100% of 10RM weight given in both hands and 45 degrees knee flexion × 5 repetitions	50%, 75% and 100% of progressed 10 RM weight given in both hands and 45 degrees knee flexion × 10 repetitions
Step ups and step downs	Low step with 2-3 inches in height × 5 repetitions	Step 3-4 inches in height × 10 repetitions	50%, 75% and 100% of 10RM weight added in both hands and forward and backward step ups and step downs × 5 repetitions	50%, 75% and 100% of progressed 10RM weight added in both hands and forward and backward step ups and step downs × 10 repetitions
Lunges	Forward lunges with 5 degrees of forward knee flexion × 5 repetitions	Forward lunges with 10 degrees of forward knee flexion × 10 repetitions	50%, 75% and 100% of 10RM weight added in both hands and forward lunges with 15 degrees of knee flexion × 10 repetitions	50%, 75% and 100% of progressed 10RM weight added in both hands and forward lunges with 10 degrees of knee flexion × 10 repetitions
Wall slides	Knee flexion up to 30 degrees × 5 repetitions	Knee flexion up to 45 degrees × 5 repetitions	Knee flexion up to 60 degrees × 5 repetitions	50%, 75% and 100% of 10 RM and up to 60 degrees of knee flexion × 5 repetitions

[Table/Fig-3]: Closed kinetic chain exercises progression.

was tested by Paired t-test within the groups for WOMAC and Y-balance test. Between the groups, analysis was done by Unpaired t-test. A p-value <0.05 was considered as significant.

RESULTS

In the present study, [Table/Fig-4] gives details of demographic data of the participants that include mean age and gender distribution in both groups.

Parameters	Group A	Group B	p-value
Age (years) (mean)	54.07±6.00	55.6±4.94	0.452
Gender			
Male	10	7	-
Female	5	8	

[Table/Fig-4]: Demographic data analysis.

[Table/Fig-5] indicates intra group and inter group comparison of Y-balance scores in Group A and B. Intra group comparison revealed that there was improvement in dynamic balance at the end of two weeks and four weeks of intervention in both the groups. However, CKC exercises showed better improvement in Y-balance scores when compared between groups after four weeks of intervention.

Groups	Y-balance scores (Mean±SD)			p-value (Intra group analysis)	
	Preintervention	Post 2 weeks	Post 4 weeks	Pre-Post 2 weeks	Pre-Post 4 weeks
Group A	0.554±14.6	0.570±14.1	0.586±13.8	<0.001*	<0.001*
Group B	0.583±7.8	0.612±6.8	0.645±7.0	<0.001*	<0.001*
p-value (inter group analysis)	0.197	0.154	0.051*	-	-

[Table/Fig-5]: Y-balance scores for Group A and Group B (Paired t-test for intra group analysis and Unpaired t-test for inter group analysis).
*p<0.05 was considered as significant

[Table/Fig-6] indicates the comparison of sub scores of WOMAC in both groups. Within groups analysis showed improvement in all the components of WOMAC post four weeks of intervention in CKC exercise group. However, better improvement was seen in functional ability component for CKC exercises when compared between groups.

Sub parameters of WOMAC	Time frame	Group A (n=15)	Group B (n=15)	Inter group analysis
		Mean±SD	Mean±SD	P1 value
Pain	Preintervention	9.93±4.367	10.93±3.15	0.777
	Post 2 weeks	9.53±2.8	9.73±2.789	
	Post 4 weeks	7.93±2.604	7.53±1.995	0.595
	P2 value Pre-Post 2 weeks	0.472	0.031*	
	Pre-Post 4 weeks	0.012*	0.001*	
Stiffness	Preintervention	3.53±1.76	3.86±1.68	0.301
	Post 2 weeks	3.33±1.11	3.06±1.33	
	Post 4 weeks	3.00±0.08	2.53±1.50	0.250
	P2 value Pre-Post 2 weeks	0.582	0.001*	
	Pre-Post 4 weeks	0.192	0.002*	
Functional score	Preintervention	27.33±8.466	26±6.82	0.487
	Post 2 weeks	25.13±9.657	22.8±5.30	
	Post 4 weeks	27.87±1.023	21.8±6.52	0.024*
	P2 value Pre-Post 2 weeks	0.062	0.075	
	Pre-Post 4 weeks	0.828	0.031*	
Total WOMAC score	Preintervention	41.2±10.53	40.87±8.33	0.001
	Post 4 weeks	34.53±10.12	30.47±7.22	

[Table/Fig-6]: Comparison of sub scores of WOMAC in Group A and Group B.
*p<0.05 was considered as significant; P1- Inter group analysis; P2- Intra group analysis

DISCUSSION

The purpose of the study was to assess the effects of open chain exercises and closed chain exercises in individuals with knee osteoarthritis with respect to dynamic balance and health status. Dynamic balance is the ability of the body to maintain balance while the body is moving but keeping its centre of gravity over the base of support [21].

Improvement was observed after four weeks of intervention in OKC exercise group as well as CKC exercise group in terms of dynamic balance. OKC exercises have been found to identify strength deficits and improve muscle performance of individual muscles or muscle groups thus, supporting the joint for dynamic stability [22]. Alghamdi MA et al., stated that OKC exercises, which are non weight-bearing involves less wear and tear of the joint cartilage, prevents the disease progression, and also helps purely in improving strength of the muscles rather than just improving the functional status of an osteoarthritic individual, thus promoting dynamic stability [23].

The CKC exercises also showed significant improvement in Y-balance scores. These exercises control more of muscular stabilisation to control joints and structures proximal and distal to the targeted joint and also resemble our day-to-day functional activities. Thus, these help in improving the dynamic stability of joints [22]. These exercises cause the co-contraction of agonist and antagonistic muscles and also stimulate the intra and extra-articular mechanoreceptors which improves muscle strength, provides increased articular stability, increases proprioception, improves body awareness that consequently reflects in the control of body positioning during daily activities, and also aids

in postural control which helps in preventing falls [2,24]. Mehta K and Sorani D stated that when OKC and CKC exercises were compared for pain, range of motion and functional performance in individuals with knee osteoarthritis for two weeks, it was found that CKC exercises were more effective than OKC exercises because CKC exercises consist of movements over multiple joints which involve more than one muscle group [25].These exercises help in recruiting more muscles like quadriceps, hamstrings, hip flexors, soleus, and gastrocnemius in a very short time period, which includes reduced shearing forces, increased joint compression, and improves the stability of joints. These also help in enhancing the movements as the CKC exercises are more related to daily life functional activities, which help promote dynamic stability [22]. Balance control includes both reliable sensory and motor involving sufficient muscular force. Hence, improvement of either sensory or motor components may improve balance performance. Dannelly BD et al., studied female participants to evaluate the effect of CKC and OKC exercises on balance through Star Excursion Balance Test (SEBT). After 13 weeks of training, it was found that there was significant improvement in balance of both lower extremities in posteromedial direction. The SEBT that was used in their study focused on the ability to reach while standing on one leg in eight reach directions [26]. However, the present study, employing Y-balance test, measured balance in anterior, posteromedial, and posterolateral directions.

Wilk KE et al., investigated tibiofemoral joint kinetics and Electromyography (EMG) activity of quadriceps, hamstrings and gastrocnemius muscles during OKC and CKC exercises. They concluded that with CKC exercises, there was significant greater compressive force as compared with OKC knee extension. Also, they concluded that co-contraction of quadriceps and hamstrings is not produced in all closed kinetic exercises, but the magnitude of co-contraction depends on trunk position relative to knee joint [27].

The pain component of WOMAC scale showed significant improvement after four weeks of intervention with OKC exercises. Reduction of pain following quadriceps strengthening exercises leads to increased stability of the knee joint. The findings are in agreement with another study, which suggests that quadriceps strengthening may activate pain suppressing β-endorphins and help in gate control mechanism by regulating pain perception. It also improves blood flow and cartilage nutrition [28].

All the components of WOMAC showed significant improvement after four weeks of intervention with CKC exercises in terms of pain relief, decrease in stiffness, and improved functional ability. Verma S, conducted a study, wherein she compared OKC exercises with CKC exercises, along with hot packs in knee osteoarthritis and revealed that CKC exercises were more effective than OKC exercises in terms of quadriceps muscle strength and functional status of women with knee osteoarthritis. In recent years, much importance has been given to CKC exercises in terms of rehabilitation, as it replicates functional movements [29].

Limitation(s)

Long-term follow-up after intervention could have been assessed. Further studies can be done taking combined kinetic chain exercises into consideration.

CONCLUSION(S)

The present study concluded that both OKC and CKC exercises improved dynamic balance and helped in reducing pain, stiffness and improving physical function, when administered for four weeks in patients with osteoarthritis of the knee joint. However, CKC exercises showed better improvement in terms of physical function. Hence, these can be included as routine exercises for knee osteoarthritis patients to improve dynamic balance and health status.

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