COMPARISON OF THE EFFECT OF KINETIC CHAIN EXERCISE REGIMES ON ARTICULAR CARTILAGE OF KNEE JOINT EVALUATED USING SONOGRAPHY

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Abstract

Background: Kinetic chain exercises have been used in the management of the patients with knee osteoarthritis but whether these exercises has any impact on the articular cartilage of knee is yet to be investigated.

Material & Method: 60 subjects in the age range of 40-70 years and satisfying the inclusion and exclusion criteria were made part of study and were divided into two groups of 30 subjects each. Group A received open kinetic chain and group B received closed kinetic chain exercises. Baseline readings were noted down of pain, ROM of flexion and cartilage health parameters of clarity, interface and thickness using sonography. Exercise protocol was given for 3 times per week for 12 weeks.

Results: The cartilage clarity and interface was presented as frequency distribution of subjects in different grades. The findings of paired t-test showed that there was statistically significant improvement in pain, quality of life and cartilage thickness at sulcus aspect of left knee in group A and sulcus aspect of both knees of group B. The findings of unpaired t-test suggested significant difference in pain and statistically non-significant difference of all other parameters between the two groups.

Conclusion: The findings were suggestive that both open and closed kinetic chain exercises brought improvement in clinical symptoms but none of the exercise regime was effective in improving the health of cartilage health.

Keywords/ Index Terms: Clarity, Interface, Cartilage health, Sonography

INTRODUCTION

Articular cartilage is one of the specialized connective tissue covering the joint surface whose function is to synergistically deal with the mechanical load encountered over lifetime (Ateshian and Wang, 1995; Cohen *et al.*, 2003). Due to its unique structural composition and biomechanical properties, articular cartilage has a property of transferring and distributing the mechanical loads across the joint surface without sustaining substantial wear.

The health of articular cartilage is maintained by mechanical loading which acts as a significant factor in regulating metabolism and enzymatic activity, required for the production of proteoglycans, that act as a sort of shock absorbers, as they get compressed and dissipate force on the rest of the joint surface, thereby minimizing the pressure on articular cartilage (Eckstein *et al.*, 2006), hence is important in maintaining healthy articular cartilage. Besides mechanical loading, aging also influences articular cartilage homeostasis and is, thereby, involved in the pathogenesis of degenerative joint diseases such as osteoarthritis (Degroot *et al.*, 1999; Loeser *et al.*, 2000; Martel- Pelletier, 2004; Eckstein *et al.*, 2006; Scott *et al.*, 2010; Hugle *et al.*, 2012; Hosseini *et al.*, 2013; Li *et al.*, 2013; Musumeci, 2016).

Osteoarthritis (OA) is a chronic degenerative disorder of multifactorial etiology characterized by loss of articular cartilage, hypertrophy of bone at the margins, subchondral sclerosis and range of biochemical and morphological alterations of the synovial membrane and joint capsule (Dicesare and Abramson, 2005). Pathological changes in the late stage of OA include softening, ulceration and focal disintegration of the articular cartilage; synovial inflammation also may occur. Typical clinical symptoms are pain, particularly after prolonged activity and weight bearing whereas stiffness is experienced after inactivity (Dicesare and Abramson, 2005).

With the continued growth of the elderly population worldwide, the incidence of osteoarthritis has also increased. In U.S.A. more than 27 million people are affected by this menace. More than 6.1 million Australians (75 per 1000) are reported to have arthritis or a musculoskeletal condition (March and Bagga, 2004). The scenario of osteoarthritis in India is no different. According to one study conducted by TNS and TNS Arogya, osteoarthritis is the second most prevalent clinical problem in India. Earlier osteoarthritis use to affect only elderly population but these days in India, people in their 30's are started getting effected by this problem (Sinha, 2009). Community survey data in rural and urban areas of India shows the prevalence of osteoarthritis to be in the range of 17 to 60.6%. The prevalence of osteoarthritis among elderly was found out to be 56.6% in Chandigarh. The prevalence of osteoarthritis amongst elderly in rural areas of Amritsar was 60.6% (Sharma et al, 2007).

There have been many researches (Madsen et al, 1995; Wessel, 1996; Slemenda et al, 1997) that have studied the relationship of quadriceps strength and osteoarthritis. Consequently, the management of OA is focused more on the strengthening exercises. Strengthening exercises are basically divided into open kinetic chain exercises and closed kinetic chain exercises.

Open kinetic chain exercises (OKCE) are the exercises in which the hand or foot is free to move with the movement occurring at the knee joint independent of the motions occurring at other joints. Closed kinetic chain exercises (CKCE) are exercises in which the hand or foot is fixed with the surface, usually the ground or the base of a machine. The movement takes place at knee in association with the movement of other joints (Lutz et al, 1990).

There have been lots of debate going on regarding the effectiveness of open kinetic chain exercises and closed kinetic chain exercises in patients with osteoarthritis of knee joint. According to a study conducted by Baker and McAlindon in 2000, the closed kinetic chain exercises were found to give better results than open kinetic chain exercises in patients with osteoarthritis of knee joint. This result was also supported by a study done by Kenji in 2003. But Morrissey et al in 2002 and Witvrouw et al in 2004 in their studies found that that there is no difference in the effects of open kinetic chain exercises and the closed kinetic chain exercises.

The results of the above mentioned studies are based on the relief of clinical symptoms. There has been scarcity of studies reported till date which focuses on the effect of these exercises on the articular cartilage of knee in spite of the fact that it is the first structure to get involved by this disease. Thus, it seems that successful assessment of osteoarthritis progression and therapeutic response to interventions that could control the course of the disease depends on establishing objective methods for monitoring articular cartilage damage. Various objective methods that can be used to view the status of articular cartilage are radiographs, sonography and Magnetic Resonance Imaging (MRI).

Radiographs are the main outcome measure in epidemiological studies of osteoarthritis. Radiographs have limitations that visualization of articular cartilage is indirect and its ability to image soft tissue disease is limited (Tarhan et al, 2003). However, although imperfect, radiographs still remain the closest to a gold standard for epidemiological studies of knee OA (Spector et al, 1993). MRI remains a powerful tool that is able to visualize a broad spectrum of osteoarthritis disease, but its cost, limited availability and exclusionary criteria for use in certain patients are practical disadvantages (Tarhan et al, 2003).

High resolution sonography is an accurate, inexpensive, readily accepted, non- ionizing and non-invasive method for imaging the musculoskeletal system (Naredo et al, 2005). Sonographic assessment of articular cartilage degeneration has been extensively studied. This may provide information about the integrity and thickness of cartilage by assuming a predefined ultrasound speed within the tissue (Kuroki et al, 2008). Sonography can also visualize cartilage, bone and soft tissue structures. Thus sonography permits an extensive evaluation of most joint changes present in osteoarthritis and gives the opportunity to monitor disease progression (Iagnocco, 2010).

AIM OF THE STUDY

The present study was aimed to investigate and compare the impact of closed and open kinetic chain exercise on the cartilage health of knee joint as evaluated using sonography.

OBJECTIVE OF THE STUDY

The objectives of the present study was to investigate and compare the effect of open and closed kinetic chain exercise on pain, range of motion and quality of life.

MATERIALS AND METHOD

Research design: The present study had experimental study design comparative in nature.
Research setting: This study was done in Outpatient Department of Physiotherapy, Gian Sagar Hospital and Gian Sagar College of Physiotherapy, Rajpura.
Sample size: 60 patients
Sampling technique: Random Sampling Technique (lottery method)
Ethical approval and informed consent: This study was approved by the ethical committee of Gian Sagar group of institutes. All the subjects were duly informed about the procedure, duration of procedure and the associated risk factors and precautions involved in the study. A written informed consent was taken from all the subjects before the initiation of the study.

SAMPLING CRITERIA

Inclusion criteria:

- Age: 40 to 70 years.
- Grade 2-3 of osteoarthritis according to K-L grading scale
- Both sexes are included
- Mild to moderate pain on VAS

Exclusion criteria:

- Any history of fracture or soft tissue injury in lower limb in the last 1year.
- If subject had undergone any surgery in lower limb during the last 1 year.
- If subject had any history of tumor.
- Diagnosed neuromuscular disorder

PROCEDURE

60 subjects satisfying the inclusion and exclusion criteria were made part of the experiment. Whole procedure of the study was explained to the patient and written informed consent was taken from the participants prior to inclusion in the study. The subjects were then randomly divided into two groups of 30 patients each. The groups were made according to the exercise regimes administered as following.

Group A: Open kinetic chain (OKC) exercises

Group B: Closed kinetic chain (CKC) exercises

Baseline readings of pain using VAS, quality of life using lequesne index, ROM of knee flexion using universal goniometer and cartilage health parameters (clarity, interface and thickness) were noted down. Cartilage clarity and interface was evaluated using grades as recommended by International Cartilage Repair Society. Cartilage thickness was measured at medial, lateral and sulcus aspect of knee joint.

The exercise session (based on regime of Deyle *et al.* in 2000 and Witvrouw *et al.* in 2004) begins with warm up session. In this, hot packs was given to effected knee for 10 minutes followed by ROM exercises to the joints of upper limb and lower limb for 5 minutes duration. This was followed with self stretching exercises to calf, hamstrings and quadriceps for 5 minutes duration.

The second session was intervention session. In this session, the subjects received exercises according to the group allocated. All the exercises were given for 3 sets of 10 repetitions each with a rest period of 1 minute between sets.

In group A, each exercise will be held for a count of 6 seconds with 3 seconds rest between repetitions. In group B, each exercise will be performed dynamically without any hold period and 3 seconds rest between repetitions.

The last session was cool down session. In this session, subjects performed ROM exercises to all the major joints of the upper limb and lower limb for 5 minutes duration.

The duration of each exercise session was 45-60 minutes.

This whole protocol was given 3 times per week for 12 weeks. After the completion of 12 weeks of exercise training, post treatment readings were noted down.

VARIABLES OF THE STUDY

Dependent Variables

- Cartilage Health
  - Cartilage clarity
  - Cartilage interface
  - Cartilage thickness
- Pain assessed by VAS
- Quality of life by Lequesne index

Independent Variables

- Open kinetic chain exercises
- Closed kinetic chain exercises

RESULTS & DISCUSSION

The data was analyzed using SPSS 16.0 software and Microsoft excel software of windows 7 ultimate. The data was calculated and presented as mean ± SD. Paired t-test was calculated to estimate whether the difference between the pre and post-treatment readings with group was statistically significant at $p < 0.05$. Unpaired t-test was applied to examine whether the difference in the effect produced in both the groups were statistically significant at $p < 0.05$.

Table 1: Comparison of Age and BMI of Subjects between Different Interventional Groups

Parameters	Group A (Mean ± SD)	Group B (Mean ± SD)	t- score
Age (Years)	52.53 ± 8	49.73 ± 4.81	1.64 (NS)

BMI (Kg/m²)	28.62 ± 4.31	29.06 ± 3.83	-0.42 (NS)

NS = Not significant, $p<0.05$

Table 1 illustrates the comparison of mean values of age and BMI of the subjects between both interventional groups. Unpaired t-test was applied and the t- value shows statistically non-significant differences of both the parameters between the two groups ensuring homogeneity of both interventional groups.

Table 2: Gender Distribution of Subjects in Different Interventional Groups

Parameters	**Group A**	**Group B**
Sex (Male) (%)	12 (40%)	17 (56.67%)
Sex (Female) (%)	18 (60%)	13 (43.33%)

Table 2 represents the gender distribution of subjects. The data showed maximum number of male participants in group B and female participants in group A.

Table 3: Changes Induced in Frequency Distribution of Subjects by Kinetic Chain Exercises with reference to Different Grades of Cartilage Clarity

Cartilage Parameters		**Group A (n = 30)**		**Group B (n = 30)**	
		Pre-treatment	**Post-treatment**	**Pre-treatment**	**Post-treatment**
Right Cartilage Clarity N (%)	**Grade I**	12 (40%)	9 (30%)	13 (43.33%)	15 (50%)
	Grade II	16 (53.33%)	19 (63.33%)	17 (56.67%)	14 (46.67%)
	Grade III	2 (6.67%)	2 (6.67%)	0 (0)	1 (3.33%)
	Grade IV	0 (0)	0 (0)	0 (0)	0 (0)
Left Cartilage Clarity N (%)	**Grade I**	12 (40%)	12 (40%)	19 (63.33%)	17 (56.67%)
	Grade II	15 (50%)	17 (56.67%)	11 (36.67%)	12 (40%)
	Grade III	3 (10%)	1 (3.33%)	0(0)	1 (3.33%)
	Grade IV	0 (0)	0 (0)	0 (0)	0 (0)

Table 3 exhibits changes induced in number of subjects with different grades of cartilage clarity after the administration of kinetic chain exercise in group A and group B for 12 weeks.

Table 4: Changes Induced in Frequency Distribution of Subjects by Kinetic Chain Exercises with reference to Different Grades of Cartilage Interface

Cartilage Parameters		**Group A (n = 30)**		**Group B (n = 30)**	
		Pre-treatment	**Post-treatment**	**Pre-treatment**	**Post-treatment**
Right Cartilage Interface N (%)	**Grade 0**	0 (0)	0 (0)	0 (0)	0 (0)
	Grade I	11 (36.67%)	9 (30%)	19 (63.33%)	15 (50%)

	Grade II	15 (50%)	18 (60%)	11 (36.67%)	13 (43.33%)
	Grade III	4 (13.33%)	3 (10%)	0 (0)	2 (6.67%)
	Grade IV	0 (0)	0 (0)	0 (0)	0 (0)
Left Cartilage Interface N (%)	**Grade 0**	0 (0)	0 (0)	0 (0)	0 (0)
	Grade I	11 (36.67%)	10 (33.33%)	18 (60%)	17 (56.67%)
	Grade II	13 (43.33%)	18 (60%)	10 (33.33%)	12 (40%)
	Grade III	6 (20%)	2 (6.67%)	2 (6.67%)	1 (3.33%)
	Grade IV	0 (0)	0 (0)	0 (0)	0 (0)

Table 4 exhibits changes induced in number of subjects with different grades of cartilage clarity after the administration of kinetic chain exercise in group A and group B for 12 weeks.

The post-treatment exhibition of cartilage clarity and interface were suggestive of the fact that after the completion of intervention phase, the findings were marked by both degression as well as promotion of subjects from higher grades and lower grades respectively. This finding gives an indication of inconsistent efficacy of kinetic chain exercises on cartilage clarity and interface in both the groups. This is a maiden study to the best knowledge of the present researchers. No other study has evaluated the efficacy of kinetic chain exercises on grade wise variation in frequency of subject's cartilage clarity and interface as evaluated using sonography.

Table 5: Comparison of Sonographic Evaluation of Thickness of Articular Cartilage at Medial Level of Measurement between Different Interventional Groups

Groups	Right Medial		t-score	Left Medial		t-score
	Pre-treatment	Post-treatment		Pre-treatment	Post-treatment	
Group A	1.92 ± 0.83	2.09 ± 0.66	-0.91 (NS)	1.96 ± 1.07	1.94 ± 0.72	0.1 (NS)
Group B	2.05 ± 0.57	2.09 ± 0.52	-0.31 (NS)	1.95 ± 0.55	1.92 ± 0.47	0.39 (NS)

Table 5 describes the changes induced in the thickness (in mm) of articular cartilage at medial level of both knees, by kinetic chain exercise within different groups. The table presents the pre and post-treatment readings of thickness of both the interventional groups. The calculated value of t came out to be less than the tabled value of t at $p < 0.05$ at medial aspect for both knees of group A and group B indicating statistically non-significant difference between pre- and post-treatment readings of cartilage thickness at medial aspect.

Table 6: Comparison of Sonographic Evaluation of Thickness of Articular Cartilage at Lateral Level of Measurement between Both Interventional Groups

Groups	Right Lateral		t-score	Left Lateral		t-score
	Pre-treatment	Post-treatment		Pre-treatment	Post-treatment	
Group A	2.03 ± 0.88	2.18 ± 0.81	-0.87 (NS)	1.84 ± 0.61	2.03 ± 0.59	-1.48 (NS)
Group B	1.82 ± 0.6	1.79 ± 0.68	0.36 (NS)	1.83 ± 0.48	1.99 ± 0.58	-1.61 (NS)

Table 6 presents the pre and post-treatment readings of articular cartilage thickness at lateral aspect of right and left knee for both the interventional groups. The calculated value of t came out to be less than the tabled value of t at $p < 0.05$ at lateral aspect for both knees of group A and group B indicating non-significant difference between pre-treatment and post-treatment readings of cartilage thickness at lateral aspect.

Table 7: Comparison of Sonographic Evaluation of Thickness of Articular Cartilage at Sulcus Level of Measurement between Both Interventional Groups

Groups	Right Sulcus		t-score	Left Sulcus		t-score
	Pre-treatment	Post-treatment		Pre-treatment	Post-treatment	
Group A	2.33 ± 0.93	2.49 ± 0.86	0.68 (NS)	2.39 ± 0.71	2.66 ± 0.71	-1.93 (S)
Group B	2.14 ± 0.69	2.43 ± 0.7	-2.69 (S)	2.24 ± 0.56	2.4 ± 0.57	-2.34 (S)

Table 7 describes the comparison of mean scores of pre and post-treatment readings of thickness of articular cartilage at sulcus level within groups A and B. The calculated value of t came out to be less than the tabled value of t at $p<0.05$ for right knee of group A indicating non-significant difference between the pre and post treatment readings. The t-value for left knee for group A and both knees of group B came out to be more than the tabled value of t at $p<0.05$ indicating significant differences between the pre and post-treatment readings of joint thickness at sulcus level of measurement.

The post-treatment observations of cartilage thickness indicates non-significant differences at majority of the levels of measurement of both knees in all the groups except at sulcus aspect of left knee in group A and both knees in group B. Thus, kinetic chain exercise produced inconsistent improvement in both the groups. This inconsistent change, in the cartilage thickness, exhibited by both the experimental groups is in accordance with Feliciano *et al.*, (2017) who also concluded non-significant improvement in cartilage thickness. The probable reason for the findings of the present study could be that the articular cartilage once atrophied and degenerative changes have set in, exercise can only partially restore the cartilage thickness (Gahunia and Pritzker, 2012).

Table 8: Comparison of Mean Scores of Pre-treatment and Post-treatment Readings of Pain and Lequesne Index between Both Interventional Groups

Groups	VAS		t-score	Lequesne index		t-score
	Pre-treatment	Post-treatment		Pre-treatment	Post-treatment	
Group A	5.47 ± 1.5	3.13 ± 1.14	13.86 (S)	11.15 ± 3.92	8.83 ± 3.34	10.45 (S)
Group B	5.53 ± 1.38	3.57 ± 1.28	14.08 (S)	10.82 ± 3.29	8.53 ± 2.63	8.89 (S)

Table 8 presents the change in pain and lequesne index score, induced by kinetic chain exercise, within different groups. Statistically significant t- value suggests significant reduction in pain and lequesne index score. The relief in pain in both the groups could be attributed to the fact that knee osteoarthritis has been associated with decline in strength and proprioception of the quadriceps (Alnahdi *et al.*, 2012; Slemenda *et al.*, 1997; Segal *et al.*, 2010). Strengthening exercises leads to increased sensitivity and coordination of the proprioceptors within the quadriceps muscle during walking and other weight bearing activities thereby preventing the higher impact and impulsive loads being transmitted through the joint (Topp *et al.*, 2002).

The significant improvement in the both the groups are supported by the studies done by Imoto *et al.*, (2012) and Dincer *et al.*, (2016) who have also reported improvement in both pain and quality of life.

Table 9: Comparison of Mean Score of Pre and Post-treatment Range of Motion (ROM) of Flexion of Both Knees between Both Interventional Groups

Groups	Right Flexion		t-score	Left Flexion		t-score
	Pre-treatment	Post-treatment		Pre-treatment	Post-treatment	
Group A	112 ± 18.03	116.83 ± 12.7	3.71 (S)	114.33 ± 13.24	116.83 ± 11.85	3.53 (S)
Group B	111.17 ± 10.4	118.5 ± 6.18	5.81 (S)	115.17 ± 9.24	119.5 ± 4.42	3.79 (S)

Table 9 represents the change produced in ROM of flexion of both the knees by kinetic chain exercises between different interventional groups. t- value was calculated for ROM of flexion of both knees in all groups. The t-value came out to be more than the tabled critical value of t at $p < 0.05$ for both knees indicating significant difference between the pre and post-treatment readings of flexion of both right and left knee for all the interventional groups at $p < 0.05$.

The significant improvement of range of motion of knee flexion in both the groups can be attributed to the fact that the reduction in pain led to the reduction in associated muscle spasm.

Table 10: Comparison of the Effectiveness of Kinetic Chain Exercise between Both Group A and B

S.No.	Parameter	t-score
1	VAS	1.68 (S)
2	Lequesne Score	0.01 (NS)
3	ROM of Flexion of Right Knee	1.38 (NS)
4	ROM of Flexion of Left Knee	1.36 (NS)
5	Cartilage Thickness of Right Knee at Medial Aspect	0.63 (NS)
6	Cartilage Thickness of Right Knee at Lateral Aspect	0.93 (NS)
7	Cartilage Thickness of Right Knee at Sulcus Aspect	-0.52 (NS)
8	Cartilage Thickness of Left Knee at Medial Aspect	0.08 (NS)
9	Cartilage Thickness of Left Knee at Lateral Aspect	0.2 (NS)
10	Cartilage Thickness of Left Knee at Sulcus Aspect	0.69 (NS)

Table 10 demonstrates the comparison of the effect produced on various parameters by open kinetic chain and closed kinetic chain exercises. The value of t-test showed that there was non-significant difference of all the parameters between group A and B except VAS which showed statistically significant difference at $P < 0.05$. The mean value of VAS showed that the open kinetic chain exercises were more effective than closed kinetic chain exercises in improving pain.

CONCLUSION

Therefore, it can be inferred that though the kinetic chain exercises has produced significant improvement in clinical symptoms of pain, ROM of flexion and quality of life, but none of the kinetic chain exercise regime has brought marked improvement in cartilage health parameters of clarity, interface and thickness.

LIST OF ABBREVIATIONS:

BMI- Body Mass Index
MRI- Magnetic Resonance Imaging
OA- Osteoarthritis
ROM- Range of Motion
VAS- Visual Analog Scale

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CONFLICT OF INTEREST:

None

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