SONOGRAPHICALLY EVALUATED EFFICACY OF STRENGTHENING EXERCISE REGIMES ON ARTICULAR CARTILAGE OF KNEE

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Abstract

Background: Kinetic chain exercises have been used in the symptomatic relief of symptoms in patients with knee osteoarthritis but the impact of these exercises on the primary structure getting involved in osteoarthritis i.e. articular cartilage, still needs 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 combination of open and 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 medial and lateral aspect left and right knee respectively of group B. The findings of unpaired t-test suggested significant difference in cartilage thickness at lateral aspect of right knee and sulcus aspect of left knee and statistically non-significant difference of all other parameters between the two groups.

Conclusion: The findings were indicative that kinetic chain exercises are an effective in managing clinical symptoms associated with knee osteoarthritis but they have inconsistent effect on the articular cartilage health.

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

INTRODUCTION

Synovial joints are composed of specialized connective tissue, which has a unique property to efficiently and effectively deal with mechanical loads encountered over a lifetime. Articular cartilage is one of the most important connective tissue that is contributing this normal articular function. Due to the unique structural composition and biomechanical properties, articular cartilage is able to achieve this function efficiently without sustaining substantial wear (Ateshian and Wang, 1995; Cohen *et al.*, 2003; Singh et al., 2017).

Articular cartilage is composed of chondrocytes surrounded by the extracellular matrix comprised of fibrillar network of both collagens and non-collagenous proteins immersed in a viscous water-based substance (Musumeci, 2016). Another peculiar feature of cartilage is that it is composed of 70-80% water, which is controlled to a large extent by the presence of aggrecan, with proteoglycan being a large aggrecan found in the cartilage matrix. Aggrecan is composted of highly sulfated glycosaminoglycan chains that are very hydrophilic and are responsible for the resiliency in cartilage (Loeser, 2010).

Optimum mechanical loading is a significant factor in regulating metabolism and enzymatic activity, required for the production of proteoglycans, which act as a sort of shock absorbers, 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. Aging leads to impaired ability of chondrocytes to maintain the surrounding extracellular matrix (Li et al., 2013). Consequently, in aged chondrocytes, synthetic activity is decreased and proteoglycans are smaller and more irregular (Buckwalter *et al.*, 1994; Bolton *et al.*, 1999), thereby reducing cartilage resiliency and hydration, resulting in increased degradation of cartilage, increased roughness of its surface and increased susceptibility to 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).

The advancing age has been closely associated with initiation and progression of osteoarthritis and almost half of all persons, aged 65 years and above is found to be effected by this condition (Lawrence *et al.*, 2008; Murphy *et al.*, 2008). With the continued growth of the elderly population worldwide, the incidence of osteoarthritis has also increased. The prevalence of symptomatic knee osteoarthritis increases with each decade of life, with the annual incidence being highest between 55 to 64 years old age group. There are almost 14 million individuals in United States with symptomatic knee osteoarthritis with 2 million are under the age of 45 years and 6 million between the age 45 to 64 years (Deshpande *et al.*, 2016). More than 6.1 million Australians (75 per 1000) are reported to have arthritis or a musculoskeletal condition (March and Bagga, 2004). It is predicted that by 2030, it is estimated that 20% of the people in Europe and United States will suffer from osteoarthritis (De Bari *et al.*, 2010).

The scenario of the prevalence of osteoarthritis in India is no different. 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 and 60.6% in rural areas of Amritsar (Sharma *et al*., 2007).

Due to the high prevalence, osteoarthritis place a significant burden on the community, both economic and personal, including the use of hospital and primary care services, disruptions to daily life and lost productivity through disability. In United Kingdom, the average direct and indirect costs incurred to the economy due to knee osteoarthritis are £47 billion. In Hong Kong, the total cost involved is HK $ 3.2 – 3.9 billion. Due to such a high cost involved in osteoarthritis, accurate financial planning needs to be done in the near future, for the provision of healthcare services for the management of osteoarthritis (Chen *et al*., 2012).

International recommendations for management of osteoarthritis are often divided into three main categories namely pharmacological, non-pharmacological and surgical. (Zhang & Jordan, 2010). During the last few years, much emphasis of the management of osteoarthritis has been on non-pharmacological mode of treatment and physiotherapy forms the mainstay of non-pharmacological treatment of osteoarthritis (Fernandes *et al.*, 2013). Physiotherapy management includes both exercise therapy and electrotherapy. While, electrotherapy includes application of various pain relieving modalities, exercise therapy includes range of motion exercise, stretching, strengthening exercises etc.

Due to the proven negative impact of osteoarthritis on muscle strength (Madsen *et al.*, 1995; Wessel, 1996; Slemenda *et al.*, 1997; Haq *et al.*, 2003; Alnahdi *et al.*, 2012; Anwer & Alghadir, 2014), strengthening exercises forms the stronghold of the exercise therapy regime for managing the patients with knee osteoarthritis. These exercises are basically divided into open kinetic chain (OKC) exercises and closed kinetic chain (CKC) exercises.

Nevertheless, there have been lots of debates going on, regarding the effectiveness of OKC and CKC exercises, in patients with osteoarthritis of knee joint (Baker and McAlindon, 2000; Kenji in 2003; Morrissey *et al.*, 2002; Witvrouw *et al.*, 2004) The results of these studies are based on the relief of clinical symptoms. There have been very few 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 (Dincer *et al.*, 2016). Thus, it seems that successful assessment of osteoarthritis progression and therapeutic response to interventions, which could control the course of the disease, depends on establishing objective methods for monitoring articular cartilage damage (Singh et al., 2017). Various objective methods that can be used to view the status of articular cartilage are radiography, magnetic resonance imaging (MRI) and sonography.

Radiographs are the main outcome measure in epidemiological studies of osteoarthritis. The major limitation of the radiograph is its inability to directly visualize articular cartilage and other soft tissues (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). Sonography can also visualize cartilage, bone and soft tissue structures. This may provide information about the integrity and thickness of cartilage by assuming a predefined ultrasound speed within the tissue (Kuroki et al, 2008). 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 kinetic chain exercises on the articular cartilage health of knee joint evaluated using sonography.

OBJECTIVE OF THE STUDY

The objectives of the present study was to investigate and compare the effect of open kinetic chain exercise alone and in combination with 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 males and females 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: Combination of open and closed kinetic chain (CKC) exercises

Baseline readings of pain, quality of life, ROM of knee flexion 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. Each OKC exercise was held for a count of 6 seconds with 3 seconds rest between repetitions and each CKC exercise was 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)
Age (Years)	52.53 ± 8	49.6 ± 5.22
BMI (Kg/m^2)	28.62 ± 4.31	29.03 ± 2.58

Table 2: Gender Distribution of Subjects in Different Interventional Groups

Parameters	Group A	Group B
Sex (Male) (%)	12 (40%)	14 (46.67%)
Sex (Female) (%)	18 (60%)	16 (53.33%)

Table 2 represents the gender distribution of subjects. The data showed maximum number of the participants were females in both the groups.

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%)	12 (40%)	12 (40%)
	Grade II	16 (53.33%)	19 (63.33%)	18 (60%)	18 (60%)
	Grade III	2 (6.67%)	2 (6.67%)	0 (0)	0 (0)
	Grade IV	0 (0)	0 (0)	0 (0)	0 (0)
Left Cartilage Clarity N (%)	**Grade I**	12 (40%)	12 (40%)	16 (53.33%)	14 (46.67%)
	Grade II	15 (50%)	17 (56.67%)	13 (43.33%)	16 (53.33%)
	Grade III	3 (10%)	1 (3.33%)	1 (3.33%)	0 (0)
	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%)	15 (50%)	9 (30%)
	Grade II	15 (50%)	18 (60%)	15 (50%)	21 (70%)
	Grade III	4 (13.33%)	3 (10%)	0 (0)	0 (0)
	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%)	19 (63.33%)	15 (50%)
	Grade II	13 (43.33%)	18 (60%)	10 (33.33%)	15 (50%)
	Grade III	6 (20%)	2 (6.67%)	1 (3.33%)	0 (0)
	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 degressions of subjects from higher grades as well as promotion of subjects from lower grades. This gives an inference that the efficacy of kinetic chain exercises on health of articular cartilage health parameters of clarity and interface was inconsistent. This is a maiden study to the best knowledge of the researcher team. 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	2.06 ± 0.56	2.08 ± 0.58	-0.33 (NS)	2.08 ± 0.55	1.84 ± 0.49	2.34 (S)

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 right knee of group B indicating statistically non-significant difference between pre- and post-treatment readings of cartilage thickness at medial aspect. The t-score of left knee of group B came out to be more than the tabled value indicating statistically significant difference between the pre and post-treatment values at $P < 0.05$.

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	2 ± 0.84	1.7 ± 0.71	2.53 (S)	1.83 ± 0.54	1.9 ± 0.56	-1.08 (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 left knee of group B indicating non-significant difference between pre-treatment and post-treatment readings of cartilage thickness at lateral aspect. The calculated value of t-test came out to be more than the tabled value of t indicating statistically significant difference between the pre and post-treatment values at $P < 0.05$. This gives an impression that the combination of OKC and CKC produced an improvement in the articular cartilage thickness in right knee.

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	2.13 ± 0.76	2.19 ± 0.82	-0.43 (NS)	2.38 ± 0.65	2.26 ± 0.64	1.46 (NS)

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 and both knees of group B indicating statistically non-significant difference between the pre and post treatment readings. The t-value for left knee for group A 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 medial aspect of left knee and lateral aspect of right knee in group B and sulcus aspect of left knee in group A. 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	5.17 ± 1.15	3.13 ± 1.33	9.864 (S)	10.47 ± 2.76	7.8 ± 2.33	7.744 (S)

Table 8 presents the change in pain and lequesne index score, induced by kinetic chain exercise, within different groups. The calculated value of t-test came out to be more than the tabled value of t for both the parameters in group A as well as B indicating that both the strengthening exercise protocols produced statistically significant improvement in both VAS and lequesne score of quality of life at $P < 0.05$. This improvement 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).

This finding of the present study is in compliance with the studies done by Imoto *et al*., (2012) and Dincer *et al*., (2016) who have also reported significant 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	115 ± 11.6	119.67 ± 7.76	3.68 (S)	117 ± 10.95	120 ± 7.31	2.76 (S)

Table 9 represents the mean values of pre and post-treatment values of ROM of knee flexion within different interventional groups. t- value was calculated for ROM of flexion of both knees in all the groups. The calculated value of t for all the parameters came out to be more than the tabled critical value of t at P < 0.05 indicating statistically significant difference between the pre and post-treatment readings. This gives an inference that there was significant improvement in ROM of knee flexion in both the groups. This finding could be attributed to the fact that decrease in pain led to reduction in muscle spasm and hence increase in ROM of knee flexion (Singh et al, 2017)

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

S.No.	Parameter	t-score
1	VAS	-1.13 (NS)
2	Lequesne Score	0.85 (NS)
3	ROM of Flexion of Right Knee	0.09 (NS)
4	ROM of Flexion of Left Knee	0.38 (NS)
5	Cartilage Thickness of Right Knee at Medial Aspect	0.7 (NS)
6	Cartilage Thickness of Right Knee at Lateral Aspect	2.16 (S)
7	Cartilage Thickness of Right Knee at Sulcus Aspect	0.38 (NS)
8	Cartilage Thickness of Left Knee at Medial Aspect	0.94 (NS)
9	Cartilage Thickness of Left Knee at Lateral Aspect	0.84 (NS)
10	Cartilage Thickness of Left Knee at Sulcus Aspect	2.4 (S)

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 cartilage thickness at lateral aspect of right knee and sulcus aspect of left knee. This is a maiden study and the research team has no concrete reason to support this finding.

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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