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Research Article

PULSED ELECTROMAGNETIC FIELD THERAPY USING SENTIENT ELEMENT FOR MANAGEMENT AND CHONDROPROTECTIVE EFFECTS ON HUMAN ARTICULAR CARTILAGE IN EARLY-STAGE OSTEOARTHRITIS: AN OBSERVATIONAL AND OPEN-LABEL PILOT STUDY

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ABSTRACT

Objectives: The present study aimed to evaluate the role of pulsed electromagnetic field therapy (PEMF) in managing pain, stiffness, and chondroprotective effects on human articular cartilage in early-stage osteoarthritis (OA).

Methods: In the present study the effectiveness of PEMF in Osteoarthritis (OA) patients was conducted using an open-label pilot study and observational data. Ten people with OA in their left and right knees were included. The standard error of the mean, or Mean±Standard deviation, was used to express all data. An IBM Statistical package for the social sciences (SPSS) software (version 11.0) was used to analyse the significance of evaluated parameters. T-test was used to examine the information gathered from clinical interventions.

Results: The result of the study discussed the before and after effect of the PEMF therapy in OA patients with knee pain in both legs. The knee pain and physical function were decreased in the patients for both the legs after the therapy. Using statistical tests, pain score, stiffness score, and cartilage health were analyzed in the patients to record a significant effect of PEMF therapy.

Conclusion: All the examination reports exerted positive effects of the implementation of the therapy in pain management and enhancing mobility of the knee joints.

Keywords: Osteoarthritis, Stiffness, Electromagnetic field, Cartilage, Joints, Pain, Chondroprotective.

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INTRODUCTION

Osteoarthritis (OA) has been considered as world's biggest cause of disability of the knee, one of the most prevalent chronic degenerative joint disorders affecting the aging population globally. It affects mainly big weight-bearing joints such as the knees and hips [1]. Muscle weakening, loss of physical function, and a lower quality of life are the outcomes of knee OA (KOA). As the illness progresses, pain and incapacity get worse. The breakdown and loss of the affected joint's cartilage is caused by a decrease in the amount of collagen and aggrecan and an increase in collagenases [2]. Around the joints, new bone formation may be prompted by cartilage degradation and inflammation. Joint discomfort, edema, and stiffness are caused by these degenerative changes [3]. Since there is no cure for OA, the goal of treating KOA has been to improve function and reduce symptoms. One of the best indicators of functional limits in individuals with KOA is knee-extensor muscle weakness, which is also a known risk factor for the onset and progression of the disease [4]. While waiting for total knee replacement, end-stage KOA patients frequently showed a 35% decrease in knee-extensor strength as compared to healthy, age-matched volunteers. There are two types of OA: Primary (idiopathic) and secondary (usually following trauma or surgery). This ailment has a significant impact on patients' quality of life, but due to the expenses associated with managing it, it also affects the healthcare system. It is evident that OA is not just a musculoskeletal ailment; it is also linked to the development of mental and cardiovascular diseases [5].

For many years, physical treatments such deep and superficial heat, cold, electrotherapy, and exercises have been employed either alone or in combination [3,4]. Nevertheless, there is currently no optimal treatment for the treatment of KOA. An alternate method of treating bone and joint disorders has been offered since the 1970s by pulsed electromagnetic field (PEMF) therapy, particularly for elderly patients or those with specific hepatorenal insufficiency who are unable to have surgery or take medication [6]. Furthermore, a substantial amount of fundamental research has demonstrated that PEMF therapy can encourage chondrocyte proliferation and extracellular matrix production, both of which are advantageous for repairing cartilage degradation brought on by KOA [7]. According to a study, using hyaluronic acid can help slow down the deterioration of articular cartilage [8]. According to the OA model, this treatment inhibits the growth of osteophytes. However, prolonged use of any medication can have serious adverse effects in older adults. Thus, the use of "Pulsed Electromagnetic Field Therapy" (PEMF) opens up a new avenue for the treatment of early-stage OA pain, stiffness, and chondroprotective benefits. PEMFs play a role in the synthesis and mineralization of extracellular matrix as well as the

expression of genes that support osteogenic cell differentiation [9]. Because PEMFs are too weak to produce membrane depolarization at the cell membrane level, they enhance the transmembrane signal by promoting ligand-receptor binding, which initiates intracellular processes related to immunological modulation, cell proliferation and differentiation, and osteogenesis [10].

Sentient Element's founder (Larry Langdon) has used his engineering background to enhance PEMF therapy [11]. Sentient Element, located at 13403 N Government Way, Hayden, ID 83835, manufactures stated that PEMF devices improved cellular function and encourage natural healing using precise electromagnetic frequencies [12]. Without the use of medicines or surgery, this treatment approach to "cartilage and bone-associated pathologies" is integrated.

The literature's randomized controlled trials on PEMFs' effectiveness in treating OA have produced mixed findings. In a systematic review of systematic reviews, Markovic *et al*., found that only five out of ten studies examined indicated that PEMF use improved the physical function and disability of patients with OA, while another study found no statistically significant impact of PEMFs [13]. This illustrates the conflicting findings in the research about PEMF use for OA treatment. The varying lengths of PEMF therapy in the various trials, the varying weekly use frequencies, and the use of different PEMF devices could all contribute to the variation in outcomes. PEMFs' effectiveness may be obscured if other OA treatments are used concurrently with them. The clinical use of PEMF therapies in orthopedics has been approved for over 40 years and commonly entail analgesic benefits [14,15]. When specifically targeting the knee, however, evidence that the technology improves pain, physical function, and quality of life has been inconclusive, probably due to the unaddressed muscle weakness [16,17]. Therefore, an approach employed in the present study was a pilot study to analyze the effect of PEMF on the pain, stiffness, and chondroprotective effects on articular cartilage in early-stage OA, along with the other parameters such as erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP); hence, the efficacy and safety of the therapy was analyzed.

METHODS

Objectives of the study

The present study was investigated on the effects of PEMF therapy for managing pain, stiffness, and chondroprotective effects on human cartilage in early-stage OA. The clinical efficacy of PEMF therapy for KOA in elderly patients was literally focused.

Study design

This study was an observational, placebo-controlled, and open-label pilot study to assess the efficacy of the therapy in OA. It included a total of ten participants with OA in left and right knees. Reports of before and after therapy were measured through the visual analog scale (VAS), "Western Ontario McMaster University Osteoarthritis index" (WOMAC), and knee range of motion (ROM) of the patients. Imaging techniques such as magnetic resonance imaging (MRI) were used for identification of the bone conditions.

Exclusion criteria

It involved the prohibition of engaging participants who have gone through dental implant surgeries. Furthermore, the exclusion of pregnant women in the application of PEMF therapy in case of assessing effectiveness and data collection was excluded from the study.

Inclusion criteria

The research samples OA patients of both males and females who have symptoms such as severe knee pain, stiffness in muscles, and stress in mobility were included in the study.

OA confirmed by radiography

The radiographic pre-operative assessment involved a "standing anteroposterior long-leg radiograph," which included ankles and hip regions. Furthermore, a flexion view of 45° and standing anteroposterior, skyline patellofemoral observation, MRI, and lateral knee view was assessed.

Therapeutic regimentation

The medical approach of PEMF in OA patients utilizes the Sentient Element Classic tool containing both single and dual coil systems to foster therapeutic management. This device is capable of providing PEMF without causing any complexity. The device is carriable, which is beneficial for its use whenever required [18]. The PEMF therapy has been delivered at a frequency of 72–78 Hz and an intensity of 22.5 Amp. However, the device must start from a low-frequency range to reduce any associated potential risks of the therapy. It has a coil system for treatment but is also accessible with a single coil system. In addition to the PEMF therapy, participants were administered Ancient Nutrition Bone Broth Protein Powder, Himalayan Organics Glucosamine Chondroitin MSM with *Boswellia* as Cartilage and Joint Support Supplement and Himalayan Organics Plant-Based Bone Strength supplement to ensure comprehensive management of OA symptoms. For this particular case study, the PEMF therapy includes treatment sessions with duration of 1 h for 5 weeks among ten patients having OA. They were administered electromagnetic therapy in both limbs.

Preparation of protocol for treatment

The protocols of the treatment for the prevention of managing pain, stiffness, and chondroprotective effects on human articular cartilage in early-stage OA entail a structured regimen. According to these protocols, the patients were treated in sessions for not more than 12 weeks. The norms outlined an adequate time limit for executing the care plan of the therapy to receive optimal and appropriate benefits from the therapy by minimizing the risk factors. In addition, the protocols allowed a time for evaluation of the effectiveness of the PEMF therapy with positive outcome in the patients.

Ethics

In the present investigation, informed consent form was obtained from the participants for collection of information and data. Ethical committee approval was obtained from Apollo Institute of Medical Sciences and Research, Jubilee, Hyderabad – 500096, Telangana, India bearing protocol number as AIMSR/IRB/RC/2023/06/016.

Statistical analysis

Statistical tests were performed by the Statistical package for the social sciences (SPSS) program (version 11.0). All data were expressed as mean ± standard deviation or standard error of the mean. For testing the validity of the hypothesis, a statistical analysis is performed using the IBM SPSS software. This includes the t-test which analyses the data collected from clinical interventions. This frequency statistics on SPSS confirms and gives quantitative backing to the qualitative insights gathered from the patients.

RESULTS

The primary results of the observation were pain relief, activity level improvement, motion range, and symptom improvement. The range of patients' satisfaction was recorded accordingly. The primary outcomes of the study after the application of PEMF were recorded and represented through the following tables.

By observing the Table 1 and analyzing the report of Knee ROM, the differences between the pre- and post-condition of knee mobility were obtained. On July 17th, 2023 before the application of the electromagnetic therapy, the range of knee motion was relatively low in all patients. Contrarily, the report of 31st October after 12 weeks of therapy has a higher value in both left and right knees. This table demonstrated the positive effects of PEMF therapy on knee ROM, with patients experiencing significant gain in flexibility and mobility following the treatment regimen.

Table 2 represented the data of ten patients about their full flexion of the knees in the left and right legs at the start of the treatment and after the treatment. Before starting the therapy, the flexion of the right knee in

OA patients ranges from 110° to 118°. This turned into 126–134° after 12 weeks of therapy. Similarly, in the case of the left knee, the patient rotates around 115–125° at the initial stage of the PEMF therapy. The after-effect of the therapy within 3 months showed changes in flexion to 130–140° on average.

Table 3 demonstrated the report of the VAS in OA patients ranging from 0 to 10. Before PEMF therapy, patients reported varying levels of pain in both their right and left knees, with VAS scores ranging from 8.5 to 10, indicating a significant pain. After the therapy for 3 months, the outcomes at 12th week indicated that the pain levels in the patients had decreased. The value of the VAS was lowered in all OA patients, for example, it was down from 9.5 to 5.5 in the right knee and from 7.5 to 5 in the left knee for the 1st patient. The outcomes showed that PEMF therapy had beneficial effects in the reduction of the pain associated with OA in patients.

Table 4 represented the value of the WOMAC scale in evaluating the Knee Physical Function ranging from 0 to 68. The data of the 10 sample OA patients from week 0 (before PEMF Therapy) to week 12 (after PEMF Therapy) was depicted in the same. In the initial phase, the value ranged from 25 to 45 indicating functional limitations of the physical condition of both knees. In the 12th week, the WOMAC scores ranged from 0 to 20 from 45 in the right knee and from 37 to 22 in the left knee in the 5th patient. Similarly, moreover, all the patients reported a lowering of WOMAC scores after the implementation of the PEMF therapy. Therefore, it can be concluded that the PEMF therapy exerts a positive effect on increasing knee function in OA patients. The scores of the WOMAC scale significantly exhibited the changes in the knee's physical function including effective intervention in mobility [18].

Table 1: Knee range of motion (ROM) in the OA patients before and after application of "PEMF Therapy"

Knee range of motion (ROM)								
Patient ID	**Left knee**				**Right knee**			
	Week-0	**Week-1**	**Week-6**	**Week-12**	**Week-0**	**Week-1**	**Week-6**	**Week-12**
SL-1	3	5	5	8	3	4	6	8
SL-2	4	4	5	7	2	3	5	7
SL-3	4	3	8	6	4	5	7	9
SL-4	5	7	7	10	3	4	6	8
SL-5	6	4	3	8	4	5	7	9
SL-6	3	4	5	6	2	3	5	7
SL-7	5	4	3	2	1	2	4	6
SL-8	4	5	8	8	3	4	6	8
SL-9	5	4	3	2	2	3	5	7
SL-10	4	5	6	7	5	6	8	10

Source: Self-developed, PEMF: Pulsed electromagnetic field therapy, OA: Osteoarthritis

Table 2: Outcomes of FULL FLEXION in the OA patients before and after the application of "PEMF Therapy"

Patient ID	**Full flexion**							
	Right knee				**Left knee**			
	Week-0	**Week-1**	**Week-6**	**Week-12**	**Week-0**	**Week-1**	**Week-6**	**Week-12**
SL-1	115	120	125	130	120	125	130	135
SL-2	117	122	128	135	125	130	135	140
SL-3	110	115	122	128	115	120	125	130
SL-4	113	120	126	132	120	125	130	135
SL-5	112	116	121	127	115	120	125	130
SL-6	113	118	124	131	119	124	129	134
SL-7	118	123	128	134	122	127	132	137
SL-8	115	120	125	129	117	122	127	132
SL-9	117	122	127	133	121	126	131	136
SL-10	110	115	120	126	116	121	126	131

Source: Self-developed, PEMF: Pulsed electromagnetic field therapy, OA: Osteoarthritis

Table 3: Visual analog scale (VAS) in the OA patients before and after the application of "PEMF Therapy"

Patient ID	**Visual analog scale (VAS) (0–10)**						
	Week-0	**Week-1**	**Week-6**	**Week-12**	**Week-1**	**Week-6**	**Week-12**
	Right knee				**Left knee**		
SL-1	9.5	8.5	6	5.5	7.5	6.5	5
SL-2	9	8	6	5	8	7	4.5
SL-3	10	8	6.5	4.5	8	7	5
SL-4	9.5	7.5	6	5	8.5	7.5	5.5
SL-5	10	8	7.5	5.5	7.5	7	4.5
SL-6	9	7.5	7	4.5	7	6.5	5
SL-7	9.5	8	7.5	5.5	8	6	5.5
SL-8	9.5	7.5	7	5.5	8.5	6	4.5
SL-9	10	8	7	4.5	8.5	7	5
SL-10	8.5	7.5	7	5	7.5	6.5	5

Source: Self-developed, PEMF: Pulsed electromagnetic field therapy, OA: Osteoarthritis

Table 5 represented the values of ESR, and CRP levels in the serum of 10 OA patients before and after the application of PEMF therapy. The values of CRP on 17 July 2023 ranged from 1.00 to 5.10 mg/L and ESR value from 8.78 to 13.15 mm/h. The ESR decreased from 8.78 to 6.13 mm/h, and CRP decreased from 5.00 to 1.97 mg/L on October 31, 2023. These values were evident for the effectiveness of PEMF therapy with an intervention of improving the knee function in individuals with OA [19].

Descriptive statistics indicated a systematic description of the overall dataset. Standard deviation value indicated fairness of data distribution; fairness is indicated by valued between (−2) and (+2). The below table indicated that all information was not fairly distributed. The pre-pain score measured values ranged from 2 to 9, with a mean of 5.40 and a standard deviation of 2.221. It suggested a moderate variability in pain levels before the intervention. In the post-intervention, Cartilage Health ranged from 65 to 80, with a mean of 70.20 and a standard deviation of 5.116 showed an improvement after the therapy, as depicted in Table 6.

Frequency analysis of pain score (pre) and (post) in the present study

The above Table 7a and b presented pre- and post-pain score among ten participants. The total valid entries constituted 66.7% of the data, with the remaining 33.3% being system-missing entries. The frequency distribution was presented for the pain score (pre and post) depend on the distribution of pain scores among ten subjects. Fig. 1 represented different levels of pre- and post-pain score among 10 participants. The Supplementary Figs. (1-3) represented images of Magnetic resonance imaging report of first three patients.

The above Table 8a presented a variety in pre stiffness score among ten participants. The frequency distribution table for the stiffness score (pre) provided a breakdown of stiffness levels, offered that total valid entries make up 66.7% of the data, with 33.3% being system-missing entries. Furthermore, in Table 8b, different post-stiffness scores among 10 participants were presented. This distribution indicated a shift in stiffness levels post-intervention, with more subjects reporting lower stiffness scores. The total valid entries constituted 66.7% of the data, while 33.3% were system-missing entries. The values are depicted in Fig. 2.

Table 4: "WOMAC - Knee Physical Function" in the OA patients before and after the application of "PEMF Therapy"

WOMAC - Knee physical function (0–68)								
Patient ID	**Week-0**	**Week-1**	**Week-6**	**Week-12**	**Week-0**	**Week-1**	**Week-6**	**Week-12**
	Right knee				**Left knee**			
SL-1	45	34	28	24	40	35	28	25
SL-2	40	35	35	28	45	38	30	27
SL-3	42	40	38	25	38	32	25	23
SL-4	40	35	27	25	42	36	29	26
SL-5	45	33	25	20	37	31	24	22
SL-6	40	38	35	26	41	34	27	24
SL-7	45	35	32	29	44	37	30	28
SL-8	45	35	30	28	39	33	26	23
SL-9	40	33	28	25	43	36	29	26
SL-10	40	35	33	30	36	30	23	21

Source: Self-developed, PEMF: Pulsed electromagnetic field therapy, WOMAC: Western Ontario McMaster University Osteoarthritis index, OA: Osteoarthritis

Table 5: Blood reports of the OA patients before and after the application of "PEMF Therapy"

Patient-ID	Age years	Gender	ESR (mm/h)		CRP in serum (mg/L)	
			July 17, 2023	October 31, 2023	July 17, 2023	October 31, 2023
SL-1	56	Female	10.10	8.00	4.79	2
SL-2	55	Female	12.11	9.83	5.00	1.38
SL-3	61	Female	10.00	8.17	3.00	2.4
SL-4	51	Female	9.45	8.49	4.00	1.00
SL-5	60	Male	8.78	6.13	5.00	1.97
SL-6	51	Male	12.80	9.40	4.40	3.46
SL-7	65	Female	13.15	8.70	5.10	4.00
SL-8	63	Male	12.90	9.13	4.90	2.00
SL-9	55	Female	11.87	7.45	3.90	2.19
SL-10	47	Female	10.78	8.19	4.87	3.00

Source: Self-developed, PEMF: Pulsed electromagnetic field therapy, OA: Osteoarthritis, ESR: Erythrocyte sedimentation rate, CRP: C-reactive protein

Table 6: Descriptive statistical analysis in the present study

Descriptive statistics					
Indices	**n**	**Minimum**	**Maximum**	**Mean**	**Standard deviation**
Subject ID	10	1	10	5.50	3.028
Pain score (pre)	10	2	9	5.40	2.221
Pain score (post)	10	1	7	4.30	1.767
Stiffness score (pre)	10	1	5	3.00	1.491
Stiffness score (post)	10	0	4	2.50	1.269
Cartilage health (pre)	10	62	78	69.60	4.648
Cartilage health (post)	10	65	80	70.20	5.116
Valid N (list wise)	10				

Source: SPSS: Statistical Package for the Social Sciences

Below (Table 9a and b) presented various pre- and post-cartilage health scores among 10 participants. In the pre-cartilage health score, the valid scores ranged from 62 to 78. Each score of 62, 65, 67, 68, 69, 72, 75, and 78 appeared once, representing 6.7% of the valid data each. In the post-cartilage health score assessment, among the ten participants the after-intervention cartilage health score was 67, 69, 70, 72, 78, and 80 respectively. The score of the valid data had cumulatively accounted for 30%, 60%, 70%, 80%, 90%, and 100%, respectively (Fig. 3).

Hypothesis testing

For testing the validity of the hypothesis, a statistical analysis was performed using the IBM SPSS software. This was included with the t-test which analyzed the data collected from clinical interventions. This frequency statistics on SPSS confirmed and gave a quantitative backing to the qualitative insights gathered from the patients. The quantitative analysis gave more nuanced understanding of the data collected with PEMF therapy on pain relief.

Table 7a: Frequency analysis of pain score (pre)

Pain score (pre)				
Indices	**Frequency**	**Percent**	**Valid percent**	**Cumulative percent**
Valid				
2	1	6.7	10.0	10.0
3	1	6.7	10.0	20.0
4	2	13.3	20.0	40.0
5	1	6.7	10.0	50.0
6	2	13.3	20.0	70.0
7	1	6.7	10.0	80.0
8	1	6.7	10.0	90.0
9	1	6.7	10.0	100.0
Total	10	66.7	100.0	
Missing				
System	5	33.3		
Total	15	100.0		

Table 7b: Frequency analysis of pain score (post)

Pain score (post)				
Assessment	**Frequency**	**Percent**	**Valid percent**	**Cumulative percent**
Valid				
1	1	6.7	10.0	10.0
2	1	6.7	10.0	20.0
4	3	20.0	30.0	50.0
5	3	20.0	30.0	80.0
6	1	6.7	10.0	90.0
7	1	6.7	10.0	100.0
Total	10	66.7	100.0	
Missing				
System	5	33.3		
Total	15	100.0		

The result of one sample t-test at test value 0 indicated that patients with early-stage OA obtained significant changes in pain reduction after the PEMF therapy (Tables 10 and 11). The outcomes of the group analysis offered a significant effect of the therapy having a t=5.745 with a mean difference of 5.500. The 0.000 value of p in all parameters was highly significant for the hypothesis. In the case of pain score, the pre-treatment t value of pain score was 5.400 and post-treatment was 4.300. This notable reduction reflected an effective pain relief and capability of the PEMF treatment. In the same way, stiffness scores were decreased significantly from pre-treatment with a mean value of 2.500 from 3.000 and t=6.364 to post-treatment with a t=6.228, indicative of improvement.

It included three major aspects such as pain score, stiffness score, and cartilage health in the patients before and after application of the therapy. For pain score, before the intervention, the sum of squares between groups was 44.400 with 9° of freedom (df), and a mean Square of 4.933. The mean of stiffness score was 2.222 in pre-intervention and 1.611 in post-intervention. After the application, the sum of squares for cartilage health was 235.600, which was higher than before. This outcome showed positive effects of PEMF therapy among the patients (Table 12).

DISCUSSION

According to the present study, PEMF therapy helps OA patients operate better by lowering pain and stiffness. A small number of studies have examined PEMF's efficacy in KOA. Clinical research and animal investigations have demonstrated the positive benefits of PEMF; nevertheless, its effectiveness has not yet been compared to that of another physical agent. Using WOMAC as well, a study found that PEMF enhanced daily living activities and decreased pain [20,21]. Similar findings regarding pain reduction, even over an extended period of time, were reported by Fischer *et al*., and Thamsborg *et al*., respectively [22,15,23]. The current study's findings are consistent with those of other recent investigations. Nevertheless, these studies differ in terms of frequency, efficacy, and safety of the therapy. In the present study, the knee ROM was improved significantly, gained with flexibility and mobility following the treatment regimen. The flexion was at 110–118°, then after the therapy turned to 115–125° initially, then later on, after the treatment with PEMF for a period of 3 months, on an average the flexion was at 130–140°.

The most commonly used self-administered measures to gauge the degree of joint pain in patients with OA of the knee or hip in randomized clinical trials are the visual analog scales (VAS) for global

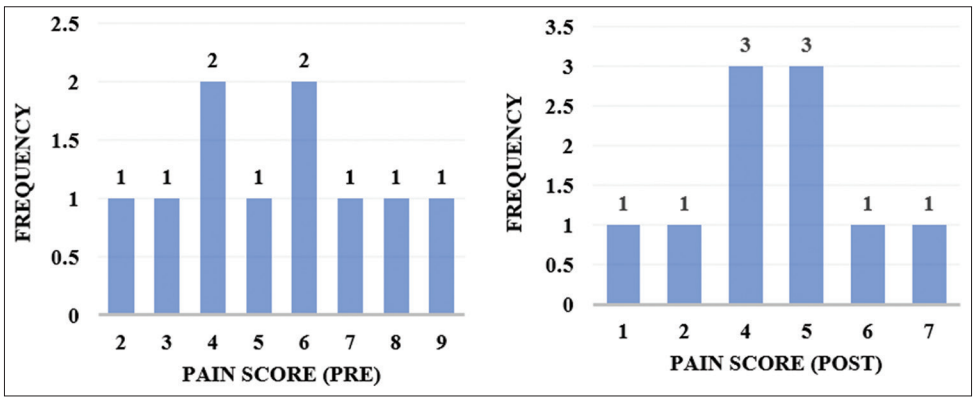

Fig. 1: Frequency analysis of pain score (pre) and (post) in the osteoarthritis patients

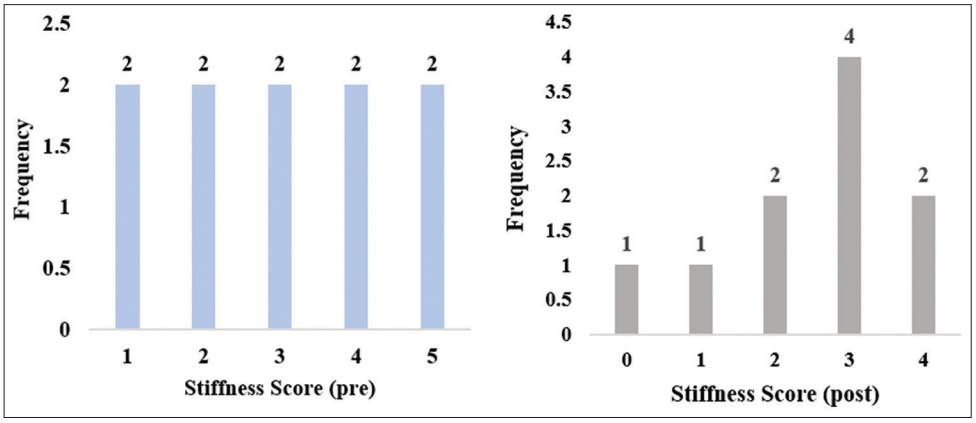

Fig. 2: Frequency analysis of stiffness score (pre) and (post) in the osteoarthritis patients

Table 8a: Frequency analysis of stiffness score (pre)

Stiffness score (pre)				
Assessment	**Frequency**	**Percent**	**Valid percent**	**Cumulative percent**
Valid				
1	2	13.3	20.0	20.0
2	2	13.3	20.0	40.0
3	2	13.3	20.0	60.0
4	2	13.3	20.0	80.0
5	2	13.3	20.0	100.0
Total	10	66.7	100.0	
Missing				
System	5	33.3		
Total	15	100.0		

Table 8b: Frequency analysis of stiffness score (post)

Stiffness score (post)				
Assessment	**Frequency**	**Percent**	**Valid percent**	**Cumulative percent**
Valid				
0	1	6.7	10.0	10.0
1	1	6.7	10.0	20.0
2	2	13.3	20.0	40.0
3	4	26.7	40.0	80.0
4	2	13.3	20.0	100.0
Total	10	66.7	100.0	
Missing				
System	5	33.3		
Total	15	100.0		

OA pain and the Western Ontario and McMaster University (WOMAC) pain subscale [24]. While VAS is based on a single-item questionnaire measuring any sort of pain unique to the index joint, the WOMAC pain subscale uses five items, each of which relates to a distinct activity type (e.g., walking, standing, etc.) [25]. In the present study, initially, the values of WOMAC indicated functional restrictions in both knees' physical states. Following the application of PEMF therapy, all patients reported a decrease in their WOMAC ratings. Consequently, it can be said that PEMF therapy helped the patients with OA by improving the knee function.

The ESR is useful for tracking certain individuals with systemic lupus erythematosus and for identifying low-grade bone infections [26]. Compared to the ESR, CRP is a more accurate measure of inflammation. It reacts to changes in the clinical environment faster and with more sensitivity [27]. Certain acute phase proteins are increasingly more frequently tested to evaluate inflammation, even if the ESR is still

Table 9a: Frequency analysis of cartilage score (pre)

Cartilage health (pre)				
Assessment	**Frequency**	**Percent**	**Valid percent**	**Cumulative percent**
Valid				
62	1	6.7	10.0	10.0
65	1	6.7	10.0	20.0
67	1	6.7	10.0	30.0
68	1	6.7	10.0	40.0
69	1	6.7	10.0	50.0
70	2	13.3	20.0	70.0
72	1	6.7	10.0	80.0
75	1	6.7	10.0	90.0
78	1	6.7	10.0	100.0
Total	10	66.7	100.0	
Missing				
System	5	33.3		
Total	15	100.0		

Table 9b: Frequency analysis of cartilage score (post)

Cartilage health (post)				
Assessment	**Frequency**	**Percent**	**Valid percent**	**Cumulative percent**
Valid				
65	2	13.3	20.0	20.0
67	1	6.7	10.0	30.0
68	2	13.3	20.0	50.0
69	1	6.7	10.0	60.0
70	1	6.7	10.0	70.0
72	1	6.7	10.0	80.0
78	1	6.7	10.0	90.0
80	1	6.7	10.0	100.0
Total	10	66.7	100.0	
Missing				
System	5	33.3		
Total	15	100.0		

Table 10: Values of t-test (value=0)

One-sample statistics				
Indices	**n**	**Mean**	**Standard deviation**	**Standard error mean**
Subject ID	10	5.50	3.028	0.957
Pain score (pre)	10	5.40	2.221	0.702
Pain score (post)	10	4.30	1.767	0.559
Stiffness score (pre)	10	3.00	1.491	0.471
Stiffness score (post)	10	2.50	1.269	0.401
Cartilage health (pre)	10	69.60	4.648	1.470
Cartilage health (post)	10	70.20	5.116	1.618

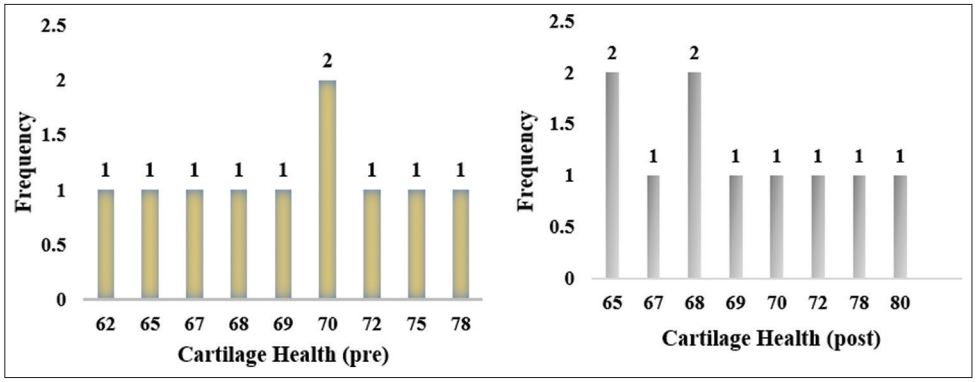

Fig. 3: Frequency analysis of cartilage health (pre) and (post) in the osteoarthritis patients

Table 11: Result of t-test analysis between pre-and post-condition of PEMF therapy at t value=0

One sample test					
Indices	**Test value=0**				
	t	**df**	**Sig. (2-tailed)**	**Mean difference**	**95% confidence interval of the difference**
					Lower
Subject ID	5.745	9	0.000	5.500	3.33
Pain score (pre)	7.688	9	0.000	5.400	3.81
Pain score (post)	7.695	9	0.000	4.300	3.04
Stiffness score (pre)	6.364	9	0.000	3.000	1.93
Stiffness score (post)	6.228	9	0.000	2.500	1.59
Cartilage health (pre)	47.357	9	0.000	69.600	66.28
Cartilage health (post)	43.388	9	0.000	70.200	66.54

Source: IBM Statistical package for the social sciences, PEMF: Pulsed electromagnetic field therapy

Table 12: The outcomes of statistical analysis of ANOVA for the ten participants in PEMF therapy

ANOVA				
Indices and groups	**Sum of squares**	**df**	**Mean square**	**F**
Pain score (pre)				
Between groups	44.400	9	4.933	.
Within groups	0.000	0	.	
Total	44.400	9		
Pain score (post)				
Between groups	28.100	9	3.122	.
Within groups	0.000	0	.	
Total	28.100	9		
Stiffness score (pre)				
Between groups	20.000	9	2.222	.
Within groups	0.000	0	.	
Total	20.000	9		
Stiffness score (post)				
Between groups	14.500	9	1.611	.
Within groups	0.000	0	.	
Total	14.500	9		
Cartilage health (pre)				
Between groups	194.400	9	21.600	.
Within groups	0.000	0	.	
Total	194.400	9		
Cartilage health (post)				
Between groups	235.600	9	26.178	.
Within groups	0.000	0	.	
Total	235.600	9		

Source: IBM Statistical package for the social sciences, PEMF: Pulsed electromagnetic field therapy, ANOVA: Analysis of variance

utilized [28]. Procalcitonin, serum amyloid A protein, and CRP are indicators of the acute phase reaction. In patients with acute or chronic inflammatory conditions, they rise by 100 times or more. In the innate immune response, CRP attaches to microorganisms and damaged cellular components through phosphocholine, which triggers complement activation and phagocytosis. While CRP activation of complement causes tissue damage and increased inflammation, it also has some anti-inflammatory properties, acting as a promoter and down-regulator of inflammation. In the present study, both ESR and CRP were decreased following the use of PEMF therapy, which could be a useful treatment for OA patients looking to improve the knee function.

The current research included an assessment of three major aspects such as pain score, stiffness score, and cartilage health in the patients for before and after application of the therapy. In the present study, when the data were subjected to descriptive statistics, pain score, stiffness score, and cartilage health were altered. The stiffness score was lessened after the treatment, also with an improvement in the cartilage health. Patients with early-stage OA experienced significant improvements in pain reduction following PEMF therapy, according to the results of a one sample t-test with test value 0. These results demonstrated that PEMF therapy has a good impact on the patients.

CONCLUSION

The findings of the study depicted an effectiveness of PEMF therapy in enhancing healthcare measures and mitigating the adverse effects of OA patients. It underscores that MRI and blood reports of the patients before and after the application of PEMF showed significant changes in navigating the complexities of OA. This skeletal disorder and comprehensive musculoskeletal condition get treated efficiently through this therapeutic intervention. This research was concerned with the improvement of the conditions of both the right and left legs of the patients. Furthermore, the outcomes of the study showed that the therapy worked more predominantly in the right limbs of the observed participants. In spite of having bright future research and application

scopes within the application of PEMF for the treatment of OA, it holds some loopholes. The limitations included the safety guidelines during the usage of the therapy. It was observed that high-frequency PEMF has less sustainability whereas magnetic field with low frequency offers low efficiency. Therefore, this area about the effectiveness of the PEMF requires improvement for maintaining the reliability of the process along with maintenance of the safety of the patients.

Limitations

The sample in the present study was small.

SUPPLEMENTARY MATERIAL

The supplementary material is represented in the form of figures.

AUTHOR CONTRIBUTIONS

Conceptualization, A.R.; S.M.; and K.S.R.; Methodology V.K.G.; and V.A.; Software, Investigation, S.T.; S.F.; and S.I.D.; Preparation of original Draft, P.S.R.; and A.R.; project administration, A.R.; S.M.; and K.S.R. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors express no conflicts of interest.

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Nil.

ETHICS APPROVAL

All the participants expressed their consent of participation. IEC has approved the protocol with reference number AIMSR/IRB/RC/2023/06/016.

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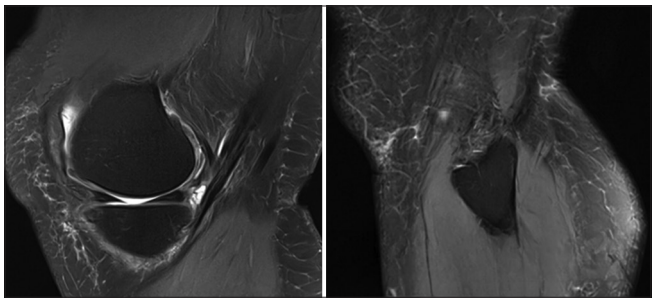
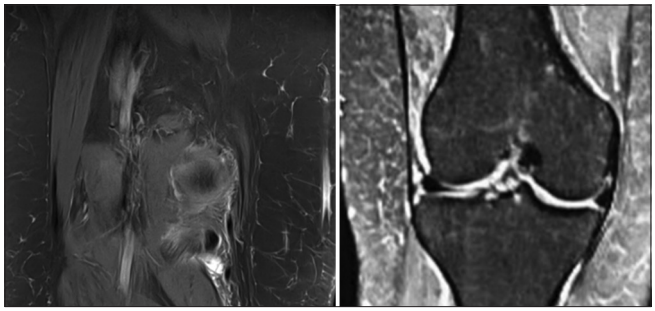
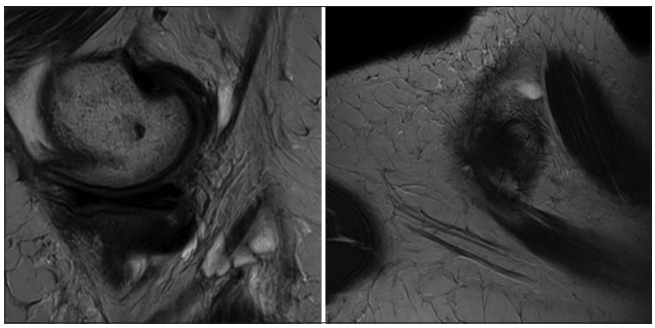
Supplementary Figures



Supplementary Fig. 1: Magnetic resonance imaging report of Sl.no. 3 of left leg on July 17, 2023, and October 31, 2023



Supplementary Fig. 2: Magnetic resonance imaging report of Sl.no. 3 of left leg on July 17, 2023, and October 31, 2023



Supplementary Fig. 3: Magnetic resonance imaging report of Sl.no. 3 of left leg on July 17, 2023, and October 31, 2023