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Efficacy of action potential simulation and interferential therapy in the rehabilitation of patients with knee osteoarthritis

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Abstract

Objective: Knee osteoarthritis (OA) is the main cause of pain, physical impairment and chronic disability in older people. Electrotherapeutic modalities such as interferential therapy (IFT) and action potential simulation (APS) are used for the treatment of knee OA. In this study, we aim to evaluate the therapeutic effects of APS and IFT on knee OA.

Methods: In this randomized clinical trial, 67 patients (94% female and 6% male with mean age of 52.80 $\pm$ 8.16 years) with mild and moderate knee OA were randomly assigned to be treated with APS ($n = 34$) or IFT ($n = 33$) for 10 sessions in 4 weeks. Baseline and post-treatment Western Ontario and McMaster Universities Osteoarthritis (WOMAC) subscales, visual analogue scale (VAS) and timed up and go (TUG) test were measured in all patients.

Results: VAS and WOMAC subscales were significantly improved after treatment in APS and IFT groups ($p < 0.001$ for all). TUG was also significantly improved after treatment in APS group ($p < 0.001$), but TUG changes in IFT was not significant ($p = 0.09$). There was no significant difference in VAS, TUG and WOMAC subscales values before and after treatment as well as the mean improvement in VAS, TUG and WOMAC subscales during study between groups.

Conclusion: Short-term treatment with both APS and IFT could significantly reduce pain and improve physical function in patients with knee OA.

Keywords: action potential simulation, function, interferential therapy, knee osteoarthritis, pain

Introduction

Osteoarthritis (OA) is the single most common form of joint disease and remains a leading cause of pain, physical impairment and decline in health-related quality of life in adults around the world [Jackson *et al.* 2004; Salaffi *et al.* 2005; Wang-Saegusa *et al.* 2011; Wu and Kalunian, 2005]. OA is a slowly progressing disease, characterized by the destruction of articular cartilage, resulting in an alteration of its biomechanical properties [Pearle *et al.* 2005; Zhang and Jordan, 2010]. It can affect the weight-bearing joints, i.e. the lower limbs. The knee joint is frequently affected by primary OA. Knee OA is the most prevalent joint disease among peripheral and axial joints of human body. It is a leading cause of chronic disability in people over the age of 50 [Michael *et al.* 2010; Zhang and Jordan, 2010].

Current therapies for OA are directed only towards pain relief and reduction of secondary functional disability including drugs such as simple analgesics, nonsteroidal anti-inflammatory drugs (NSAID) and intra-articular injections, physical measures, muscle strengthening exercises, the use of assisted devices, education, weight loss, social support and surgery [Barron and Rubin, 2007; Michael *et al.* 2010]. Physical therapies modalities especially electrotherapeutic modalities such as interferential therapy (IFT) and action potential simulation (APS) are used for the treatment of acute and chronic pain and play an important role in the treatment of OA of the knee [Barron and Rubin, 2007; Bjordal *et al.* 2007; Jan and Lai, 1991]

IFT is a common physiotherapeutic treatment modality used for pain management [Shah *et al.*

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2007; Tabasam and Johnson, 2006]. It is characterized by the interference of two medium-frequency currents, which combine to produce a new medium-frequency current whose amplitude is modulated at low frequency [DeDomenico, 1982; Noble *et al.* 2000], which produces lower impedance to the skin and allows deeper penetration into tissue [Noble *et al.* 2000]. Some studies have shown that IFT is effective in the management of various pain conditions [Bircan *et al.* 2002; Jarit *et al.* 2003; Johnson and Tabasam, 2003].

APS is used in the treatment of pain with a low-frequency electrical apparatus without stimulating skin and senses. This type of electrical modality uses an electrical current of less than 1 mA. The APS produces a current that supposedly mimics the normal physiological action potential of nerve conduction [Van Papendorp *et al.* 2000]. It is claimed that APS provides pain relief, reduces inflammation and swelling, enhances local blood circulation, increases mobility, regenerates cell and bone growth, and generates adenosine triphosphate (ATP) [Sandham, 2000; Van Papendorp *et al.* 2000].

APS [Berger and Matzner, 1999; Fengler *et al.* 2007; Odendaal and Joubert, 1999; Seegers *et al.* 2002] and IFT [Barron and Rubin, 2007; Bjordal *et al.* 2007; Jan and Lai, 1991] is shown to be effective in treating pains including pain due to knee OA. However, there are few studies comparing the efficacy of these electrotherapeutic modalities [Alves-Guerreiro *et al.* 2001], and it is not obvious which modality has better effects on pain relief. For this purpose, we aim to evaluate the therapeutic effects of APS and IFT on knee OA.

Materials and methods

In this randomized clinical trial, 70 patients over 50 years old with mild and moderate knee OA based on American College of Rheumatology criteria visiting physical medicine and rehabilitation clinics of Shohada Hospital, Tabriz University of Medical Sciences, Tabriz, Iran were randomly assigned to be treated with APS or IFT (Figure 1). Patients with severe knee OA, other rheumatologic disease, lower limbs fracture with knee joint involvement, history of knee surgery, lower limbs thrombosis, intra-articular corticosteroid injection in previous 6 month, balance control deficit, neuropathy or sensory deficit and skin breakdown in knee region as well as epilepsy, cancers, heart conduction block disease and having electrical implants such as a pacemaker were excluded.

The protocol was approved by the local ethics committee of our institution, and informed consent was obtained from all study participants. Clinical trial registration ID is IRCT201403024641N8.

The trial is powered to detect an effect size of $d \geqslant 0.70$ as statistically significant in a two-tailed test with $\alpha = 0.05$ and power of 0.80 with $N = 32$ per condition. As there was possibility that some patients do not complete the study, we included 35 patients in each group. Using RANDLIST 1.2 software, random numbers were produced and according to sample size, patients were enrolled into the study. During the study period, one patient from APS group and two patients from IFT group were lost to follow-up and were excluded. All three patients refused to continue therapy because of personal issues (Figure 1).

In the IFT, the four electrodes are positioned around the knee so that each channel runs perpendicular to the other and the two current crosses at a midpoint in the centre of the knee. The electrodes were placed onto the knee region with intensity in the tactile sensation threshold. IFT was conducted with following characteristics: isoplanar vector field with 6:6 sweep mode; carrier frequency 4 kHz; beat frequency 100 Hz; and sweep frequency 150 Hz.

In APS, a negative electrode was placed on the anterior knee joint line and a positive electrode was placed posteriorly on the popliteal fossa. APS was conducted for study patients with following characteristics: frequency 151 Hz; pulse width 800 ms; constant current; maximum amplitude 1.5 mA.

The duration of IFT and APS was 20 minutes. The study protocol was designed to perform in 10 sessions in 4 weeks. All treatments in both groups were applied in the same manner by the same physiotherapist. The patients were informed about the two modalities (APS or IFT) regarding how they work, but were blinded to which therapy they are allocated to. In order to ensure the blinding, the electrode pads in similar shape were used for both modalities that the patients could not differentiate between two devices. The physician supervising the treatment protocol was aware of the randomization but the physician assessing the therapy outcome was blinded. Quad sets exercise

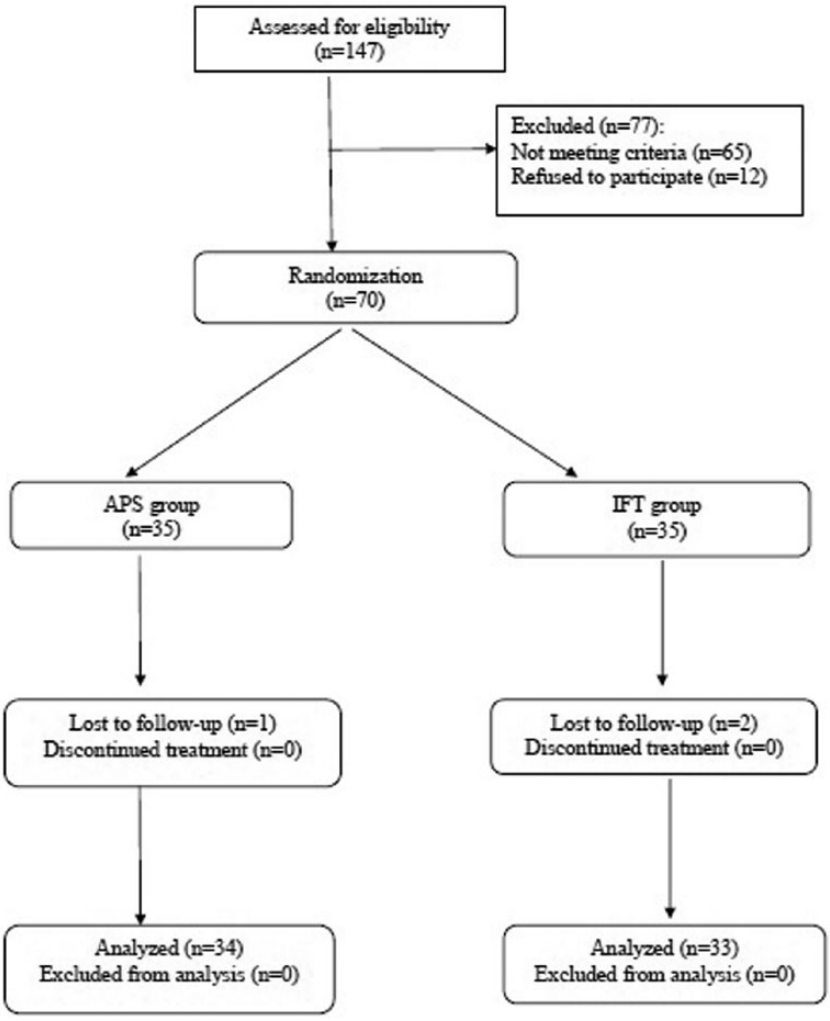

Figure 1. Flow diagram of the study protocol.

(to strengthen the quadriceps muscles) were applied for both groups. Patients were advised to use Acetaminophen in case of unbearable pain during the study period.

Baseline Western Ontario and McMaster Universities Osteoarthritis (WOMAC) values, visual analogue scale (VAS) parameters were recorded. Timed up and go (TUG) test was also measured at baseline. Variables were also evaluated at the end of the intervention.

Pain was measured using a 10 cm VAS. Pain intensity is referred as 0 to 10, in which 0 = no pain at all and 10 = the worst pain possible. Patients were asked to sign the place on the VAS that corresponded to their pain level.

We also evaluated TUG before and after training in both groups. TUG is a simple test used to assess a subject's mobility and it requires both static and dynamic balance. This test measures the time required for a patient to stand up from a 45-cm-high chair, at the cue of 'start' and walk 3 m at a fast, still comfortable speed in front of them, cross a line on the floor, turn around, walk back and sit down in the chair. The patient was encouraged to do the test as fast as possible. No support from another person was allowed during testing but verbal guidance could be given. The participant will be timed starting from when the instructor says 'go', and will stop when the participant sits again with their back against the back of the chair. We measured the TUG test performance time in seconds.

The WOMAC questionnaire is used for evaluation of patients' functions in rheumatic diseases especially knee OA. The WOMAC is a 24-item questionnaire with 3 subscales measuring pain

(5 items), stiffness (2 items), and physical function (17 items). Answers to each of the 24 questions are scored on 5-point Likert scales (none = 0, slight = 1, moderate = 2, severe = 3, extreme = 4), with total scores ranging from 0 to 96. Higher scores indicate greater disease severity [Bellamy *et al.* 1988; McConnell *et al.* 2001]. The WOMAC scale was also validated for Iranian population by Nadrian and colleagues [Nadrian *et al.* 2012].

The patients were allowed to use acetaminophen (to a maximum of 4 g daily) during the study period as considered appropriate by the physician.

Statistical analysis

All statistical tests were performed using SPSS for windows Version 17 (Chicago, IL, USA). Quantitative data were presented as mean ± standard deviation (SD), while qualitative data were demonstrated as frequency and percentage (%). Independent *t* test for quantitative date and chi-square test or Fisher's exact tests, as appropriate were used to compare data between groups of patients. Paired samples *t* test was used to compare findings before and after training in each group. A p value of <0.05 was considered statistically significant.

Results

In this study 70 patients with knee OA were divided into APS and IFT groups, but during study 3 patients (1 from APS and 2 from IFT group) failed to complete the trial and were excluded. Among 67 patients, 63 (94%) were female with mean age of 52.80 ± 8.16 years. Patients' demographic findings are shown in Table 1. There was no difference between groups in baseline findings.

Table 2 demonstrates VAS and WOMAC scores pre- and post-treatment between groups. There was no significant difference between groups in VAS, WOMAC subscales and TUG before and after treatment. In both groups VAS and WOMAC subscales were significantly improved after treatment ($p<0.001$ for all). TUG was also significantly improved after treatment in APS group ($p<0.001$), but TUG improvement in IFT was not significant ($p=0.09$).

Figure 2A and B also demonstrate TUG before and after treatment between groups. There was no significant difference between groups in TUG before ($p=0.79$, 95% confidence interval [CI] –1.33 to 1.74) and after treatment ($p=0.31$, 95% CI –2.12 to 0.69).

The mean changes in VAS, TUG and WOMAC subscales after treatment compared with values before treatment was also calculated to define the best modality in obtaining better results (Table 3). Although the improvement in TUG and WOMAC stiffness subscale was higher in APS group, there were no significant differences between groups in any variable.

Discussion

In this randomized clinical trial, we evaluated the efficacy of APS and IFT as electrotherapeutic modalities in rehabilitating patients with knee OA. During treatment period, we observed significant reduction in pain intensity and improvement in stiffness and physical function status in both groups, but there were no significant differences between groups.

IFT is an electrotherapy modality that is thought to decrease pain, increase range of motion, and decrease oedema [Jarit *et al.* 2003; Jorge *et al.* 2006; Werners *et al.* 1999]. Similar to our findings, other studies has shown significant improvement in VAS, and WOMAC subscales including pain, stiffness and physical function in knee related pathologies [Burch *et al.* 2008; Cheing and Hui-Chan, 2003; Gundog *et al.* 2012]. Burch and colleagues [Burch *et al.* 2008] believed that IFT stimulation provides better pain management and allows the underlying OA condition to be more comfortably treated with patterned muscle stimulation. Atamaz and colleagues [Atamaz *et al.* 2012] showed that using physical therapy including IFT can reduce pain more effectively than therapies without electrostimulation, which was observed with lower paracetamol use during the study. The beneficiary effects of IFT in improving pain and disability have been evaluated in some other disease and have shown a great improvement with its treatment [Lara-Palomo *et al.* 2013; Montes-Molina *et al.* 2012a, 2012b].

APS is another electrotherapy modality that is used for controlling pain. Studies about the efficacy of APS on pain in different types of disease have yielded conflicting results. Some previous studies have reported positive effects of APS on chronic neck pain [Van Papendorp *et al.* 2000],

Table 1. Patients' demographic findings between APS and IFT groups.

		APS (*N*=34)	IFT (*N*=33)	*p* value	95% CI of the difference
Age (years)		54.35±5.99	51.21±9.75	0.11	−0.79 to 7.07
Female (*n*, %)		31 (91.2%)	32 (96.9%)	0.61	———
Weight (kg)		74.02±10.14	76.27±7.36	0.3	−6.57 to 2.09
Height (cm)		161.64±6.36	161.87±6.17	0.88	−3.29 to 2.83
BMI (kg/m^2)		28.93±5.05	29.12±2.58	0.84	−2.15 to 1.87
Knee involved	Left	4 (11.8%)	6 (18.2%)	0.10	———
	Right	5 (14.7%)	11 (33.3%)		
	Both sides	25 (73.5%)	16 (48.5%)		
Severity	Mild	13 (38.2%)	10 (30.3%)	0.49	———
Moderate	21 (61.8%)	23 (69.7%)			

APS, action potential stimulation; IFT, interferential therapy; BMI, body mass index; CI, confidence interval.

Table 2. VAS and WOMAC scores pre- and post-treatment between groups.

		APS (*N*=34)	IFT (*N*=33)	*p* value	95% CI of the difference
Pre-treatment	VAS	7.02±1.93	6.27±1.79	0.10	−0.15 to 1.66
	WOMAC subscales				
	Pain	11.29±3.34	9.78±3.74	0.08	−0.22 to 3.23
	Stiffness	3.97±2.22	3.03±1.72	0.05	−0.03 to 1.91
	Physical function	36.35±10.77	32.27±11.03	0.13	−1.23 to 9.40
	Total	51.61±14.84	45.09±15.44	0.08	−0.86 to 13.91
Post-treatment	VAS	4.52±1.95	4.09±1.70	0.33	−0.45 to 1.33
	WOMAC subscales				
	Pain	7.58±3.28	5.96±4.36	0.09	−0.26 to 3.50
	Stiffness	2.50±1.77	2.09±1.35	0.29	−0.36 to 1.18
	Physical function	25.29±11.37	21.36±11.01	0.15	−1.53 to 9.39
	Total	35.38±15.57	29.42±14.07	0.10	−1.29 to 13.28

APS, action potential stimulation; IFT, interferential therapy; VAS, visual analogue scale; WOMAC, Western Ontario and McMaster Universities Arthritis Index; CI, confidence interval.

knee pain [Akbari and Forough, 2005], knee OA [Sepehri and Akbari, 2012] and musculoskeletal pains [Johnson and Martinson, 2007]. Pyszora and colleagues in their pilot study observed significant and similar improvement in pain intensity in both TENS and APS therapies indicating the efficacy of these two methods [Pyszora *et al.* 2007a]. In another study, Pyszora and colleagues also showed APS therapy may be an effective method of nonpharmacological treatment of chronic pain in musculoskeletal disorders [Pyszora *et al.* 2007b]. However, some of these results did not have control group that limits the observed results. In our study, the short-term equivalent effects of both APS and IFT are consistent with the literature. In our study, both treatments showed similar positive results on patients with knee OA with no significant difference between groups.

Unlike our study and above-reported research, few studies have failed to find positive results for APS compared with placebo or control group in reducing pain and improving patients' status with fibromyalgia [Fengler *et al.* 2007], OA [Berger and Matzner, 1999] or chronic backache [Odendaal and Joubert, 1999]. Double-blind studies on the effects of APS, TENS and IFT on skin temperature and mechanical pain threshold in healthy people have also failed to find any

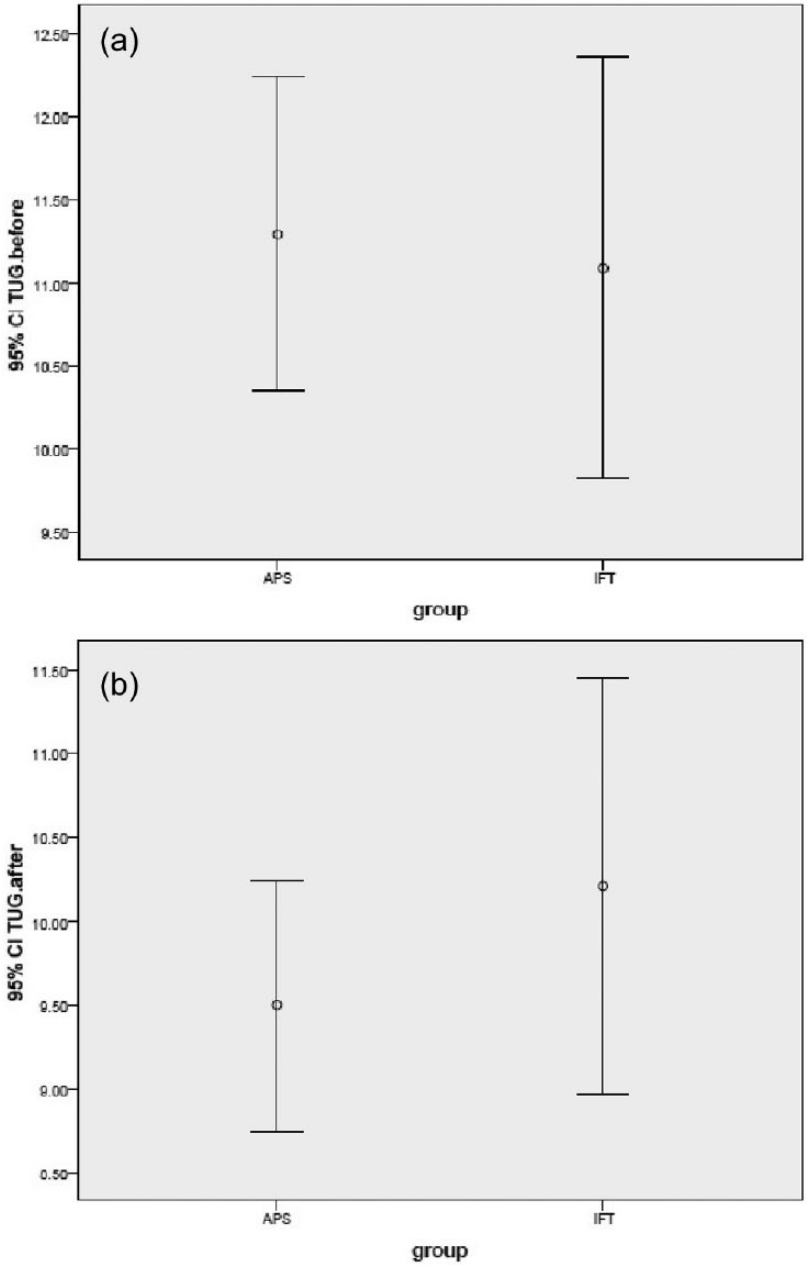

Figure 2. Mean TUG between groups before (a) and after (b) treatment.

Table 3. Change from baseline values in VAS, TUG and WOMAC subscales in each group.

	APS (*n*=34)	IFT (*n*=33)	*p* value	95% CI of the difference
VAS	−36.30±24.36%	−35.04±22.90%	0.82	−12.8 to 10.28
TUG	−14.52±13.36	−5.05±31.30	0.11	−21.15 to 2.21
WOMAC subscales				
Pain	−36.30±22.39	−38.60±34.03	0.74	−11.71 to 16.31
Stiffness	−34.80±35.83	−22.91±60.71	0.36	−37.90 to 14.12
Physical function	−34.74±22.55	−34.24±26.68	0.93	−12.54 to 11.54
Total	−35.56±21.19	−34.26±23.70	0.81	−12.25 to 9.66

APS, action potential stimulation; IFT, interferential therapy; VAS, visual analogue scale; TUG, timed up and go; WOMAC, Western Ontario and McMaster Universities Arthritis Index; CI, confidence interval.

significant differences between groups [Alves-Guerreiro *et al.* 2001]. They reported that none of the modalities reduce the superficial sense of normal people, thus, they would not be able to relieve pain.

There are some possible mechanisms of action for APS and IFT techniques. It has been clinically shown that there are neurohormonal changes following APS therapy, which have a clinical effect on the biochemical balance in the area being treated. So, where physiological functions are impaired due to a breakdown in biochemistry and nerve function, it is feasible to attempt to therapeutically reactivate those physiological functions electronically by the use of APS therapy. APS lead to an increase of specific neurohormones such as melatonin and leucine enkephalin reducing anxiety, pain, and aiding sleep. This is achieved without creating any clinically relevant changes in serotonin or cortisol concentrations which are important hormones to maintain other important neural functions. It also creates an increase of oxygen towards the positive electrode (anode) by breaking down electrolytes [Weiner *et al.* 1998; Berger and Matzner, 1999; de Wet *et al.* 1999; Odendaal and Joubert, 1999; Van Papendorp *et al.* 2000]

IFT allows an increased dosage applied in a greater depth because of the body tissue's better tolerance of medium-frequency currents. IFT could stimulate local nerve cells that can have a pain reducing/anaesthetic effect due to potentially blocking the transmission of the pain signals or by stimulating the release of pain reducing endorphins [Shah *et al.* 2007; Tabasam and Johnson, 2006]. It is possible that both these modalities cause there effects by stimulating nerve cells and making regional changes.

VAS is a test for general purposes and reduction in its values may achieve by even smaller reduction in pain quality; however, WOMAC is a test specifically designed for OA of the knee. Observing a significant improvement in WOMAC subscales is indicative of satisfactory and conclusive results which could not be observed in placebo or controlled groups. For this reason we believe that both electrotherapeutic modalities, APS and IFT, could be used with great improvement in patients with knee OA.

Unlike most studies on IFT which yielded positive results in most clinical situations, studies on APS are mainly inconclusive and do not support the beneficiary effects of this treatment. As there are no complaints or side effects reported and considering the low cost involved in treatment with APS and IFT, it could be recommended that patients with knee OA receive APS or IFT therapy for relieving pain. Another advantage of these methods is the fact that the treatment session takes a short time and in many cases can be applied by the patient himself at home.

During the treatment, none of the methods had complications. Although patients were advised to use acetaminophen for pain control, unfortunately, we did not measure the rate of acetaminophen consumption between groups and could not tell whether the acetaminophen use was comparable or different between groups.

Conclusion

Short-term treatment with both APS and IFT could significantly reduce pain and improve physical function in patients with knee OA. These results are indicative that both physical methods can be used as an alternative to drugs or complementary methods for pain management in knee OA. It should be noted that this study is the first to compare APS and IFT in treatment of knee OA, so further studies are needed to confirm these findings.

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Conflict of interest statement

The authors declare that there is no conflict of interest.

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