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The effects of TECAR therapy on pain, range of motion, strength and subscale of HAGOS questionnaire in athletes with chronic adductor related groin pain: a randomized controlled trial

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Abstract

Introduction Groin pain is a common issue among athletes. Adductor-related pain is known as the most common cause of groin pain. Although, non-operative treatments have limited efficacy, Capacitive and Resistive Energy Transfer (TECAR), can be used in the treatment of musculoskeletal conditions. The objective of the present study is to explore the effect of TECAR therapy on pain, range of motion (ROM), strength, and subscales of the "Copenhagen Thigh and Groin Assessment Scale"(HAGOS) questionnaire in athletes suffering from adductor-related groin pain (ARGP).

Methods This study was a two arm parallel groups randomized sham-controlled superiority trial. A total of 22 male professional athletes (mean age 21.36 years) were randomly assigned to either the real TECAR therapy ($n=11$) or sham TECAR therapy ($n=11$) group, using block-balanced randomization. Both groups received stretching exercises. Intervention group received 10 sessions of TECAR therapy while, the control group received sham TECAR therapy. Primary outcome was pain that was measured by Visual Analogue Scale (VAS). Secondary outcomes included ROM, strength, and HAGOS questionnaire subscales. All outcomes were assessed at baseline, after 5 sessions, after 10 sessions, and one month after treatment. Analysis of Variance (ANOVA) and Analysis of Covariance were used to compare between-group mean differences. *P*-value was set at 0.05. Effect size Cohen's d was also reported. This study took place from September 2022 to August 2023 at the Rehabilitation Clinic at Iran University of Medical Sciences.

Results A total of 22 male athletes were included (11 in each group), with a mean age of 21.09 years in the TECAR group and 21.63 years in the sham group. TECAR therapy was associated with significant reductions in pain intensity across all evaluation sessions. Specifically, after 5 sessions, there was a large effect size for pain reduction ($p=0.01$, Cohen's d = -1.09 [95% CI: -0.195 to -1.987]); after 10 sessions, the effect was even larger ($p=0.001$, Cohen's d = -2.153 [95% CI: -1.103 to -3.203]); and at the 1-month follow-up, the pain reduction persisted ($p=0.001$, Cohen's d = -1.96 [95% CI: -0.944 to -2.978]). In terms of secondary outcomes, there was a significant improvement in hip adduction ROM at the 1-month follow-up ($p=0.03$, Cohen's d = 0.908 [95% CI: 0.03 to 1.78]). However, no statistically significant differences were found for other secondary outcomes, with effect sizes ranging from no effect to intermediate.

Conclusion The results of this study suggest that TECAR therapy may reduce pain and improve hip adduction range of motion in athletes with adductor-related groin pain.

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Trial registration This trial was registered at the (https://www.irct.ir), (IRCT20220622055250N1) on 18/09/2022.
Keywords TECAR, Groin, Pain, Range of motion, Strength, HAGOS questionnaire

Introduction

Background

The prevalence of groin pain is notably high in athletes engaged in activities such as running, kicking, executing explosive turns, and making sudden changes in acceleration or direction of movement [1]. The incidence of this injury has been reported to range from 6 to 27% in related sports [2]. Among athletes, groin injuries, with a prevalence of 58%, are most associated with ARGP [2–4]. ARGP was the most prevalent defined clinical entity in 61% of athletes [5]. Adductor tenderness and pain on resisted adduction testing are the diagnostic criteria for adductor-related groin pain [4, 6]. Risk factors for ARGP include stiffness of the adductor muscles, a history of previous adductor injuries, an imbalance in strength between the adductor and abductor muscles (with a ratio less than 0.8), and participation in high levels of competition [7–11]. There are two categories of interventions including surgical interventions and conservative treatments [12]. According to studies, surgical interventions have shown greater success rates in facilitating the return of athletes to their sport [12]. This study states that one of the reasons for this superiority is the lack of high-quality studies in conservative treatments [12]. Non-operative treatments including Compression clothing therapy, Prolotherapy, Manual therapy and strengthening exercise, Pulse-Dose Radiofrequency, Injection therapy, Intra-tissue percutaneous electrolysis and Platelet-rich plasma therapy. Between all of them, compression clothing therapy, manual therapy and strengthening exercises, and prolotherapy showing the greater level of strength of evidence (moderate) and the greater grade of recommendation (C) are [3]. Compression shorts reduce pain during athletic activities without a significant effect on performance [3, 4]. The conservative programmes focused on manual therapy and strengthening exercises are mainly based on therapeutic exercise, focusing on hip and abdominal muscle strengthening and manipulation consisting of transversal friction massage, assisted passive movements such as hip adduction, abduction and stretching of abductor muscles [3].Multimodal treatment including manual adductor manipulation can result in a faster return to play, but not a higher treatment success, than a partially supervised active physical training program [4]. Prolotherapy by increasing the level of glucose in the extracellular matrix, causes a local irritation of the tissues and triggers an acute inflammatory response that stimulates fibroblast proliferation and collagen synthesis leading to tissue healing [3]. However, despite the promising outcomes of conservative treatments, such as strengthening exercises, these therapies often require a prolonged duration (8–12 weeks) to show significant effects [3]. Given the high incidence of ARGP among athletes and the critical need for effective treatments that offer quicker recovery times there is an urgent demand for more efficacious therapeutic approaches. Reducing pain and improving range of motion (ROM) are crucial for accelerating recovery, enabling an earlier return to sport, and minimizing the long-term consequences of the injury.

Moreover, a recent systematic review highlighted that TECAR therapy was an effective approach for the rehabilitation of musculoskeletal disorders and it has been effective on pain, ROM, and performance in cervical, shoulder, leg, knee, and back injuries [13]. TECAR therapy uses capacitive and resistive energy transfer to enhancing blood circulation and accelerating the body's natural healing mechanisms and reduce pain [14, 15]. However, to the best of our knowledge, the effects of TECAR therapy in treating ARGP have not been explored. Considering the potential efficacy of TECAR therapy in improving pain, mobility, and function in different body tissues, the current randomized controlled trial was conducted to explore the impact of TECAR therapy on pain, ROM, strength, and subscales of the HAGOS questionnaire in athletes suffering from ARGP.

Objectives

This trial's primary objective was to determine the effect of TECAR therapy on pain and the secondary objectives were to determine the effect of TECAR therapy on ROM, strength, and Subscale of HAGOS Questionnaire in Athletes with chronic Adductor Related Groin Pain. This study hypothesized that the patients who received TECAR therapy in comparison with control group that received TECAR with zero output, would exhibit greater improvements.

Method

Trial design

This study was a two arm parallel groups randomized sham-controlled superiority trial. 22 participants were randomized into real TECAR therapy or sham TECAR therapy using block-balanced randomization method. The allocation ratio was 1:1. This study follows the CONSORT guidelines, checklist and flowchart. Both

groups received stretching exercises. Intervention group received 10 sessions of TECAR therapy while, the control group received sham TECAR therapy. Primary outcome measurement of the present study was Visual Analogue Scale (VAS). Secondary outcomes included ROM, strength, and HAGOS questionnaire subscales. All outcomes were assessed at baseline, after 5 sessions, after 10 sessions, and one month after the end of the study. Analysis of Variance (ANOVA) and Analysis of Covariance were used to compare between-group mean differences. *P*-value was set at 0.05. Effect size Cohen's d was also reported. This RC was registered with the Iranian clinical trial number registry (IRCT20220622055250N1) and took place from September 2022 to August 2023 at the Rehabilitation Clinic at Iran University of Medical Sciences.

Participants

A sports physician with 10 years of experience conducted tests that involves assessing the abdomen, inguinal, and pubic areas using palpation and strength testing [6] and ultrasounds to exclude potential conditions like inguinal or femoral hernias that might contribute to the pain. If the athletes met the included criteria (Table 1), he referred to the rehabilitation clinic of IRAN medical university. The first participant meeting lasted approximately 45 to 60 min, during which time the participants were provided with information regarding the study's conditions, their questions and concerns were addressed. The significance of this awareness is enhancing the effect of therapy and their stay in the follow-up procedures. A physical therapist then did re-check to determine the athletes' suitability to enrolled in RCT, according to inclusion criteria and with the aim of confirming the presence of ARGP based on a consensus agreement. This involves assessing the abdomen, inguinal, and pubic areas using palpation and strength testing [6]. The criteria for inclusion and exclusion are presented in Table 1 [16–23]. All athletes who satisfied the predetermined inclusion criteria and provided their consent were included in the study. Conversely, 22 participants included in this study were only male professional athletes. The prevalence of individuals participating in soccer was 77%, while futsal accounted for 18% and volleyball 5% of the total population (Table 2).

Interventions

The participants were assigned to either the intervention ($n=11$) or sham control group ($n=11$) via block randomization. They initiated the procedure by engaging in a treadmill warm-up. Following this, TECAR therapy was administered based on the individual's assigned grouping. Finally, the participants finished the session by engaging in stretching activities.

Treadmill

In the first setup of employing a treadmill, it is typical for individuals to commence their exercise routine with an inclined setting of zero and a preselected velocity of their preference. The inclination of the treadmill should be incrementally increased by two degrees at intervals of two minutes until the individual's heart rate achieves a range of 90–85% of their maximum heart rate, as determined by the treadmill.

TECAR therapy

The participants are positioned in a supine posture, with a pillow supporting the head and the affected leg abducted and externally rotated (the four position) to facilitate easier access to the muscle origin, while the adductor muscles are put in a stretched position (Fig. 1). The Stretch Sensation Scale should rate the stretching

Table 2 Statistical frequency of sports

Sport	Intervention group	Control group	Total
Football	8	9	17(77%)
Futsal	2	2	4(17%)
Volleyball	1	0	1(5%)

Table 1 inclusion and exclusion criteria

Inclusion criteria [17–22]	Exclusion criteria [16, 18, 21–23]
• Adductor related groin pain for at least 1 months • ARGP with the approval of a sport physician • Age 18–45 year • Pain during active adduction against resistance (squeeze test) • Pain at palpation of the origin of the adductors • Ability to read and write Persian • Unilateral adductor strain	• Malignant tumors • Any hernia (inguinal, femoral) • fractures in the lower extremities • Receive treatment in the last 1 months • Contraindications for TECAR Therapy • Urinary and genital infections • Referral pain (back pain) • Unwillingness of the person to continue treatment • Another related groin pains

Fig. 1 Participants posiotion during TECAR therapy

at seven out of ten. This means that there should be a point of discomfort stretching, but no muscle vibration [24, 25]. WINBACK 3SE (France) was used for TECAR therapy in this study (Fig. 2) (Table 3). To facilitate optimal distribution of endogenous heat therapy and effective contact between the active electrodes, both capacitive and resistive, and the surface of the skin, a

Fig. 2 TECAR. WINBACK 3SE

Table 3 Settings used for the capacitive and resistive electric transfer

	Capacitive mode	Resistive mode
Power	400VA	100 W
Frequency (kHz)	300 kHz-1 MHz	300 kHz-1 MHz
Time of treatment (min)	7/5 min	7/5 min

layer of high-conductivity cream was applied to the treatment region. The plate, an inactive electrode, which had a specific size (21cm*15cm), was placed on the gluteal region. The capacitive electrode was employed for a duration of seven and a half minutes, at an intensity of 30–40%, whereas the resistance electrode was utilized for an equivalent period within the adductor muscle region at the same intensity. In order to prevent the occurrence of discomforting skin sensations resulting from localized overheating, it was essential for the operator to consistently and actively move the electrode from the origin to insertion of thigh adductor muscles. Additionally, feedback was gathered from participants to ensure that the heat felt was suitable and comfortable for them. In the control group, a procedure similar to the active treatment was applied, but with the critical difference being that the output intensity of the TECAR device was set to zero during the session. This ensured that participants in the sham group experienced all the steps and procedures of the treatment process (such as electrode placement and interaction with the therapist), but without receiving any therapeutic effects from the device. Additionally, we ensured that both the treatment and sham group were delivered under the same conditions (e.g., duration of application, environment, and clinician involvement) to control for any confounding variables.

Stretching

Following the completion of their treatment, participants were instructed to perform three stretching exercises. The stretch should be according to The Stretch Sensation Scale seven out of ten.

Number 1. The patient was placed in a sitting position with flexed knees and the soles of the feet touching each other. In this case, the individual tried to attach his knees to the surface (Fig. 3).

Number 2. The patient was placed in a sitting position, extending and separating the lower limbs, and positioned the palms between the legs on the floor. Subsequently, the patient initiated a forward movement by using force to push himself (Fig. 4).

Fig. 3 Exercise number 1

Fig. 4 Exercise number 2

Number 3. The patient took a standing position and elevated one leg by putting it on a chair placed next to him, ensuring that the knee remained in a fully extended position. The distance between the chair and the individual should be suitable for a sensation of stretching in the inner thigh region (Fig. 5).

Fig. 5 Exercise number 3

Outcomes

A blinded assessor collected demographic information (gender, age, height, and weight) and evaluated primary plus secondary outcomes at four time points: baseline (before therapy), after 5 treatment sessions, after 10 treatment sessions, and 1 month follow-up.

Primary outcome

Pain intensity The pain was evaluated based on the Visual Analog Scale (VAS) [26]. A 10 cm long linear scale without a numerical scale was used to measure pain intensity, with the left end indicating the pain-free position (best) and the right end indicating the point of severe pain (worst). The participants were asked to rate their level of pain over previous 24 h.

Secondary outcomes

The secondary outcome measurements included the hip abduction and adduction ROM, as well as the strength of hip abduction and adduction. Additionally, the subscales of the HAGOS questionnaire.

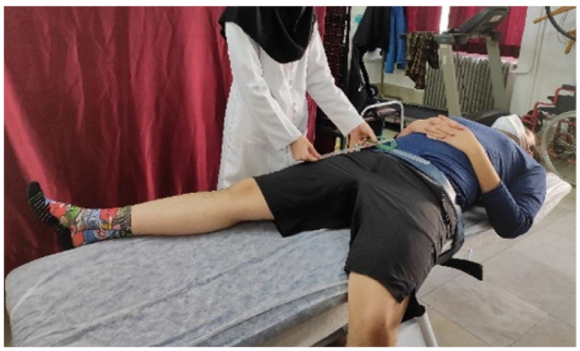

Fig. 6 Measurement of hip abduction range of motion

Fig. 8 Measurement of hip abduction strength

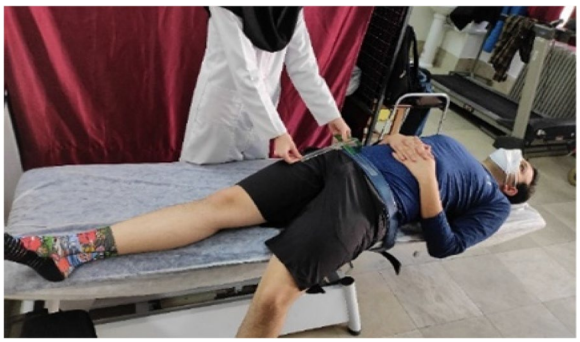

Fig. 7 Measurement of hip adduction range of motion

Fig. 9 Measurement of hip abduction strength

Hip range of motion The passive hip ROM for abduction and adduction was assessed while the participant was in a supine position. The angle was measured by employing a goniometer, where the fixed arm was aligned parallel to the line intersecting the midpoint of the anterior superior iliac spines (ASIS), with the movable arm positioned along the longitudinal axis of the femur bone (passing through the center of the patella), so setting the ASIS as the axis of reference. The leg of the uninvolved side was hanging from the bed to prevent interference with pelvic movement during abduction and to avoid restricting adduction. Subsequently, the examiner proceeded to execute passive movements until pelvic rotation was initiated (Figs. 6 and 7) [27].

Hip abductor/adductor strength To measure the amount of hip abduction strength, the patient took a lateral position while the thighs were securely fastened with a taut belt. A pillow was positioned between the two lower limbs to ensure that the upper leg remained in a neutral posture with regards to its adduction and abduction. The therapist fixed the pelvis using one hand and positioned the dynamometer on the distal end of the femur using the other hand (Fig. 8). To measure adduction strength, the patient took a supine position and flexed the knee of the non-involved leg while the examiner positioned the dynamometer approximately five centimeters above the medial malleolus (Fig. 9). Subsequently, the participants were directed to use maximal force on the dynamometer and sustained the contraction for a duration of five seconds. It was recommended to incorporate 30 s rest intervals between three sets. Ultimately, the average strength was recorded [16, 17].

HAGOS questionnaire The HAGOS questionnaire is the questionnaire used to assess hip and groin pain in young and middle-aged active as well as athletes, which includes six subscales, namely symptoms, pain, physical activity in daily living, sports and recreational activity, participation in physical activities, and quality of life. It encompasses a total of 37 questions. Each subscale of the HAGOS questionnaire uses a 0–100 scale, where a higher score indicates better function and less pain or limitation. In this scoring system, a higher score is considered more favorable, meaning that a score closer to 100 reflects a better outcome. This scoring method allowed us to quantify and compare the severity of symptoms and functional impairments in a standardized manner. In the Symptoms subscale, the frequency and severity of hip and groin symptoms, such as stiffness

and discomfort, are assessed. The Pain subscale evaluates the intensity of pain during activities such as walking, running, and other movements. The Physical Activity in Daily Living subscale measures how the symptoms affect routine physical activities, including actions such as climbing stairs or sitting. The Sports and Recreational Activity subscale assesses limitations in sports performance and recreational activities, including running, jumping, and activities involving changes in acceleration or direction. The Participation in Physical Activities subscale evaluates the individual's ability and willingness to engage in both organized sports and recreational physical activities. Finally, the Quality-of-Life subscale focuses on the overall impact of groin pain on the individual's emotional well-being and social functioning [28, 29]. we utilized all six subscales of the HAGOS questionnaire.

Sample size

Randomization

The calculation of the required sample size was based on previous research studies and was conducted using G*Power 3.1.9.4 software. The minimal clinically significant difference (MCID) for pain measured by the VAS was established at 1.5 points based on Martin RL et al.'s study [30]. The sample size estimation of this software took into account an effect size of 0.282 and a dropout rate of 10%, resulting in a sample size of 22 participants [31]. Power and α error values were set to 80% and 0.05, respectively.

Sequence generation Prior to the randomization process, the patients who met the inclusion criteria were invited to the physiotherapy clinic and then the eligible participants were allocation ratio of 1:1. The participants were assigned to either the intervention or control group by a block-balanced randomization method. The randomization schedule was transferred into written instructions and placed in sequentially numbered, opaque, and sealed envelopes. In this randomization method was used six sets, with each set consisting of four blocks containing letters A or B (A: intervention group, B: control group). The randomization results were written and placed in numbered, opaque, and sealed envelopes. The numbered envelopes were randomly selected and the patients were placed in the corresponding group according to the letters in that envelope.

Blinding

The participants and the assessor were blinded. The assessor was independent of the research team and was not involved in the randomization process and maintained a state of unawareness regarding the allocation of participants into groups. To avoid data contamination, patients were advised not to give the assessor any information about their treatment protocol.

Statistical methods

For the statistical analysis of data, Stata statistical software version 13 was used and in addition, MedCalc Statistical Software version 19.0.5 was employed to draw some graphs. Prior to doing the statistical analysis, the normality of the outcome measures was assessed by examining Shapiro–Wilk test, skewness, kurtosis, and visually inspecting histograms to ensure the data were consistent with a normal distribution. The demographic data of the groups were compared using statistical tests, including the independent-sample t test and Chi-square test. In order to evaluate the differences between the two groups in relation to the dependent variables, a repeated measures analysis of variance (ANOVA) was conducted, with the group acting as the independent variable. Additionally, to minimize the potential influence of the difference in the baseline of the primary outcome analysis, the repeated measures Analysis of covariance (ANCOVA) approach was employed, taking into account the baseline as a confounding factor [32]. Thus, the primary outcome data were presented in adjusted and unadjusted values. Primary and secondary outcomes were analyzed using an intention-to-treat approach, where participants were analyzed according to their original randomization group, regardless of their compliance. Missing data were handled using multiple imputation. In addition to utilizing the statistical measures of the significance level and the average difference between the two groups, the comparison of the two groups also involved the use of Cohen's d effect size, falling within the standardized mean difference (SMD) category. The intragroup effect size was supplied to facilitate the comparison of the intervention's impact in the intragroup evaluation sessions.

Result

A total of 25 participants diagnosed with ARGP were assessed for potential inclusion in the study. After the exclusion of three participants, a total of 22 individuals became eligible to participate in the study. Randomization was used to allocate 11 participants to the intervention group and another 11 participants to the control group. The study had a dropout rate of two participants, one in control and another in intervention group (Fig. 10). The data revealed a normal distribution and did not contain any outliers. There were no significant differences, meaning no change in significance, between the intention-to-treat analysis and the per-protocol analysis results. Table 4 presents the baseline characteristics of the participants in each group.

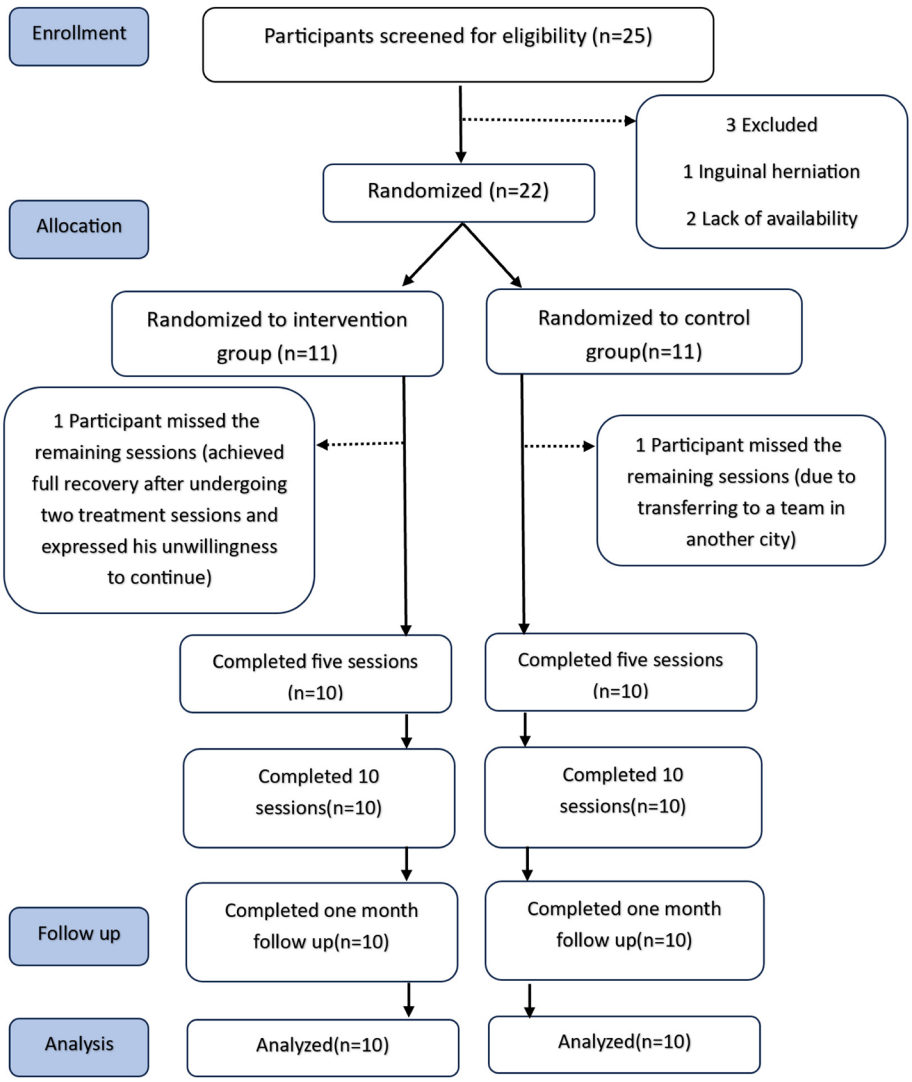

Fig. 10 CONSORT flowchart diagram

Table 4 Baseline characteristics

Variables		Intervention	Control
Age[a]		21.09(2.62)	21.63(4.67)
BMI[a]		23.3(1.93)	23.32(2.81)
Gender[b]	Men	11(100%)	11(100%)
	Women	0(0%)	0(0%)
Dominant side[b]	Right	11(100%)	9(81.8%)
Pain side[b]	Right	7(63.6%)	6(54.5%)

Abbreviations: *BMI* body mass index

[a] Data expressed as mean (standard deviation), [b]Data expressed as number (%)

Compliance and adverse effects

A total of 20 athletes (90.9%) completed all stages of the trial. One participant (4.54%) in the intervention group achieved full recovery after undergoing two treatment sessions and expressed his unwillingness to continue with the treatment sessions. Additionally, another participant (4.54%) in the control group, after completing three treatment sessions, was excluded from the study due to transfer to a team in a different city. Following the use of TECAR, the participants reported no complications.

Primary outcome

The repeated-measures analysis of covariance (ANCOVA) in the primary outcome variable, pain intensity, demonstrated a statistically significant improvement in the intervention group when compared to the control group after 5 and 10-session treatment, and it remained after 1-month follow-up. Notably, the effect

size was found large throughout all evaluations (Table 5). Regarding the within group changes, in the intervention group, the results showed a significant reduction in pain intensity following 5 (p-value = 0.001, effect size = −1.09) and 10 (p-value = 0.001, effect size = −2.153) treatment sessions, as well as during the 1-month follow-up (p-value = 0.001, effect size = −1.96). The effect sizes were found to be large. The results of the within-group analysis indicated that there was no significant reduction in pain intensity observed within the control group (after 5 sessions: p-value = 1, effect size = 0 after 10 sessions: p-value = 0.65, effect size = 0.1 after month follow-up: p-value = 0.20, effect size = 0.563) (Figs. 11 and 12).

Secondary outcomes

While comparing the intervention group with the control group at the different time points, all secondary outcomes were not significant, except a significant difference reported in the hip adduction ROM one month after the treatment, as displayed in Fig. 13 (Table 6). To determine the differentiation between the two groups, we summarized the primary and secondary outcomes based on the standardized effect size (Cohen's d), as indicated in Fig. 14.

Discussion

To the best of authors' knowledge, this study is the first RCT to evaluate the efficacy of TECAR therapy on athletes experiencing ARGP. The study results demonstrated a statistically significant reduction in pain intensity and increase in hip adduction ROM in the intervention group compared to the control group. The results of between-group analysis showed no significant statistical differences in other secondary outcome measurements. The sample size of the present study is estimated based on the VAS [30]. Therefore, the power of our study in secondary

Table 5 Mean (SD) for primary outcome at each assessment point for between-group mean difference (95% CI) at each assessment point

	Between-group differences		
	5-session	10-session	1 month following
	Intervention-control	Intervention-control	Intervention-control
VAS	0.4 (−1.09 to 1.89)	1.5 (0.001 to 2.99)	1.3 (−0.19 to 2.79)
Unadjusted p-value	0.59	0.050	0.08
Adjusted p-value	0.01	0.001	0.001
Adjusted Cohen's d (95% CI)	−1.09(−0.195 to −1.987)	−2.153(−1.103 to −3.203)	−1.96(−0.944 to −2.978)

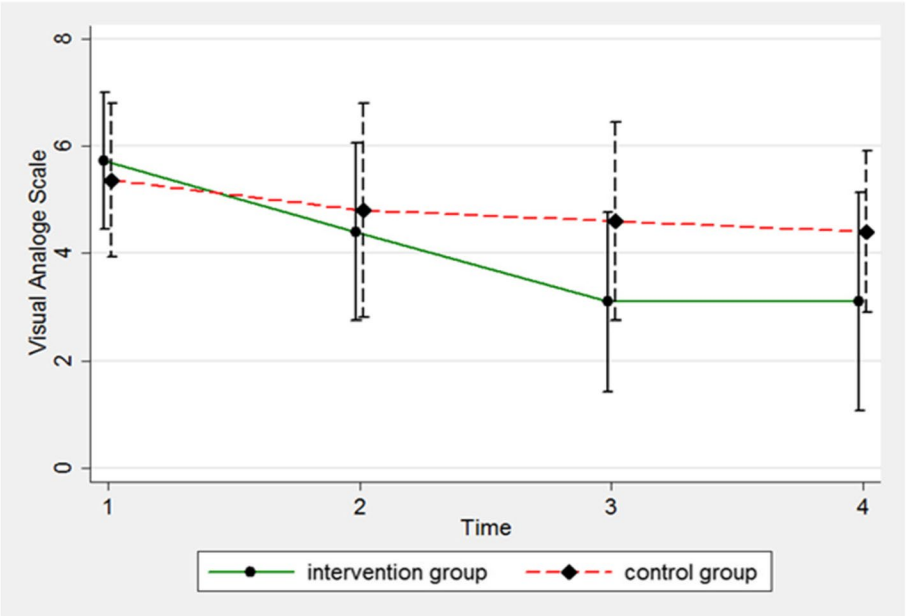

Fig. 11 The unadjusted difference in pain intensity between groups

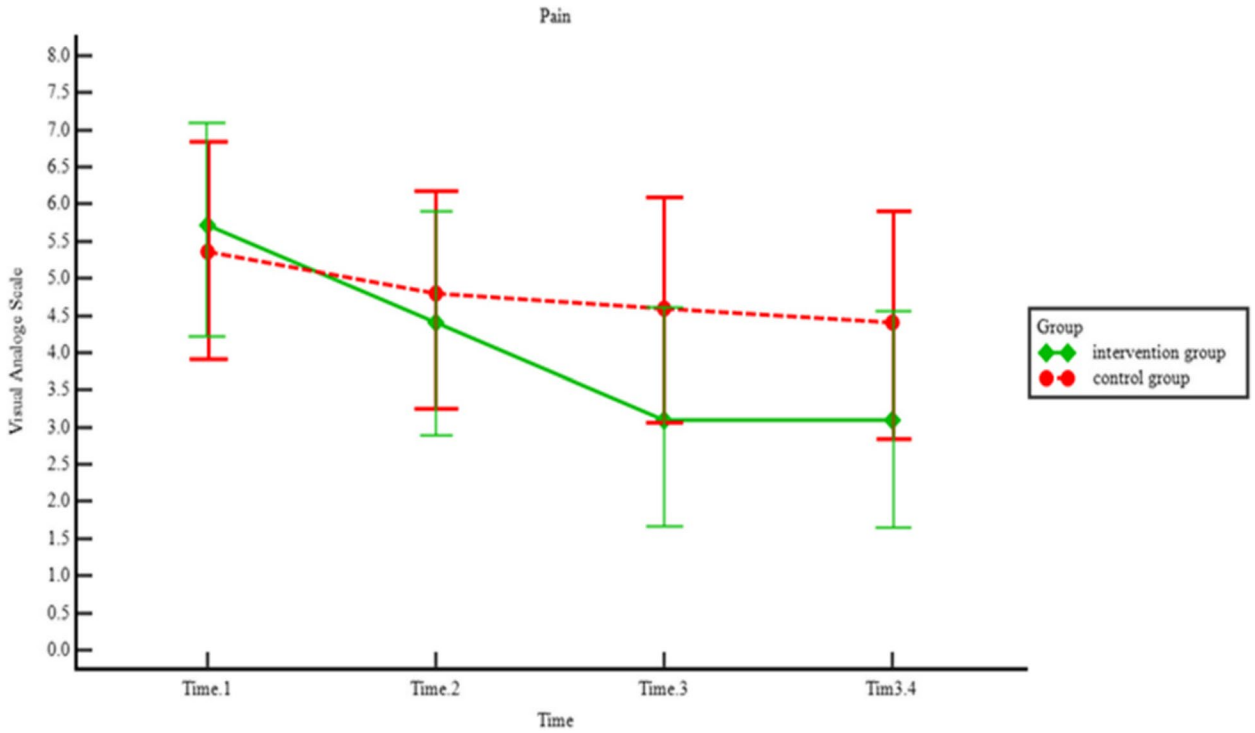

Fig. 12 The adjusted difference in pain intensity between groups

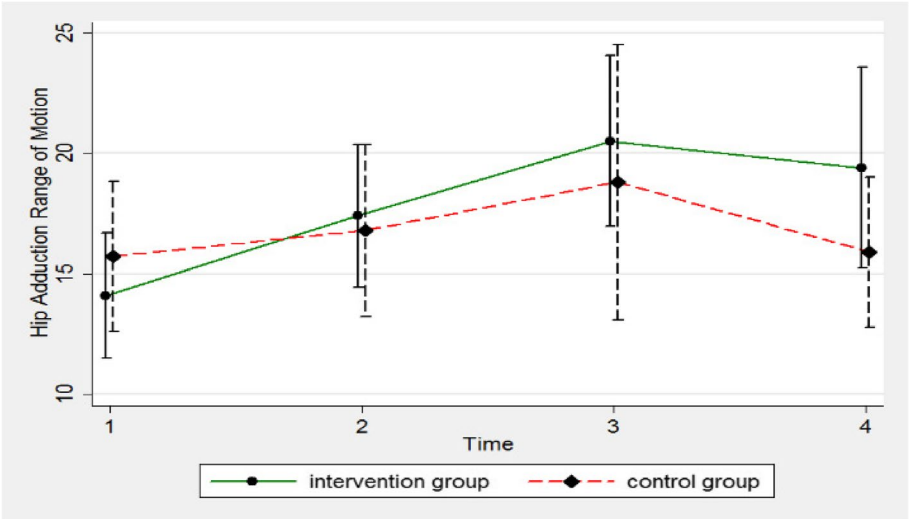

Fig. 13 The difference in hip adduction ROM between groups

outcomes is limited and further studies with larger sample sizes and greater statistical power are required to reach a conclusive result.

Pain intensity

The findings of this study demonstrated that TECAR therapy is an efficacious therapeutic intervention for the management of pain in athletes with ARGP. On the other hand, the intra-group results in the intervention group revealed that the effect size of TECAR therapy was found large after 5 sessions as it was after 10 sessions. This suggests that even short-term use of TECAR therapy may effectively reduce an athlete's pain and facilitate their return to sports. The creation

Table 6 Comparison between groups for secondary outcomes

Outcome	Time	Intervention group [mean (95% CI)]	Control group [mean (95% CI)]	mean difference between group	Cohen's d (95% CI)	*P* value
Adduction ROM	5 sessions	3.3 (−0.08 to 6.68)	1.1 (−2.28 to 4.48)	−0.6 (−3.87 to 2.67)	0.153 (−0.683 – 0.99)	0.71
	10 sessions	6.4 (3.01 to 9.78)	3.1 (−0.28 to 6.48)	−1.7 (−4.97 to 1.57)	0.439 (−0.538—1.144)	0.30
	1 month following	5.3 (1.91 to 8.68)	0.2 (−3.18 to 3.58)	−3.5 (−6.77 to-0.22)	**0.908** (0.030- 1.786)	**0.03**
Abduction ROM	5 sessions	7.6 (2.47 to 12.72)	5.1 (−0.02 to 10.22)	0.2 (−5.50 to 5.90)	−0.029 (−0.865—0.805)	0.94
	10 sessions	10.4 (5.27 to 15.52)	5 (−0.12 to 10.12)	−2.7 (−8.40 to 3.001)	0.400 (−0.443—1.244)	0.34
	1 month following	9.9 (4.77 to 15.02)	5.2 (0.07 to 10.32)	−2 (−7.70 to 3.70)	0.298 (−0.541 – 1.138)	0.48
Adduction strength	5 sessions	5.80 (−6.60 to 18.21)	6.05 (−6.35 to 18.45)	2.80 (−17.31 to22.91)	−0.119 (−0.955—0.717)	0.78
	10 sessions	14.56 (2.15 to 26.97)	3.71 (−8.69 to 16.12)	−8.29 (−28.40to11.82)	0.349 (−0.492—1.191)	0.41
	1 month following	15.17 (2.76 to 27.58)	10.43 (−1.97 to 22.84)	−2.18 (−22.29to 17.93)	0.093 (−0.742—0.93)	0.83
Abduction strength	5 sessions	17.82 (0.14 to 35.51)	11.54 (−6.13 to 29.23)	13.76 (−6.83 to 34.35)	−0.567 (−1.419—0.285)	0.18
	10 sessions	30.86 (13.17 to 48.54)	6.11 (11.56 to 23.80)	−4.70 (−25.30 to 15.89)	0.196 (−0.641—1.033)	0.65
	1 month following	29.39 (11.70 to 47.07)	8.25 (−9.43 to 25.93)	−1.09 (−21.69 to 19.50)	0.046 (−0.788 – 0.882)	0.91
Symptoms	5 sessions	7.5 (−1.30 to 16.30)	1.81 (−6.99 to 10.62)	3.92 (−10.85to 18.70)	−0.226 (−1.064—0.612)	0.59
	10 sessions	15 (6.19 to 23.80)	1.80 (−7.00 to 10.60)	−3.58 (−18.36to 11.19)	0.204 (−0.633—1.042)	0.63
	1 month following	17.88 (9.08 to 26.69)	0.74 (−8.06 to 9.54)	−7.52 (−22.31 to 7.25)	0.434 (−0.410—1.280)	0.31
Pain	5 sessions	2.50 (−7.55 to 12.55)	−1.5 (−11.55 to 8.55)	−2.5 (−15.12 to 10.12)	0.166 (−0.670—1.003)	0.69
	10 sessions	7.25 (−2.8 to 17.30)	−3 (−13.05 to 7.05)	−8.75 (−21.37 to 3.87)	0.588 (−0.265—1.442)	0.17
	1 month following	10 (−0.05 to 20.05)	−2.25 (−12.30 to 7.80)	−10.75 (−23.37 to 1.87)	0.724 (−0.137—1.587)	0.09
physical activity in daily living	5 sessions	1.5 (−9.13 to 12.13)	−0.5 (−11.13 to 10.13)	−6.5 (−20.01 to 7.01)	−0.093 (−0.930—0.742)	0.82
	10 sessions	1.5 (−9.13 to 12.13)	−1 (−11.63 to 9.63)	1 (−12.51 to14.51)	−0.064 (−0.899—0.772)	0.88
	1 month following	8.5 (−2.13 to 19.13)	−1.5 (−12.13 to 9.13)	1.5 (−12.01 to15.01)	0.409 (−0.435—1.253)	0.34
sports and recreational activity	5 sessions	6.66 (−3.21 to 16.53)	3.75 (−6.12 to 13.62)	−2.5 (−22.22to 17.22)	0.106 (−0.729—0.942)	0.80
	10 sessions	14.47 (4.60 to 24.34)	7.18 (−2.68 to 17.06)	−6.87 (−26.60to 12.85)	0.294 (−0.546– 1.134)	0.49
	1 month following	22.91 (13.03 to 32.78)	9 (−0.87 to 18.87)	−13.5 (−33.22 to 6.22)	0.579 (−0.273—1.433)	0.17
participation in physical activities	5 sessions	5 (−7.43 to 17.43)	−5 (−17.43 to 7.43)	−6.25 (−25.24to 12.74)	0.281 (−0.558—1.121)	0.51
	10 sessions	3.75 (−8.68 to 16.68)	−0.05 (−12.48 to 12.38)	−0.05 (−19.04to 18.94)	0.004 (−0.831—0.84)	0.99
	1 month following	10 (−2.43 to 22.43)	2.45 (−9.98 to 14.88)	−3.8 (−22.79to 15.19)	0.170 (−0.666—1.007)	0.69

Table 6 (continued)

Outcome	Time	Intervention group [mean (95% CI)]	Control group [mean (95% CI)]	mean difference between group	Cohen's d (95% CI)	*P* value
quality of life	5 sessions	5 (−4.67 to 14.67)	1 (−8.67 to 10.67)	−2 (−18.59to 14.59)	0.102 (−0.733—0.938)	0.81
	10 sessions	11 (1.32 to 20.67)	4 (−5.67 to 13.67)	−5 (−21.59to 11.59)	0.255 (−0.583—1.095)	0.55
	1 month following	17 (7.32 to 26.67)	4 (−5.67 to 13.67)	−11 (−27.59 to 5.59)	0.562 (−0.289—1.415)	0.19

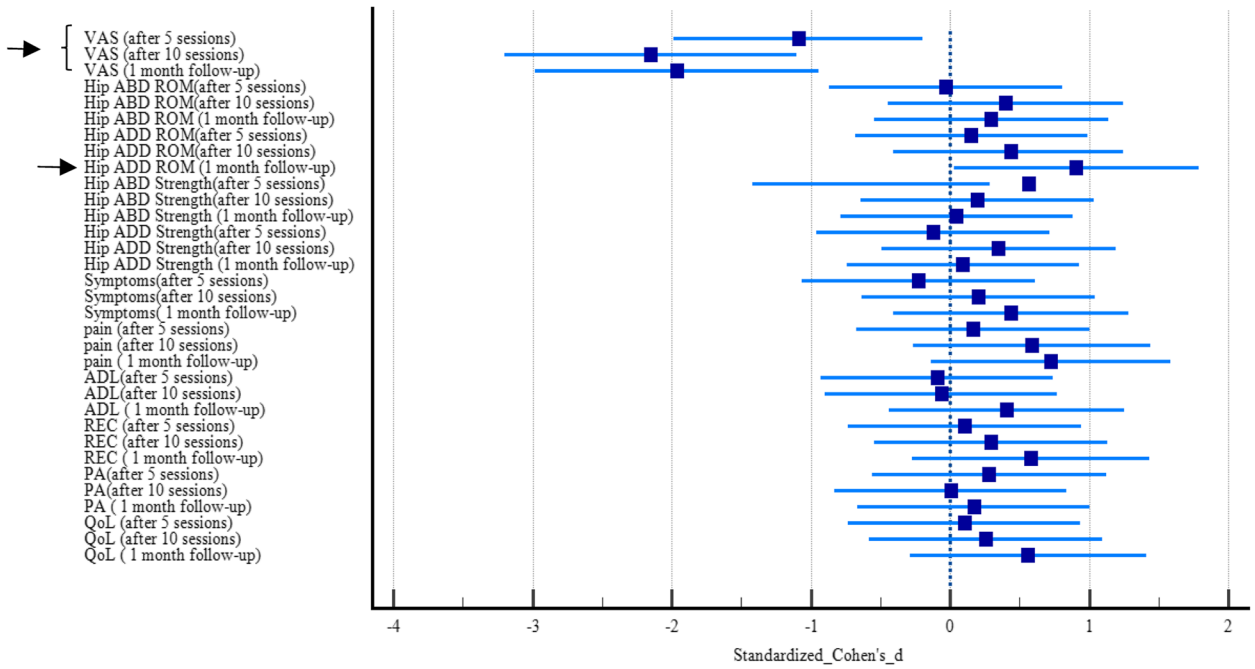

Fig. 14 Standardized effect sizes (Cohen d, 95% CI) for the TECAR therapy group compared with the control group in all outcome measurements

and release of algesic substances, which are themselves sources of pain, occur due to a lack of oxygen to the body tissues. Thus, by elevating the temperature, enhancing the saturation of hemoglobin in the affected regions, and oxygenating the tissue, the therapy could reduce the presence of pain-relieving chemicals in the area and subsequently relieve the pain [14]. Thus, the decline in pain experienced by the intervention group can be attributed to the potential impacts of TECAR therapy. This current study is in line with the review done by Mitie Ida et al. in 2023. Their evaluation analyzed 38 clinical trial publications examining the use of TECAR therapy on body tissues. Their conclusion provides compelling data supporting the effectiveness of TECAR therapy in reducing musculoskeletal pain [13].

Range of motion

The present study found no notable difference in the ROM between the two groups, except for thigh adduction ROM one month after the treatment with a large effect size. Pain can elicit movement changes, for example, by causing muscle spasm to avoid painful activities. Although the presence of changes is discussed. TECAR therapy has been shown to reduce pain. Therefore, you can argue that by reducing pain in the hip adductors, it has helped to increase the ROM in hip adduction [33, 34]. Considering that participants were in the chronic phase of their injury; after reducing the pain and increasing their tissue flexibility through stretching, it took time and the real effects revealed after a month. Moreover, it may be possible to relate the increase of tissue flexibility

to the effect of the TECAR itself. TECAR therapy can alter the viscoelastic characteristics of muscles and collagenous tissues by raising the tissue temperature. Conversely, by enhancing blood flow to the muscle and decreasing fluid accumulation that leads to muscle hardness, flexibility is enhanced [15, 35, 36]. Joint flexibility can only be dependent on tissues that cross the joint (e.g. fascia) [37]. Changes in the fascia's properties (e.g. altered stiffness) might therefore restrict muscular extensibility [37]. Now, it is possible in the present study, among the factors that affect flexibility, TECAR did not have an effect on the fascia, which subsequently did not affect the extensibility of the adductor muscles, and no significant changes were seen in the ROM of abduction. However, due to lack of sufficient evidence for the mechanism of the effect of pain on the ROM limitation and lack of resources to examine flexibility and elasticity separately, we cannot solely rely on these arguments to analyze the obtained results. Therefore, conducting studies with higher statistical power and more detailed examination of the factors involved in changes in ROM can help. The study conducted by Szabo et al. examined the impact of TECAR therapy on enhancing knee flexion following anterior cruciate ligament surgery in athletes. The study found that the TECAR therapy group achieved a faster ideal knee flexion range of motion compared to the group that underwent routine physiotherapy treatment [38]. Finding of this study align with the current stud. According to the research by Yeste-Fabregat et al., the sole use of TECAR therapy had no impact on the ankle dorsiflexion range of motion in professional basketball players. However, when TECAR therapy was combined with joint mobilizations, it proved to be helpful [39]. Regardless of the different tissues examined, the outcomes of the present investigation are incongruent with the latter study, which can be attributed to variations in the dosage of the therapy applied, including the number of sessions and the modulations of the TECAR device.

Strength

The intergroup analysis revealed no significant difference between the two groups. Due to the lack of statistical significance and the small effect sizes, it can be concluded that the use of TECAR therapy for the strength variable has no practical utility. One of the key mechanisms through which TECAR therapy enhances muscle temperature and it changes has been shown to affect many factors determining the strength: blood flow, oxygen uptake, removal of metabolic byproducts and resting membrane potential [14, 40, 41]. In the prior studies that found had an effect on strength, the studied conditions were very different from our research, such as knee osteoarthritis and delayed-onset muscle soreness (DOMS) in athletes [40, 42]. In a 2022 study conducted by Nakamura et al., the application of TECAR therapy was found to be efficacious in enhancing the strength of the knee's extensor muscles after DOMS, which conflicts with the findings of the current investigation [40]. The assessment was conducted 48 h after eccentric exercise (one intervention session). The duration of TECAR usage was greater in comparison to the current investigation (30 min). Additionally, a larger sample size of 28 individuals was evaluated. These factors have the ability to influence variations in the outcome. Yet, conducting studies with higher statistical power can potentially lead to different results.

HAGOS questionnaire

The TECAR therapy raises temperature and enhances hemoglobin saturation in affected areas, thereby improving oxygen supply to the tissue, and also modifies the viscoelastic properties of muscles plus collagen-rich tissues. We hypothesized that it could potentially influence the subscales of the HAGOS questionnaire [14, 35, 36]. Nevertheless, the intergroup analysis did not reveal any significant differences. Furthermore, the calculated effect sizes were not significant, indicating that TECAR therapy has no practical significance for these variables. According to the International Classification of Functioning, Disability and Health (ICF) model, it may be possible to claim that until a significant effect on body structure and function such as strength was not achieved, matters such as a participation in physical activities or quality of life are not affected.

Limitations

One of the limitations of our study is the relatively small sample size, which may have reduced the statistical power to detect significant differences in certain outcomes. Although our study was designed to explore the efficacy of TECAR therapy, the sample size may not have been large enough to achieve statistical significance in some of the secondary outcome measures. One of the key limitations of this study is the lack of control over the participants' activities between the last treatment session and the follow-up session one month later. During this period, participants may have engaged in various physical activities or resumed their regular training, which could have influenced recovery outcomes. This lack of control introduces the possibility that external factors, such as the intensity or type of physical activity performed during this month, may have confounded our findings. As a result, the changes observed at the one-month follow-up may not solely reflect the effects of TECAR therapy. Another limitation is the lack of functional tests to control for the possibility of re-injury or functional decline before and after participants return to sport. While the

focus of our study was on recovery and return to sport, we did not directly assess the risk of re-injury or monitor performance levels during the follow-up period. Furthermore, all of our participants were male to minimize confounding variables, especially considering the small sample size our results. Finally, the present study did not account for or measure certain potential confounding variables, such as medication use or tear characteristics, in its methods or statistical analysis.

Future studies should aim to include a larger sample size to increase statistical power and more confidently detect differences, particularly for secondary outcomes. It is advisable to track injury-related activities. Functional tests can be measured before returning to sports or performance evaluations after a period of returning to sports, so that the risk of re-injury can be more closely monitored. To evaluate the efficacy of TECAR therapy across genders, future research should include a balanced sample of both male and female participants and consider incorporating these variables into their methods to better isolate the effects of the interventions.

Conclusion

The results of this RCT suggest TECAR therapy could effectively mitigate pain and increase the hip adduction ROM in athletes with ARGP. Therefore, it is recommended to consider TECAR therapy into the treatment protocol for athletes with ARGP for future investigations.

Abbreviations

TECAR	Capacitive and resistive energy transfer
ARGP	Adductor-related groin pain
RCT	Randomized controlled trial
VAS	Visual Analogue Scale
ROM	Range of motion
MCID	The minimal clinically important difference
ANOVA	Analysis of variance
ANCOVA	Analysis of covariance
SMD	The standardized mean difference

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Authors' contributions

SN: 1. Principal investigator, 2. Therapist of the study; 3. Manuscript's writer; SS: 1. Trial coordinator, 2. Study design and methodology; JS: 1. Study design and methodology; HA:1. Recruitment coordinator; AT:1. Statistical analysis, 2. Study design and methodology. This trial was performed under the supervision of all the mentioned authors and all of them read and approved the final manuscript.

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Data availability

Data is provided within the supplementary information files. Dataset will be made available by sending a justifiable email to the corresponding author (SS).

Declarations

Ethics approval and consent to participate

This study was conducted in compliance with the ethical principles set forth in the Declaration of Helsinki. The trial was approved by the Ethics Committee of Iran University of Medical Sciences (Reference number: IR.IUMS.REC.1401.076). The informed consent form was designed in accordance with the standards of this committee. All participants were informed about the nature of the intervention and voluntarily signed the consent form prior to their participation in the study.

Consent for publication

The model has given informed consent for the use of the images in the article. The consent form was created based on the template provided on the journal's website.

Competing interests

The authors declare no competing interests.

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