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Research Article

Comparing the Effect of Capacitive and Capacitive-Resistive TECAR Therapy on Hamstring Muscle Flexibility in Individuals with Hamstring Shortness: A Randomized Controlled Trial

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Abstract

Background: Flexibility refers to the ability of muscles and joints to move freely through their full range of motion. It is a key component of physical fitness, contributing to good posture, injury prevention, and enhanced overall movement quality. The hamstring muscle is particularly prone to injury due to reduced flexibility. Deep heat modalities are commonly used to improve muscle flexibility. Previous studies suggest that trans-electrical capacitive and resistive (TECAR) therapy offers an effective alternative for producing heat in deep tissues.

Objectives: This study aims to compare the effects of capacitive TECAR therapy (CTT) and capacitive-resistive TECAR therapy (CRTT) on hamstring muscle flexibility in individuals with hamstring shortness.

Methods: This randomized, double-blinded clinical trial involved 33 individuals with hamstring shortness. Participants were randomly allocated into three groups: The CTT group (11 individuals), the CRTT group (11 individuals), and the sham group (11 individuals). Each participant underwent five intervention sessions on alternate days. The straight leg raising (SLR) and passive knee extension (PKE) tests were used to assess hamstring flexibility before the treatment and after the fifth session.

Results: A total of 33 participants (mean age: 24.85 ± 4.82 years; 16 males and 17 females) completed the study. Both the CTT and CRTT groups showed significant improvements in SLR and PKE by the fifth session ($P < 0.001$). However, no significant differences were observed between the CTT and CRTT groups in terms of their effectiveness ($P > 0.999$).

Conclusions: Both CTT and CRTT were effective in improving hamstring flexibility compared to the sham treatment, demonstrating their clinical utility. The lack of significant differences between the two modalities suggests that either can be selected based on clinical judgment or patient preference. Further research is recommended to evaluate the long-term effects of these therapies.

Keywords: Hamstring Shortness, High-Frequency Diathermy, TECAR Therapy, Capacitive-Resistive TECAR Therapy, Thermo Therapy

1. Background

Flexibility has long been recognized as a critical component of physical fitness and general well-being (1). Research on flexibility gained momentum in the early 20th century, primarily due to the rise in orthopedic problems following World War I and the earlier polio epidemic (2). Flexibility, in simple terms, is defined as "the range of motion that a joint or a group of joints can achieve" (1). This range of motion varies across different joints and is influenced by several factors (3). It is widely acknowledged that muscles and ligaments play a vital role in determining flexibility, whereas tendons are considered to have significantly less influence (3). The stretchability of muscles and connective tissues, particularly ligaments, is essential for maintaining flexibility (1). Since the elasticity and extensibility of these tissues directly affect joint movement, this study also defines flexibility in terms of the length of muscle and connective tissue. Consequently, discussions about flexibility will focus on either the range of joint movement or the length of muscle and connective tissue.

Hamstring shortness is a prevalent musculoskeletal issue observed in athletes, students, and university populations, often resulting in reduced flexibility, an increased risk of injury, and decreased athletic performance (4, 5). The hamstring muscles are considered among the most important in the body, as they cross two joints and attach to the pelvic bone (6). This muscle group comprises the semimembranosus, semitendinosus, and biceps femoris, and tightness in these muscles is increasingly common, particularly among athletes (7). As flexors, hamstrings can become shortened without any specific pathological cause, primarily due to repetitive movements that limit their full range of motion (8). Such shortening directly affects knee function and indirectly impacts the hip and ankle joints (4).

The thermotherapy method is commonly employed to enhance flexibility and restore lost range of motion (9). Heat therapy promotes the expansion of collagen tissue and reduces tissue viscosity (10, 11). Trans-electrical capacitive and resistive (TECAR) therapy is a form of endogenous thermotherapy that generates heat in both superficial and deep tissues (12). This treatment is based on the concept of diathermy, which involves the generation of heat through high-frequency currents passing through tissues (13, 14).

High-frequency diathermy (HFD) produces heat by inducing molecular vibrations in deeper tissues. Studies have demonstrated that HFD improves blood flow and tissue elasticity, leading to muscle relaxation (15). It also increases the local tissue temperature to 40°C - 45°C, which raises the pain threshold, alleviates discomfort, and facilitates effective stretching while minimizing the risk of injury (16, 17). Traditional HFD devices, however, are often cumbersome due to their large, fixed electrodes. In contrast, TECAR devices provide greater ease of use, allowing therapists to apply treatment more dynamically (18, 19). These devices employ the TECAR technique, operating at a long-wave radio frequency of 0.5 MHz, and can deliver both capacitive energy transfer for surface-level treatment and resistive energy transfer for deeper tissue engagement (20).

Capacitive TECAR therapy (CTT) is particularly effective for soft tissue injuries, as it uses coated electrodes to rapidly transmit heat to the skin and surrounding tissues, including muscles and cartilage (21). This method primarily targets tissues with higher electrolyte content and lower impedance (i.e., those rich in water). In contrast, resistive TECAR therapy (RTT) employs uncoated electrodes to gradually heat deeper structures. The RTT focuses on tissues with higher resistance, such as bones, tendons, and joints (22).

Previous research has shown that HFD enhances blood circulation and flexibility, promoting muscle relaxation (18, 19). It also elevates local tissue temperatures to 40°C - 45°C, which increases pain thresholds, reduces discomfort, and enables safe stretching (21). Moreover, TECAR therapy is widely recognized as an effective modality for improving muscle flexibility and relieving pain in individuals with hamstring shortness (23). However, few studies have examined TECAR therapy as an innovative form of heat therapy. Most of these studies have primarily utilized the capacitive method to evaluate flexibility (19, 23), despite the fact that the capacitive and resistive methods target different tissue elements (the capacitive method affects contractile elements, while the resistive method impacts non-contractile elements) (21, 22).

2. Objectives

Additionally, the majority of prior studies involved only single-session interventions and focused on parameters such as blood circulation and oxygen saturation in the area, with limited attention to flexibility as a clinical outcome (18, 19, 24). To address these gaps, we designed a randomized controlled trial to compare the effects of CTT and CRTT over five sessions on muscle flexibility in individuals with hamstring shortness. We hypothesize that CRTT will demonstrate superior effectiveness in improving hamstring flexibility.

3. Methods

3.1. Trial Design

This research, conducted at the Rehabilitation Faculty of Tabriz University of Medical Sciences between July 2023 and September 2023, was a double-blind, randomized controlled trial. The ethics committee of Tabriz University of Medical Sciences approved the study procedures (IR.TBZMED.REC.1402.015), and the trial was registered in the Iranian Registry of Clinical Trials (IRCT20210316050727N3).

3.2. Study Participants

Initially, 37 healthy individuals participated in the study, but four withdrew as they chose not to continue. Therefore, data from 33 participants were analyzed (Figure 1). All participants were fully informed about the study's purpose and provided written informed consent.

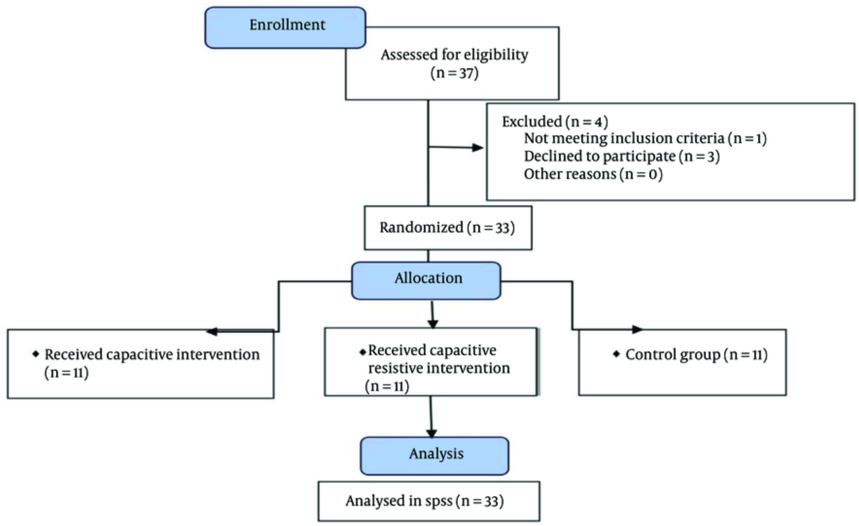

Figure 1. Flow chart of hamstring shortness during trans-electrical capacitive and resistive (TECAR) therapy

The study included 16 men and 17 women, aged 18 to 35 years. Inclusion criteria were based on a limited range of motion in the hamstring muscles, defined as less than 160 degrees in the passive knee extension (PKE) test and less than 70 degrees in the straight leg raising (SLR) test, as supported by previous studies (19, 24-27).

3.3. Individuals

Participants with any of the following conditions were excluded from the study: Spine injury (28); history of whiplash neck injury; lower limb fracture or surgery (28); history of disc herniation; previous muscle-tendon or neuro-motor injury in the hamstring within the past year (23); numbness, paresthesia, or reduced sensation of pain or heat in the application area (23); engagement in lower limb stretching exercises in the last six months; or being physically active in the past three months.

3.4. Participant Flow

The study included 33 participants with hamstring shortness, with 11 participants in each group, as shown in Figure 2. Participants were evenly distributed between males and females, with a mean age range of 18 - 35 years.

3.5. Recruitment

The study was conducted between July 2023 and September 2023. Recruitment was discontinued once the required number of participants was reached.

3.6. Interventions

The participants were divided into the following groups.

3.6.1. Capacitive Trans-Electrical Capacitive and Resistive Therapy Group

Participants in this group received five sessions of CTT, each lasting 20 minutes, administered every other day.

3.6.2. Capacitive-Resistive Trans-Electrical Capacitive and Resistive Therapy Group

Participants in this group received five sessions of TECAR capacitive-resistive therapy every other day. Each session consisted of 10 minutes of CTT followed immediately by 10 minutes of RTT.

3.6.3. Sham Group

Participants in this group did not receive an active intervention. The TECAR device was turned on but the start button was not pressed. The device was used for 20 minutes in the same manner as for the intervention groups.

For all groups, the TECAR device was set to continuous mode, and either capacitive or resistive mode was selected based on the group assignment.

Figure 2. Passive knee extension (PKE) measurement

3.7. Outcome Measures

The range of motion for the knee and hip was assessed using the PKE and SLR tests, both of which are recognized for their high reliability. The PKE test has an intraclass correlation coefficient (ICC) of 0.99, while the SLR test has an ICC of 0.92 - 0.95 (24-27).

Passive knee extension and SLR measurements were taken on the same day before the intervention began and immediately after the fifth session in all three groups. Baseline data, including age, body mass, height, gender, and Body Mass Index (BMI), were recorded before the intervention.

3.7.1. Passive Knee Extension Measurement

The PKE test was performed to evaluate the length of the hamstring muscles. A universal goniometer was used to measure the knee extension angle. Participants lay in a supine position with their pelvis and opposite

Figure 3. Straight leg raising (SLR) measurement

thigh secured by straps to maintain the natural lumbar spine curve and prevent compensatory movements.

The test began with the participant's hip and knee flexed at 90°, and the ankle relaxed (neither dorsiflexed nor plantarflexed). The examiner extended the knee until the first sensation of stretch was felt, at which point the knee extension angle was recorded. The goniometer's axis was aligned with the lateral epicondyle of the femur. The stable arm was positioned laterally near the femoral epicondyle, while the movable arm was aligned with a line connecting the fibular head to the lateral malleolus.

This procedure was repeated three times for each participant, and the average result was recorded as a measure of hamstring flexibility (Figure 2) (25, 26).

3.7.2. Straight Leg Raising Measurement

The SLR test was performed with the participant lying supine on an examination table, with the opposite limb secured using a belt. The participant was instructed to lift their leg, keeping the knee straight, until they felt the first stretch in the back of the leg.

The goniometer's axis was positioned on the greater trochanter of the femur, with the stable arm placed parallel to the examination table along the body and the movable arm aligned with a line extending from the greater trochanter to the lateral epicondyle of the femur.

The angle was measured three times, and the average was reported for analysis (Figure 3) (26, 27).

3.8. Randomization

A randomized controlled trial design was employed to ensure the validity of our findings. Participants were randomly assigned to either the intervention or control groups using a computer-generated random number sequence. This method minimized selection bias and ensured that each participant had an equal chance of being allocated to either group.

After obtaining informed consent, each participant was assigned a unique identification number. The randomization sequence was generated prior to the start of the trial and securely stored until all participants were enrolled. Once a participant was enrolled, their identification number was entered into

Table 1. Demographics of Individuals with Hamstring Shortness Undergoing Trans-Electrical Capacitive and Resistive Therapy [a]

Variables	Group			P-Value
	CTT (n = 11)	CRTT (n = 11)	Sham (n = 11)	
Female	5 (45.6)	5 (45.6)	7 (63.6)	0.616 [b]
Age (y)	26.73 ± 5.65	24.18 ± 4.95	23.64 ± 3.44	0.284 [c]
Height (cm)	171.20 ± 6.99	172.91 ± 8.40	167.18 ± 8.73	0.249 [c]
BMI (kg/m ^{2})	23.17± 0.86	23.10 ± 0.51	22.87 ± 0.86	0.298 [c]
SLR (cm)	54.61 ± 3.96	55.75 ± 3.49	53.35 ± 3.69	0.510 [c]
PKE (cm)	118.45 ± 4.89	118.51 ± 4.76	118.22 ± 5.55	0.990 [c]

Abbreviations: SLR, straight leg raising; PKE, passive knee extension; TECAR, trans-electrical capacitive and resistive; BMI, Body Mass Index; CTT, capacitive TECAR therapy; CTT, capacitive TECAR therapy; CRTT, capacitive resistive TECAR therapy.

[a] Values are expressed as frequency (%) or mean ± standard deviation.

[b] Chi-square test.

[c] One-way ANOVA.

the randomization software, which provided the group assignment.

This process was conducted by a research assistant who was not involved in participant recruitment or data collection. Treatment assignments were placed in sealed, opaque envelopes labeled with the corresponding participant identification numbers. These envelopes did not disclose the treatment details and were stored in a secure location accessible only to the research assistant managing the randomization.

To maintain blinding, the individuals responsible for recruiting participants were unaware of the treatment assignments. Both participants and investigators remained blinded to treatment allocation until the study was completed, ensuring unbiased outcomes and reporting.

3.9. Sample Size

To determine the sample size, initial data, including the mean and standard deviation of the SLR variable, were obtained from the study by Yolanda Castellote-Caballero et al. (28). Similarly, data for the PKE variable were taken from the study by Shadmehr et al. (29). Based on a 95% confidence level, 80% test power, and a two-tailed test, the minimum sample size required for each group was calculated to be 9 participants for the SLR variable and 8 participants for the PKE variable. To account for a potential 20% dropout rate, the final sample size was increased to 11 participants per group.

3.10. Statistical Analysis

Frequency and percentage were used to describe qualitative variables, while mean and standard deviation were applied to quantitative variables. The Shapiro-Wilk test confirmed that all variables followed a normal distribution. Considering the small sample size, a general linear model with Bonferroni correction for pairwise comparisons was used to analyze both within-group and between-group differences. All statistical analyses were conducted using SPSS (statistical package for the social sciences, version 22.0, IBM Corp.), with a P-value of less than 0.05 considered statistically significant.

4. Results

A total of 33 individuals, with a mean age of 24.85 ± 4.82 years, participated in the study. The gender distribution was approximately balanced, with 16 males and 17 females. Further details regarding the participants' baseline characteristics are presented in Table 1. The results indicate that the study groups were comparable in terms of demographic characteristics and baseline values, as shown in Table 1.

The within-group pairwise comparisons revealed that both CTT (mean change: 8.22 ± 0.71, P < 0.001) and CRTT (mean change: 8.11 ± 0.71, P < 0.001) significantly improved SLR performance by the fifth session. Similarly, participants experienced substantial improvements in PKE with CTT (mean change: 8.49 ± 0.53, P < 0.001) and CRTT (mean change: 10.10 ± 0.53, P < 0.001). However, the mean changes in SLR (P = 0.759) and PKE (P = 0.782) were not statistically significant for the sham group, as detailed in Table 2.

Regarding between-group comparisons, the improvement in SLR for the CTT group (mean difference: 9.25 ± 1.89, P < 0.001) and the CRTT group (mean difference: 10.26 ± 1.89, P < 0.001) was significantly

Table 2. Within-Group Comparison of Leg Raising and Knee Extension in Hamstring Shortness During Transelectrical Capacitive and Resistive Therapy [a,b]

Variables	Groups		
	CTT (n = 11)	CRTT (n = 11)	Sham (n = 11)
SLR			
Session 0	54.62 ± 3.97	55.75 ± 3.47	53.38 ± 3.71
Session 5	62.84 ± 6.16	63.75 ± 2.24	53.60 ± 3.97
Mean changes	8.22 ± 0.71	8.11 ± 0.71	0.22 ± 0.71
95% CI	(6.78 to 9.66)	(6.67 to 9.55)	(-1.23 ± 1.61)
P-value	< 0.001	< 0.001	0.759
PKE			
Session 0	118.46 ± 4.90	118.52 ± 4.77	118.23 ± 5.56
Session 5	126.94 ± 3.58	128.62 ± 5.37	118.38 ± 6.00
Mean changes	8.49 ± 0.53	10.10 ± 0.51	0.15 ± 0.48
95% CI	(97.42 to 9.55)	(9.04 to 11.17)	(-0.92 to 1.22)
P-value	< 0.001	< 0.001	0.782

Abbreviations: SLR, straight leg raising; PKE, passive knee extension; CRTT, capacitive resistive TECAR therapy; CTT, capacitive TECAR therapy.

[a] Values are expressed as mean ± standard deviation.

[b] The results are based on generalized linear model.

greater than that observed in the sham group. Although participants in the CRTT group demonstrated a greater improvement in SLR compared to those in the CTT group (mean difference: 1.02 ± 1.89), this difference was not statistically significant (P > 0.999), as shown in Table 3 and Figure 4.

The increase in PKE was significantly greater in both intervention groups compared to the sham group, with a mean difference of 8.56 ± 2.16 for the CTT group versus the sham group (P < 0.001) and a mean difference of 10.24 ± 2.16 for the CRTT group versus the sham group (P < 0.001). The improvement in PKE for the CRTT group was approximately 1.68 ± 2.16 greater than that of the CTT group; however, this difference was not statistically significant (P > 0.999), as indicated in Table 3 and Figure 5.

5. Discussion

The primary objective of this study was to evaluate the effectiveness of CTT and CRTT on hamstring muscle flexibility in individuals with hamstring shortness. The results demonstrated that both CTT and CRTT significantly improved flexibility compared to the sham treatment, with no substantial difference found between the two TECAR modalities.

5.1. Implications of Findings

The improvement in flexibility observed in both TECAR groups aligns with existing literature that highlights the importance of heat application in enhancing muscle elasticity and joint range of motion. Heat therapy has long been recognized for its ability to increase tissue temperature, which can lead to improved blood flow, reduced muscle stiffness, and enhanced viscoelastic properties of muscles (30, 31). The findings suggest that TECAR therapy, whether capacitive or resistive, effectively utilizes these principles, making it a valuable tool in rehabilitation settings.

The lack of a significant difference between CTT and CRTT indicates that both modalities may activate similar physiological mechanisms, leading to improvements in flexibility. This is noteworthy, as it suggests that practitioners can choose either modality based on patient preference, availability of equipment, or specific clinical contexts without compromising treatment outcomes. It is possible that a greater number of sessions or a longer treatment duration could reveal differences between the two groups.

Additionally, the absence of a placebo effect in the sham group reinforces the notion that TECAR therapy produces tangible benefits, emphasizing its potential role in therapeutic interventions for musculoskeletal issues. The underlying mechanisms by which TECAR therapy enhances flexibility can be attributed to several factors. The capacitive mode primarily targets superficial tissues, promoting increased circulation and reducing muscle tension, while the resistive mode penetrates deeper tissues, potentially affecting muscle fibers and connective tissues more directly (32). Both modes generate heat through different mechanisms,

Table 3. Between-Group Comparison of Leg Raising and Knee Extension in Hamstring Shortness During TECAR Therapy [a,b]

Variables	Groups		
	CTT vs. CRTT	CTT vs. Sham	CRTT vs. Sham
SLR			
Mean difference	1.02 ± 1.85	9.25 ± 1.87	10.26 ± 1.89
95% CI	(-3.76 to 5.80)	(4.47 to 14.03)	(5.48 ± 15.44)
P-value	0.999 <	< 0.001	< 0.001
PKE			
Mean difference	1.68 ± 2.16	8.56 ± 2.11	10.24 ± 2.14
95% CI	(-3.06 to 14.06)	(3.06 to 14.06)	(4.74 to 15.74)
P-value	0.999 <	< 0.001	< 0.001

Abbreviations: SLR, straight leg raising; PKE, passive knee extension; CRTT, capacitive resistive TECAR therapy; CTT, capacitive TECAR therapy.

[a] Values are presented as mean ± standard deviation.

[b] The results are based on generalized linear model.

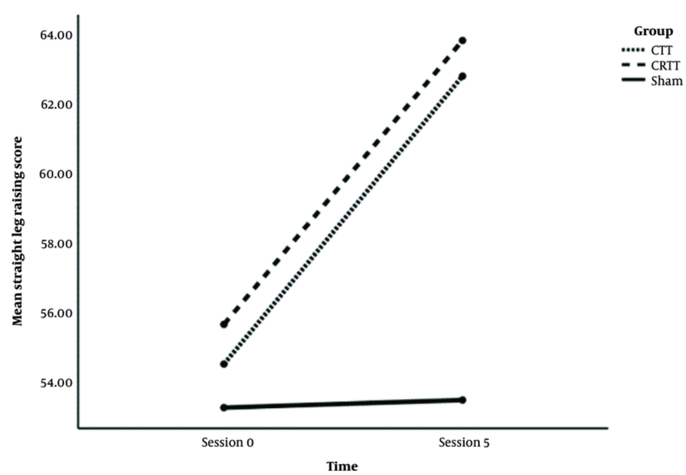

Figure 4. Mean changes in straight leg raising (SLR) score in hamstring shortness during Transelectrical capacitive and resistive (TECAR) therapy

which may synergistically contribute to improved flexibility.

Moreover, the thermal effects induced by TECAR therapy could stimulate the production of collagenase, an enzyme that aids in the remodeling of collagen fibers within the muscles and tendons. This remodeling process may facilitate greater extensibility of the hamstring muscles over time (33, 34). The ability to achieve significant flexibility gains within just five sessions is particularly noteworthy, as it highlights the potential for these therapies to expedite recovery and enhance functional mobility.

The implications of this study extend beyond academic interest and have practical significance for clinicians working with populations at risk for hamstring injuries or those involved in rehabilitation programs. An important aspect of any therapeutic intervention is patient adherence and experience. The ease of application and comfort level associated with CTT and CRTT could significantly influence patient compliance. As healthcare systems increasingly focus on cost-effectiveness, conducting economic evaluations of CTT and CRTT would be beneficial.

Assessing the cost per unit of flexibility gained or the overall impact on recovery time could provide valuable insights for healthcare providers and insurance companies. Both CTT and CRTT work by delivering radiofrequency energy to tissues, resulting in deep

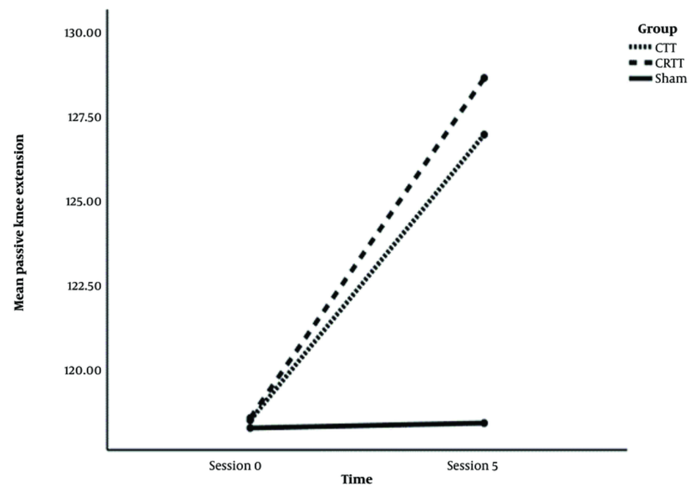

Figure 5. Mean changes in passive knee extension (PKE) score in hamstring shortness during trans-electrical capacitive and resistive (TECAR) therapy

heating (31). This thermal effect promotes increased blood flow, which can enhance tissue metabolism and accelerate healing (35). The heat generated can also facilitate collagen remodeling in soft tissues, which is crucial for restoring flexibility and function (18). The electromagnetic fields produced can stimulate cellular activity, enhancing the repair processes in injured tissues (36).

These therapies may also help modulate pain through the gate control theory of pain, potentially leading to an improved range of motion (24, 37). Athletes often experience muscle strains and injuries that require effective rehabilitation. Capacitive TECAR therapy and CRTT can be integrated into recovery protocols to expedite healing and restore flexibility (22). These therapies can also be used as part of warm-up routines to enhance muscle elasticity and reduce the risk of injuries during performance.

Patients with chronic joint conditions, like osteoarthritis, may benefit from improved flexibility and reduced pain associated with CTT and CRTT (15). These therapies could provide relief for individuals suffering from fibromyalgia by reducing muscle stiffness and enhancing overall mobility (38). Comparing findings from studies on CTT and CRTT with other therapeutic modalities can offer a broader understanding of their effectiveness in enhancing flexibility and promoting recovery. Studies have shown that CTT and CRTT can significantly reduce pain levels in patients with musculoskeletal disorders (15, 17, 24).

Comparatively, traditional modalities like ultrasound therapy have also been shown to reduce pain but often require longer treatment durations to achieve similar results (39). A meta-analysis indicated that while ultrasound is effective, its efficacy is sometimes less pronounced than that of radiofrequency-based therapies (40). Research has shown that both CTT and CRTT can enhance flexibility and range of motion, particularly in athletes recovering from injuries (22, 41). One study demonstrated significant improvements in joint mobility among participants who underwent TECAR therapy compared to those who received conventional physiotherapy.

Manual therapy techniques, such as myofascial release and stretching, have also been shown to improve flexibility (42). However, some studies suggest that the deep heating effect of TECAR therapy may result in more substantial and longer-lasting improvements in flexibility than manual techniques alone (23, 43). Several studies have reported that patients undergoing CTT and CRTT experience shorter recovery times from injuries (33, 44). In comparison, traditional rehabilitation methods, including rest and ice therapy, often result in longer recovery periods. A systematic review highlighted that while rest is essential for acute injuries, integrating active modalities like TECAR therapy can expedite recovery (11, 45).

Patient satisfaction rates for CTT and CRTT are generally high, attributed to the non-invasive nature and perceived benefits of the therapy. Patients report feeling more engaged and motivated during treatment sessions.

In contrast, some patients may find traditional therapies, such as electrotherapy or passive modalities, less engaging, which can lead to lower compliance rates. Studies indicate that active therapies tend to foster better patient engagement and adherence (46). The significant enhancement in hamstring flexibility observed with both CTT and CRTT underscores the potential of these modalities as effective interventions in rehabilitation settings. Improved flexibility can facilitate better movement patterns, reduce the likelihood of muscle strains, and enhance overall athletic performance.

For clinicians, incorporating these therapies into rehabilitation protocols could lead to more efficient recovery processes for patients experiencing tightness or stiffness in the hamstrings. Both CTT and CRTT offer non-invasive alternatives to traditional methods, such as manual stretching or more invasive procedures like surgery. The ability to achieve significant improvements in flexibility without resorting to invasive techniques can enhance patient satisfaction and adherence to treatment plans. This is particularly relevant for populations that may be apprehensive about more invasive interventions or those with contraindications for certain therapies.

The lack of a substantial difference between CTT and CRTT suggests that clinicians can tailor treatments based on individual patient preferences or specific clinical scenarios without compromising effectiveness. This flexibility allows for a more personalized approach to rehabilitation, which is increasingly recognized as critical for optimizing outcomes. Patients may respond better when they feel their treatment aligns with their comfort and preferences.

These results advocate for the integration of TECAR therapies into broader rehabilitation frameworks. For instance, combining these treatments with strengthening exercises, proprioceptive training, and functional movement assessments could yield synergistic effects, further enhancing flexibility and overall muscle function.

5.2. Conclusions

The findings demonstrate that both CTT and CRTT yield promising results in pain management, flexibility enhancement, and recovery times. Compared with traditional therapeutic modalities, TECAR therapies often provide quicker results and higher patient satisfaction. However, ongoing research is essential to establish the full scope of benefits for individuals undergoing rehabilitation. Given the high prevalence of hamstring injuries in athletes and individuals with sedentary lifestyles, effective interventions that enhance flexibility are crucial for injury prevention and performance optimization (47, 48). The results also support the integration of TECAR therapy into broader rehabilitation frameworks.

5.3. Limitations

This study has several limitations. First, the sham group was not completely blinded, so it is uncertain whether participants could distinguish between the real and sham interventions. Second, potential impairments in other components of the kinetic chain were not evaluated within the inclusion criteria. Therefore, future studies should include more intervention sessions and follow-up sessions to assess the long-term effects of TECAR therapy, such as the durability of its impact on flexibility, pain reduction, inflammation control, and performance improvement.

Footnotes

Authors' Contribution: Z. M., A. S., J. A., and B. A.: Study design; Z. M. and A. S.: Data collection; J. A. and Z. M.: Data analysis; Z. M.: Writing-original draft; J. A., Z. M., and A. S.: Writing-review & editing.

Clinical Trial Registration Code: IRCT20210316050727N3 .

Conflict of Interests Statement: There are no conflicts of interest related to this research. All authors have disclosed any potential conflicts of interest, financial or otherwise, that could influence the results or interpretation of the study.

Data Availability: Data are available upon reasonable request to the corresponding author.

Ethical Approval: IR.TBZMED.REC.1402.015 .

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Informed Consent: All participants were fully informed about the study's purpose and provided written informed consent.

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