International Journal of Hyperthermia

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ihyt20

Effects of deep heating modalities on the morphological and elastic properties of the non-insertional region of achilles tendon: a pilot study

Daniele Munari, Anna Serina, Arianna Leonardelli, Davide Lanza, Alberto Caramori, Andrea Guerrini, Modenese Angela, Mirko Filippetti, Nicola Smania & Alessandro Picelli

To cite this article: Daniele Munari, Anna Serina, Arianna Leonardelli, Davide Lanza, Alberto Caramori, Andrea Guerrini, Modenese Angela, Mirko Filippetti, Nicola Smania & Alessandro Picelli (2022) Effects of deep heating modalities on the morphological and elastic properties of the non-insertional region of achilles tendon: a pilot study, International Journal of Hyperthermia, 39:1, 222-228, DOI: 10.1080/02656736.2022.2026497

To link to this article: https://doi.org/10.1080/02656736.2022.2026497

Published online: 30 Jan 2022.

INTERNATIONAL JOURNAL OF HYPERTHERMIA
2022, VOL. 39, NO. 1, 222–228
https://doi.org/10.1080/02656736.2022.2026497

Effects of deep heating modalities on the morphological and elastic properties of the non-insertional region of achilles tendon: a pilot study

Daniele Munari[a], Anna Serina[a], Arianna Leonardelli[b], Davide Lanza[b], Alberto Caramori[a], Andrea Guerrini[a], Modenese Angela[b], Mirko Filippetti[a], Nicola Smania[a,b] and Alessandro Picelli[a,1]

[a]Neuromotor and Cognitive Rehabilitation Research Center, Section of Physical and Rehabilitation Medicine, Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Verona, Italy; [b]Department of Neuroscience, University Hospital of Verona, Verona, Italy

ABSTRACT

Background: Over the last 20 years, both diathermy and ultrasound have been popular choices for many clinicians in treating musculoskeletal disorders. However, there is a lack of clinical evidence of deep heating modalities to treat tendon pathology, There is no study to investigate the effects of such as physical modalities on morphological and elastic properties on the human tendons.
Objective: the objective of the present study was to compare the effects of diathermy and ultrasound therapies on cross sectional area, transversal height and hardness percentage of the non-insertional region of the Achilles tendon in able-bodied subjects.
Methods: healthy volunteers were divided in diathermy and ultrasound group received six 15-min treatment sessions. Before and after treatment a sonographic assessment was conducted by mean of ultrasonography and the following parameters were recorded: cross sectional area, transversal height and hardness percentage.
Results: thirty-two subjects were enrolled. Between-group comparisons showed a significant change on hardness percentage ($p = 0.004$) after treatment in diathermy therapy group. Within-group comparison showed a significant improvement in the hardness percentage for the diathermy ($p = 0.001$) and ultrasound ($p = 0.046$) after two weeks of treatment.
Conclusion: this pilot study demonstrated larger effects on morphological and elastic properties of the non-insertional region of the Achilles tendon after diathermy than ultrasound therapy in normal tendons. Diathermy may be a useful deep heat modality for treating non-insertional Achilles tendinopathy.

ARTICLE HISTORY
Received 30 June 2021
Revised 23 December 2021
Accepted 24 December 2021

KEYWORDS
Physical therapy modalities; ultrasonography; tendons; elasticity imaging techniques; diathermy

Introduction

Treatment modalities for non-insertional Achille tendinopathy vary and include non-operative and operative options. Nonoperative treatment modalities include physical therapy, extracorporeal shockwave therapy, injectable agents, and bracing and taping [1]. Based on a recent review, the initial option for patients with Achilles tendinopathy would be a non-operative physical therapy approach [1]. Basically, physical therapy modalities fall under four main categories: heat, cold, electricity, and manual therapy [2]. In the clinical setting, heating physical therapies are the most often used modalities for treating musculoskeletal disorders [3]. The gains are basically due to the hyperthermia effects of heat application which induces an increase in tissue temperature [4], cellular metabolism [5], nerve conduction velocity [6,7] and vasodilation [8]. By impacting functional impairments, such as stiffness and pain, the appropriate use of heat physical therapies by clinicians can speed up the recovery phase of treatment and prevent the onset of new injury or chronic dysfunction [9]. In theory, the correct use of an applied heating modality can directly impact both the rate and quality of return to function without limitation [2].

Commonly, therapeutic heating modalities are separated into two categories: superficial and deep applications. Over the last 20 years, both diathermy and ultrasound have been popular choices for many clinicians due their capacity to safely heat deeper structures; for instance, diathermy utilizes the properties of electromagnetic waves generated by highly conductive metal coils whereas ultrasound relies on acoustical energy [2]. A system for capacitive and resistive energy transfer diathermy, called ‘Tecar therapy’, has been used during clinical practice, however only few studies investigated its clinical efficacy reporting positive results in reducing pain and improving function musculoskeletal clinical impairments [10–12]. Tecar is a physical therapy modality promotes the natural physiological processes of tissue metabolism by

CONTACT Nicola Smania nicola.smania@univr.it Neuromotor and Cognitive Rehabilitation Research Center, Section of Physical and Rehabilitation Medicine, University of Verona, P.le Ludovico Antonio Scuro, 10, Verona 37134, Italy
[1]Current affiliation: Canadian Advances in Neuro-Orthopaedics for Spasticity Congress (CANOSC), Kingston, ON, Canada

Figure 1. Treatment setting and standardized reference frame for the application of diathermy on the Achilles tendon in one participant.

transferring energy without introducing radiant energy from the exterior. Tecar which uses the physical principle of the condenser, consists of a device composed of 2 facing and separated elements by an insulating material, these elements are connected to a current generator (machine body) that produces a potential difference between the 2 plates. TECAR system enables the production of an endothermic effect that depends on the applied power and the impedance offered by the tissues upon passage of the current [11]. Ultrasound is a therapeutic agent commonly used to treat sports-related musculoskeletal conditions such as tendinopathy, bursitis, contracture, and fractures [13]. Despite the widespread popularity of both deep heating modalities to treat tendon pathology, there remains a lack of evidence for their efficacy from high-quality studies [3,14,15]. Up to our knowledge, only few studies to investigate the effects of such as physical modalities on morphological and elastic properties on the human tendons; furthermore these studies were conducted in non-living specimens [16–17].

The main aim of this pilot study was to compare the effects of diathermy and ultrasound therapies on cross sectional area, transversal height and hardness percentage of the non-insertional region of the Achilles tendon in healthy subjects after two treatment weeks. Our hypothesis was that we would observe a difference on morphological and elastic properties of the Achilles tendon after diathermy and ultrasound therapies.

Material and methods

Participants

This pilot study 42 included healthy adult (age greater than 18 years) volunteers. The enrollment period was from June 2017 to May 2019. Exclusion criteria were inclusion in other trials, painful conditions involving the lower limbs, contraindications to diathermy or ultrasound therapies: neoplasia or current/previous infections of the treatment area, a cardiac pacemaker, or pregnancy, epilepsy, angina pectoris, cardiovascular pathologies, breastfeeding, skin lesions, nervous system disorders, diabetes mellitus, thermal sensitivity dysfunction, drug or alcohol abuse, radiation therapy or chemotherapy in the past year and metallic implants.

After screening, the principal investigator (PI) randomly assigned eligible patients to the diathermy or the ultrasound groups group according to a simple software-generated randomization scheme. The PI was unaware of which group the subject would be allocated to (allocation was by sealed opaque envelopes). The randomization list was locked in a desk drawer accessible only to the PI.

All volunteers gave their informed, written consent to participate in the study, which was carried out according to the Declaration of Helsinki and approved by the local review board.

Treatment procedures

An expert physiotherapist performed all the treatment sessions. Subjects received a single 15-min treatment sessions once a day, 3 days a week, for 2 consecutive weeks (Mon-Wed-Thu). During treatment the subjects laid in the prone position with their feet off the table and a soft cushion beneath the ankle. The treated area was standardized using a reference system based on anatomical landmarks for non-insertional Achille tendinopathy and the application of the physical therapies was performed along its course, 2 to 6 cm proximally to the calcaneal insertion. The procedure region was defined with four strips of tape (Figure 1) [18], applied before each session.

Diathermy was delivered by means of an I-TECH.AR. device (I.A.C.E.R. srl, Martellago, Venice, Italy). During treatment a neutral plate coated with conductive cream, was positioned under the tibialis anterior muscle of the lower limb for the whole treatment period. This methodology was based on previous studies [19–20]. The diathermy treatment had two phases, capacitive (CAP) and resistive (RES), each lasted 7 min. The CAP phase electrode has a polyamide coating that acts as a dielectric medium, insulating its metallic body from the skin surface, thus forming a capacitor with the treated tissues. The RES electrode is uncoated and passes radiofrequency energy directly through the body and into the neutral plate. The power of energy in both phases was the same: 10–12 VA, equivalent to 0.42 J/cm^2, applied to an area of 28.2 cm^2 [20]. The CAP phase used a frequency of 600 kHz while the RES phase used a frequency of 450 kHz. A manufacturer-supplied conductive cream was employed as a coupling medium between the electrode and the skin surface.

The ultrasound therapy was administered using a DW 200 device (DW Elettronica Pagani s.r.l., Paderno Dugnano Milan, Italy) with a transducer which has 4 cm^2 application area, at 1.5 W/cm^2, 1 MHz frequency, continuous mode in the area for 15 min [21]. Aquasonic gel was used along with the full contact technique in rotational movements at a vertical angle to the skin.

Evaluation procedures

All subjects were evaluated before (T0) and immediately after the last treatment session (T1). They underwent ultrasound evaluation using a MyLab 70 XVision system (Esaote SpA, Genoa, Italy) interfaced with a linear transducer (scanning frequency 13 MHz) and equipped with sonoelastography (ElaXto) software. They remained in the prone position with their legs outstretched. The Achilles tendon was examined 2 to 6 cm proximally to the calcaneal insertion, along its course. The probe was positioned perpendicular to the tendon surface in order to reduce any bias related to anisotropy [22]. The following tendon features were evaluated: thickness, cross-sectional area (CSA) and hardness percentage (%HRD). The anterio-posterior tendon thickness and CSA were measured perpendicular to the greatest width of the Achilles tendon by means of conventional real-time B-Mode US. The %HRD was evaluated through sonoelastography, which was performed with the ElaXto software by applying light vertical rhythmic compression with the transducer over the non insertional region of the Achilles tendon (Figure 2). The optimal compression scale for measurement of the ElaXto software ensured exam quality [22]

Statistical analysis

Statistical analysis was carried out using the Statistical Package for Social Science for Macintosh, version 20.0 (IBM SPSS Inc, Armonk, NY, USA). Non-parametric tests were applied for inferential statistics because of the non-normal data distribution (Shapiro). The Mann-Whitney U-test was used to assess the homogeneity of the two groups at baseline and the effect of treatment between groups. For this purpose, we computed the differences in performance between T1 and T0 (T1-T0) for all outcome measures. Within-group comparisons (T1 vs. T0) were performed with the Wilcoxon signed-rank test for all outcomes. Descriptive analysis was used to evaluate the effect size measures between groups (Cohen's d calculation) and the 95% confidence intervals. We estimated that a total of 32 subjects (16 patients per group) would provide 80% power to detect a difference of 0,3 cm^2 on the CSA between two measurements, assessing standard deviation (SD) = 0.4, correlation = 0.7, and alpha = 0.05 [23]. The alpha level for significance was set at $p < 0.05$

Results

Thirty-two healthy volunteers (15 males and 17 female; mean age 27,09 ± 3,99) were consecutively recruited at our Research Center. Nineteen patients were allocated to the Diathermy group and 13 persons were allocated to the Ultrasound group. There were no drop-outs and no adverse events occurred during the trial in any of the groups. The study diagram is illustrated in Figure 3. Information about the demographic and physical characteristics of our sample is detailed in Table 1.

Between-group comparison showed a significant change on the %HRD (*p* = *0.004; Z:-1.992*) after treatment (Table 2). Within-group comparison showed a significant improvement in the %HRD for the diathermy (*p* = *0.001; Z:-3.823*) and ultrasound (*p* = *0.046; Z:-2.521*) after treatment. No significant changes were detected in both groups in the other outcome measures (Table 2).

Discussion

The main aim of this pilot study was to compare the effects of diathermy and therapeutic ultrasound on the morphological and elastic properties of Achilles tendon in healthy volunteers. Taking into account the numbers of healthy subjects involved in the present pilot study, our preliminary findings showed that tendon elasticity obtained a significantly greater improvement on %HRD in subjects who underwent diathermy than those treated by means of therapeutic ultrasound. This is in line with previous clinical studies, which demonstrated changing in tissue extensibility due to the higher depth efficiency of short-wave diathermy [3,24,25].

The clinical effects of diathermy are well documented, however there is a lack of clinical evidence from high-quality studies; Tecar therapy represents the technological evolution of diathermy [26–28]. Although Tecar has been widely used in physical therapy practise as a physical therapy agent for almost 20 years, there are only a few studies that have investigated its clinical efficacy [11,29]. Furthermore, there seems to be a substantial lack of knowledge on the physiologic responses induced by Tecar application [30].

To the best of our knowledge, this is the first study that investigates the effects of such as deep heat physical modalities on morphological and elastic properties on the Achilles tendon in able-bodied subjects. Järvinen *et al.* mentioned that tendinopathy as being among the most common clinical diagnoses of Achilles disorders (55–65%) [31] and the nonoperative care, e.g. physical therapy, extracorporeal shockwave therapy, injectable agents, and bracing and taping, is initial option for patients with Achilles non-insertional tendinopathy [1]. Despite the popularity of diathermy as Tecar therapy, there is a lack of clinical evidence on Achilles tendinopathy.

Currently, both diathermy and ultrasound therapies have been popular choices for many clinicians in treating muscoskeletal disorders; in practice, understanding when and how to use therapeutic modalities to aid in healing and the recovery of function can often be unclear [2].

In our preliminary study, we found out a significant change on the %HRD after diathermy therapy compared to therapeutic ultrasound. This difference can be mainly explained as the results of the deeper heat application induced by the diathermy therapy and basically, two possible factors could contribute to detect this difference.

The first factor is that the thermal property of diathermy induces a superficial and deep hyperthermia. As temperature increases, the tissue viscosity is modified by the improvement of the collagen extensibility and the reduction connective, subsequently, the extensibility of soft tissues is increased [2,32]. Basically, diathermy therapy promotes the natural physiological processes of tissue metabolism by transferring

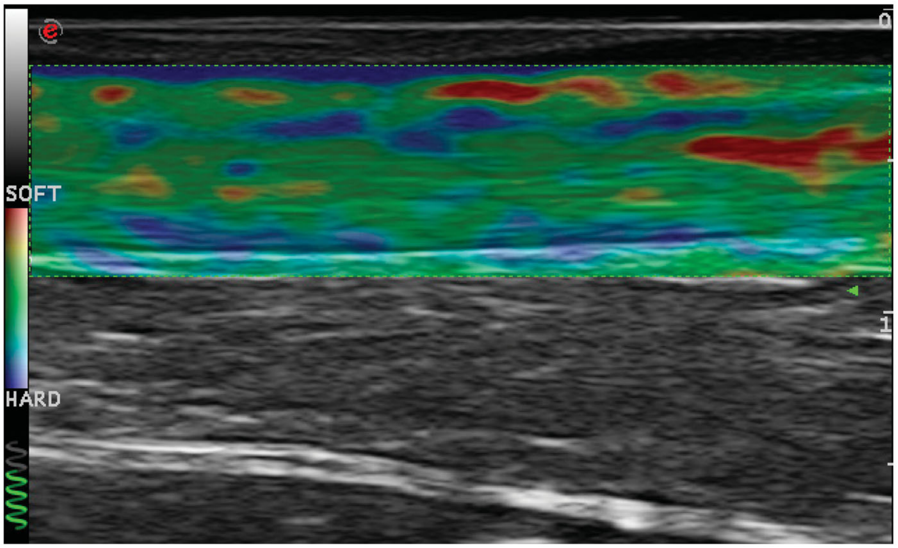

Figure 2. Sonoelastography image of an Achilles tendon.

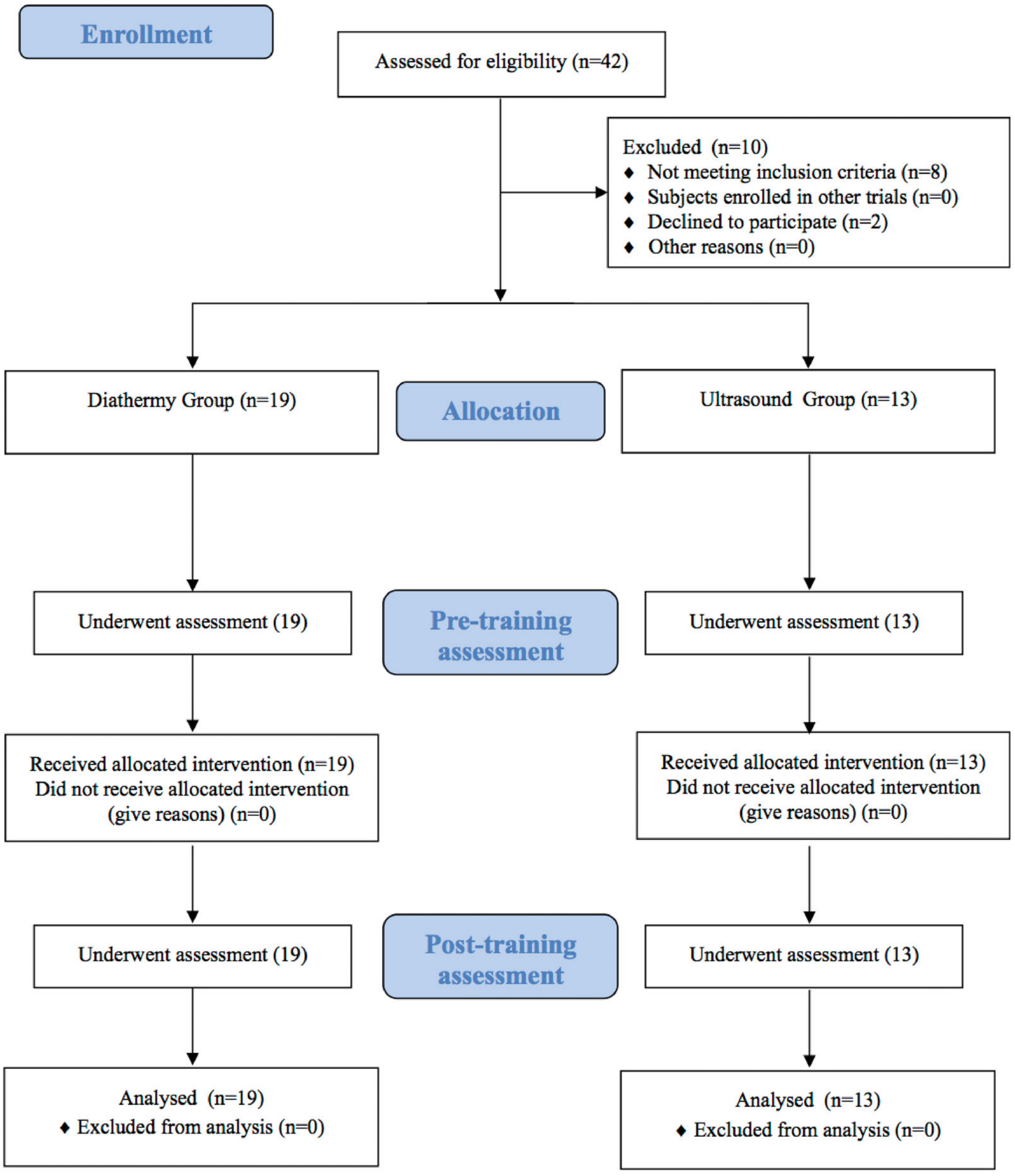

Figure 3. CONSORT Flow diagram of the study.

energy without introducing radiant energy from the exterior rather by using the physical principle of the condenser. This enables the production of an endothermic effect that depends on the applied power and the impedance offered by the tissues upon passage of the current [33,34]. Indeed the effect of the capacitive system is due to the increase in cell membrane potential, due to the kinetic effect of the ions in both intracellular and intermediate fluid and due to the subsequent increase in internal temperature [35].

The underlying key mechanisms of Tecar are CAP and RET techniques: the first works in tissue containing a high content of electrolytes such as muscles, while the second works in tissues with higher resistance such as bones, tendons, and joints. In our study we decided to use both techniques in the diathermy group. Therefore, we hypothesized that the application of diathermy on the Achilles tendon area warms up the superficial and deep tissues and the passage of current itself induces an electromagnetic field and these effects could increases the extensibility of the connective tissue. Researchers have studied the effects of diathermy modalities on increasing the extensibility of soft tissues and often these studies incorporate a stretching protocol following the application of heat [36,37]. Moreover, there has been conflicting evidence with studies suggesting either positive [2] or no effects [9] on tissue extensibility. Our pilot study is line with similar studies [19,37,38]. Yokota and collaborators suggested that capacitive and resistive electric transfer by means of high radiofrequency device, is an effective intervention to improve muscle flexibility [37]. However, no direct assessments on morphological and elastic properties of the tendon were performed. We also observed that in the ultrasound group significant changes were detected on %HRD tissue hardness of the Achilles tendon. Ultrasound may induce thermal and non-thermal physical effects in tissues; however, it has been suggested that the non-thermal effects of ultrasound, including cavitation and acoustic micro-streaming, are more important in the treatment of soft tissue lesions than the thermal physical effects [39]. Most clinicians remain convinced that ultrasound is useful in the treatment of musculoskeletal impairments. Despite this, there is little clinical research documenting the efficacy of ultrasound in treating tendinopathy or promoting tendon healing [14,40] and these studies presented contradictory results. As suggested by Magalhães FE and collaborators, the application of ultrasound has no therapeutic effects on connective tissues and muscular extendibility [41]. However, further research should be performed since Lounsberry NL presented the contradictory results that therapeutic ultrasound treatment applied to the hamstrings can increase muscular extendibility [38]. The absence of clearly evidence for benefit for ultrasound in soft tissue extendibility may be due to a true lack of effect, but poor study design or technical factors may play a role.

The second factor is the increase of local hyperemia induced by the diathermy which allows vasodilatation with an increase of local blood circulation in the tissues [11,42] contributing to the re-supply of oxygen and nutritional substances as well as the removal of catabolytes [27]. These effects could lead to an improvement of the extensibility of the collagenous and a decrease of viscosity. Therefore, we infer that these improvements are supported by our preliminary results where the %HRD was reduced.

Temperature and blood flow changes secondary to radiofrequency exposure are largely thermophysiological responses [4]. While the literature suggests that a small rise in tissue temperature of about 1 °C will help to relieve mild inflammation, many of the clinical benefits of heating such as increasing tissue extensibility occur when temperatures are raised by 2–4 °C [43,44]. Therapeutically, an increase of 3–4 C of skin temperature can produce changes in tissue extensibility and improves the contractile performance of muscle, as it increases ATPase activity and changes the mechanical properties of collagen in tendons [45]. Diathermy applications could reach a peak skin temperature of 35 C [44]. Despite a direct assessment of blood flow was not performed, our study is line with others that demonstrated that local hyperemia induced by deep heating application, increases the tissue extensibility more than superficial heating or no heating [3,44].

This pilot study had some limitations. First, the small sample size of the current study calls for caution in the interpretation of results and no power analysis was conducted. Second, a limitation of the present study is a possible placebo effect of diathermy therapy that can influence perceptions and performance [19]. A sham diathermy therapy group rather than a control group would eliminate any chance for psychologically-induced effects of a subject's

Table 1. Demographic and physical features of subjects.

	Diathermy Group $n = 19$ mean (SD)	Ultrasound Group $n = 13$ mean (SD)
Age (years)	26.42 ± 4.19	28.58 ± 3.59
Sex (n. male/female)	(7/12)	(8/5)
Height (cm)	169.84 ± 6.72	171.54 ± 9.73
Weight (kg)	64.15 ± 10.92	71.60 ± 13.28

n: number; SD: standard deviation.

Table 2. Comparison of treatment effects within and between groups in outcome measures.

Outcome variables	Group	Pretreatment mean (SD)	Post-treatment mean (SD)	Comparisons Wilcoxon signed ranks test *p* Value (Z)	Mann-Whitney test between-group differences Pretreatment vs. Post-treatment *p* Value (Z)	Effect size
CSA (mm^2)	Diathermy Group	52.89 ± 12.56	53.63 ± 9.31	0.431 (−0.788)	0.623 (−0.520)	−0.13
	Ultrasound Group	51.08 ± 10.45	52 ± 9.01	0.475 (−0.714)		
TH (mm)	Diathermy Group	4.15 ± 0.62	4.16 ± 0.49	0.864 (−0.172)	0.677 (−0.444)	0.68
	Ultrasound Group	5.27 ± 0.40	5.28 ± 0.70	0.961 (−0.105)		
HRD (%)	Diathermy Group	79.89 ± 18.92	57.79 ± 20.47	0.001 (−3.823)*	0.004 (−2.559)*	−0.33
	Ultrasound Group	48.92 ± 13.48	43.73 ± 18.97	0.046 (−1.992)*		

CSA: Cross Sectional Area; TH: Transversal Height; HRD: hardness percentage measurement; SD: standard deviation; $^*p < 0.05$.

belief. Third, we did not include any clinical and functional evaluations and instrumental assessment related to blood flow or temperature to detect the direct effects of the physical therapies on local vasodilation (e.g. Doppler ultrasound) and thermal effects. Fourth, the study was conducted considering a short-term application on healthy volunteers and we can not prove the effectiveness of both physical therapies for treating non-insertional Achilles tendinopathy; therefore it should be emphasized that the strength of our speculations and conclusions is limited. Fithth, in line with the pilot nature of this pilot study, assessment bias and selection bias have to be considered.

Our findings provide evidence that diathermy therapy leads greater improvement %HRD of the Achilles tendon than ultrasound therapy due to the higher depth efficiency of short-wave diathermy. Diathermy may be a useful deep heat modality for treating non-insertional Achilles tendinopathy.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Author contributions

All authors approved the submitted manuscript and contributed actively to the study and the manuscript.

Funding

The author(s) reported there is no funding associated with the work featured in this article.

ORCID

Daniele Munari http://orcid.org/0000-0001-6740-1560
Nicola Smania http://orcid.org/0000-0001-7630-1887
Alessandro Picelli http://orcid.org/0000-0002-3558-8276

References

[1] Fares MY, Khachfe HH, Salhab HA, et al. Achilles tendinopathy: Exploring injury characteristics and current treatment modalities. Foot. 2021;46:101715.

[2] Leadbetter JD. The effect of therapeutic modalities on tendinopathy. In: Maffull N, Renstrom P, Leadbetter WB,editors. Tendon injuries. London: Springer; 2005; p. 233–241.

[3] Robertson VJ, Ward AR, Jung P. The effect of heat on tissue extensibility: a comparison of deep and superficial heating. Arch Phys Med Rehabil. 2005;86(4):819–825.

[4] Kumaran B, Watson T. Skin thermophysiological effects of 448 kHz capacitive resistive monopolar radiofrequency in healthy adults: a randomised crossover study and comparison with pulsed shortwave therapy. Electromagn Biol Med. 2018;37(1): 1–12.

[5] Hill J, Lewis M, Mills P, et al. Pulsed short-wave diathermy effects on human fibroblast proliferation. Arch Phys Med Rehabil. 2002; 83(6):832–836.

[6] Matsumoto S, Kawahira K, Etoh S, et al. Short-term effects of thermotherapy for spasticity on tibial nerve F-waves in post-stroke patients. Int J Biometeorol. 2006;50(4):243–250.

[7] Xie C, Li X, Fang L, et al. Effects of athermal shortwave diathermy treatment on somatosensory evoked potentials and motor evoked potentials in rats with spinal cord injury. Spine. 2019; 44(13):E749–58.

[8] Yilmaz Kaysin M, Akpinar P, Aktas I, et al. Effectiveness of shortwave diathermy for subacromial impingement syndrome and value of night pain for patient selection: a double-blinded, randomized, placebo-controlled trial. Am J Phys Med Rehabil. 2018;97(3):178–186.

[9] Giombini A, Giovannini V, Di Cesare A, et al. Hyperthermia induced by microwave diathermy in the management of muscle and tendon injuries. Br Med Bull. 2007;83(1):379–396.

[10] Wiegerinck JI, Kerkhoffs GM, van Sterkenburg MN, et al. Treatment for insertional achilles tendinopathy: a systematic review. Knee Surg Sports Traumatol Arthrosc. 2013; 21(6): 1345–1355.

[11] Clijsen R, Leoni D, Schneebeli A, et al. Does the application of tecar therapy affect temperature and perfusion of skin and muscle microcirculation? A pilot feasibility study on healthy subjects. J Altern Complement Med. 2020;26(2):147–153.

[12] Costantino C, Pogliacomi F, Vaienti E. Cryoultrasound therapy and tendonitis in athletes: a comparative evaluation versus laser CO2 and t.e.ca.r. Therapy. Acta Bio-Medica. 2005;76(1):37–34.

[13] DeLisa JA, Gans BM, Walsh NE. Physical medicine and rehabilitation: Principles and practice 4th ed. Philadelphia (PA): USA Lippincott Williams and Wilkins; 2005.

[14] Tsai WC, Tang ST, Liang FC. Effect of therapeutic ultrasound on tendons. Am J Phys Med Rehabil. 2011;90(12):1068–1073.

[15] Kim GW, Won YH, Park SH, et al. Effects of a newly developed therapeutic deep heating device using high frequency in patients with shoulder pain and disability: a pilot study. Pain Res Manag. 2019; 2019 May 2;2019:8215371.

[16] López-de-Celis C, Hidalgo-García C, Pérez-Bellmunt A, et al. Thermal and non-thermal effects off capacitive-resistive electric transfer application on the achilles tendon and musculotendinous junction of the gastrocnemius muscle: a cadaveric study. BMC Musculoskelet Disord. 2020;21(1):46.

[17] Rodríguez-Sanz J, Pérez-Bellmunt A, López-de-Celis C, et al. Thermal and non-thermal effects of capacitive-resistive electric transfer application on different structures of the knee: a cadaveric study. Sci Rep. 2020;10(1):22290.

[18] Mansur NSB, Faloppa F, Belloti JC, et al. Shock wave therapy associated with eccentric strengthening versus isolated eccentric strengthening for achilles insertional tendinopathy treatment: a double-blinded randomised clinical trial protocol. BMJ Open. 2017;7(1):e013332.

[19] Duñabeitia I, Arrieta H, Torres-Unda J, et al. Effects of a capacitive-resistive electric transfer therapy on physiological and biomechanical parameters in recreational runners: a randomized controlled crossover trial. Phys Ther Sport. 2018;32:227–234.

[20] Osti R, Pari C, Salvatori G, et al. Tri-length laser therapy associated to tecar therapy in the treatment of low-back pain in adults: a preliminary report of a prospective case series. Lasers Med Sci. 2015;30(1):407–412.

[21] Speed CA. Therapeutic ultrasound in soft tissue lesions. Rheumatology (Oxford)). 2001; 40(12):1331–1336.

[22] Picelli A, Filippetti M, Melotti C, et al. Does botulinum toxin treatment affect the ultrasonographic characteristics of Post-Stroke spastic equinus? A retrospective pilot study. Toxins. 2020;12(12): 797.

[23] Zhang ZJ, Ng GY, Lee WC, et al. Changes in morphological and elastic properties of patellar tendon in athletes with unilateral patellar tendinopathy and their relationships with pain and functional disability. PLoS One. 2014;9(10):e108337.

[24] Lentell G, Hetherington T, Eagan J, et al. The use of thermal agents to influence the effectiveness of a low-load prolonged stretch. J Orthop Sports Phys Ther. 1992;16(5):200–207.

[25] Henricson A, Fredriksson K, Persson I, et al. The effect of heat and stretching on the range of hip motion*. J Orthop Sports Phys Ther. 1984;6(2):110–1114.

[26] Haldeman S, Dagenais S. What have we learned about the evidence-informed management of chronic low back pain? Spine J. 2008;8(1):266–277.
[27] Shields N, Gormley J, O'Hare N. Short-wave diathermy: current clinical and safety practices. Physiother Res Int. 2002;7(4): 191–202.
[28] Notarnicola A, Maccagnano G, Gallone MF, et al. Short term efficacy of capacitive-resistive diathermy therapy in patients with low back pain: a prospective randomized controlled trial. J Biol Regul Homeost Agents. 2017;31(2):509–515.
[29] Cau N, Cimolin V, Aspesi V, et al. Preliminary evidence of effectiveness of TECAR in lymphedema. Lymphology. 2019;52(1):35–43.
[30] Visconti L, Forni C, Coser R, et al. Comparison of the effectiveness of manual massage, long-wave diathermy, and sham long-wave diathermy for the management of delayed-onset muscle soreness: a randomized controlled trial. Arch Physiother. 2020;10(10):1.
[31] Järvinen TA, Kannus P, Maffulli N, et al. Achilles tendon disorders: etiology and epidemiology. Foot Ankle Clin. 2005;10(2):255–266.
[32] Warren CG, Lehmann JF, Koblanski JN. Heat and stretch procedures: an evaluation using rat tail tendon. Arch Phys Med Rehabil. 1976;57(3):122–126.
[33] Lehmann JF, Masock AJ, Warren CG, et al. Effect of therapeutic temperatures on tendon extensibility. Arch Phys Med Rehabil. 1970;51(8):481–487.
[34] Onesta E, Parolo M. Hyperthermia through resistive and capacitive energy transfer in the treatment of acute and chronic musculoskeletal lesions. La Riabilitazione. 1998;2:81–83.
[35] Giannopoulou P, Giannopoulos A, Koutsojannis C. The therapeutic efficiency of hyperthermia compared with Short-Wave diathermy. Act Scie Ortho. 2020;3(2):01–07.
[36] Knight CA, Rutledge CR, Cox ME, et al. Effect of superficial heat, deep heat, and active exercise warm-up on the extensibility of the plantar flexors. Phys Ther. 2001;81(6):1206–1214.
[37] Yokota Y, Sonoda T, Tashiro Y, et al. Effect of capacitive and resistive electric transfer on changes in muscle flexibility and lumbopelvic alignment after fatiguing exercise. J Phys Ther Sci. 2018; 30(5):719–725.
[38] Lounsberry NL. Terapeutic heat: effects of superficial and deep heating modalities on hamstring flexibility. Osprey J Ideas Inquiry. 2008;138:4–7.
[39] Dyson M, Suckling J. Stimulation of tissue repair by ultrasound: a survey of the mechanisms involved. Physiotherapy. 1978;64(4): 105–108.
[40] Sawyer PC, Uhl TL, Mattacola CG, et al. Effects of moist heat on hamstring flexibility and muscle temperature. J Strength Cond Res. 2003;17(2):285–290.
[41] Magalhães FE, Junior AR, Meneses HT, et al. Comparison of the effects of hamstring stretching using proprioceptive neuromuscular facilitation with prior application of cryotherapy or ultrasound therapy. J Phys Ther Sci. 2015;27(5):1549–1553.
[42] Jauchem JR. Effects of low-level radio-frequency (3kHz to 300GHz) energy on human cardiovascular, reproductive, immune, and other systems: a review of the recent literature. Int J Hyg Environ Health. 2008;211(1-2):1–29.
[43] Lehmann J, DeLateur B. Therapeutic heat. In: Therapeutic heat and cold. 4th ed. Baltimore: Williams & Wilkins; 1990. p. 470–474.
[44] Kumaran B, Watson T. Thermal build-up, decay and retention responses to local therapeutic application of 448 kHz capacitive resistive monopolar radiofrequency: a prospective randomised crossover study in healthy adults. Int J Hyperthermia. 2015;31(8): 883–895.
[45] Prentice W, Draper D. 2011. Shortwave and microwave diathermy. In: Prentice, W. eds. Therapeutic modalities in rehabilitation. 4th ed. New York: McGraw- Hill. p. 433–462.