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Effect of Shortwave Diathermy versus Ultrasound Waves on Increasing Range of Motion and Decreasing Pain after Extensor Tendon Reconstruction

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ABSTRACT

Objectives: To assess and contrast the impact of shortwave diathermy and ultrasonic waves on improving range of motion (ROM) and reducing discomfort following extensor tendon reconstruction (ETR).

Methods: Sixty adult patients (33 males and 27 females), ranging in age from twenty to thirty, were included in the study. Patients categorized into three equal groups at random (n=20). The three groups received the same traditional physical therapy program (TPTP) (splinting, stretching exercises, strengthening exercises and ROM exercises). Group A received 14-minute Pulsed shortwave diathermy (PSWD) sessions, group B received a 10-minute Ultrasound waves, while group C received only TPTP. All were conducted through a supervised session of three sessions per week for 2 months. Digital goniometer measures of metacarpophalangeal (MCP) flexion,proximal interphalangeal (PIP) flexion, Distal interphalangeal (DIP) flexion and total finger flexion and visual analogue scale (VAS) scores of pain were recorded before treatment and after 8 weeks.

Results: Non-significant variations had been existed across (A, B and C) groups on the pre-treatment regarding of all measured variables ($p > 0.05$), whereas after treatment, there were statistically substantial variations in all evaluated variables, both within and among groups ($p<0.001$).

Conclusion: Pulsed Shortwave Diathermy and Ultrasound waves are effective methods for treating patients with ETR but Pulsed Shortwave

Diathermy is superior to Ultrasound waves in enhancing ROM and reducing discomfort following ETR.
Keywords: Extensor Tendon Reconstruction, Pulsed Shortwave Diathermy, Ultrasound waves.

INTRODUCTION

Tendons are a distinct kind of connective tissue that perform a vital function in the musculoskeletal system by establishing a connection between muscles and bones, enabling movement. These tissues possess distinct mechanical characteristics that allow it to recognize and adjust to the forces exerted by muscles. Tendon injuries, both acute and chronic, are prevalent and lead to significant pain and impairment. Tendon ruptures, whether partial or total, cause a disruption in the continuity of the tendon. This results in a decrease or complete loss of transmitted forces, which may possibly result in a loss of mobility **(1).** Tendon issues account for about 30% of consultations of general practice regarding musculoskeletal pain. Tendon injuries may impact individuals across all age groups and can hinder the performance of both young and elderly people in their professional or athletic pursuits. Multiple external and internal variables contribute to the development of both acute and chronic tendon injuries. Gender, age, and conditions including type 2 diabetes mellitus and obesity are common inherent risk factors for tendon problems **(2).** Genetic predisposition may also impact the likelihood of tendon injury **(3).** The most acknowledged external factor contributing to tendon damage is atypical stress on tendons, that is associated with physiological activity, sports, and particular occupational environments **(1,4).** Treatment options for acute and chronic injuries of tendons vary. Reconstructive surgery outcomes differ according to the kind and the injurylocation. Regardless of whether surgical methods or non-surgical therapy are used for tendon damage, rerupture frequently happens due to scarring that weakens the tendon tissues **(1).** Exercise-based therapy is advised for the treatment of both acute and chronic tendon injuries. Platelet-rich plasma (PRP) is an increasingly popular and safe therapeutic method used for treating tendon injuries. This substance is a blood derivative that contains elevated concentrations of growth factors, which are recognized for their ability to stimulate the repair of tissues. Nevertheless, the efficacy of injecting PRP for tendon rehabilitation is still a subject of debate **(5-7).** Alternative methods, including phonophoresis, therapeutic ultrasound, or low-level laser therapy, might be considered as additional choices for treating tendon injuries **(8).**

Stem-cell-based treatment is a promising alternative that may be accessible in the future **(1).** The primary therapies now available for injuries to tendons are surgery, exercise-based rehabilitation, and autologous growth factor injections **(9).** Shortwave diathermy (SWD) refers to the utilization of shortwave electromagnetic radiation to generate heat inside the deeper layers of soft tissues. Electromagnetic waves are the result of the interaction of field-oriented perpendicular electric and magnetic fields. The thermal effects of SWD are attributed to the oscillation of ions and rotation of dipoles, generating kinetic energy which is subsequently converted into thermal energy. This thermal energy is hypothesized to induce various biological effects, including enhanced blood circulation, elevated cellular metabolism, improved tissue elasticity, and reduced joint viscosity. It is hypothesized that these modifications will result in improved pain and wound control, in addition to an enhanced joint mobility **(10).** SWD employs electromagnetic waves with frequencies ranging from 10 to 100 MHz to induce tissue heating. The application is performed utilizing a pulsed-mode, whereby the flow of electrical current is intermittently interrupted, resulting in the generation of pulses. PSWD has the ability to induce both thermal and non-thermal impacts **(11).** PSWD is a therapeutic technique that effectively raises the tissues temperature withina 5 cm depth. It is capable of heating a wider area compared to ultrasound, while yet reaching identical to that depth of penetration as 1-MHz US. This makes PSWD particularly suitable for heating bigger joints including the shoulder, elbow, knee, hip, and ankle **(12,13).** Ultrasound refers to sound waves that have frequencies higher than 20,000 Hertz (Hz) that cannot be detected by the human ear. However, clinical ultrasonography Utilizes greater frequencies, typically between 1 to 20 megahertz (MHz), occasionally reaching up to 75 MHz in specialized disciplines like ophthalmology and dermatology. Piezoelectric crystals produce ultrasound. These materials consist of electric dipoles which are randomly orientated. Crystal distortion occurs when a force is applied, the dipoles rearrange themselves, resulting in the generation of a net charge throughout the crystal **(14).** It is a frequently utilized technique by physicians for managing orthopedic and muscular problems and is regularly employed for pain management. Under the guidance of a skilled therapist, ultrasound therapy may provide several advantages in the treatment of sprains, strains, tissue regeneration, and pain management **(15).**

SUBJECTS AND METHODS

- **Study Design:**

The current investigation has been planned for as a prospective randomized controlled trial. This is a prospective work performed over 6 months duration from July 2023 to January 2024. KAFR EL-SHIEKH University's Department of Physical Therapy's Committee on the Ethics of Scientific Research provided the initial ethical approval (KFSIRB200-29) and clinical trials record number of NCT06113250.

- **Study participants and recruitment:**

Patients were split evenly between three groups using a computer algorithm written by a clinician who did not take part in the study. Patients' randomization codes remained unopened in sealed envelopes until after they had given their permission to participate in the research.According to the flow chart displayed in (Figure 1), a total of 60 individuals were deemed suitable for this research. However, 12 individuals were excluded from the study because they resided too far away. The Block Stratified Randomization Software has been employed to allocate the remaining (60) individuals (using version 6.0 of the randomization application, Rand.exe) in a manner that ensures an equal distribution of samples across three groups, even when there are several stratified factors.

The following were used as criteria for inclusion: Patients were after extensor tendon reconstruction surgeries, their ages were between 20 and 30 years, and they were of both genders. Patients were those with Photosensitivity, Sensory impairments, Intellectual disorders, pregnant women and uncooperative patients were excluded.

- **Interventions:**

All the patients were examined medically for completion of medical history and clinical, laboratory and radiological assessment before treatment decision and regular evaluation. Participants had been allocated at random into one of three treatment groups:

- **Treatment administration:**

Ultrasound Protocol:

The therapeutic ultrasound is applied at frequencies ranging from 0.5 to 3.0 MHz, using a continuous-mode of application. The level of intensity is set at 1.5 w/cm. Each session lasts for 10 minutes, and there are three sessions per weekfor a period of 2 months. This treatment is carried out for a duration of 2 months **(16,17).**
After surgery hands were immobilized in relaxed position using static progressive splints.The dressings on the dorsal side were taken off. The coupling gel had been administered to the back of the hand. The ultrasonic therapy head was positioned directly on the site of the tendon reconstruction and carefully maneuvered to smooth out any discrepancies in the immediate vicinity and prevent the formation of standing waves caused by reflection **(18).** Precautions were made to avoid excessive motions of the reconstructed finger. The dressings were meticulously repositioned following ultrasonic treatment.

Shortwave diathermy protocol:
Patients received 14-min of 10-100 MHz, 40–60 W, PSWD, 3 sessions /week for a period of 8 weeks**(19).**
The administration of diathermy was facilitated using a Physiotherm device. Throughout the therapy, a neutral plate covered with conductive cream was placed on the back of hand. This technique was derived from other investigations **(20,21).** The diathermy therapy consisted of two distinct stages, namely capacitive (CAP) and resistive (RES), with each phase lasting for a duration of 7 minutes. The CAP phase electrode is coated utilizing polyamide, that functions as a conducting dielectric medium. This coating insulates the metallic body of electrode out of the skin's surface, creating a capacitor with the considered tissues. RES electrode is devoid of any coating and transmits radiofrequency waves straight through the body and into the neutral plate. The energy power in the two phases was identical, measuring 10–12 VA, which is comparable to 0.42J/cm^2**(20).** The CAP phase utilized frequencies of 600 kHz, while the RES phase utilized frequencies of 450 kHz. As a conduit, conductive cream was applied between the electrode and the surface of the skin.

TPTP:
Splinting, stretching exercises, strengthening and ROM exercises for 20 minutes, 3 sessions /week for a period of 8 weeks **(22).**

- **Measuring outcomes:**

- Visual analogue scale (VAS): The VAS utilised to evaluate intensity of pain prior and following the treatment. The VAS entails a 10 cm line and a scale completed by the subject.The scores, which begin from the zero-point indicating "no pain" are marked by the subject using a ruler.

- Digital Goniometer: Due to its great accuracy, the digital goniometer is a reliable and valid tool for evaluating joint ROM. Baseline & Digital Absolute Axis Goniometer (12-1027 China) is a legitimate tool for determining joint ROM, and it has comparable inter- and intra-rater reliability to the universal goniometer.

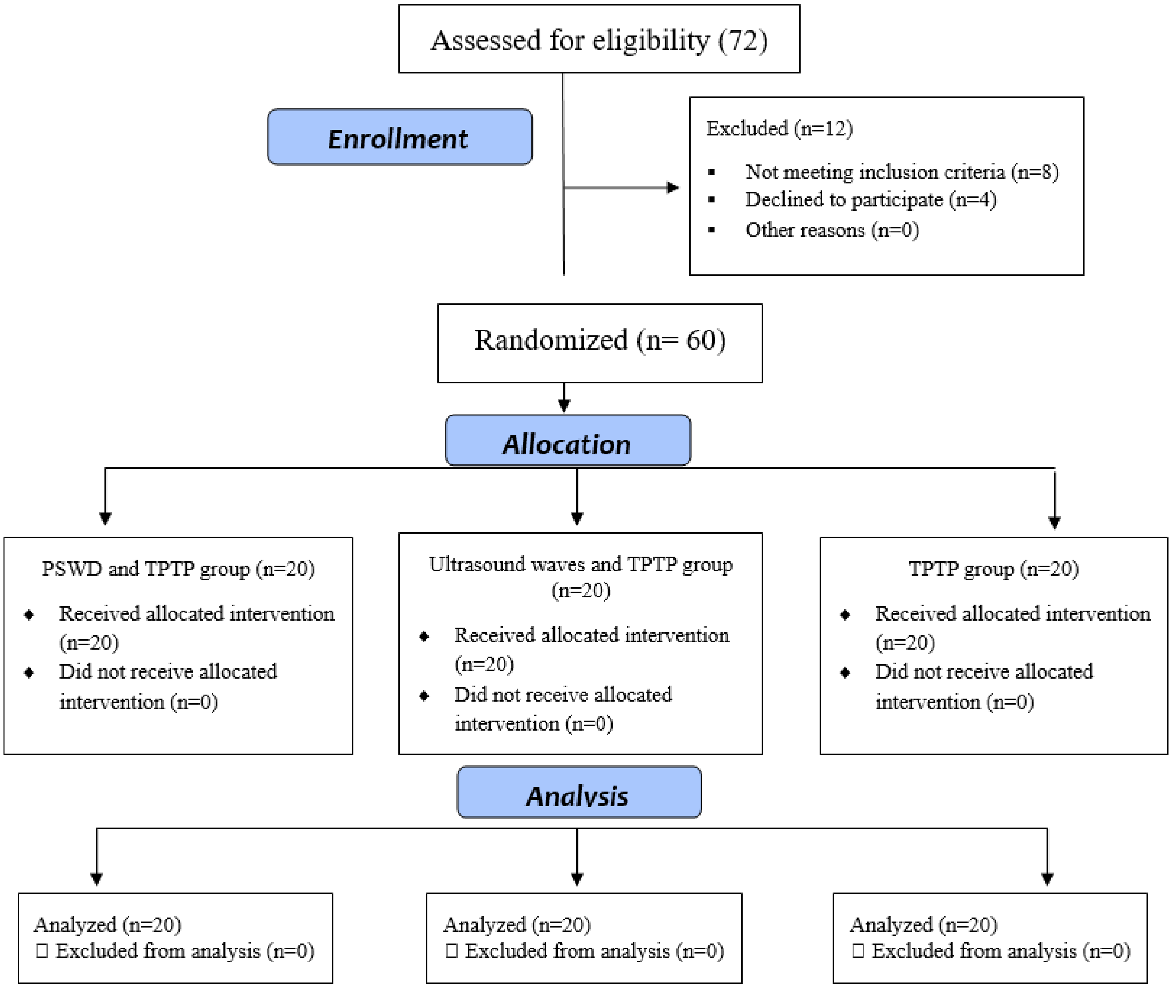

Figure (1): The flow chart of the study.

- **Data analysis:**

Shapiro-Wilk test had been performed for evaluating the normality of data. For contrasting of gender between groups, chi squared test was performed. Kruskal wallis H test had been utilised for contrasting of age among the three groups Repeated measures MANOVA had been performed for evaluating the variation among participants in the three groups in the level of alteration in their scores on the outcome measurements.Level of significance was set at P. value < 0.05**(23)**

RESULTS

Multivariate tests showed significant effects for the main effects of groups: Wilk's Λ=0.093, F =24.14, P< 0.001, significant effects for the main effects of time: Wilk's Λ=0.001, F =10778.79, P < 0.001 and significant effects for the interaction among groups and time: Wilk's Λ=0.006, F =131.88, P< 0.001. Univariate ANOVAs revealed a significant change in MCP flexion: F =359.28, P< 0.001, in PIP flexion: F =42.12, P< 0.001, in DIP flexion: F = 116.58, P< 0.001, in Total finger flexion: F =576.3, P< 0.001 and in pain: F =11.4, P=0.002.

I- Gender distribution:

According to the gender distribution data of boys to girls for groups (A, B & C), there was no significant variation among three groups ($p > 0.05$) (Table 1).

Table (1): Comparison of gender distribution between the three groups (A, B and C).

	Gender distribution N (%)			X^2	p-value
	Group (A)	Group (B)	Group (C)		
Males	11 (55%)	10 (50%)	12 (60%)	0.25	0.656^{NS}
Females	9 (45%)	10 (50%)	8 (40%)		

$\overline{X}$: Mean. SD: Standard Deviation. X^2: Chi squared value.
p-value: Probability value. NS: Non- significant.

II- Between- group comparisons:

- Pre treatment comparison:

No substantial variation was existed among the three groups for age (P=0.149), pain (P=0.38), MCP flexion (P=0.13), PIP flexion (P=0.42), DIP flexion (P=0.18) and Total finger flexion (P=0.22) (Table 2).

Table (2): Comparison of Pre treatment mean values among the three groups.

Pre treatment	Group A	Group B	Group C	F. value	P. value	Sig.
Age	25.5±5.92	24.5±5.92	27.6±2.5	1.97	0.149	NS
Pain	6.75±0.85	6.35±1.14	6.5±0.69	0.98	0.38	NS
MCP flexion	26.2±1.61	27.6±3.12	27.6±2.51	2.11	0.13	NS
PIP flexion	55±1.62	53.6±3.12	53.5±5.92	0.89	0.42	NS
DIP flexion	24.5±5.58	25.6±3.12	26.85±2.96	1.74	0.18	NS
Total finger flexion	105.7±3.08	106.8±9.36	110.2±10.78	1.55	0.22	NS

Data showed as mean ±SD, P-value =Probability, F-value =F-statistic, Sig. =Significance, NS =Non-significant.

- **Post treatment comparison:**

Repeated measures MANOVA test showed that a substantial variation had been existed among the three groups for all outcome parameters (P< 0.001). Regarding pain, post hoc tests revealed that there was a substantial variation among A and B Groups in favour of group A (P=0.01) and among A and C Groups in favour of Group A (P<0.001), while no substantial variation was existed among Group B and Group C (P=1), While regarding MCP flexion, post hoc tests revealed that there was a substantial variation among Group A and Group B in favour of group A (P<0.001) and among A and C Groups in favour of Group A (P<0.001), while no substantial variation was existed among B and C Groups (P=0.16). Regarding PIP flexion, post hoc tests revealed that there was a substantial variation among A and B Groups in favour of group A (P<0.001) and among A and C Groups in favour of Group A (P<0.001), while no substantial variation was existed among Group B and Group C (P=1) and while regarding DIP flexion and total finger flexion, a substantial variation was existed among all pairs of comparisons (P< 0.001) (Table 3, 4, 5, 6, 7 & 8).

Table (3): Comparison of Post treatment mean values among the three groups.

Post treatment	GroupA	GroupB	GroupC	F-value	P-value	Sig.
Pain	3.6±0.88	4.7±0.92	5±1.45	8.724	< 0.001	S
MCP flexion	69±2.56	56.5±2.95	55±1.45	202.3	< 0.001	S
PIP flexion	115.6±2.14	106.5±2.95	107±11.83	10.25	< 0.001	S
DIP flexion	65.6±3.12	59.5±2.95	47.55±6	92.88	< 0.001	S
Total finger flexion	105.7±3.08	106.8±9.36	110.2±10.78	67.24	< 0.001	S

Data showed as mean ±SD, P-value =Probability, F-value =F-statistic, Sig. =Significance, S =Significant.

Table (4): multiple comparisons of post-treatment mean values Pain among the three groups.

Multiple comparisons: Post hoc tests (Benneferroni)			
Groups	**MD**	**P-value**	**Sig.**
GroupA - GroupB	-1.1	0.01	**S**
GroupA - GroupC	-1.4	< 0.001	**S**
GroupB - GroupC	-0.3	1	**NS**

MD =Mean difference, Sig. =Significance, P-value =Probability, S =Significant, NS =Non-significant.

Table (5): multiple comparisons of post treatment mean values MCP flexion among the three groups.

Multiple comparisons: Post hoc tests (Benneferroni)			
Groups	**MD**	**P-value**	**Sig.**
GroupA - GroupB	12.5	< 0.001	**S**
GroupA - GroupC	14	< 0.001	**S**
GroupB - GroupC	1.5	0.16	**NS**

MD =Mean difference, P. value =Probability, Sig. =Significance, S =Significant, NS =non-significant.

Table (6): multiple comparisons of post treatment mean values PIP flexion among the three groups.

Multiple comparisons: Post hoc tests (Benneferroni)			
Groups	**MD**	**P. value**	**Sig.**
GroupA - GroupB	9.1	< 0.001	**S**
GroupA - GroupC	8.6	< 0.001	**S**
GroupB - GroupC	-0.5	1	**NS**

MD =Mean difference, P. value =Probability, Sig. =Significance, S =Significant, NS =non-significant.

Table (7): multiple comparisons of post treatment mean values DIP flexion among the three groups.

Multiple comparisons: Post hoc tests (Benneferroni)			
Groups	**MD**	**P-value**	**Sig.**
GroupA - GroupB	6.1	< 0.001	**S**
GroupA - GroupC	18.05	< 0.001	**S**
GroupB - GroupC	11.95	< 0.001	**S**

MD =Mean difference, P. value =Probability, Sig. =Significance, S =Significant.

Table (8): multiple comparisons of post treatment mean values total finger flexion among the three groups.

Multiple comparisons: Post hoc tests (Benneferroni)			
Groups	**MD**	**P-value**	**Sig.**
GroupA - GroupB	27.7	< 0.001	**S**
GroupA - GroupC	40.65	< 0.001	**S**
GroupB - GroupC	12.95	< 0.001	**S**

MD =Mean difference, P. value =Probability, Sig. =Significance, S =Significant

Within group Comparison:

- In group A and C, Repeated measures MANOVA test revealed that a substantial variations for all outcome variables were existed (P < 0.001) (Table 9).
- In group B, Repeated measures MANOVA test showed that a substantial variations were existed for pain, MCP flexion, PIP flexion, DIP flexion and Total finger flexion with P. value of 0.001, < 0.001, < 0.001, < 0.001 and < 0.001 correspondingly(Table 9).

Table (9): Comparison for pre and post treatment mean values of outcome variables:

Outcome measures	**Group (n=20)**		**Group (n=20)**		**Group (n=20)**	
	MD	**P-value**	**MD**	**P-value**	**MD**	**P-value**
Pain	3.15	< 0.001*	1.65	0.001*	1.5	< 0.001*
MCP flexion	-42.8	< 0.001*	-28.9	< 0.001*	-27.4	< 0.001*
PIP flexion	-60.6	< 0.001*	-52.9	< 0.001*	-53.5	< 0.001*
DIP flexion	-41.15	< 0.001*	-33.9	< 0.001*	-20.7	< 0.001*
Total finger flexion	-144.5	< 0.001*	-115.7	< 0.001*	-99.35	< 0.001*

MD =Mean difference, * =Statistically significant.P-value =Probability value,

DISCUSSION

This researchaimed to evaluate the disparity in the effects of PSWD and Ultrasonic waves on enhancing ROM and reducing discomfort following ETR. The current study results showed no substantial variations was existed among the three groups of all measured variables ($p> 0.05$), while after treatment, Repeated measures MANOVA test showed that substantial variations were existed among the three groups for all outcome parameters ($P< 0.001$).

Studies have shown that heating tissues in humans may enhance the ability of collagen to stretch as well as enhance flexibility. Therefore, it is recommended to warm tissues before stretching to get the best results as regard lengthening **(24-26).**

Presently, diathermy and ultrasonic therapy are widely favored by physicians for the treatment of musculoskeletal problems. However, determining the appropriate timing and method for using therapeutic modalities to facilitate healing and restore function may sometimes be confusing**(27).**

Tang, (28) conducted a comprehensive analysis of clinical outcome data related to flexor tendon reconstruction over a period of 15 years. The study found that the most favorable functional improvements, with 75% of cases achieving outstanding to good outcomes, were seen when earlier active mobilization was used. The incidence of rupture varied between 4% and 10%. The author determined that the issues of adhesion creation and stiffness in the fingers continue to be sources of frustration. They proposed that using modern biologic methods might be one way to enhance the results.

Da Cunha et al., (29) and **Saini et al., (30)**performed a work to examine the impact of US on the reconstructed flexor tendons healing process in chicken limbs. The researchers discovered that the use of ultrasound led to an expansion in the ROM, acceleration of scar development, and decrease in the presence of inflammatory cells.

Early-phase tendons healing may be safely facilitated with the use of pulsed-ultrasound treatment. Our research demonstrates that initiating ultrasound treatment with frequencies of 1-MHz on the 7th day after surgery, with 0.7 w/cm^{2}intensity,produces an elevated percentage of favorable to satisfactory results, without any occurrences of ruptures or PIP joint flexion contractures. When using 3-MHz frequencies, it is necessary to first set the intensity at a reduced level and then make adjustments based on the patient's reaction following a period of 3 weeks **(18).**

Tissue resistance to the transfer of electromagnetic energy, which causes an increase in temperature, is the foundation for the physical applications of SWD **(31).** Continuous short-wave therapy induces analgesia by generating deep tissue heating, enhancing the flexibility of connective tissues, and promoting blood circulation in the targeted region by stimulating the expansion of arterioles and capillaries.

Two systematic reviews released 19 years apart, that assessed the proof for utilizing SWD for treating chronic low back pain (CLBP), both reached the same conclusion: there is limited evidence regards the impacts of SWD in this area. The reviews found that there are few articles specifically addressing pain and most of them have different levels of methodological quality **(32,33).**

Conversely, recent studies have shown that the combination of continuous SWD (cSWD) and exercise outperformed placebo SWD and PSWD in reducing pain in individuals with CLBP **(34).**

Research conducted by **Shakoor et al.,(35)** evaluated the effects of cSWD to sham cSWD, in addition to administering anti-inflammatory medication and exercises.

Robertson et al., (36) and **Zhang et al.,(37)**showed that diathermyusing resulted in a much larger enhancement in tendon elasticity and hardness % compared to therapeutic ultrasonic treatment. This aligns with prior clinical research, which showed alterations in extensibility of the tissues as a result of the enhanced depth effectiveness of SWD.

In a pilot investigation, **Munari et al., (38)** found that the effects of diathermy on the morphological and elastic properties of the non-insertional segment of the Achilles tendon were more profound compared to ultrasonic treatment in healthy tendons. Diathermy is an advantageous technique that uses deep heat to treat Achilles tendinopathy that does not need insertion.

Our current study showed that Shortwave diathermy is more effective than Ultrasonic waves in enhancement of ROM and reducing pain following extensor tendon repair.

Data Availability

Datasets used and/or created during this investigation can be obtained from the relevant author with a reasonable request.

Disclosure statement

No author has a vested interest in the results of this study or has benefited monetarily in any way.

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