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Muscle Heating With Megapulse II Shortwave Diathermy and ReBound Diathermy

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Context: A new continuous diathermy called ReBound recently has been introduced. Its effectiveness as a heating modality is unknown.

Objective: To compare the effects of the ReBound diathermy with an established deep-heating diathermy, the Megapulse II pulsed shortwave diathermy, on tissue temperature in the human triceps surae muscle.

Design: Crossover study.

Setting: University research laboratory.

Patients or Other Participants: Participants included 12 healthy, college-aged volunteers (4 men, 8 women; age = 22.2 ± 2.25 years, calf subcutaneous fat thickness = 7.2 ± 1.9 mm).

Intervention(s): Each modality treatment was applied to the triceps surae muscle group of each participant for 30 minutes. After 30 minutes, we removed the modality and recorded temperature decay for 20 minutes.

Main Outcome Measure(s): We horizontally inserted an implantable thermocouple into the medial triceps surae muscle to measure intramuscular tissue temperature at 3 cm deep. We measured temperature every 5 minutes during the 30-minute treatment and each minute during the 20-minute temperature decay.

Results: Tissue temperature at a depth of 3 cm increased more with Megapulse II than with ReBound diathermy over the course of the treatment ($F_{6,66} = 10.78$, $P < .001$). ReBound diathermy did not produce as much intramuscular heating, leading to a slower heat dissipation rate than the Megapulse II ($F_{20,220} = 28.84$, $P < .001$).

Conclusions: During a 30-minute treatment, the Megapulse II was more effective than ReBound diathermy at increasing deep, intramuscular tissue temperature of the triceps surae muscle group.

Key Words: continuous diathermy, intramuscular temperature, heat

Key Points

- The Megapulse II pulsed shortwave diathermy was a better device than the continuous ReBound diathermy for deep heating.
- Given its lower power output, ReBound diathermy can be used as a moderate heating modality.
- Further research should be performed to understand the heating distribution of ReBound diathermy throughout its sleeve.

Thermotherapy is the therapeutic use of heat: the application of a device or substance with a temperature greater than that of body temperature, causing heat to pass from the thermotherapy device or substance to the body. Heat is a form of energy produced by the movement of atoms and molecules.[1]

The 2 classifications of thermotherapy are superficial and deep. *Superficial thermotherapy* is the application of a device that is used primarily to heat structures to 1 cm deep. *Deep thermotherapy* is the application of a device that can cause a tissue temperature rise at 3 to 5 cm deep. Examples of superficial-heating modalities are dry and moist hot packs, paraffin baths, hot whirlpools, and hot tubs. Deep-heating modalities include therapeutic ultrasound and continuous or pulsed shortwave diathermy (PSWD).

Although the depth of tissue heating varies with each thermotherapy modality, the primary physiologic effects and benefits of using heat remain relatively constant and include the following: increased circulation,[2,3] increased metabolism,[3] decreased pain,[4–6] and decreased tissue stiffness.[7–10] The degree of physiologic effects depends on the residual temperature change in the tissues. *Mild heating* is defined by a 1°C tissue-temperature change and increases the metabolic rate of the heated tissues. A 2°C to 3°C temperature increase characterizes *moderate heating*, in which a greater metabolic response occurs and causes an increase in circulation to dissipate the heat. *Vigorous heating* occurs at temperatures above 4°C. Greater metabolic and circulatory responses occur, but more important, a decrease in tissue stiffness occurs only during vigorous heating, creating an optimal time to use joint range-of-motion techniques.[11–13]

Shortwave diathermy effectively increases tissue temperature, using high-frequency electromagnetic waves to heat deeper structures.[14] In the tissues, the electromagnetic waves are converted into heat, and as the tissue temperature increases, a temperature gradient occurs, allowing for heat to be transferred through conduction.[1] Shortwave diathermy is best used to heat larger anatomic structures because the effective treatment area is much larger than for other deep-heating modalities.[15]

Shortwave diathermy can be used in either a pulsed or continuous form. Pulsed shortwave diathermy effectively increases tissue temperature to the levels at which optimal healing can occur.[2,5,7–10,15–17] Although not as commonly used, continuous shortwave also effectively heats deep tissues.[14,18]

The ReBound (ReGear Life Sciences, Inc, Pittsburgh PA) continuous diathermy device, which was introduced into the clinical setting in 2008, uses an induction helical-coil sleeve purported to heat deep into the muscle at the variables of 35 W and 13.56 MHz.[19] The effectiveness of ReBound diathermy as a deep-heating therapeutic modality has not been determined. Therefore, the purpose of our study was to compare tissue-temperature increase and decay of the ReBound diathermy with a known, effective deep-heating modality, the Megapulse II PSWD, at a depth of 3 cm in the triceps surae muscle.

METHODS

We used a 2×27 repeated-measures crossover design in which all participants were treated with the ReBound and the Megapulse II PSWD diathermies on the same leg. The dependent variable was the tissue temperature of the triceps surae muscle group at 3 cm deep measured to the nearest 0.1°C. The independent variables were 2 levels of treatment group (ReBound diathermy, Megapulse II PSWD) and time. We measured time pretreatment (baseline) and every 5 minutes 6 times during the 30-minute treatment, for a total of 7 measurements. We measured temperature decay each minute for 20 minutes posttreatment.

Participants

We described our participants and inclusion criteria in Hawkes et al.[20]

Instruments

In another study, we described the thermocouples, imaging ultrasound, and therapy garment sleeve.[20] The ReBound diathermy and Megapulse II devices both met the recommended calibration guidelines.

Procedures

We described our procedures common to both treatments in Hawkes et al.[20] However, we used a small carpenter square in this study to measure perpendicularly from a line marked on the posterior skin surface to a 3-cm posterior-to-anterior distance on the medial side of the calf. We drew a dot on the skin on the medial side of the triceps surae at a 3-cm measured distance. We inserted a 20-gauge, 1.88-in (4.78-cm) catheter (BD Medical, Franklin Lakes, NJ) 3 cm deep into the medial aspect of the posterior triceps surae, then inserted 1 IT-21 thermocouple (Physitemp Instruments Inc, Clifton, NJ) via the catheter to 3 cm deep.

ReBound Treatment. Our procedures for ReBound treatment are described elsewhere[20] with the exception that we measured tissue temperatures at a depth of 3 cm in this study.

Megapulse II Treatment. After inserting the thermocouple and measuring baseline temperature, we placed the drum of the diathermy over the posterior belly of the triceps surae muscle, with the middle of the drum above the inserted thermocouple. The diathermy was turned on and set for a 30-minute treatment at 800 pulses per second and a pulse width of 400 microseconds, creating a mean power output of 48 W. After 5, 10, 15, 20, 25, and 30 minutes of treatment, we paused the diathermy for about 20 seconds to obtain an accurate reading. We measured tissue temperatures at 3 cm deep and recorded the average of 3 measurements using the Iso-Thermex electrothermometer (Columbus Instruments, Columbus, OH).

Statistical Analysis

The statistical analysis is described in Hawkes et al.[20]

RESULTS

Treatment

We found a treatment-by-time interaction ($F_{6,66} = 10.78$, $P < .001$) and main effects of treatment ($F_{1,11} = 37.50$, $P < .001$) and time ($F_{6,66} = 115.93$, $P < .001$). Over the course of the treatment, the Megapulse II produced greater tissue temperatures at 3 cm than the ReBound diathermy did (Figure 1). The Table depicts the mean peak absolute tissue temperatures and mean peak residual, or change from baseline, tissue-temperature increase for each modality.

Temperature Decay

Although the Megapulse II diathermy produced a greater temperature increase, the ReBound diathermy produced a slower rate of heat dissipation over the 20-minute decay ($F_{20,220} = 28.84$, $P < .001$). Mean temperatures over the duration of decay between the 2 diathermies are illustrated in Figure 2.

DISCUSSION

The primary purpose of our study was to examine the temperature increases and decay produced by 2 modalities: ReBound continuous shortwave diathermy and Megapulse II PSWD. Given the absence of research specifically on the ReBound diathermy, we wanted to better understand its role as a deep-heating modality. To do this, we examined its ability to increase tissue temperature and measured how tissue temperature dissipated after the treatment.

At a tissue depth of 3 cm, the temperature increased at a higher rate and to a greater peak temperature with the Megapulse II than with the ReBound diathermy. Our results of tissue-temperature increases with the Megapulse II PSWD device at 3 cm (4.32°C ± 1.79°C) are comparable with the results reported by other authors[15,16] using PSWD devices who found a 4.6°C tissue temperature increase at 3 cm deep. To our knowledge, we are the first to evaluate temperature increases with ReBound diathermy.

The amount of electromagnetic energy delivered to the target tissues is related directly to the frequency of the device.[1] Given that we compared 1 continuous shortwave

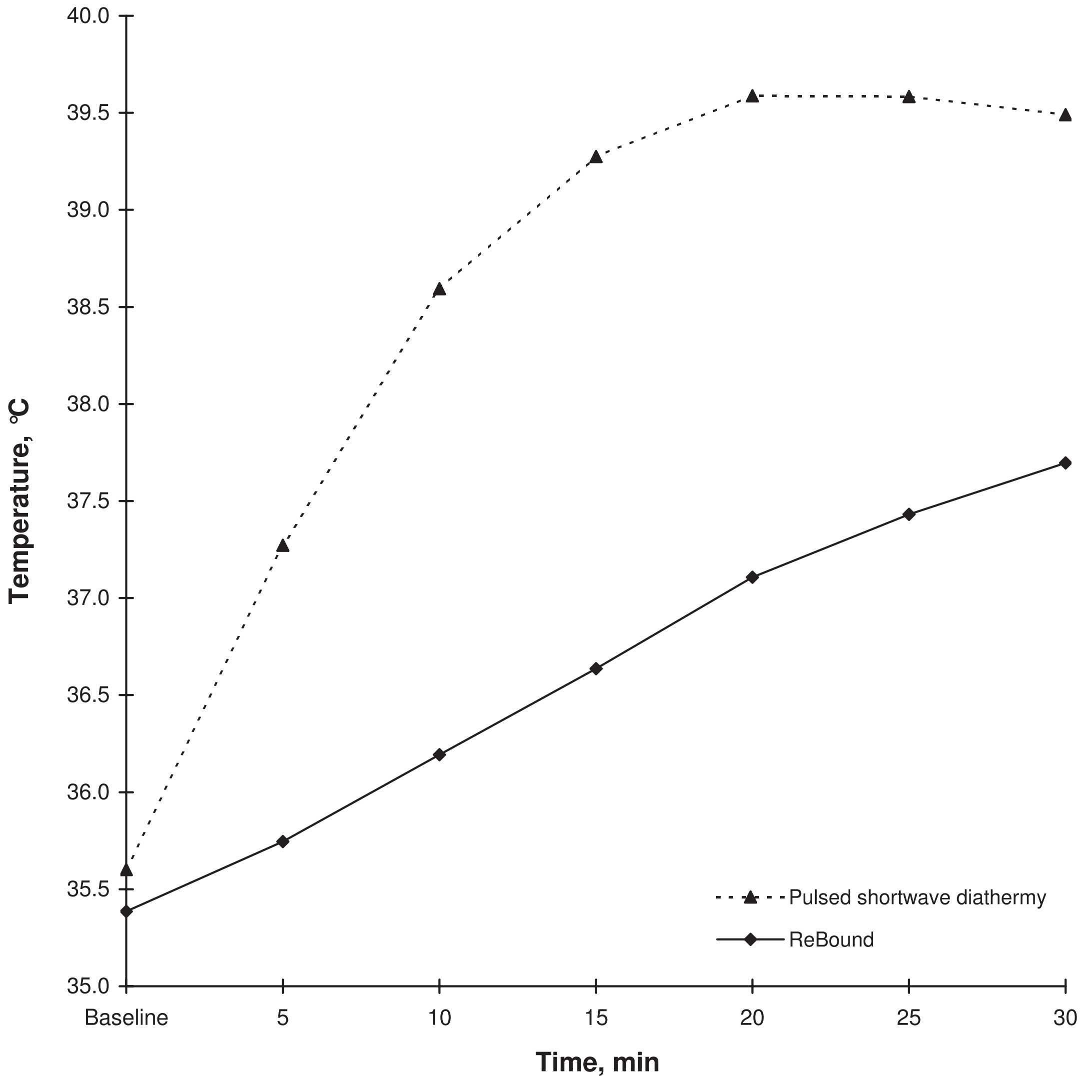

Figure 1. Mean temperature increases at a depth of 3 cm deep in the triceps surae muscle during a 30-minute application of the ReBound diathermy system (ReGear Life Sciences, Inc, Pittsburgh, PA) or pulsed shortwave diathermy.

diathermy (ReBound) with 1 PSWD (Megapulse II), a comparison of the power output is a better indicator of the amount of heating that the device might produce. The continuous ReBound diathermy has a fixed power output of 35 W.[19] To properly increase tissue temperatures to vigorous heating levels using the Megapulse II PSWD, a 48-W power output is recommended.[15,16] Thus, a factor to explain the lesser deep-heating capabilities seen with ReBound diathermy is that the power output is too low. If the power output of the continuous ReBound diathermy were increased, greater tissue temperature might be produced.

When turned on, the ReBound device interfered with any electrical device that was within a few feet of it, including the imaging ultrasound, laptop, and Iso-Thermex electrothermometer. Some interference occurred between the Iso-Thermex electrothermometer and the Megapulse II but not to the same extent as with the ReBound diathermy. We hypothesize that we saw greater interference with the ReBound diathermy because more stray electromagnetic waves were emitted through the ReBound sleeve. We have 2 concerns with this. First, the stray electromagnetic waves could be a safety concern for people who have pacemakers. Second, and more important to tissue-temperature increase, more stray electromagnetic waves mean that less energy is being directed into the tissues. This may have a role in a smaller tissue-temperature increase.

ReBound diathermy increased tissue temperatures to levels known as moderate heating, or a 2°C to 3°C change. During moderate heating, researchers have proposed that the metabolic rate in the tissues is accelerated, muscle spasm and pain are reduced, and blood flow is increased.[10,11]

The Megapulse II was the only device that increased tissue temperatures by 4°C, which is thought to reflect vigorous heating. During vigorous heating, the physiologic

Table. Absolute and Residual Tissue Temperatures After a 30-Minute Application (Mean ± SD)

Treatment	Absolute Temperature, °C	Residual Temperature, °C
Megapulse II pulsed shortwave diathermy	39.97 ± 1.13	4.32 ± 1.79
ReBound diathermy	37.64 ± 0.75	2.31 ± 0.87

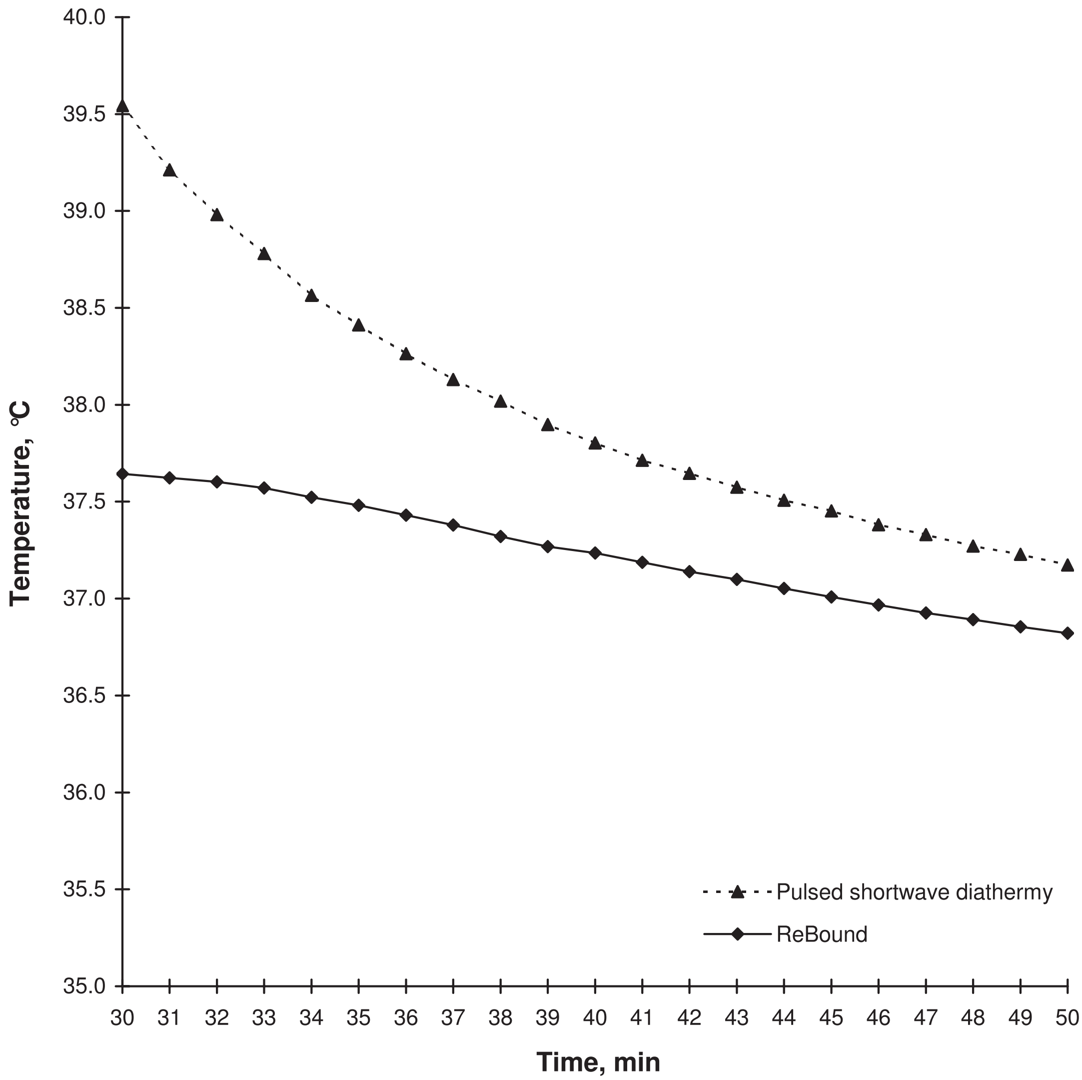

Figure 2. Mean temperatures during the 20-minute temperature decay at a depth of 3 cm deep for the ReBound diathermy system (ReGear Life Sciences, Inc, Pittsburgh, PA) and pulsed shortwave diathermy.

effects of moderate heating are proposed to occur, as well as an inhibition of sympathetic activity and heating levels, which may alter more permanently the viscoelastic properties of collagen when a mechanical stress is applied.[10,11] Therefore, modalities that alter the tissue temperature to vigorous heating levels with an applied joint range-of-motion technique are proposed to increase range of motion to a greater degree.[10]

Given that the initial change in tissue-temperature increase is important for producing various physiologic effects, the decay in the temperature increase is also vitally important to a clinician when trying to increase joint range of motion.[7,21,22] A diathermy device that initially causes a 4°C tissue-temperature increase, producing more potential to elongate the tissues, and then has a slower temperature decay will give a clinician a longer stretching window, during which joint mobilizations and stretching will be more effective.[1] After the 30-minute treatment, ReBound diathermy produced a slower temperature decay than the Megapulse II diathermy.

The difference in temperature decay between the diathermies could be attributed to the 30-minute duration of our treatments. The peak temperature we observed with ReBound diathermy occurred at the 30-minute treatment mark, whereas the peak temperature of the Megapulse II diathermy occurred at 20 minutes. The decrease in temperature after 20 minutes of the Megapulse II treatment could be due to the body's natural response to attempt to cool the tissues during vigorous heating by increasing blood flow.[23] This increase in blood flow results in the faster temperature decay associated with the Megapulse II and is a reason why the ReBound diathermy did not have a more rapid temperature decay.

The rate of temperature decay is not as important as the residual temperature produced by the device to properly elongate tissues. The higher residual temperature that the Megapulse II produced is important because it allows the clinician a greater potential to elongate the tissues when a mechanical stress is applied and a longer stretching window in which to apply the mechanical stresses, such as stretching or joint mobilizations.[18] Researchers[13,21,22] have found that these high-temperature increases when followed by joint mobilizations increase range of motion in the shoulder, elbow, knee, and ankle. ReBound diathermy was inadequate to heat the tissues to a level of vigorous heating. Thus, when applying heat and a mechanical stress, ReBound diathermy will not have the potential to increase joint range of motion to the same degree as the Megapulse II.

The typical Megapulse II heating drum has a surface area of 200 cm^2 (about the size of a salad plate). However, the heating distribution throughout the surface area of this drum may vary. Using the Megapulse PSWD, Garrett et al[15] found that heat is produced throughout the diathermy drum, but the heating distribution under the diathermy drum is not equal. They observed the greatest temperature increases under the center of the drum (4.6°C), whereas the edges of the drum heated the tissues to a lesser degree (3.2°C). They hypothesized that this heat distribution occurs due to conduction of heat to the surrounding cooler tissues that are not directly under the diathermy drum.[15] We took all of our measurements directly in the middle of the diathermy drum, thus recording the highest temperature produced by the Megapulse II diathermy.

The ReBound diathermy sleeve we used is 13 in (33.02 cm) long and has helical coils that run circumferentially throughout the length of the sleeve. This sleeve is about twice the length of a diathermy drum. We do not know whether a particular area of the sleeve produces a greater concentration of electromagnetic energy, thereby creating more heat. We made all of our tissue-temperature recordings close to the middle of the sleeve. In the future, researchers may determine whether ReBound diathermy produces heat in a uniform pattern throughout the sleeve or whether the heating pattern produced is similar to that produced with a Megapulse PSWD drum.

Although the Megapulse II diathermy heated the tissue to a greater temperature than the ReBound diathermy, the latter still has some advantages. It is lighter and more mobile and, therefore, is easier to transport, whereas most PSWDs tend to be bulky and heavy, making them hard to transport. A PSWD can be as much as 2 to 4 times more expensive than ReBound diathermy. The ReBound device includes a sleeve that wraps around the whole limb segment, which may provide a greater heating area.

Our study had limitations. Our results only can be applied directly to the 2 specific modality devices that we used (Megapulse II PSWD, continuous ReBound diathermy). We investigated healthy, college-aged students with a subcutaneous fat thickness measurement of less than 15 mm over the treatment area, and we do not know how the results will transfer to other populations and injured individuals. Our results also can be inferred only with regard to treatments lasting 30 minutes.

Further research should be performed with ReBound continuous diathermy. Measuring increases in temperature with ReBound diathermy at different areas throughout the muscle may be important in continuing to understand the effects of the device on tissue temperature over its entire treatment area. Research involving an injured population may help in understanding the effect the ReBound diathermy has on the healing process. Testing the device in various populations also could help clinicians decide whether to use the ReBound device throughout other populations.

CONCLUSIONS

Our results indicated that the Megapulse II is a better device than the continuous ReBound diathermy for deep heating. The Megapulse II PSWD can produce vigorous heating to deep tissues, elongating them and providing a stretching window for clinicians. Given its lower power output, ReBound diathermy can be used as a moderate heating modality. Because we are the first to evaluate the heating characteristics of the ReBound diathermy, further research should be performed to understand heating distribution throughout its sleeve.

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