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The Effects of the ReBound Diathermy Unit, Megapulse II Shortwave
Diathermy Unit and Moist Hot Packs on Tissue Temperature
Increase of the Triceps Surae Muscle Group

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A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of
Master of Science

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ABSTRACT

The Effects of the ReBound™ Diathermy Unit, Megapulse II® Shortwave Diathermy Unit and Moist Hot Packs on Tissue Temperature Increase of the Triceps Surae Muscle Group

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Master of Science

Context: Clinicians use a number of superficial and deep heating modalities, including pulsed shortwave diathermy (PSWD) and moist hot packs, in the clinical setting. Recently, a continuous diathermy unit called ReBound was introduced into the clinical setting. Its effectiveness as a heating modality is unknown. **Objective:** To compare the effects of PSWD, moist hot packs and the ReBound unit on tissue temperature in the triceps surae muscle. **Design:** A 3 x 27 factorial cross-over design with repeated measures. **Setting:** University research laboratory. **Subjects:** Twelve healthy college-aged volunteers (4 men, 8 women; age = 22.2 ± 2.25 ; calf subcutaneous fat thickness = $.72 \text{ cm} \pm .19 \text{ cm}$). **Interventions:** On three different days separated by at least 48 hours, one of three modality treatments (PSWD, moist hot packs or ReBound unit) selected using a Latin-square was applied to the triceps surae muscle of each participant for 30 minutes. After the 30 minute treatment, the modality was removed and temperature decay was recorded for 20 minutes. **Main Outcome Measures:** Medial triceps surae intramuscular tissue temperature at 1 cm and 3 cm deep was measured using implantable thermocouples inserted horizontally into the muscle. Measurements were taken every 5 minutes during the 30 minute treatment and every minute during the 20 minute temperature decay for a total of 50 minutes. A 3 x 27 mixed model analysis of variance blocking by subject was used to assess the effects of treatments and time, and their interaction on the tissue temperature at 1 cm and 3 cm depths. **Results:** A significant treatment by time interaction main effect was found for tissue temperature increase at each depth, 1 cm ($F_{52, 572} = 14.66, p < .0001$) and 3 cm ($F_{52, 572} = 17.86, p < .0001$). Post-hoc measures revealed that tissue temperature significantly increased with the PSWD over the ReBound unit and moist hot packs at 1 cm and 3 cm depths. There was no significant difference between the ReBound unit and moist hot packs throughout the treatment and temperature decay. The greatest mean tissue temperature increase from baseline was observed with the PSWD unit at 1 cm ($5.96^\circ\text{C} \pm 2.04^\circ\text{C}$) and at 3 cm ($4.32^\circ\text{C} \pm 1.79^\circ\text{C}$). There was no statistical difference between the increases observed with the ReBound (1 cm: $3.69^\circ\text{C} \pm 1.50$; 3 cm: $2.31^\circ\text{C} \pm .87$) and moist hot packs (1 cm: $2.82^\circ\text{C} \pm .90$; 3 cm: $1.56^\circ\text{C} \pm 1.00$). **Conclusions:** During a 30 minute treatment, PSWD was the most effective at increasing intramuscular tissue temperature of the triceps surae muscle group. There was no significant difference between the effectiveness of moist hot packs and the ReBound continuous diathermy unit in increasing intramuscular tissue temperature.

Keywords: shortwave diathermy, continuous diathermy, intramuscular temperature, heat.

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Introduction

Heat has been used as a therapeutic modality for a number of years and is described by two categories: superficial and deep heating agents. 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 shortwave diathermy. While the depth of tissue heating varies with each thermotherapy modality, the primary physiological effects and benefits of using heat remain relatively constant and include the following: increased circulation and blood flow,^{1,2} increased metabolism,² increased muscle temperature,^{1,3-6} increased tissue temperature,^{1,3,5-9} decreased pain,¹⁰⁻¹² decreased tissue stiffness,¹³⁻¹⁶ and muscle spasm relaxation.^{13,16} Indications for heat include muscle strain, sprain, contusion, tendinitis, tenosynovitis, bursitis, myofascial trigger points, pain, removal of byproducts of the inflammatory process, and joint contracture.^{2,5,6,10-16,22,23}

Recent literature suggests that tissue temperature must increase by at least 1.0°C for mild heating, 2°—3°C for moderate heating and by 4°C or more for vigorous heating to occur, with an increase in physiological effects as tissue temperature increases.¹⁷⁻²⁰ Moist hot packs are perhaps the most widely used form of superficial heating in the clinical setting. Multiple studies have measured tissue temperatures at 1 cm deep after a 15-minute application of moist hot packs and have found varying results of 3.8°C⁴ and 2.2°C²¹ in the triceps surae muscle group and 3.0°C³ in the thigh muscle. Hot packs have also been shown to increase tissue temperature at 3 cm deep in the triceps surae muscle to 0.74°C.⁴

Pulsed shortwave diathermy (PSWD) units such as the Megapulse® II unit have been shown to effectively increase tissue temperature to the desired levels at which optimal healing can occur.^{2,5,6,10-16,22,23} A mean temperature increase in the triceps surae muscle group after 20

minutes of treatment with PSWD has been observed to be as great as 4.6°C at 3 cm deep.⁶ Based on these findings, the tissue temperature increase at 3 cm observed with diathermy is greater than the tissue temperature increase that has been observed with moist hot packs thus allowing for heat to penetrate deeper tissues.

Little research has been published on the effectiveness of continuous shortwave diathermy as a deep heating modality.^{24,25} Its use today is not as common as pulsed shortwave diathermy due to the rapid heating produced by the machine.^{24,25} The settings of a continuous shortwave diathermy machine when compared to PSWD are typically of a higher wattage (80—450 W) and megahertz resulting in too much heat, which may result in burning to patients.²⁵

In 2008, a newer form of continuous diathermy, the ReBound™ unit was introduced into the clinical setting. The ReBound™ unit appears to be an attempt to overcome the issues of rapid and intense heating produced by previous continuous diathermy units. The ReBound™ unit is a form of continuous shortwave diathermy that uses an induction helical coil sleeve to heat deep in the muscle.²⁶ It heats at the parameters of 35 W and 13.56 MHz²⁶, which is different than PSWD units, which usually have settings of 27.12 MHz and 48 to 100 W.^{4-6,15,16,27,28} The lower settings of the ReBound™ unit allow for the machine to produce continuous waves at a lower wattage making it safe for use and more comparable to pulsed shortwave diathermy units.

Due to the lack of research on this new form of continuous diathermy, (the ReBound™ unit) we felt the need to evaluate its effectiveness compared to that of moist hot packs, and PSWD by measuring the effect of each modality on tissue temperature increase of the triceps surae muscle group at 1 cm and 3 cm deep.

Methods

A 2 x 3 x 27 repeated measures design directed data collection in our study for temperature heating (every minute during decay). The dependent variables were the tissue temperature of the triceps surae muscle group at 1 cm and 3 cm deep. The independent variables were three levels of treatment groups—the ReBound™ diathermy unit, the Megapulse II® PSWD unit and moist hot packs—and time as we recorded 27 measurements over the course of a 30-minute treatment (measured every five minutes) and 20-minute tissue temperature decay (measured every minute). A crossover design was implemented, meaning that all subjects were treated with the ReBound™ unit, Megapulse II® PSWD diathermy unit and moist hot packs. A Latin-square was utilized to randomize treatment order for the subjects and successive treatments were administered with at least a 48 hour recovery period in between.

Subjects

Four male and eight female healthy college-aged volunteers were used for this study (age = 22.2 ± 2.25 ; calf subcutaneous fat = $.72 \text{ cm} \pm .19 \text{ cm}$). Each subject was screened for disqualifying conditions which included pregnancy, fever, peripheral vascular disease, infection, injury to the triceps surae muscle in the past two months, compromised circulation, compromised sensation to the area being treated, and subcutaneous fat thickness of the calf greater than 15 mm. Subjects were instructed to not exercise for at least two hours prior to testing. Before participating in the study, each subject signed a consent form for participation in the study and the study was approved by the Institutional Review Board (IRB) at Brigham Young University.

Instruments

Implantable IT-21 thermocouples (Physitemp Instruments Inc, Clifton, NJ) were used and inserted via a 20-gauge catheter (Johnson & Johnson Medical, Arlington, TX) to measure

intramuscular temperature. These were plugged into an Iso-Thermex electrothermometer (Iso-Thermex, Columbus Instruments, Columbus, OH) to record the temperatures. After each use the thermocouples were disinfected with CidexPlus (Johnson & Johnson Medical, Arlington, TX) for 24 hours.

Standard (10”x 12”) hydrocollator steam hot packs (Model #1064, Chattanooga Corporation, Industry, CA) were used in our study. An insulated terry cloth cover (Chattanooga Corporation, Industry, CA) that folds over the moist hot pack along with one large towel were used as a barrier between the moist hot pack and the skin. Throughout the study the hydrocollator (Model E-1, Chattanooga Corporation, Industry, CA) was checked to ensure that the water level was correct and the water temperature was consistent with the manufacturer’s recommended guidelines of 71—74°C. The two diathermy units used in our study were the ReBound™ diathermy machine (Game Ready and ReGear Life Sciences, Pittsburgh, PA) and a pulsed shortwave diathermy machine (Megapulse II; Accelerated Care Plus, Reno, NV). Each of the diathermy machines used met the recommended calibrated guidelines. A therapy garment sleeve size 18 was used (Game Ready and ReGear Life Sciences, Pittsburgh, PA) to provide the ReBound™ diathermy treatment.

A Doppler ultrasound machine (Model LogiQ 5e, General Electric Company, Fairfield, CT) was used to image the subjects’ subcutaneous fat thickness and aided in verifying the depth of the inserted thermocouples.

Procedures

Test set-up procedures— Each subject wore shorts for the treatments and reported to the modalities lab at Brigham Young University. Subjects lay prone on the treatment table.

Ultrasound gel was applied to the right posterior calf. Using the Doppler ultrasound machine, an

image was produced of the posterior triceps surae muscle, and the thickest portion of the muscle or area of the muscle with the largest muscle girth was observed. A line was marked on the posterior skin to indicate where the largest girth was observed. We then measured and recorded subcutaneous fat thickness using the Doppler ultrasound machine at the marked site. It was confirmed that each subject had less than 15 mm subcutaneous fat thickness over the treatment area. A ruler was used to measure perpendicular from the already marked line on the posterior skin surface to a 1 cm and 3 cm posterior to anterior distance on the medial side of the calf. A dot was marked on the skin at the 1cm and 3cm measured distances.

Thermocouple insertion— The skin was prepped using an iodine swab and wiped clean using an isopropyl alcohol prep pad. A 20-gauge catheter was inserted horizontally through the previously marked dot at 1 cm and another catheter was inserted at 3 cm deep into the medial aspect of the posterior triceps surae. The depth of the insertion of the catheter was then verified to be within 0.2 cm of the desired depth using the Doppler ultrasound machine. After verification by the Doppler ultrasound machine, one IT-21 thermocouple was inserted via the catheter at 1 cm deep and another via the catheter at 3 cm deep. Each catheter was then slowly removed leaving the thermocouples intact. The two thermocouples were secured to the skin with clear medical tape. The thermocouples were attached to an Iso-Thermex machine (Columbus, OH). The Iso-Thermex machine was set up to measure each temperature every five seconds. Baseline temperature was recorded and considered reached when the temperature change was no greater than 0.1°C for two minutes.

ReBound™ treatment— After the thermocouples were inserted and baseline temperature measured, the diathermy sleeve was pulled over the triceps surae muscle of the subject and the ReBound™ machine was then turned on, set for a 30-minute treatment and tuned. In order to

ensure that the peak temperature increase was observed, each subject was treated with each modality for a 30-minute treatment duration. During the pilot study, when the unit was turned on, it interfered with the readings of the Iso-Thermex machine. The unit also interfered with any other computer or machine in close proximity to the unit. The diathermy unit therefore needed to be paused, allowing for an accurate tissue temperature reading. After five, ten, fifteen, twenty, twenty-five and thirty minutes of treatment, we paused the diathermy machine and tissue temperatures at 1 cm and 3 cm deep were measured and recorded by an average of three recordings using the Iso-Thermex machine. The ReBound™ machine was paused for an average of 20 seconds during each recording session.

Megapulse II® treatment— After the thermocouples were inserted and baseline temperature was measured, the drum of the diathermy unit was placed over the posterior belly of the triceps surae muscle with the middle of the drum above the already inserted thermocouples. The machine was then turned on and set for a 30-minute treatment at 800 pulses per second (pps), and a pulse width of 400 microseconds. After five, ten, fifteen, twenty, twenty-five and thirty minutes of treatment, we paused the diathermy machine and tissue temperatures at 1 cm and 3 cm deep were measured and recorded by an average of three recordings using the Iso-Thermex machine.

Moist hot pack treatment— After baseline temperature was measured and recorded, a moist hot pack covered by a terry cloth sleeve was laid on the triceps surae muscle of the subject. One towel folded in half was placed between the moist hot pack and the skin. After five, ten, fifteen, twenty, twenty-five and thirty minutes of treatment, the tissue temperatures at 1 cm and 3 cm deep were measured and recorded using an average of three recordings using the Iso-Thermex machine. After treatment, the moist hot pack was returned to the heating unit and left

there for at least 24 hours to allow for reheating of the hot pack to occur. During treatment, if subjects reported that the hot pack got too hot, another towel folded in half was applied and recorded.

Post-treatment procedures— After treatment had concluded, the hot pack and towel were removed, the diathermy machine was turned off, the ReBound™ sleeve was removed and tissue temperature decay was measured. The thermocouples were left in the tissue post treatment for twenty minutes and temperature decay per minute during this time was measured and recorded using the Iso-Thermex machine and recorded by us.

After temperature decay was measured, the thermocouples were carefully removed and bacitracin ointment and an elastic bandage were applied over each insertion site. Subjects were instructed as to the appropriate care for the insertion site. The thermocouples were sterilized in a 2% CidexPlus solution for 24 hours, and needles and catheters were disposed of in a sharps biohazard container.

Statistical Analysis

We used a 3 x 27 mixed model analysis of variance blocking by subject to assess the effects of treatments and time, and their interaction on the two dependent variables of tissue temperature at 1 cm and 3 cm deep. We accounted for the differences in baseline by adding baseline temperatures to the model. Post-hoc tests were used to determine specific differences between the three treatment groups. Statistical analyses were performed with JMP 9.0 (SAS Inc., Cary, NC), and the priori alpha level was set at $p \leq 0.05$ for the statistical tests.

Results

Twelve healthy college-aged volunteers were used for this study (age = 22.2 ± 2.25 ; subcutaneous fat = $.72 \text{ cm} \pm .19 \text{ cm}$). All subjects were fully compliant and compensated for

their time. During the moist hot pack treatment, none of the subjects required more than one towel to be placed between the treatment area of the triceps surae muscle group and the moist hot pack. There was no reason for termination of a treatment for any of the three modalities throughout the study.

We found significant main effects for treatment and time, and their interaction at both depths, 1 cm and 3 cm. We were particularly interested in the significant difference of the interaction of treatment by time for our analysis. At 1 cm the Megapulse II® PSWD unit produced significantly greater tissue temperatures than the ReBound™ unit and moist hot packs over the course of the treatment and temperature decay ($F_{52,572} = 14.66, p = < .0001$). There was no significant difference between the ReBound™ unit and moist hot packs at 1 cm deep throughout the measured time periods.

There was a significant difference at 3 cm deep, with the Megapulse II® PSWD unit being significantly greater for the course of the treatment and temperature decay than the ReBound™ unit and moist hot packs ($F_{52,572} = 17.86, p = < .0001$). There was no significant difference between the ReBound™ unit and moist hot packs at 3 cm deep throughout the measured time periods.

The mean of the peak temperature increases throughout the measured time were as follows: PSWD unit at 1 cm was $5.96^{\circ}\text{C} \pm 2.04$ and at 3 cm $4.32^{\circ}\text{C} \pm 1.79$; moist hot packs at 1 cm were $2.82^{\circ}\text{C} \pm .90$ and 3 cm $1.56^{\circ}\text{C} \pm 1.00$; and the increases with the ReBound™ unit were $3.69^{\circ}\text{C} \pm 1.50$ at 1 cm and $2.31^{\circ}\text{C} \pm .87$ at 3 cm deep (Table 1). The mean of the absolute peak temperatures were as follows: PSWD unit at 1 cm was $40.36^{\circ}\text{C} \pm 1.33$ and 3 cm $39.97^{\circ}\text{C} \pm 1.13$; moist hot packs at 1 cm $37.60^{\circ}\text{C} \pm .39$ and 3cm $37.15^{\circ}\text{C} \pm .43$; and increases with the ReBound™ unit were $37.94^{\circ}\text{C} \pm .85$ at 1cm and $37.64^{\circ}\text{C} \pm .75$ at 3 cm (Table 2).

Discussion

The primary purpose of our study was to examine the temperature increases of three modalities: the ReBound™ continuous shortwave diathermy unit, moist hot packs and a pulsed shortwave diathermy (PSWD) unit, the Megapulse II®. Due to the absence of research specifically on the ReBound™ diathermy unit, we wanted to better understand its role as a heating modality. In order to do this, we felt the need to examine its ability to increase tissue temperature.

Temperature increases

In our study, the greatest mean temperature increases were observed with the PSWD unit at 1 cm and 3 cm depths. Our results of tissue temperature increases with the PSWD unit (Figure 1 and Figure 2) at 1 cm ($5.96^{\circ}\text{C} \pm 2.04$) and 3 cm ($4.32^{\circ}\text{C} \pm 1.79$) are comparable to those of earlier studies of 4.6°C at 3 cm deep.^{4,6,21} All earlier studies that have compared PSWD and moist hot packs have reported similar results to ours, in which we found that PSWD produces greater tissue temperature increases.^{4,6,21}

The mean increase we observed with moist hot packs at 1 cm ($2.82^{\circ}\text{C} \pm .90$) is similar to the temperature increase shown with previous studies of 2.2°C ²¹ in the triceps surae muscle. In our study, moist hot packs at 3 cm deep exhibited greater tissue temperatures ($1.56^{\circ}\text{C} \pm 1.00$) than those of previous studies of 0.74°C .⁴ The greater temperature increase that we saw with moist hot packs at 3 cm deep could possibly be attributed to the treatment duration of our study. With previous studies using hot packs, the treatment durations were only 15 minutes. Our study, however, included a 30-minute treatment duration. Perhaps if the previous studies used a 30-minute treatment duration, then our results and their results would have been more similar.

To our knowledge, our study was the first to evaluate mean temperature increases with the ReBound™ unit. We observed greater temperature increases with PSWD at 1 cm and 3 cm deep than with the ReBound™ unit at the same depths. We found no significant difference between temperature increases with the ReBound™ unit and moist hot packs at either depth. One factor to explain our results could be that the ReBound™ unit heats at the parameters of 35 W and 13.56 MHz²⁶, which is less than PSWD units, which usually have settings of 27.12 MHz and 48 W.^{4-6, 15, 16, 27, 28} The lower settings of the ReBound™ unit compared to that of other continuous diathermy units allow the unit to be safe for use, but perhaps these settings are too low for the unit to heat at levels comparable to that of PSWD machines. These settings, however, heat at a level more comparable to that of moist hot packs. It is possible that if the parameters were increased with the ReBound™, it could heat at a higher temperature more comparable to that of PSWD machines.

Physiological effects

Pulsed shortwave diathermy was the only treatment that increased tissue temperature to the absolute level stated in previous research (40°C) required for all the desired physiological effects to occur in the muscle (Table 2).²⁹ This does not mean that the other two modalities tested did not produce any physiological effects. Recent articles written by researchers suggest that tissue temperature must increase by at least 1.0°C over baseline temperature for mild heating, 2°—3°C for moderate heating and by 4°C or more for vigorous heating to occur.¹⁷⁻²⁰ At these different stages of heating various physiological effects will occur. For example, mild heating modalities may accelerate the metabolic rate in tissue, whereas moderate heating modalities may also reduce muscle spasm, pain, chronic inflammation, increase blood flow and accelerate the metabolic rate.¹⁷⁻²⁰ Vigorous heating modalities may do all the things of mild and moderate

heating modalities as well as alter the viscoelastic properties of collagen and inhibit sympathetic activity.¹⁷⁻²⁰ Based on our data, moist hot packs provide moderate heating at 1 cm and mild heating at 3 cm deep. PSWD provides vigorous heating at either depth. The ReBound™ unit provides moderate heating at either depth. Though the ReBound™ unit does not produce vigorous heat like that of the PSWD, it can still be thought of as a moderate heating modality and can create the physiological effects as noted in the moderate heating range.

Treatment duration

The difference in temperature increases between the modalities used in our study could possibly be attributed to the 30 minute duration of our treatments. The peak temperature we observed with the ReBound™ unit occurred at the 30-minute treatment mark, whereas with PSWD, peak temperature occurred at the 20-minute mark. The decrease in temperature after 20 minutes of treatment could be due to the body's attempt to cool the tissue by increasing blood flow. Greater temperature increases were observed with the PSWD unit which is why the body attempted to cool the tissue sooner than with the ReBound™ treatments. This suggests that at least a 30-minute treatment duration should be recommended for ReBound™ treatments. We stopped the treatments at 30 minutes, so it is unknown if a greater temperature increase could have been observed past the 30-minute mark or when the body might attempt to cool the tissue as with the PSWD unit.

In our study we used a 30-minute treatment duration whereas with previous studies a 15-minute treatment duration was used.^{3,4,21} During this 30-minute treatment duration we observed increases in tissue temperature at 3 cm deep past the 15-minute treatment mark. Since other studies only used a 15-minute treatment duration it is unknown if similar increases past 15 minutes could have been observed had the treatments during those studies not been stopped. In

one particular study there was a steady increase in tissue temperature at 3 cm deep observed with a moist hot pack treatment, however the treatment was ceased after 15 minutes and a 10 minute ultrasound treatment was then applied.⁴ Further temperature increases were then observed during the ultrasound treatment. One reason why we observed further temperature increases after 15 minutes could be because the moist hot pack is in fact retaining heat for a full 30 minutes. If the hot pack however is no longer retaining heat it is possible that the heat is still being absorbed throughout the muscle. Perhaps it takes up to 30 minutes for the heat to penetrate 3 cm deep in the triceps surae muscle even if the hot pack is no longer warm. Further research should be performed to investigate the optimal moist hot pack treatment duration that produces the greatest temperature increases in the triceps surae muscle.

Size of heating area

The typical PSWD heating drum has a surface area of 200 cm² (about the size of a salad plate). The heating distribution throughout the surface area of this drum may vary however. A group of researchers found that although PSWD heated areas as large as the surface area of the drum, the heating distribution under the diathermy drum was not equal.⁶ The greatest temperature increases were observed under the center of the drum (4.5°C), while the edges of the drum heated tissue to 3.2°C.⁶ The researchers stated that this could be due to conduction from cooler tissues not under the diathermy drum.⁶ The measurements we recorded using the PSWD in our study were all directly under the middle of the drum. This allowed for us to observe the greatest possible temperature increases with PSWD. The ReBound™ diathermy sleeves are 13 inches in length. This is about twice the length of a diathermy drum. Helical coils run circumferentially throughout the whole length of the sleeve and are not centered at one particular area like the diathermy drum. It is unknown if there is a particular area of the sleeve that heats

the greatest similar to how a diathermy drum produces heat. The heat could be spread across the whole area of the sleeve which could be a reason why greater temperature increases were not found with the ReBound™ unit. Perhaps this heating pattern causes even heating rather than centered at a specific area. Conduction from surrounding muscle tissue could also aid in cooling parts of the muscle being heated under the sleeve like with the outer edges of the diathermy drum.⁶

Radio frequency wave interference

When turned on, the ReBound™ unit interfered significantly with any machine that was in close proximity to the unit. It interfered with the Doppler ultrasound machine, laptops, the Iso-Thermex machine and any other electronic device we were using within a few feet of the unit. Although there was some interference between the Iso-Thermex machine and the PSWD machine, the interference was not to the same extent as with the ReBound™ unit. This interference was due to radio frequency waves from the diathermy unit being emitted into the environment and is a reason why the machine should not be used on a patient who has a pacemaker. It appears that the ReBound™ unit emitted more waves into the environment and not directed at the muscle to be heated. With more waves directed at a muscle, more heat could be produced. This could be another reason why we did not see more significant temperature increases with the ReBound™ unit.

Advantages of the ReBound™ unit

Although the PSWD unit heated the muscle to a greater temperature increase than the ReBound™ unit, there are still some advantages to the ReBound™ device. The ReBound™ unit is lighter and more mobile and is therefore easier to travel with, while the PSWD units and hydrocollators tend to be bulky and heavy, making them hard to travel with. Pulsed shortwave

diathermy machines can be upwards of two to four times more expensive than the ReBound™ unit, however the ReBound™ unit is more expensive than hot packs. The ReBound™ unit possibly heats a greater surface area than the PSWD units. The ReBound™ unit includes a sleeve that wraps around the whole body part to be heated, but more research needs to be performed in order to study if the ReBound™ unit actually heats throughout the whole surface area that is covered by the sleeve. Another advantage is that the ReBound™ unit doesn't require a reheating period like moist hot packs do. The advantages and disadvantages of PSWD units, the ReBound™ unit and moist hot packs should be taken into account when trying to choose the modality best suited for an individual.

Limitations

The results of this study can only be directly applied to the three specific modality units that we used: the Megapulse II® pulsed shortwave diathermy unit (Accelerated Care Plus, Reno, NV), standard (10"x 12") hydrocollator steam hot packs (Model #1064, Chattanooga Corporation, Industry, CA), and the ReBound™ diathermy machine (Game Ready and ReGear Life Sciences, Pittsburgh, PA). We also used healthy, college-aged students with a subcutaneous fat thickness measurement of less than 15 mm over the treatment area, and it is unknown how the results transfer to injured individuals. The results of our study can also only be inferred upon treatments lasting 30 minutes or less.

Further research

We suggest that further research be performed with the ReBound™ continuous diathermy unit. Measuring increases in temperature with the ReBound™ unit at different areas throughout the muscle may be important in continuing to understand the effects of the unit on tissue temperature over its entire treatment area. Research using an injured population may help in

understanding the effect the ReBound™ unit has on the healing process. Testing the unit in an older population could also be beneficial in aiding clinicians' decisions in using the ReBound™ unit throughout all populations.

Conclusion

The results of our study indicate that PSWD is the optimal device to use for superficial and deep heating. The ReBound™ unit does not increase tissue temperature to a greater level than moist hot packs to be statistically significant. The ReBound™ unit therefore can be considered an effective superficial heating modality but perhaps not a deep heating modality.

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Figure 1: 1 cm Temperature Increases

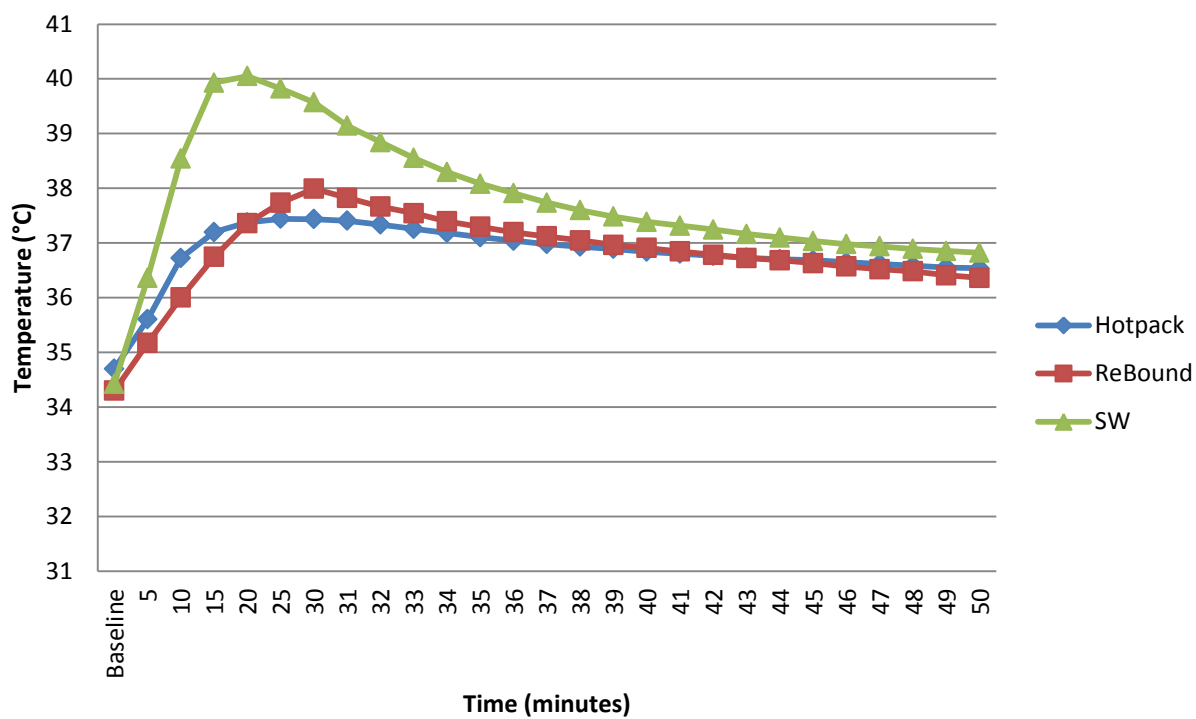


Figure 2: 3 cm Temperature Increases

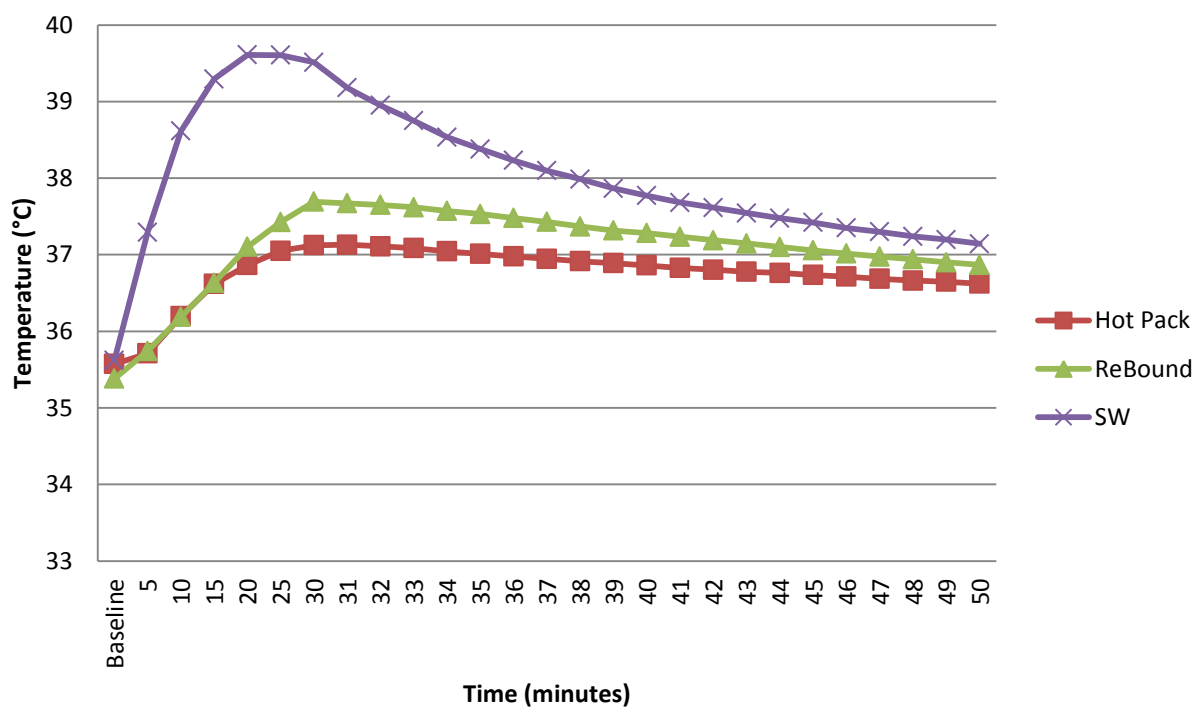


Table 1: Mean temperature increase (°C; mean \pm SD)

Treatment	1 cm	3 cm
Hot Pack	2.82 \pm .90	1.56 \pm 1.00
PSWD	5.96 \pm 2.04*	4.32 \pm 1.79*
ReBound	3.69 \pm 1.50	2.31 \pm .87

* Indicates significant difference

† PSWD is pulsed shortwave diathermy

Table 2: Absolute temperature increase mean ($^{\circ}\text{C}$; mean \pm SD)

Treatment	1 cm	3 cm
Hot Pack	37.60 \pm .39	37.15 \pm .43
PSWD	40.36 \pm 1.33*	39.97 \pm 1.13*
ReBound	37.94 \pm .85	37.64 \pm .75

* Indicates significant difference

† PSWD is pulsed shortwave diathermy

Prospectus

Chapter 1

Introduction

Heat has been used as a therapeutic modality for a number of years and is described by two categories: superficial and deep heating agents. 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 shortwave diathermy. As the depth of tissue heating varies with each thermotherapy modality, the primary physiological effects and benefits of using heat remain relatively constant and include: increased circulation and blood flow,^{1,2} increased metabolism,² increased muscle temperature,^{1,3-6} increased tissue temperature,^{1,3,5-9} decreased pain,¹⁰⁻¹² decreased tissue stiffness,¹³⁻¹⁶ and muscle spasm relaxation.^{13,16} Indications for heat include muscle strain, sprain, contusion, tendinitis, tenosynovitis, bursitis, myofascial trigger points, pain, removal of byproducts of the inflammatory process, and joint contracture.

It has been suggested that superficial and deep heat must increase skin temperature to at least 40°C and no more than 45°C in order for it to produce the desired physiological effects.¹⁷ More recent articles suggest that tissue temperature must increase by at least 1.0°C for mild heating, 2°C—3°C for moderate heating and by 4°C or more for vigorous heating to occur, with an increase in physiological effects as tissue temperature increases.¹⁸⁻²¹ Moist hot packs are perhaps the most widely used form of superficial heating in the clinical setting. In past studies researchers have observed a 3.0°C³ and 2.2°C²² increase in tissue temperature at 1 cm deep after fifteen minute applications of hot packs. Temperature increases differ by study however as with

a more recent study, where researchers observed the temperature increase after the use of hot packs to be 3.8°C at a depth of 1 cm and .74°C at a depth of 3 cm after fifteen minutes.⁴

Shortwave diathermy has been shown to effectively increase tissue temperature to the desired levels which optimal heating can occur.^{2,5,6,8-16,23,24} Most of the research has been focused on pulsed shortwave diathermy (PSWD) units such as the Megapulse® II unit.^{2,5,6,10-16,23,24} A mean temperature increase in the triceps surae muscle after twenty minutes of treatment has been observed to be as great as 4.6°C at 3 cm deep.⁶ Other researchers have observed a mean temperature increase of 3.5°C at the same depth.⁵ Based on these findings, the tissue temperature increase at 3 cm observed with diathermy is greater than the tissue temperature increase that has been observed with moist hot packs thus allowing for heat to penetrate deeper tissues.

Little research has been published on the effectiveness of continuous shortwave diathermy as a deep heating modality.^{25,26} Its use today is not as common as pulsed shortwave diathermy due to the rapid heating produced by the machine.^{25,26} The settings of a continuous shortwave diathermy machine when compared to PSWD are typically of a higher wattage (80—450W) and megahertz resulting in too much heat which cause burning to patients.²⁶

In 2008, a newer form of continuous diathermy, the ReBound™ unit was introduced into the clinical setting. The ReBound™ unit appears to be an attempt to overcome the issues of rapid and intense heating produced by previous continuous diathermy units. The ReBound™ unit is a form of continuous shortwave diathermy that uses an induction helical coil sleeve to heat deep in the muscle.²⁷ It heats at the parameters of 35W and 13.56 MHz²⁷, which is different compared to PSWD units which usually have settings of 27.12 MHz and 48 W.^{4-6,15,16, 28, 29} The lower settings of the ReBound™ unit allow for the machine to produce continuous waves at a lower wattage making it safe for use and more comparable to pulsed shortwave diathermy units.

A pilot study was completed to measure the tissue temperature increase of the triceps surae muscle with the ReBound™ diathermy unit. The peak temperature increase was observed at 10 minutes of treatment. At 10 minutes at 1cm deep there was an increase of 3°C and only 1°C at 3cm deep. Baseline temperature was restored after only 5 minutes post treatment. These temperature increases are similar to previously observed tissue temperature increases with moist hot packs and lower than those observed with pulsed shortwave diathermy. These results continue the question of whether or not the ReBound™ unit produces the heat necessary for superficial heating and/or deep heating or its ability to increase tissue temperature comparable to that of other heating modalities specifically moist hot packs and the Megapulse II® pulsed shortwave diathermy machine.

Statement of the Problem

The purpose of this study is to evaluate the effectiveness of moist hot packs, the ReBound™ diathermy unit and the Megapulse II® pulsed shortwave diathermy unit by measuring the effect of each modality on tissue temperature increase of the triceps surae muscle at 1 cm and 3 cm deep.

Null Hypothesis

There will be no difference in tissue temperature increase between the moist hot packs, Megapulse II® diathermy unit and the ReBound™ diathermy unit at 1 cm and 3 cm deep.

Hypothesis

1. There will be a greater tissue temperature increase with the ReBound™ unit than the moist hot packs at 1 cm and 3 cm deep.
2. There will be a greater increase in the tissue temperature of the Megapulse II® diathermy unit than the ReBound™ diathermy unit and moist hot packs at 1 cm and 3 cm deep.
3. Temperature will return to baseline within fifteen minutes post treatment.

Assumptions

1. The thermocouples will remain at the same depth throughout the treatment.
2. There is no variability between moist hot pack temperatures.
3. The application of the ReBound™ unit will be consistent.

Limitations

1. The position of the thermocouples between patients could vary.

Delimitations

1. The subjects will range from ages 18 to 35.
2. The treatment will be limited to only the triceps surae group.

Significance of the Study

Clinical practice may be affected by the results of this study. If the ReBound™ unit heats at a greater depth than moist hot packs or similar to that of other deep heating modalities such as the Megapulse II® diathermy machine it could then be used as an effective deep heating modality. If the ReBound™ unit does not heat any deeper than moist hot packs clinicians might not use it as a deep heating modality.

Chapter 2

Review of Literature

Literature Searched

Literature articles were found through searching the following online search engines: U.S. Department of Education Resource Information Center (ERIC), SPORTDiscus, Web of Science, Academic Search Premier, MEDLINE, and ProQuest. Keywords searched include: diathermy, shortwave diathermy, microwave diathermy, helical coil, induction coil, hot packs, hydrocollator packs, moist hot packs, heat modalities, continuous diathermy, and pulsed diathermy.

Moist Heat Packs

Perhaps the most widely used form of superficial heating is the hydrocollator steam pack (Chattanooga Corp; Chattanooga, Tenn). These hot packs are typically made of silicate gel and are heated in water temperatures of 71°C to 74°C.³⁰ Other forms of hot packs have been used such as the ProHeat pack (ProHeat Inc.; Pheonix, Ariz).

Superficial heat must increase skin temperature to at least 40°C and no more than 45°C in order for it to produce the desired biological results.¹⁷ It has also been suggested that tissue temperature must increase by at least 2.0°C—4.0°C for many of the physiological effects of heating to occur.¹⁸ Tissue temperature increase and skin temperature increase therefore are common measurements used in the comparison of modalities.

Researchers who compared the ProHeat hot packs to moist hot packs found that both forms of superficial heating heated the skin surface at or above 40°C for more than 27 minutes. Both types of hot packs, therefore, can be used as an effective superficial heating modality.⁷

Researchers also studied the other effects of superficial modalities. The researchers concluded that superficial heating increased tissue extensibility and therefore helped to increase

the range of motion of a joint.¹³ Moist heat applied before stretching also has been shown to result in an increase in range of motion of a joint.¹⁴

Tissue Temperature and Moist Hot Packs

A hot pack must increase skin temperature to at least 40°C in order for the necessary physiological effects to occur.¹⁷ It has also been suggested that tissue temperature must increase by at least 2.0°C—4.0°C for many of the physiological effects of heating to occur.¹⁸ A group of researchers studied hot packs and their ability to heat the tissue and skin to that necessary temperature.⁷ In that study, skin temperature after ten minutes was measured to be 45°C and after thirty minutes was 41°C.⁷ The mean temperature rise time at the skin was 1.88 minutes and the total time at or above 40°C was 27.88 minutes.⁷ The hottest temperature that was observed was 48°C at the sixth minute of treatment. An important thing to note was that two towels folded in half were applied between the hot pack and skin. Many clinicians tend to remove towels or add towels during treatment. One weakness in this study is that the total skin temperature was measured before, during, and after the treatments, but neither the increase in skin temperature nor the increase in tissue temperature was recorded. Based on these studies moist hot packs do heat the skin to the necessary 40°C allowing for the positive physiological effects to occur.

Some researchers have studied the total tissue temperature increase at specific depths and the most effective length of heating application. Those researchers have observed a 3.0°C³ and 2.2°C²² increase in tissue temperature at 1 cm deep with heating by hot packs. In a more recent study, researchers observed the temperature increase after the use of hot packs to be 3.8°C at a depth of 1 cm and .74°C at a depth of 3 cm.⁴ The temperature at those tissue depths continued to rise throughout the application of the hot packs and reached their maximum heating effect 15 minutes after application.⁴ The skin temperature, however, would decrease at about eight

minutes among the subjects, much like with the study previously mentioned.⁷ These results provide evidence that 15 minutes is the ideal application time for moist heat packs. The total temperature at the conclusion of each study was not recorded in this study. The increase in tissue temperature observed was within the effective and safe limits of effective heating in order for the desired physiological effects to occur.

The specific effects of tissue temperature increase by the application of moist hot packs have also been studied. The researchers who studied hot packs found those effects to be an increase in tissue extensibility,^{13,14} increase in range of motion of a joint¹⁴ and a decrease in muscle spasm.

Some contraindications of heat include applying heat to an acute injury within the first 48 to 72 hours of injury and applying heat to an area with compromised circulation and/or compromised sensation.

Diathermy

When deep heating is desired, a modality such as diathermy or therapeutic ultrasound is typically used. There are two types of diathermy: shortwave and microwave. Microwave diathermy uses a higher frequency (up to 250 W) than shortwave diathermy.²⁵ Microwave diathermy can be used for soft tissue lesions, some localized infections, and degenerative or chronic arthropathy.²⁵ Shortwave diathermy, however, is more commonly used than microwave diathermy because microwave diathermy can cause burns and its use is currently banned in the United States.

Diathermy uses radio-frequency electromagnetic energy or waves that produce heat or allow for heating to occur. These waves cause an increase in the motion of molecules in the body, creating eddy currents (circular currents of fluid, often moving against the main flow).

Those eddy currents create the friction energy that results in heat being created in the affected area.²⁶

The two forms of shortwave diathermy are continuous shortwave and pulsed shortwave. Continuous shortwave diathermy involves the use of a continuous or constant current to produce heat. Continuous shortwave devices are not commonly used today because they can result in too much heating, which can result in burns to the patient.²⁶ Continuous diathermy is also poorly researched.²⁶ Pulsed shortwave diathermy (PSWD) works in much the same way except for the waves are pulsed, meaning there is an off period between waves.²⁶ The off period allows for some cooling between the waves or pulses and the heat is not as strong or hot as with continuous shortwave diathermy.

Many positive effects exist of using diathermy as a deep heating modality. One such study on continuous diathermy showed that it helped to relieve pain, relax the muscle, reduce swelling, aid in vasodilation, increase elasticity of connective tissue, increase joint range of motion, and decrease joint stiffness.²⁶ Other effects of continuous and pulsed shortwave diathermy include increased tissue temperature^{6,8} increased blood flow, vasodilation,²⁶ relaxation of muscle,¹³ decreased joint stiffness,^{13,15,16} increased tissue and cellular metabolism,^{26,31} alterations in physical properties of fibrous tissues,²⁶ reduction in pain and increase in pain threshold,²⁶ reduction in knee synovitis,¹⁰ reduction of the inflammatory process,² enhanced healing,^{2,23} and increased muscle tissue extensibility.^{26,15,16}

Indications for shortwave diathermy include muscle strain, sprain, contusion, tendinitis, tenosynovitis, bursitis, myofascial trigger points, pain, removal of byproducts of the inflammatory process, joint contracture, and other indications of a deep heating modality.

Contraindications include use over a cardiac pacemaker,³² pregnant women,³² malignant tumor,³² fever,³² sites of infection,³² over eyes or genitals, epiphyseal plates in children,³² and protruded nucleus pulposus.³²

Tissue Temperature and Pulsed Shortwave Diathermy

Few studies were found that researched only tissue temperature increase with shortwave diathermy. Most studies were used to evaluate the effects of diathermy on increasing range of motion, increasing flexibility of a muscle, etc. A group of researchers who did study tissue temperature increase found there to be a 1.75°C temperature increase in the intramuscular temperature of the vastus lateralis muscle at 2.5 cm deep.⁸ Temperature decay started to occur five minutes after the treatment. One difference in this study from others is that it involved parameters of 40 W rather than the 48 W to 100 W parameters for PSWD. This may have affected the results of this study.

In another study temperature increase was also observed. In this study the width of the induction drum of the PSWD was traced on the skin over the medial head of the triceps surae muscle. After tracing the drum width, three temperature probes were inserted in the muscle under the proximal, middle, and distal areas of the drum at 3 cm deep. With a twenty minute 48W shortwave diathermy treatment the center probe had the greatest increase of 4.6°C.⁶ The center probe had been inserted in the center of the medial head of the triceps surae muscle. Peak temperature was not recorded but the final skin temperature after the twenty-minute treatment was recorded to be 40°C. Post-treatment tissue temperature dropped by 1°C after about seven minutes.⁶ The same parameters used in this study were used in a separate study but with one probe at 3 cm deep. This probe was inserted in the subject's medial triceps surae where the widest portion of the posterior surface of the muscle was determined. After 20 minutes of

treatment, the mean temperature increase was 3.5°C in the gastrocnemius muscle.⁵ The peak heat temperature occurred after fifteen minutes of treatment. Temperature decay was $.97^{\circ}\text{C}$ at five minutes and 1.78°C after ten minutes. Mean peak temperature was 40°C .

Continuous Shortwave Diathermy

Few research articles exist that involve an investigation of continuous shortwave diathermy.^{9,25, 26}

Induction Coil Diathermy

In 1969, a specific type of shortwave diathermy using a helical induction coil was investigated. The main purpose of this study was to investigate the temperature distribution produced in human beings by shortwave diathermy and the effect of subcutaneous fat thickness on tissue temperature.²⁴ In order to measure the temperatures, a thermistor probe was inserted into each subject's quadriceps. The total temperature of the tissue was then measured throughout the twenty-minute application of diathermy. In the subjects who had a thick subcutaneous fat layer (greater than or equal to 2 cm thick) the temperature at 1 cm deep rose by 5.6°C . In the subjects who had a thin layer (less than or equal to 1cm thick) of fat the tissue temperature rose by 9.5°C .²⁴ The higher increase in the tissue temperature of the subjects with a thinner layer of fat shows that the thickness of subcutaneous fat did affect the results. At approximately 1 cm depth, peak temperature was measured to be 44°C with a mean temperature increase of 10°C . This was the highest peak temperature measured of all the depths. At approximately 3 cm deep the peak temperature was measured at 42°C with a mean temperature increase of 3°C .²⁴ The temperature increase observed in these helical coil studies was greater than the increase in tissue temperature observed in other shortwave diathermy machines.

Another study was performed investigating helical coil diathermy. This study, however, was conducted in order to compare the effectiveness of two types of applicators, a minode and a monode applicator. The monode applicator produced a higher elevation in temperature.⁹ At 2 cm deep the mean temperature increase was recorded to be about 2°C. That was recorded to be the highest temperature increase of the different depths. The researchers concluded that the modality studied can be effective as a superficial heating modality but not a deep heating modality.⁹ One large weakness of this study was that the subjects were pigs and not humans. More information needs to be compiled on this topic as well as more studies performed.

Superficial Heating versus Deep Heating

A few studies exist that compared the effectiveness of hot packs versus diathermy or compared them both to other modalities.¹¹⁻¹³ One such study compared the effectiveness of shortwave diathermy, hot packs, transcutaneous electrical nerve stimulation (TENS), and ultrasound in decreasing pain and increasing muscular strength (measured by angular velocity). The greatest improvements were shown to be in the TENS group and also the diathermy group. The researchers concluded that TENS and diathermy are the best modalities in increasing exercise performance, reducing pain, and improving function.¹¹

Another study compared just hot packs and shortwave diathermy in their effectiveness in relieving pain. They measured the pain on the trigger points or the sensitivity of the trigger points. Both SWD and hot packs were effective in decreasing pain. Shortwave diathermy, however, was the most effective in decreasing the sensitivity of the trigger points.¹²

Researchers performed another study to compare the effectiveness of shortwave diathermy and hot packs in increasing the extensibility of a tissue. This was observed by measuring the range of motion of the ankle after treatments by the specific modality. An average

of 1.8° increase in range of motion was measured after the use of diathermy whereas a .7° increase was measured after the use of hot packs.¹³ Both modalities, therefore, were effective in aiding in the increase of range of motion; however, shortwave diathermy was more effective.

ReBound™

In November 2008, Game Ready™ and ReGear Life Sciences™ introduced ReBound™. ReBound™ is a form of radio-frequency diathermy.²⁷ The ReBound™ unit is a form of continuous shortwave diathermy that uses an induction helical coil sleeve to heat deep in the muscle. It is compact and portable unlike the other diathermy machines that are commonly used. It heats at the parameters of 35 W and 13.56 MHz. The sleeve also makes it easier to heat around the area of the body that is desired to be heated. No research has been performed yet on the ReBound™ machine.

Temperature Probes

Instruments such as thermocouples are commonly used to measure the tissue temperature of a muscle. It is important that the thermocouple used in a research study is valid and reliable; otherwise the data may be skewed. A set of researchers decided to test the validity and reliability of three specific thermocouples. The three types of thermocouples that were used in this study include Implantable IT-21, Implantable IT-18, and Surface PT-6.³³ Six thermocouples of each type were used in this study. Four of the six were previously used and two were brand new. All these types of thermocouples were inserted through the wall of a foam polystyrene cooler. The cooler was then filled with water and the temperature of the water was measured. This process was repeated for five different water bath temperatures ranging from 5°C to 35°C. The results of the study showed that at extreme temperatures (5°C and 35°C) the validity and reliability of the measurements decreased specifically with the IT-21 thermocouples.³⁰ The PT-6 and IT-18 were

of similar validity and reliability however the PT-6 was less so. Researchers stated that the IT-18 thermocouples were less valid at temperatures lower than 10°C and are more appropriate for measuring in vivo temperatures rather than skin temperatures.³³

Conclusion

Moist hot packs have been shown to increase skin temperature to the temperature needed for the desired physiological effects to occur. They have also been recorded to increase tissue temperature by 3.8°C at 1 cm deep and .74°C at 3 cm deep.⁴ We expect to observe the same tissue temperature increases in our study.

Shortwave diathermy also has many of the same effects as moist hot packs. Researchers have found a tissue temperature increase with shortwave diathermy treatments to be as great as 4.6°C in the triceps surae muscle at 3 cm deep.⁶ Pulsed shortwave diathermy has therefore been shown to heat deeper than moist hot packs.

Little research exists on continuous shortwave diathermy.²⁶ The new ReBound™ diathermy machine is a continuous shortwave diathermy machine that uses an induction coil to heat deep in the tissue.²⁷ No research exists on this new ReBound™ unit, therefore, it is important that researchers study this new machine to evaluate the effectiveness of the device compared to other heating modalities such as moist hot packs.

We expect that in our study, the ReBound™ diathermy unit will allow for greater increases in tissue temperature at 3cm deep than moist hot packs and will have a slower decay in tissue temperature post-treatment.

Chapter 3

Methods

Design

A 2 x 3 x 27 repeated measures design will be used for this study for temperature heating (every minute during decay). The dependent variables in this study will be the tissue temperature of the triceps surae muscle at 1 cm and 3 cm deep. The independent variables are the ReBound™ diathermy unit, the Megapulse II® diathermy unit and moist hot packs. A crossover design will be implemented, meaning that all subjects will be treated with the ReBound™ unit, Megapulse II® diathermy unit and moist hot packs. A Latin-square will be utilized to randomize treatment order for the subjects and successive treatments will be administered with at least a 48 hour recovery period in between.

Subjects

Twelve subjects will be recruited who are between the ages 18 and 35. The subjects will be recruited via word of mouth and through classrooms announcements at Brigham Young University. The exclusion criteria will include pregnancy, fever, peripheral vascular disease, infection, injury to the triceps surae muscle in the past two months, compromised circulation or compromised sensation to the area being treated. The inclusion criteria will include any healthy person free of pathologies listed in the exclusion criteria, and will not have exercised for at least two hours prior to testing. During the subjects initial visit they will have the study explained to them as well, be screened for the exclusion criteria, and will sign a consent form for participation in the study. The study will be approved by the Institutional Review Board (IRB) at Brigham Young University.

Instruments

Thermocouples will be used to measure the temperature of the triceps surae muscle. An implantable IT-21 thermocouple (Physitemp Instruments Inc, Clifton, NJ) will be used and inserted via a 20 gauge catheter (Johnson & Johnson Medical, Arlington, TX). An Iso-Thermex (Iso-Thermex, Columbus Instruments, Columbus, OH) computer will be used to record the tissue temperatures. Standard (10"x 12") hydrocollator steam packs (Model #1064, Chattanooga Corporation, Industry CA) will be used in this study. An insulated terry cloth cover (Chattanooga Corporation, Industry CA) that folds over the moist hot pack along with one large towel will be used as a barrier between the moist hot pack and the skin. A ReBound™ diathermy machine (Game Ready and ReGear Life Sciences, Pittsburgh, PA) will also be used for this study. A Doppler ultrasound machine (General Electric Company, Fairfield, CT) will be used to measure the depth of the probe. A pulsed shortwave diathermy machine (Megapulse II; Accelerated Care Plus, Reno, NV) will be used for the other diathermy treatment.

Procedures

Subjects will need to wear shorts for the treatments and will report to the modalities lab at Brigham Young University. Each subject will only be treated once by the ReBound™ unit, once with PSWD and once with the moist hot packs.

Prior to application of diathermy or moist hot packs the subjects' baseline tissue temperature will be measured. The following procedures will be followed for thermocouple insertion and measurement of baseline temperature. Subjects will be wearing shorts and will comfortably lie prone on the treatment table. Ultrasound gel will be applied to the triceps surae muscle and the largest girth of the posterior triceps surae muscle will be observed using the Doppler ultrasound machine. After finding the deepest portion, a line will be marked on that part

of the skin by a marker and subcutaneous fat thickness will be measured using the Doppler ultrasound machine. A ruler will be used to measure from the marked line on the skin surface to a 1 cm and 3 cm anterior distance on the medial side of the calf. A dot will be marked on the skin at the 1 cm and 3 cm measured distance. The skin will be prepped using an iodine swab. A 20-gauge catheter will be inserted through the mark at 1 cm and another catheter inserted at 3cm deep from the posterior triceps surae. The catheter will be inserted horizontally into the medial aspect of the triceps surae muscle. The depth of the insertion of the catheter will be verified to be within 0.2cm of the desired depth using the Doppler ultrasound machine. After verification by the Doppler ultrasound machine one IT-21 thermocouple will be inserted via the catheter at 1 cm deep and another via the catheter at 3 cm deep. Each catheter will be slowly removed leaving the thermocouples intact. The two thermocouples will be secured to the skin with clear medical tape. The thermocouples will be attached to an Iso-Thermex computer. The Iso-Thermex machine will be set up to measure each temperature every 5 seconds. Baseline temperature will be recorded and considered reached when the temperature change is no greater than 0.1°C at 2 minutes.

Each subject will be treated with the ReBound™ diathermy unit once. After the thermocouples are inserted and baseline temperature is measured, the diathermy sleeve will be pulled over the triceps surae muscle of the subject and the ReBound™ machine will then be turned on and tuned. During the pilot study the unit interfered with the readings of the Iso-Thermex machine. The diathermy unit therefore needs to be paused allowing for an accurate tissue temperature reading. After five, ten, fifteen, twenty, twenty-five and thirty minutes of treatment the researcher will pause the diathermy machine and tissue temperature at 1 cm and 3 cm deep will be measured by an average of three recordings using the Iso-Thermex machine and recorded by the researcher.

Each subject will be treated with the Megapulse II® pulsed shortwave diathermy unit once. After the thermocouples are inserted and baseline temperature is measured the drum of the diathermy unit will be placed over the posterior belly of the triceps surae muscle with the middle of the drum above the thermocouples. The machine will then be turned on and set for a 30-minute treatment at 800 pulses per second (pps), and 400 microseconds. After five, ten, fifteen, twenty, twenty-five and thirty minutes of treatment the researcher will pause the diathermy machine and tissue temperature at 1 cm and 3 cm deep will be measured by an average of three recordings using the Iso-Thermex machine and recorded by the researcher.

Each subject will be treated with moist hot packs once. After baseline temperature is measured, a moist hot pack covered by a terry cloth sleeve will be laid on the triceps surae muscle of the subject. One towel folded in half will be placed between the moist hot pack and the skin. After five, ten, fifteen, twenty, twenty-five and thirty minutes of treatment the tissue temperature at 1 cm and 3 cm deep will be measured using the Iso-Thermex machine and recorded by the researcher. After treatment the moist hot pack will be returned to the heating unit. During treatment, if subjects report that the hot pack gets too hot, another towel folded in half will be applied and recorded.

After treatment has concluded the hot pack and towel will be removed, diathermy machines turned off, ReBound™ sleeve removed and tissue temperature decay will be measured. The thermocouples will be left in the tissue post treatment for twenty minutes and temperature decay per minute during this time will be measured using the Iso-Thermex machine and recorded by the researcher.

After temperature decay is measured the thermocouples will be carefully removed and bacitracin ointment and Band-Aids will be applied over the insertion site. Subjects will be

instructed as to the appropriate care for the insertion site. The thermocouples will be sterilized in a 2% Cidex solution for 24 hours and needles and catheters disposed of in a sharps biohazard container.

In order to increase the reliability of the study the same researcher will insert the thermocouples and catheters in each subject. The same procedures will be followed for each subject. There will be at least a two day period of rest between the three treatments. Subjects will be reexamined before the second and third treatments to make sure they do not have any of the pathologies listed in the exclusion criteria.

Analysis

We will use a $2 \times 3 \times 27$ repeated measures analysis of variance for the data analysis. A linear model or random coefficients model will be used to measure the slope of tissue temperature increase between the three treatments and two depths. Temperature decay will be analyzed over twenty minutes. Between subject factors will be the randomized grouping of either the moist hot pack, Megapulse II® shortwave diathermy unit or the ReBound™ treatment. Post-hoc tests will be used to determine specific differences between the three treatment groups.

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Appendix A
Statistical Tables

Table 3: Poc-hoc Tukey – Least square means: 1 cm

Level		Least Sq Mean
SW	A	37.781471
ReBound	B	36.825998
Hot Pack	B	36.819082

Table 4: Poc-hoc Tukey – Least square means: 3 cm

Level		Least Sq Mean
SW	A	38.047087
ReBound	B	37.093283
Hot Pack	B	36.753659

Table 5: Fixed Effect Tests: 1 cm

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Time	26	26	286	98.3504	<.0001
Treatment	2	2	31.74	10.6176	0.0003
Time*Treatment	52	52	571.8	14.6552	<.0001
1 cm Baseline	1	1	32.02	11.4353	0.0019

Table 6: Fixed Effect Tests: 3 cm

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Time	26	26	286.5	95.9046	<.0001
Treatment	2	2	32.09	28.3935	<.0001
Time*Treatment	52	52	572.2	17.8561	<.0001
3 cm Baseline	1	1	31.95	9.3299	0.0045

Appendix B

Doppler Ultrasound Procedures

1. Turn machine on
2. Enter patient information
3. Press Probe button
4. Set SMP mode
5. Position ultrasound head and gel
6. Use freeze button to take a picture
7. Press measure and measure the thickness of subcutaneous fat, and depths of 1 cm and 3 cm
8. B pause/set and store/P1 to store the information

Appendix C

Table 7: Literature Review Table

Author	Independent Variable	Dependent Variable	Purpose	Results	Conclusions
Mitchell, et al.	PSWD	Intramuscular temperature, surface electromyography, mechanomyography	Effect of PSWD on temp., etc	Temperature increased by 2°C at 2.5cm deep and MMG increased	Diathermy increases temperature but not EMG or absolute strength
Draper, et al.	PSWD	Gastrocnemius temperature	Rate of temperature rise and post-treatment decline	3.5°C mean temp increase at 3cm deep at 20 minutes	PSWD effective for temp elevation over large area
Garrett, Draper, et al.	PSWD, ultrasound	Calf tissue temperature	Effect of ultrasound and PSWD on tissue temperature increase	4.6° tissue temperature increase at 3cm deep	PSWD increases calf temperature more
Draper, Harris, et al.	Ultrasound, hot pack	Tissue temperature	Examine tissue temperature rise of calf after heating and ultrasound.	.8°C greater increase in tissue temp w/ hot packs and ultrasound; .74°C increase at 3cm deep and 3.8°C at 1cm	Ultrasound and hot packs have an additive effect on intramuscular temperature
Lehmann, etc	Ultrasound, hot pack	Thigh tissue temperature	Effect of ultrasound and hot packs on tissue temperature	3°C temperature increase with moist hot packs at 1cm	Greater increase in tissue temperature with hot packs when followed by ultrasound
Tomaszewski, et al.	Proheat pack and hydrocollator pack	Skin temperature	If the Proheat pack can be used as a substitute; the effect of both	Both had beneficial skin temps, Proheat maintained	No significant difference between the 2

			on skin temperature	temp a little longer	packs, both rose to 104 degrees at around the same time
Peres, et al.	Treatment group, pretest and posttest	ROM change in gastrocnemius	Effects of 3 treatments on ankle dorsiflexion ROM	ROM increase greater after heat and stretching	PSWD before stretching effective
Draper, Castro, et al.	PSWD, stretch	Hamstring flexibility measured by knee extension ROM	Compare difference in hamstring flexibility in 3 groups	Diathermy plus stretching group showed greatest increase	Hamstring flexibility greatly improved with diathermy + stretch
Draper, Castel, et al.	SWD, joint mobilizations	Elbow ROM	If joint mobilizations and SWD restore ROM	Diathermy + Joint mobs restored ROM (7 degrees w/ extension, 5 w/ flexion)	Diathermy and Joint mobs effective in restoring ROM in elbow
Draper, Miner, et al.	PSWD, stretching	Hamstring flexibility (measured with sit and reach test)	Effect of PSWD and stretching on hamstring flexibility	No significant differences in diathermy + stretching group	Diathermy + stretching no more effective than stretching alone
Cetin, et al.	SWD, hot packs, exercise, TENS, ultrasound	Pain, muscular strength (angular velocity)	Effect of SWD, etc before exercise on knee osteoarthritis	Greatest improvement in group with TENS and also group with diathermy	TENS and diathermy the best in increasing exercise performance, reducing pain and improving function
McCray, et al.	Shortwave Diathermy, hot packs	Pain (measured on trigger points)	Effect of SWD and hot packs on relieving pain	SWD the most effective in decreasing sensitivity of trigger points	Both SWD and hot packs are effective in decreasing pain
Robertson, et al.	SWD and hot packs	Ankle dorsiflexion (ROM measured) to	Effects of SWD and hot	SWD=1.8 +/- 1.9, hot	Deep heating

		test extensibility of tissue	packs on tissue extensibility	packs=0.7 +/- 1.5 degree increase in ankle dorsiflexion	most effective in increasing tissue extensibility
Knight, et al.	Static stretching, active heel raises, hot packs, ultrasound	Ankle dorsiflexion ROM	Evaluate effectiveness of superficial heat, deep heat, and exercise compared to stretching alone on extensibility	Ultrasound showed greatest increase in ROM (6.2/7.4) and hot packs second most (4.4/4.9)	Ultrasound for 7 minutes prior to stretching may be most effective in increasing ankle dorsiflexion ROM
Pasila, et al.	Pulsated shortwave diathermy,	Swelling, strength, ROM of injured ankle	Effects of PSWD on ankle injuries	Reduction of swelling and walking ability only significant results	PSWD can be used to treat ankle injuries
Lehmann, et al.	SWD w/ helical coils	Skin/intramuscular temperature	Determine the effect of biological factors, technique and fat thickness on temperature	Muscular temperature increased more than superficial, both decreased after 12 minutes, biological factors had little effect, increase in fat=decrease in heat	SWD w/ helical coils effective in deep heating, fat thickness has an effect on temperature
Seiger, Draper	PSWD, Joint Mobilizations	Ankle Dorsiflexion	If PSWD and Joint Mobilizations can improve ROM	Dorsiflexion improved by average of 13.5°	PSWD & Joint Mobs can increase dorsiflexion even with a metal implant
Hill, et al.	PSWD	Fibroblast and chondrocyte cell	If PSWD influences	PSWD at 45W for 10	PSWD associated

		proliferation rates	proliferation rates	min. increased rates	with increased fibroblast rates
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Appendix D

Figures

Figure 3: Catheter insertion



Figure 4: ReBound™ diathermy unit



Figure 5: ReBound™ diathermy sleeve

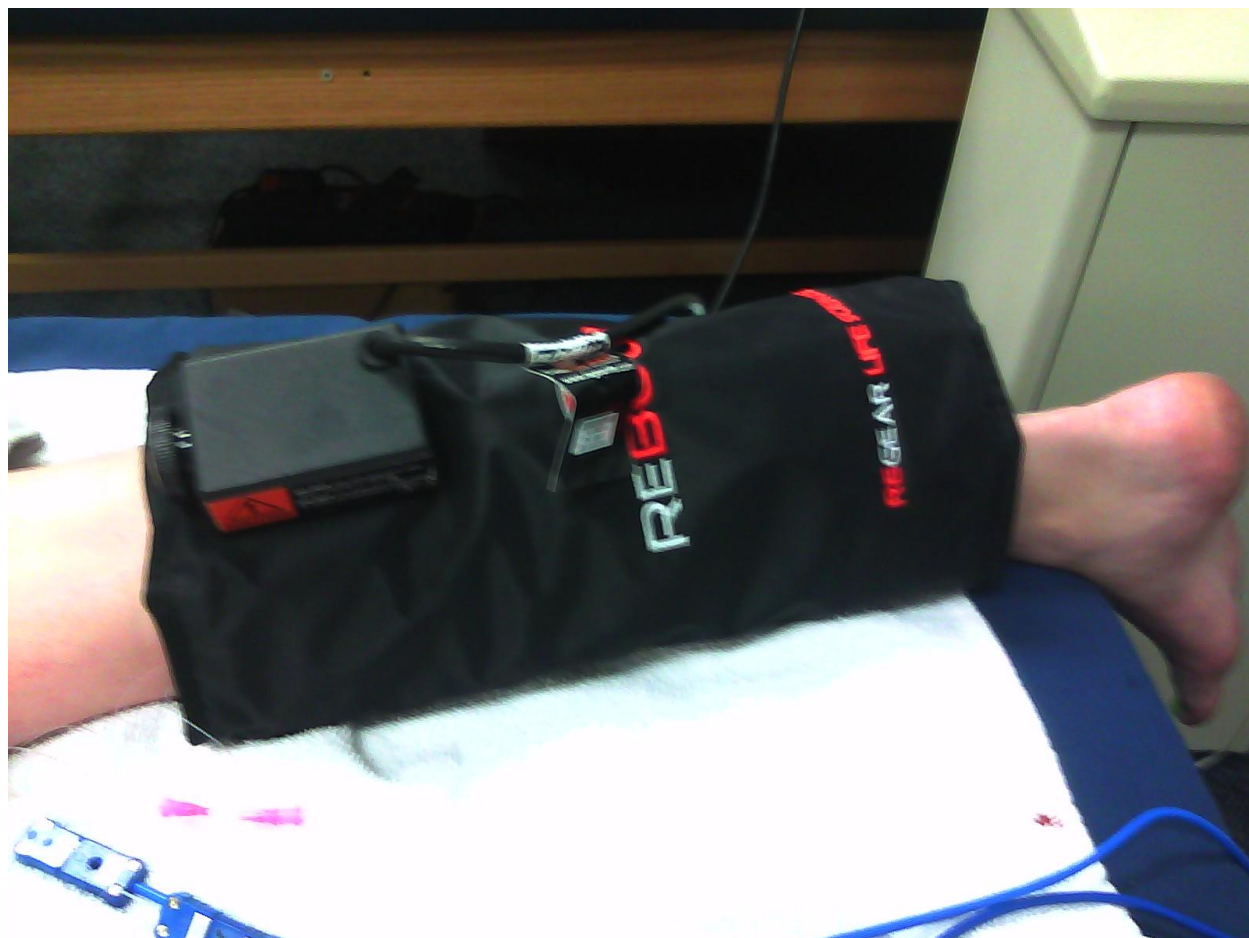


Figure 6: Thermocouple insertion verification using Doppler ultrasound

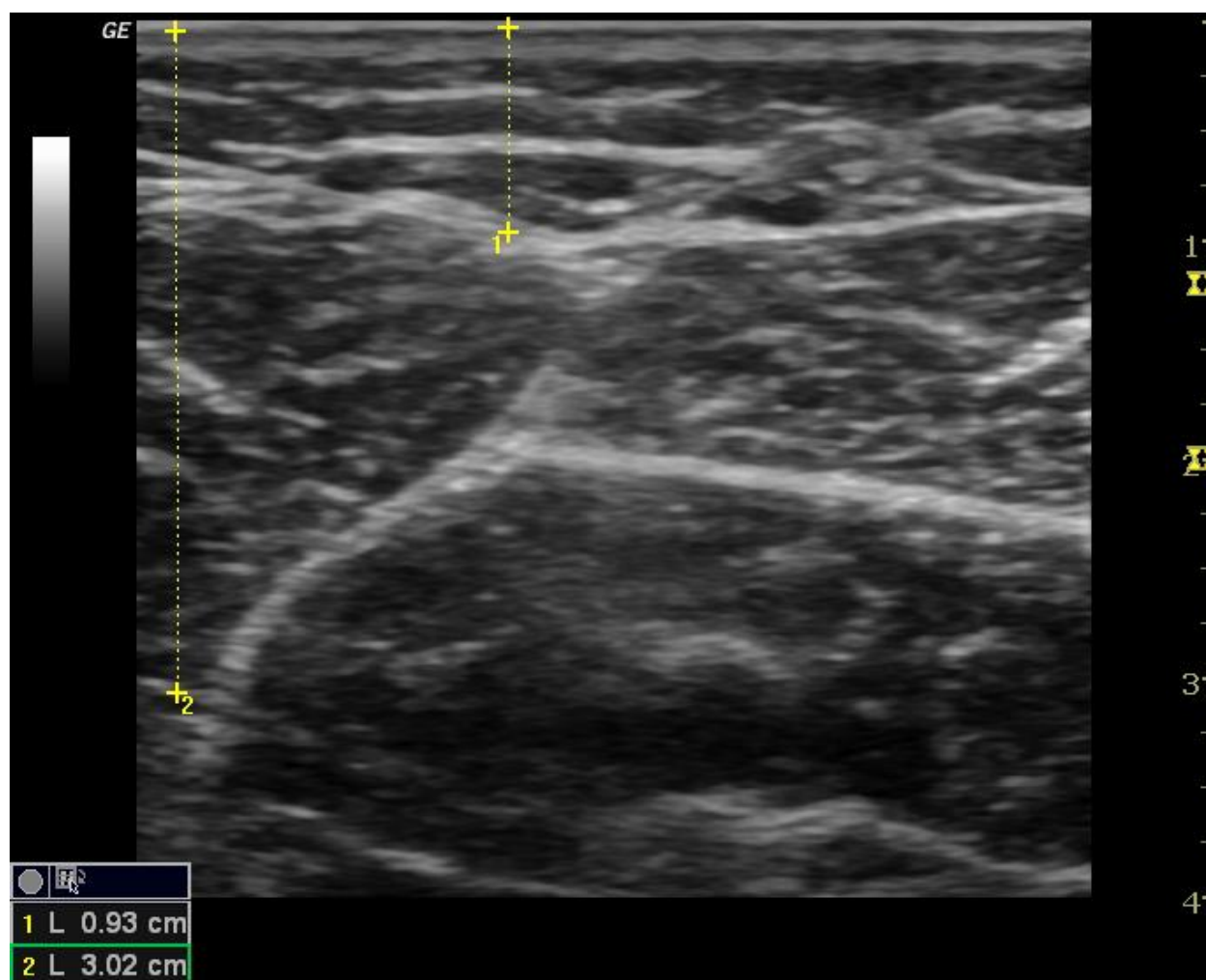


Figure 7: Subcutaneous fat thickness measurements using Doppler ultrasound

