INVESTIGATION OF SKIN TEMPERATURE INCREASES WITH REBOUND DIATHERMY

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

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In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Department:
Health, Nutrition, and Exercise Sciences

June 2016

Fargo, North Dakota

North Dakota State University
Graduate School

Title

Investigation of skin temperature increases with ReBound® Diathermy

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

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ABSTRACT

ReBound® Diathermy is a continuous shortwave diathermy device (CSWD) used as a portable heating modality. No studies have shown surface tissue temperatures of ReBound® treatments. The purpose of this study was to investigate if the ReBound® Diathermy unit produced skin temperatures in an ankle garment sleeve. The study called for 20 healthy, college-aged (18-30 years) males to participate in a single treatment session. Surface thermocouples were placed following the anterior aspect of the ankle. The session included a 30-minute treatment in which skin temperatures were recorded at each site every 5 minutes. The ReBound® Diathermy unit did not produce an increase in skin temperatures on the anterior aspect of the ankle. Skin temperatures were significantly different between baseline and all time intervals. Each site immediately decreased after 5 minutes of treatment for all sites. Remaining temperatures recorded stabilized and increased at each site, but did not return to baseline temperatures.

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1. INTRODUCTION

Allied health care professionals utilize several different heating modalities to achieve treatment goals for musculoskeletal conditions. One such modality, diathermy, is resurfacing in the clinical setting. Diathermy is a heating modality that applies high-frequency electromagnetic waves to target tissues to produce deep tissue heating. This heating is achieved by the resistance of such tissues to the passage of electromagnetic energy. [1-6]

The inclusion of this modality in a treatment plan is supported by its physiological effects. Thermal physiological effects are derived from diathermy's deep heating aspect, which include tissue temperature increase, increased blood flow, vasodilation, relaxation, increased collagen extensibility, and pain relief.[1-6] In order to be classified as deep thermotherapy, the application of a modality must cause tissue temperatures to rise in tissues 3-4 cm below skin.[7] This rise in tissue temperature is deemed therapeutic when temperatures in these tissues are raised a minimum of 1° C. Mild heating (1° C) produces mild inflammation and acceleration of cell metabolism; moderate heating (2-3° C) decreases muscle spasms and pain, increases blood flow, and reduces chronic inflammation; and vigorous heating (4° C) increases tissue elasticity in collagen-rich tissues.[1,8] Therapeutic heating of traditional drum method diathermy has been ascertained in past research. Draper et al.[7] reported the Megapulse diathermy unit, a traditional drum method set-up, was able to produce an average temperature increase of 1.36 ± 0.90°C at 5 minutes; 2.87 ± 1.44°C at 10 minutes; 3.78 ± 1.19°C at 15 minutes; and 3.49 ± 1.13°C at 20 minutes. Researchers also found that temperature decay dropped on average 0.97 ± 0.68°C at 5 minutes post-treatment; and 0.81°C at 10 minutes post-treatment, with a total temperature decay of 1.78 ± 0.69°C. Therefore, with traditional methods, therapeutic heating levels were considered vigorous and could be sustained to provide additional treatments, such as prolonged stretching windows for range of motion increases and joint mobilizations.

With research supporting the clinical application of diathermy, ReGear Life Sciences has recently developed a portable diathermy unit, called ReBound® Diathermy.[9] The manufacturer reports the use of the ReBound® based on applications of traditional diathermy. However, both units have differences when making comparisons in terms of equipment used and available parameters of each unit. In traditional diathermy, a large generator and an inductive drum is used to produce and direct pulsed shortwave diathermy (PSWD) to a specific area equal to the circumference of the drum.[1] ReBound® Diathermy includes a portable energy source and various garments including several sizes of cylindrical garments, a shoulder garment, and a back garment intended to wrap around an extremity using continuous shortwave diathermy (CSWD).[9] In addition, traditional diathermy is able to produce varying power wattages in relation to specific parameters, usually falling in the 12, 24, or 48 W range.[1] However, ReBound® Diathermy produces varying wattage based percentages of the maximum power intensity of only 35 W.[9] The four programs include 100% (35 W), 75% (26.25 W), 50% (17.5 W), and 25% (8.75 W). These differences have been noted, but have not been the main focus of recent research. In recent studies, ReBound® Diathermy has been found to increase tissue temperature 2.31°C ± 0.87°C at 3 cm deep.[10] In superficial tissues located 1 cm deep, ReBound® Diathermy has been found to increase tissue temperature 3.69°C ± 1.50°C.[11] However, these studies have only measured tissue temperature intramuscularly, located centrally on a ReBound® Diathermy garment sleeve.

1.1. Statement of the Problem

In light of past research, no studies have shown the tissue temperatures describing possible thermal sensations of ReBound® Diathermy treatments or measurements throughout the entire garment sleeve. In comparison to studies performed on traditional diathermy applications using the drum method, Garrett et al.[12] was able to define an effective radiating area (ERA) when comparing traditional diathermy to ultrasound. Similar studies should be implemented to ensure proper therapeutic heating is achieved over the entire treatment area. Therefore, the current study has improved evidence-based practice by allied health care professionals in determining if thermal effects are observed at surface levels and if thermal effects are consistent throughout a garment sleeve.

1.2. Purpose of the Study

The purpose of this study was to investigate if the ReBound® Diathermy unit produced skin temperatures in an ankle garment sleeve.

1.3. Research Questions

1. Are skin temperatures increased in an ankle garment sleeve?
2. Is skin temperature increased to a therapeutic heating level?
3. Are skin temperatures consistent throughout the entire ankle garment sleeve?

1.4. Definition of Terms

Therapeutic Heating: the application of heat for therapeutic benefit, in which tissue temperatures are raised over 38°C but fall under 45°C.[1-3]

Shortwave Diathermy: the therapeutic use of high-frequency (10-100 MHz) electromagnetic waves, similar to radio waves, to heat deep tissues.[1]

Continuous Diathermy: shortwave diathermy in which a continuous current is generated.[1]

Surface Temperature: Temperature at skin level.[1,2]

1.5. Importance of the Study

The current study is of importance to allied health professionals considering the purchase and use of the ReBound® Diathermy system. By determining the consistency of thermal effects produced by the ReBound® Diathermy unit, clinicians will be able to determine an appropriate effective treatment area for use in treatment plans, which may improve patient care.

1.6. Limitations of the Study

1. The ReBound® Diathermy Unit caused interference of other electrical devices within close proximity. The ReBound® Diathermy unit had to be paused to accurately record the surface temperature using the Iso-Thermex electrothermometer.
2. The researcher had limited experience (<1 year) in performing surface thermocouple research protocols.
3. The ReBound® Diathermy foot/ankle garment did not completely cover the foot/ankle; the anterior aspect of the garment was open, so it was further away from the treatment in comparison to the posterior, medial, and lateral aspects of the foot/ankle.

1.7. Delimitations of the Study

1. Only healthy tissue was used.
2. The participants were college-aged males from NDSU.
3. The diathermy treatment was limited to the ankle.

2. REVIEW OF LITERATURE

The purpose of this study was to investigate whether skin temperatures are produced in the application of a ReBound Diathermy treatment. The research questions that guided this study include (1) Are skin temperatures increased in an ankle garment sleeve, (2) Is skin temperature increased to a therapeutic heating level, and (3) Are skin temperatures consistent throughout the entire length of an ankle garment sleeve? The review of literature was organized into the following areas: shortwave diathermy, physiologic effects, tissue temperatures, treatment time, clinical indications/applications, contraindications/precautions, shortwave diathermy devices, ReBound® diathermy, and summary.

2.1. Shortwave Diathermy

Diathermy is a therapeutic modality used by health care professionals. This modality is classified as a thermal modality that is able heat deep tissue. There are three types of diathermy available for use including longwave diathermy, microwave diathermy, and shortwave diathermy.[1] Due to the nature of the proposed study, the following literature review expanded on available literature of shortwave diathermy.

Shortwave diathermy (SWD) is able to produce therapeutic results based on electrostatic field and electromagnetic properties. The electricity used to power the generator is converted to a useable radio frequency. The U.S. Federal Communications Commission (USFCC) has assigned three frequencies to SWD, which are 13.56 MHz, 40.68 MHz, and, most commonly, 27.12 MHz.[1] The radio frequency travels through the diathermy unit to generate an electrostatic field or alternating magnetic field. In the electrostatic field method, the patient is included within the circuit in which heating is produced by tissue resistance to energy flow.[2] In the electromagnetic method, the alternating magnetic field creates small currents in tissue. These currents are known as eddy currents. Eddy currents in tissue cause dipoles, which are pairs of equal and opposite electric charges separated by a small distance, to rotate due to polarity changes.[1] The rotation of these dipoles causes tissue kinetic energy to increase. The increase in tissue kinetic energy in both methods helps generate the nonthermal effects of diathermy, and friction between tissue resistance and the rotating dipoles generates the thermal effects of diathermy[1], which will be later discussed.

All shortwave diathermy units have two components: a generator and an applicator. The generator houses the electrical components of the diathermy unit to generate the electromagnetic waves. This portion of the shortwave diathermy device is usually placed near a wall outlet, to convert the electricity into radio frequencies used in treatment. The control panel for the unit usually is placed on top of the generator, which allows clinicians to use different parameters for different application indications. The different settings are reflected in the applicator. In order to deliver the energy produced to tissues, SWD utilizes several different applicators, or electrodes. Electrodes are organized into two different application techniques: the induction technique and the capacitative technique.[2] The capacitative technique uses the concept of electrostatic field heating. Electrodes using this method are designed to include condenser plates covered by heavy insulation for the purpose of creating the electrical circuit. The induction technique has two types of electrodes: the helical inductive coil and the single drum unit. The helical coil consists of an insulated cable ranging from 6-16 feet that is wrapped around the treated tissue to provide general, consistent heating.[2] Lehmann et al.[3] examined the induction coil application technique by wrapping coils around freshly butchered pig thighs and studying intramuscular temperature effects; the authors found induction coils to be ineffective at selectively heating deep musculature as the highest temperatures were recorded in superficial fat. The induction drum is the most common applicator used today. The drum consists of a hard plastic housing that contains one or more flat spiral copper coils. The surface area of the drum defines the effective treatment area and is dependent on the manufacturer, with an average of 200 cm^2. Some devices are equipped with multiple heads to deliver treatment for larger or contoured areas.[1] When using the induction technique, clinicians are required to follow certain practice precautions. Practice precautions include placing towels between the applicator and the skin in order to absorb dangerous perspiration during treatment and avoiding diathermy cables or coils to touch one another in order to prevent a short circuit.[2]

Shortwave diathermy is applied in one of two ways: continuous or pulsed. Continuous shortwave diathermy (CSWD) delivers a continually generated current to the target tissue. In previous research, CSWD was considered to be the preferred method of therapeutic heating.[4] However, this application is rarely used today because it causes rapid and excessive heating in superficial fat tissue, resulting in uncomfortable treatments and burns.[1] Pulsed shortwave diathermy (PSWD) is simply created by interrupting continuous shortwave diathermy at specific intervals.[2] Since older techniques of CSWD are no longer used clinically, the remainder of the literature review will examine few articles including CSWD, but in most articles, PSWD was studied.

2.2. Physiologic Effects of PSWD

The physiological effects of PSWD are divided into two separate categories: nonthermal and thermal. Pulsed shortwave diathermy produces nonthermal and thermal effects by the molecular polarity changes as described above.[1] The nonthermal effects of PSWD include repolarization of damaged cells[1,5], acceleration of cell growth/division when slow[1,6], inhibition of cell growth/division when too fast[1,6], reestablishment of sodium pump[1,15], increased microvascular perfusion[1,16], increased number of white blood cells[1,17], and fibroblast proliferation.[1,18] The thermal effects of PSWD include tissue temperature increase[1,7,8,14,19], increased blood flow[1,19,20], vasodilation[1,19], relaxation[1], decreased joint stiffness[1,20-23], membrane filtration/diffusion[1], increased metabolic rate[1], changes in enzyme reactions[1], alterations in fibrous tissues[1,24], muscle relaxation[1,23-25], pain reduction[1,20-22], reduction of knee synovitis[1,20-22], reduction of inflammatory process[1,8,17], encouragement of collagen layering[1,17], and hematoma absorption.[1,17]

2.3. Diathermy Parameters

When utilizing therapeutic modalities in the clinical setting, times of treatments are critical in determining treatment efficacy for specific goals indicated. Treatment times are calculated using different parameters that are involved in SWD, including pulse duration, pulse rate, and power. Each parameter has an effect on the goal of the treatment, and ultimately, the length of treatment.

Pulse duration, commonly known as the "on time," is defined as the amount of time required for each pulse to complete a cycle. As pulse duration, or width, increases, tissue kinetic energy increases, resulting in greater tissue temperature increases. Narrow pulse widths are used mainly for nonthermal physiologic effects while wider pulse widths are used for thermal applications of SWD.[1] Pulse rate is defined as the number of pulses delivered per second (pps) in hertz (Hz). As the pulse rate increases, the amount of energy produced increases as well. Much like pulse duration, smaller pulse rates are reserved for nonthermal effects, while larger pulse rates are utilized to bring about thermal effects.

Combining pulse duration and pulse rate gives clinicians the power, or intensity, of PSWD. This function is a measure of the amount of watts (W) delivered from the machine. To give further illustration of the relationship between pulse duration and pulse rate in regards to power, a treatment involving a long pulse duration and high pulse rate will yield more power in comparison to a treatment involving a shorter pulse duration and lower pulse rate.[1] With the three parameters used collectively, athletic training textbook parameter guidelines have been set to achieve specific physiological effects as described above based on treatment goals. For non-thermal effects, the pulse width should be set at 65 μs, the pulse rate should fall between 100-200 pps, and the resulting power should be minimal. For mild heating, the pulse width should be set at 100 μs or 200 μs, the pulse rate should be 800 pps or 400 pps, and the resulting power should be 12 W. For moderate heating, the pulse width should be set at 200 μs or 400 μs, the pulse rate should 800 pps or 400 pps, and the resulting power should be 24 W. For vigorous heating, the pulse width should be set at 400 μs, the pulse rate should be 800 pps, and the resulting power should be 48 W.[1] Today, PSWD devices have been programmed to be user-friendly. Many devices seen in facilities have preset keypads that automatically set the parameters to achieve a 1° C, 2° C, or 4°C tissue temperature increase for the appropriate heating levels desired.[1]

In order to reach optimal tissue temperatures as aforementioned, clinicians have looked to recent research to ascertain the appropriate treatment times. A couple of studies have come to agreement on appropriate treatment times regarding the thermal effects of PWSD. Draper et al.[7] found peak heating occurred at 15 minutes and leveled off at 20 minutes in healthy tissue. Similarly, Garrett et al.[12] observed tissues reaching optimal vigorous heating during a 20-minute PSWD treatment. The literature is limited to these two studies examining the correlations between optimal tissue temperatures and treatment times. Therefore, research supports using the above guidelines to determine appropriate treatment times in regards to temperature increases in treated tissue.

2.4. Tissue Temperatures

Focusing on the thermal effects of diathermy, several sources have defined the levels of heating that occurs in tissues in regards to therapeutic modalities. Mild heating occurs with 1° C (1.8°F) increase, moderate heating occurs with 2° C (3.6°F) increase, and deep heating occurs with 4° C (7.6°F) increase in tissues applied with therapeutic modalities.[1,8] With different levels of tissue temperature increases, there are different tissue responses. Mild heating produces mild inflammation and acceleration of cell metabolism; moderate heating decreases muscle spasms and pain, increases blood flow, and reduces chronic inflammation; and deep heating increases tissue elasticity in collagen-rich tissues.[1] In addition, Micholovitz[14] suggested optimal tissue heating occurs when temperature increases to temperatures between 38-45° C. Micholovitz[14] also stated, as temperature rises past the 45° C mark, thermal effects become detrimental as the structural characteristics of proteins are altered.

With the aforementioned guidelines in mind, researchers have examined the proper classification level of heating for diathermy. Draper et al.[7] was able to observe the tissue temperature increase and decay using PSWD. Subjects underwent PSWD treatment with the Megapulse diathermy unit at 27.12 MHz and a pulsed mode yielding 800 bursts per second. During diathermy treatment sessions, intramuscular temperatures were recorded at 5-minute intervals for 20 minutes. After treatment, intramuscular temperatures were recorded at 5 and 10 minutes post treatment in order to measure tissue temperature decay. Upon conclusion of the study, researchers found an average temperature increase of 1.36 ± 0.90°C at 5 minutes; 2.87 ± 1.44°C at 10 minutes; 3.78 ± 1.19°C at 15 minutes; and 3.49 ± 1.13°C at 20 minutes. According to the researchers of this study, this temperature increase shows the ability of diathermy to produce vigorous heating results as described by Lehmann[8]. Another noteworthy observation included the results of temperature decay in tissue with the use of PSWD. Researchers found tissue temperature to drop on average 0.97 ± 0.68°C at 5 minutes post-treatment; and 0.81°C at 10 minutes post-treatment. The total temperature decay was 1.78 ± 0.69°C.[7] This illustrates the ability of diathermy to prolong raised tissue temperatures for clinicians use in treatment goals.

Little research has been completed on the superficial temperature changes produced by pulsed shortwave diathermy. Pulsed shortwave diathermy had been previously considered as athermal in superficial tissue temperature changes, as the electromagnetic waves bypass fatty tissues to produce the eddy currents that cause the thermal benefits in deeper tissues.[13]These thermal benefits are then dissipated prior to reaching surface receptors. However, Murray and Kitchen[13] proposed the possibility of increasing pulse rate to produce thermal sensations in superficial tissues. In their study, 30 volunteers were randomly assigned to placebo and treatment groups. In the treatment group, the participants were treated with pulsed shortwave diathermy using the Curapuls 403 unit set at 27.12 MHz. The pulse frequency began at 26 Hz and increased every two-minutes until participants could feel a 'definite' thermal sensation. Results showed a positive correlation between pulse frequency and skin temperature (r=0.517) in which a mean pre-treatment temperature of 28.69 degrees Celsius steadily rose to a final temperature measured at 400 Hz of 31.14 degrees Celsius.[13] This shows that, if a pulse is delivered prior to the thermal effects of the previous pulse are dissipated, thermal accumulation occurs in succeeding pulses. With the ability to provide a vigorous level of heating for a prolonged amount of time, clinicians have been able to effectively utilize the thermal effects to produce successful results in practice for some of the indications/applications described below, including increased stretching windows for both range of motion increases and joint mobilizations.[24-26]

2.5. Clinical Indications/Applications

Combining the physiologic effects, reported tissue temperature changes, and optimal treatment times, shortwave diathermy has been shown to be appropriate or optimal for some clinical indications. Both PSWD and CSWD have been shown to be effective for patients suffering from knee osteoarthritis. Jan et al.[21] examined patients who underwent a series of 10 shortwave diathermy treatments which significantly reduced synovial sac thickness and associated pain measured on a 10-point visual analog scale (VAS). The shortwave diathermy treatment used the induction coil technique, in which treatments were administered 3 to 5 times a week for a total of 30 treatment sessions within 8 weeks. The intensity of the treatment was based on the patient's perception of "warmth" and lasted 20 minutes. Specific pulse duration, pulse rate, and total wattage were not provided. Similarly, Ovanessian et al.[20] focused on patient outcomes and function after completion of diathermy treatments. The researchers utilized the Knee Osteoarthritis Outcome Score (KOOS) and VAS to assess pain and function. The authors utilized the Diatermed II PSWD unit that used a frequency of 27.12 MHz, peak power of 250W, and pulse width of 400 µs. Maximum power was used with a pulse rate of 145Hz in order to obtain a mean power of 14.5W. Three groups were used in which one group underwent a 38-minute treatment, one group underwent a 19-minute treatment, and a control group did not receive treatment. The results were similar in finding a significant decrease in pain and increase in function compared to a control group receiving a placebo treatment, with no significant observations between the two different treatment times.[20] Continuing on, Fukuda et al.[22] expanded on treatment outcomes by incorporating the KOOS and an 11-point numerical pain rating scale (NPRS) within the evaluation of shortwave diathermy treatments to women suffering from knee osteoarthritis over a 3-week period with a 12-month follow-up. Much like Ovanessian et al.[20], maximum power was used with a pulse rate of 145 Hz in order to obtain a mean power of 14.5W. Researchers similarly found a significant decrease in pain and significant increase in function after treatment protocols involving the use of high and low dose PSWD. The limited research available on PSWD, support the use of shortwave diathermy to reduce pain and increase function in knee osteoarthritis. Available research does not come to a consensus on parameter guidelines in order to perform this treatment.

Another indication shown to be effective with shortwave diathermy uses the concept of heating tissues prior to mobilizations and stretching to decrease tissue restriction and to increase range of motion. This concept was first employed in muscular tissue in a study conducted by McCray and Patton.[23] Their study involved the use of comparing moist heat packs to shortwave diathermy in relieving pain associated with trigger points. For the diathermy treatment, the induction coil technique was used at a frequency of 27.12 MHz. No other parameters were listed specifically for diathermy. The moist heat pack was heated in a standard hydrocollator unit at 68 °C for a minimum of 20 minutes prior to use. Both treatments covered the trigger point and lasted 20 minutes. The researchers found that shortwave diathermy was able to relieve pain and muscle spasticity better than moist heat packs, showing the documented effectiveness of thermal diathermy to enhance muscle relaxation.[23] The same concept was applied to a study concerning the use of shortwave diathermy and hamstring flexibility in relation to knee extension. Researchers found that knee extension increased more with diathermy and stretch (15.8° ± 2.2°) than with sham diathermy and stretch (5.2° ± 2.2°) and the control groups (0.3° ± 2.2°) over a one week treatment protocol.[25] Similarly, Brucker et al.[24] examined the effects of diathermy on increasing ankle dorsiflexion. The study included an 18-day stretching regimen with or without the use of PSWD to measure differences in ankle dorsiflexion after 3 weeks. In the PSWD group, treatment was performed using the Megapulse II shortwave diathermy machine which used an operating frequency of 27.12 MHz. The treatment parameters were 800 bursts per second, 400-μs burst duration, and 800-μs interburst interval, with a peak power of 150 W per burst and an average power output of 48 W. The researchers found that the use of PSWD did not effect the amount of increase in range of motion, which led to debate the previous findings.[24] The differences in results can be attributed to duration of study or methods of diathermy treatment parameters. The first study only examined subject's changes in hamstring flexibility over a period of one week, and, in the second study, the researchers examined the effects over a period of three weeks. In such instances where range of motion is only being examined immediately after treatment, gains may be attributed to the benefits of therapeutic heat, whereas true range of motion retention must be determined over a much more significant amount of time.

Lastly, joint capsular restriction was not researched until Draper et al.[26] completed a case series involving PSWD and joint mobilizations to return normal elbow range of motion after injury or surgical intervention. The researchers incorporated a treatment protocol in six patients and observed the results. The treatment protocol included PSWD and elbow joint mobilizations 3 times per week for 4-6 treatments per patient. The pulsed shortwave diathermy treatment lasted for 20 minutes by using the Megapulse shortwave diathermy machine set at 800 pulses per second for 400 microseconds. Joint mobilizations were performed for 7 to 8 minutes immediately after the diathermy treatment. The results of this study showed PSWD was effective at helping restore AROM in 5 out of 6 patients at the end of 6 or fewer treatment sessions.[26] This study shows promise for shortwave diathermy, but caution must be taken for patients with surgically implanted metals that may cause uneven heating. Shortwave diathermy may be used for other indications that involve conditions in which a tissue temperature rise is desired in tissues deeper than 1-2cm; nonthermal effects are desired in tissues deeper than 1-2 cm; the treatment goal involves an increase in tissue temperature or nonthermal effects over large areas; or treatment is applied to irregular surfaces.[1]

2.6. Contraindications/Precautions

Shortwave diathermy presents several contraindications in order for safe clinical application of this modality. Contraindications include patients with any implanted pacemaker, neurostimulator, or defibrillator; patients with surgically implanted metals; pregnancy; application over tumors; patients showing symptoms of fever; patients with signs of infection; application over growth plates; application over testes; application on or near the eyes; application with the presence of joint effusion; and application over the spine with a protruded nucleus pulposus.[1,27] In addition, the use of shortwave diathermy also requires the clinician to take care for the following precautions: conditions where increased temperature is not desired; injuries with acute bleeding; acute inflammatory conditions; areas with reduced blood supply; areas with reduced sensitivity to temperature or pain; over fluid filled areas or organs; and during menstruation.[1] Overall, the research on SWD shows a strong clinical recommendation for its use, keeping safety in mind with the contraindications/precautions of this modality. However, with all therapeutic modalities, an understanding of the equipment and the components that are comprised is key in developing an effective treatment.

2.7. ReBound® Diathermy

Research on shortwave diathermy has included many different devices with similar descriptions of the induction drum set-up described above.[5,7,10,12,17-26] These units are usually fixed devices in the clinical setting due its size and the requirement that the unit must be plugged into a wall outlet to acquire the amount of electricity for the generator's conversion into useful radio frequencies. This set-up creates issues in settings where portability is desired. However, recent development in technology has produced a device that claims abilities of the standard set-up with the portability the traditional machine set-up lacks.

In order to help alleviate the portability issues with traditional SWD units, diathermy applications have expanded with the addition of the ReBound® Diathermy Unit, which claims similar therapeutic benefits. The ReBound® therapeutic warming system was developed by ReGear Life Sciences Inc. for the original purposes of warming SEAL members and deep sea divers for the US Navy.[9] However, this system has stepped into field of medicine for the use as a therapeutic modality in various settings. The ReBound® is FDA approved for the use of generating deep heat within body tissues for medical conditions including pain relief, muscle spasms, and joint contractures. According to the manufacturer, the nonthermal effects of diathermy are included within the thermal effects produced.[9]

The ReBound® uses a portable energy source, the ReBound ReGenerator®, and various garments including several sizes of cylindrical garments, an ankle garment, a shoulder garment, and a back garment. All cylindrical garments have a length of 13 inches with varying circumferences (11, 13, 15, 18, 21, 23, 27, 30, and 33 inches). The ReBound ReGenerator® produces continuous shortwave diathermy with parameters of 13.56 MHz and 35 W, and the unit's mere weight of 3.5 pounds allows the benefit of portability of treatments. As previously mentioned, traditional units most commonly utilize the 27.12 MHz frequency, which is higher than the ReGenerator®. The garments associated use a longitudinal heating coil design that claims to warm affected tissues gradually and uniformly, preventing any hot spots during treatments (Appendix A).[9]

Prior to recent studies, research in support of the ReBound® was loosely based on the therapeutic benefits of shortwave diathermy in general. However, two recent studies have compared the use of the ReBound® to traditional means of therapeutic heating modalities. In both studies, a size 18 cylindrical therapy garment was used in conjunction with the ReBound® unit. The purpose of the first study was to evaluate the effectiveness of the ReBound® as a deep heating modality in comparison to the Megapulse II, a traditional large PSWD unit. Conclusions were based on measurements from thermocouple insertion in the triceps surae muscle in 12 healthy, college-aged volunteers. Thermocouples were inserted in the posterior medial aspect of the triceps surae muscle at a depth of 3 cm, which is classified as deep thermotherapy.[10] Both treatments lasted for 30 minutes. The Megapulse II utilized parameters set at 800 pulses per second and a pulse width of 400 microseconds, with a mean power output of 48 W. The ReBound® Diathermy Unit does not have adjustable parameters, so authors selected the longest treatment duration (30 minutes) to observe peak tissue temperatures produced. All subjects received both treatments with a recovery period of 48 hours between treatments to ensure no crossover effects. The results included temperatures during a 30-minute application and temperature decay recorded for 20 minutes after application. During the treatment, tissue temperatures increased more with the Megapulse II than with the ReBound®, where MegaPulse II increased temperatures 4.32°C ± 1.79°C and ReBound® increased temperatures 2.31°C ± 0.87°C.12 Although the Megapulse II produced larger temperature increases, the ReBound® had a slower rate of dissipation in regards to temperature decay. This study showed that the ReBound® did not reach the designated appropriate temperature increase that is used for vigorous deep heating, but implies that the ReBound® may be used as a superficial heating modality for treatment goals that would benefit from mild to moderate heating.

The second study, with the same authors, was very similar. However, the purpose of this study was to evaluate the effectiveness of the ReBound® as a superficial heating modality in comparison to silicate-gel moist heat packs. Conclusions, again, were based on measurements from thermocouple insertion in the triceps surae muscle in 12 healthy, college-aged volunteers. Thermocouples were inserted in the posterior medial aspect of the triceps surae muscle at a depth of 1 cm, which is considered to be a superficial depth.[11] All subjects received both treatments with a recovery period of 48 hours between treatments to ensure no crossover effects. The authors reported that during a 30-minute application, tissue temperatures increased more with the ReBound® than with the moist hot packs, where ReBound® increased temperatures 3.69°C ± 1.50°C and moist heat packs increased temperatures 2.82°C ± 0.90°C.27 This study showed that the ReBound® has the capacity to effectively heat superficial structures.

The only documented research to evaluate the ReBound® Diathermy Unit include the above two studies. With the two studies combined, thermal effects of the ReBound® unit were ascertained. These thermal effects are of clinical importance, showing the ReBound® can be utilized as a moderate heating modality. However, surface temperatures relevant to continuous shortwave diathermy have not been shown in research with the ReBound® Diathermy Unit, as well as the claim that all garments produce gradual and consistent heating throughout the sleeve.

2.8. Summary

Shortwave diathermy is a therapeutic modality used by allied health care professionals for the use in treatment plans based on various goals for treatment. Diathermy utilizes eddy currents to produce nonthermal and thermal physiological effects. In regards to thermal effects, clinicians must understand the appropriate increase in tissue temperature and treatment times to achieve desired results. With the above supporting research, allied health care professionals utilize shortwave diathermy for various indications and show caution by acknowledging the contraindications and precautions involved with this modality.

Previous and current equipment utilized to conduct shortwave diathermy treatments are usually large and difficult to transport. However, ReGear Inc. has issued the ReBound® Diathermy Unit to help the growing need of treatments to be portable and accessible. Past research has been conducted to evaluate the effectiveness of the ReBound®. However, only limited research has been conducted, and this research has not yet shown the possible increase in surface temperatures, as well as the consistency of tissue temperatures produced in a garment sleeve. Therefore, it was important to critically analyze this modality's ability to produce safe and consistent results.

3. METHODS

The purpose of this study was to investigate if the ReBound® Diathermy unit produced skin temperatures in an ankle garment sleeve. This study will help allied health professionals establish evidence-based medicine when utilizing this modality in clinical practice. The research questions addressed in this study include: (1) Are skin temperatures increased in an ankle garment sleeve, (2) Is skin temperature increased to a therapeutic heating level, and (3) Are skin temperatures consistent throughout the entire ankle garment sleeve? This chapter focused on the experimental design, population of the study, instruments needed for data collection, procedures, and data analysis procedures involved.

3.1. Experimental Design

The study followed the 3x7 repeated-measures ANOVA design. The independent variables were the three placement sites of surface thermocouples (proximal, central, and distal of the ankle sleeve) and time (0 minutes, 5 minutes, 10 minutes, 15 minutes, 20 minutes, 25 minutes, and 30 minutes). The dependent variables were the seven skin temperatures consisting of a baseline/pre-treatment and temperatures every 5 minutes during the 30-minute treatment.

3.2. Population of the Study

With the research design, a pool of 20 male participants was selected for this study. Participants were healthy, college-aged (18-30 years) subjects. Participants were dismissed if an injury to the ankle had been sustained in the last six months or if contraindications with shortwave diathermy were present. Females were not used due to the contraindication to pregnant women. Other contraindications to diathermy include: any implanted pacemaker, neurostimulator, or defibrillator; patients with surgically implanted metals; application over tumors; patients showing symptoms of fever; patients with signs of infection; or the presence of joint effusion.

In order to gain the number of participants, the Masters of Athletic Training and Masters of Science in Advanced Athletic Training students from NDSU were recruited first due to familiarity to the information related. The desired amount of participants was not met, so information was distributed through NDSU List Serv to increase awareness and give others the opportunity to participate in the study. Those who wished to participate in the study underwent a simple random sampling protocol, in which the remaining number of participants was randomly selected of the pool of individuals who were interested until the desired amount of 20 participants was reached.

3.3. Instruments for Data Collection

There were several instruments required to complete data collection for this study. In order to collect skin temperatures, an electro thermometer, called the Iso Thermex (Columbus Instruments, Columbus, OH), was used to process information from skin surface thermocouples SST-1 (Physitemp Instruments, Clifton, NJ). The treatment set up included the ReBound® Diathermy Unit. The unit consisted of a power-generating unit, called the ReGenerator, and therapy garment sleeves (Appendix B). One ankle therapy sleeve was used to provide the treatment. (ReGear Life Sciences, Inc.) (Appendix C).

3.4. Procedures

Participants were asked to not perform any vigorous exercise 1 hour prior to the study. Participants reported to Bentson Bunker Field House, Room 14, at a pre-designated time decided between the researcher and the participant. Subjects laid supine on the treatment table. The placement sites were marked and followed the anterior aspect of the ankle. The central site was located on the anterior aspect of the talocrural joint. The proximal site was located approximately 3 inches above the central site, slightly lateral to the anterior aspect of the tibia. The distal site was located approximately 3 inches distal to the central site, over the anterior aspect of the 2nd metatarsal. An additional thermocouple was placed in the room to measure room temperature. If excess hair was present at the surface thermocouple placement sites, subjects were shaved around the placement area. The placement sites were cleaned with isopropyl alcohol prior to placement of the thermocouple and allowed to air-dry. Once in place, the surface thermocouple was secured to the subject by placing tape directly over the distal end of the thermocouple and placing tape over the plug-in portion of the thermocouple. The thermocouples were connected to the Iso Thermex and were ready to begin collecting data. Surface temperatures were stabilized prior to recording baseline temperatures. Initial baseline temperatures for all three sites were recorded after consistent surface temperatures were observed for three minutes.

Afterwards, treatment occurred. The surface thermocouples had to be removed prior to commencing treatment, to avoid heating the metal part of the thermocouples. Each subject was properly fitted with a ReBound® ankle sleeve according to placement sites located on the ankle. Treatment settings on the ReBound® unit were standardized, in which all subjects underwent a continuous setting at 35 W and 13.56 MHz for 30 minutes. This setting is suggested for vigorous heating.[9] The Iso Thermex reported temperatures every 5 seconds, but each placement site temperature was recorded every 5 minutes. To record temperatures, the ReBound® unit was paused during treatment to prevent electrical interference of the Iso Thermex. Surface thermocouples were placed in their respective positions described above to record skin temperatures. This process repeated every 5 minutes until treatment was completed. At completion of the treatment, the ReBound® unit was disconnected, and a final skin temperature was recorded using the surface thermocouples.

After all measurements had been completed, post-treatment procedures began. The thermocouples were disconnected from the Iso-Thermex, and the tape was removed that was previously securing the thermocouple to the participant. The thermocouples were then removed from the participant. At the end of post-treatment, subjects were thanked and compensated $20 for participation. Completion of one full session with one participant lasted approximately one hour.

3.5. Data Analysis Procedures

A 3x7 repeated-measures ANOVA test was used to determine differences between the three different measured sites using a significance level of $p<0.05$. Differences were observed, so Bonferroni was used as a post-hoc analysis to specify significant differences. The room temperature was evaluated between subjects to determine any additional effects. Statistical analysis was conducted using SPSS Statistics (IBM, Armonk, NY).

4. RESULTS

The purpose of this study was to investigate if the ReBound® Diathermy unit produced skin temperatures in an ankle garment sleeve. This study will help allied health professionals establish evidence-based medicine when utilizing this modality in clinical practice. The research questions addressed in this study include: (1) Are skin temperatures increased in an ankle garment sleeve, (2) Is skin temperature increased to a therapeutic heating level, and (3) Are skin temperatures consistent throughout the entire ankle garment sleeve?

Twenty subjects were recruited for the treatment session. There were no dropouts as all twenty subjects completed the entire treatment session. Subjects ranged in age from 19-28 years with a mean age of 22.9±2.918 years (Table 4.1).

Table 4.1. Demographics

	N	Minimum	Maximum	Mean	Std. Deviation
Age in Years	20	19	28	22.90	2.918

Temperatures were recorded for each location (proximal, central, and distal) and each time interval (0 min, 5 min, 10 min, 15 min, 20 min, 25 min, 30 min) in degrees Celsius (° C). As aforementioned, the Iso-Thermex reported temperatures every 5 seconds. For each time interval, the thermocouples were plugged into the Iso-Thermex and temperatures were taken for 20 seconds. The four temperatures within the 20 seconds was averaged and used as the official temperature for the time interval. Baseline temperatures for the proximal site (29.93±1.31° C), central site (30.41±1.44° C), and distal site (30.30±1.61° C) were recorded after consistent temperatures were observed for approximately three minutes. The skin temperatures dropped for each site immediately after 5 minutes of treatment for the proximal site (28.83±1.01° C), the central site (29.33±1.37° C), and the distal site (28.96±1.61° C) (Table 4.2). The remaining temperatures recorded stabilized and slightly increased at each site (Table 4.2).

Table 4.2. Descriptive Statistics

	Mean	**Std. Deviation**	**N**
Baseline temperature at proximal site	29.93	1.31	20
Skin temperature at proximal site (5min)	28.83	1.01	20
Skin temperature at proximal site (10min)	28.79	1.36	20
Skin temperature at proximal site (15min)	28.93	1.33	20
Skin temperature at proximal site (20min)	28.95	1.40	20
Skin temperature at proximal site (25min)	28.95	1.49	20
Skin temperature at proximal site (30min)	29.09	1.38	20
Baseline temperature at central site	30.41	1.44	20
Skin temperature at central site (5min)	29.33	1.37	20
Skin temperature at central site (10min)	29.42	1.49	20
Skin temperature at central site (15min)	29.31	1.52	20
Skin temperature at central site (20min)	29.49	1.49	20
Skin temperature at central site (25min)	29.54	1.52	20
Skin temperature at central site (30min)	29.74	1.57	20
Baseline temperature at distal site	30.30	1.61	20
Skin temperature at distal site (5min)	28.96	1.61	20
Skin temperature at distal site (10min)	29.14	1.64	20
Skin temperature at distal site (15min)	28.94	1.58	20
Skin temperature at distal site (20min)	29.03	1.64	20
Skin temperature at distal site (25min)	29.12	1.73	20
Skin temperature at distal site (30min)	29.09	1.90	20

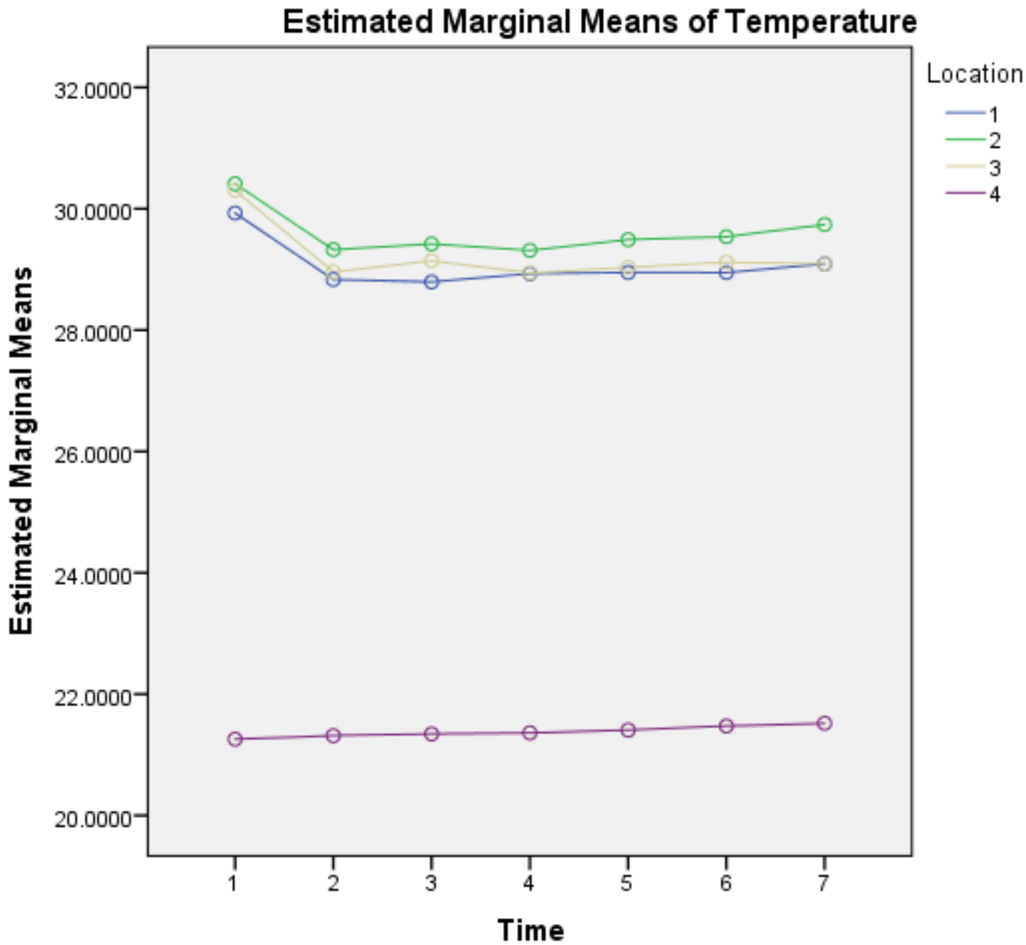

Figure 1. Line Chart of Surface Temperatures during ReBound® Diathermy Treatment.

Statistical analysis was completed to determine the effects of time, location, and the interaction between time and location on skin temperature. Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of location, $\chi^2(5) = 40.73$, $p<0.001$, the main effect of time, $\chi^2(20) = 43.67$, $p=0.002$, and the interaction between time and location, $\chi^2(170) = 224.26$, $p=0.017$. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.463$ for the main effect of location, 0.542 for the main effect of time, and 0.415 for the interaction between the main effect of time and the main effect of location.

4.1. Location

There was a significant main effect of location on skin temperature recorded, $F(1.39, 26.39) = 343.51$, $p<0.001$. Pairwise comparisons using a Bonferroni adjustment were made to determine significant differences between each location. Only locations 1 (proximal) and 2 (central) were significantly different, $p=0.001$. Location 2 had a mean positive change of 0.54±0.12° C. On average, the central location was 0.54° C warmer than the proximal location.

4.2. Time

There was a significant main effect of time of treatment on skin temperature recorded, $F(3.25, 61.83) = 34.61$, $p<0.001$. Pairwise comparisons using a Bonferroni adjustment were made to determine significant differences between each time. Time 1 (baseline, 0 min) was significantly different from the rest of the time intervals, $p<0.001$, with mean positive differences ranging from 0.62-0.87° C and a standard error ranging from 0.07-0.10° C. The skin temperatures decreased immediately after beginning the ReBound® Diathermy treatment. Time 4 (15min) was significantly different from Time 7 (30 min), $p=0.004$, with a mean negative difference of 0.22±0.05° C. There were no other significant differences (Figure 1).

4.3. Interaction between Location and Time

There was a significant interaction effect between the location and the time of treatment on skin temperature recorded, $F(7.47,141.95) = 9.43$, $p<0.001$. This indicates that significant skin temperature differences were observed for each location at each time interval recorded, similarly described as above.

4.4. Summary

Skin temperature increases were not produced on the anterior aspect of the ankle during a ReBound® Diathermy treatment. The skin temperatures were significantly different between baseline temperatures and all time intervals with mean positive differences ranging from 0.62-0.87° C. The skin temperatures dropped for each site immediately after 5 minutes of treatment for the proximal site, the central site, and the distal site. The remaining temperatures recorded stabilized and slightly increased at each site, but did not return to baseline temperatures.

Skin temperatures were not consistent throughout the entire ankle sleeve when measuring surface temperatures on the anterior aspect of the ankle. The proximal and central sites were significantly different. The central site showed increased temperatures with a mean positive difference of 0.54° C.

Skin temperatures were not increased to a therapeutic heating level on the anterior aspect of the ankle during a ReBound® Diathermy treatment. Therapeutic heating occurs when tissue temperatures increase at least 1° C.[1,8] As previously reported, the skin temperatures did not return to baseline meaning therapeutic heating was not achieved on the surface of the anterior aspect of the ankle.

5. DISCUSSION

The purpose of this study was to investigate if the ReBound® Diathermy unit produced skin temperatures in an ankle garment sleeve. This study will help allied health professionals establish evidence-based medicine when utilizing this modality in clinical practice. The research questions addressed in this study included: (1) Are skin temperatures increased in an ankle garment sleeve, (2) Is skin temperature increased to a therapeutic heating level, and (3) Are skin temperatures consistent throughout the entire ankle garment sleeve?

5.1. Summary

The ReBound® Diathermy unit is a continuous shortwave diathermy device that is used to provide therapeutic treatment for various indications. ReGear Inc. developed this unit to allow for the growing need of diathermy treatments to be portable and more accessible. Only two research articles have evaluated the effectiveness of the ReBound® Diathermy unit.[10,11] Past research has not yet evaluated the possible increase in surface temperatures, as well as the consistency of tissue temperatures produced in a garment sleeve. Therefore, this study was developed to further evaluate and critically analyze this modality's ability to produce safe and consistent results.

The study called for 20 healthy, college-aged (18-30 years) males to participate in a single treatment session. Participants were dismissed if any injury to the ankle had been sustained within the past six months or if any contraindications to treatment were present. No subjects were dismissed from the study. The Iso-Thermex digital thermometer, SST-1 skin surface thermocouples, and the ReBound® Diathermy unit were used to conduct the study. Subjects laid supine while placement sites (proximal, central, and distal) were marked following the anterior aspect of the ankle, thermocouples were secured, and a baseline temperature was recorded. After baseline temperatures were recorded, the 30-minute treatment began in which skin temperatures were recorded every 5 minutes.

The ReBound® Diathermy unit did not produce an increase in skin temperatures on the anterior aspect of the ankle in the current study. The skin temperatures were significantly different between baseline temperatures and all time intervals. The skin temperatures dropped for each site immediately after 5 minutes of treatment for all sites; the remaining temperatures recorded stabilized and slightly increased at each site, but did not return to baseline temperatures.

5.2. Discussion

The ReBound® Diathermy Unit produces electromagnetic fields to achieve treatment goals. By introducing magnetic fields to tissue, small currents known as eddy currents, create dipoles in water molecules. The dipoles are pairs of equal and opposite electric charges separated by a small distance and rotate due to polarity changes.[1] The rotation of these dipoles causes tissue kinetic energy to increase. The increase in tissue kinetic energy generates friction between tissues to produce the thermal effects of diathermy.[1] Skin and adipose do not have a high level of water content, meaning these should be unaffected when introduced to electromagnetic fields. This allows diathermy to bypass skin and adipose, and heat deeper tissues.

With the available research, the current study is the first to evaluate skin temperature changes during a ReBound® Diathermy treatment. However, two articles have investigated skin temperature increases with pulsed shortwave diathermy for use of comparison.[16,19] Mayrovitz, et al[16] reported a mean increase of 1.8° C after 40 minutes of pulsed electromagnetic field (PEMF) treatment. Pulsed electromagnetic field utilizes similar mechanisms to achieve treatment goals compared to continuous shortwave diathermy units, as both produce electromagnetic fields within tissues. Similarly, Al-Mandeel and Watson[19] reported a mean increase in comparison to an untreated limb of 7.3% in the high dose group (150 W), 1.2% in the low group (24 W), and under 0.5% for the placebo group while utilizing the Megapulse shortwave diathermy unit. The current study refutes both articles' results. Skin temperatures decreased immediately after 5 minutes of ReBound® Diathermy treatment and then slowly increased, but temperatures did not return to baseline temperatures at the end of the 30-minute treatment. This may have been attributed to several reasons. The initial decrease in skin temperature may have been attributed to the body's thermoregulation abilities. As deep heating occurs, blood vessels dilate which direct heat towards those deeper tissues. The slow increase to attempt to return to baseline is then explained as said heating dissipates to the superficial tissues.[4]

In past research, Draper, et al[10] reported the ReBound® Diathermy unit may produce stray electromagnetic waves emitted through the garments to a greater extent in comparison to the traditional drum methods. In the current study, similar difficulties occurred including interference with the laptop and the Iso-Thermex electrothermometer when the ReBound® Diathermy device was turned on. Accompanying this, the use of metallic probes for measuring skin temperature being heated by continuous shortwave diathermy may cause gross errors in data, as the metal may be heated in place of the tissue.[3] This affected the data collection procedures in which probes were repetitively placed and removed every 5 minutes to obtain skin temperature measurements, resulting in approximately 30 seconds of "off" time from treatment during each time interval, which roughly equates to 3.5 minutes of "off" time strictly for data collection. The above presents several concerns. First, as discussed by Draper, et al[10], stray electromagnetic waves could be considered a safety concern in those individuals with pacemakers. The subjects in the current study did not have pacemakers, which eliminated the possibility of that contraindication. Secondly, similarly to Draper, et al[10], stray electromagnetic waves show the possibility of less energy being directed into treated tissues. This may attribute to the lack of skin temperatures produced. Lastly, as described above, in pausing the treatment for data collection, the current study limited exposure to the electromagnetic waves during the treatment every 5 minutes. During the “off” time, the body may have had time to thermoregulate skin temperatures, or the surface thermocouples may have cooled by not being in contact directly with the skin to observe the entire treatment.

Furthermore, results may have varied due to the equipment utilized. Mayrovitz, et al[16] utilized a PEMF modality operating at 27.12 MHz and a mean power of 35 W. Al-Mandeel and Watson[19] utilized the Megapulse diathermy unit operating at 27.12 MHz and 24 W (high dose), 3 W (low dose), and 0.5 W (placebo). In contrast, the ReBound® Diathermy unit operates at 13.56 MHz with a peak power output of 35 W. In relation to parameters, one might state all units have comparable outputs to deliver a necessary amount of electromagnetic energy to the target tissues. However, differential heating may have occurred due to the choice of applicator used and its subsequent alignment and proximity to the skin.[4] Pulsed electromagnetic field treatments utilize an actuator head containing the excitation coils placed approximately 2 cm above skin surface, and the Megapulse unit utilizes an induction drum placed approximately 1.5 cm above skin surface. In the current study, the ReBound® Diathermy ankle garment does not contact the anterior aspect of the ankle, which was used due to the ease of attaching and removing the surface thermocouples to minimize the amount of “off” time, when pausing the treatment to acquire data. The garment is intended for the ankle to sit in the sleeve, in which the posterior, lateral, and medial aspects of the ankle are in direct contact with the garment (Appendix C). Many subjects reported slight warmth on the foot in areas that were in direct contact with the garment.

In addition, skin temperatures were not consistent throughout the entire ankle sleeve when measuring surface temperatures on the anterior aspect of the ankle. The proximal and central sites were significantly different. The central site showed increased temperatures with a mean positive difference of 0.54° C. This may be attributed to the associated fit of the garment sleeve (Appendix C). As mentioned prior, the applicator's alignment and proximity may produce differential heating in treated tissues.[4] The foot/ankle garment sleeve of the ReBound® encompasses the central site to allow a closer proximity in relation to the proximal and distal surface sites. With the inconsistency in locations, the effective treatment area may be reduced, as other locations may not be heated to a therapeutic heating level.

Skin temperatures were not increased to a therapeutic heating level on the anterior aspect of the ankle during a ReBound® Diathermy treatment. Therapeutic heating occurs when tissue temperatures increase at least 1° C.[1,8] As previously reported, the skin temperatures did not return to baseline meaning therapeutic heating was not achieved on the surface of the anterior aspect of the ankle.

5.3. Clinical Relevance

This study showed that anterior skin temperatures are not produced using the ReBound® Diathermy ankle garment sleeve, supporting the theory in which electromagnetic fields are able to bypass skin and adipose to treat deeper tissues. The current study did not evaluate tissue temperatures below surface level, but previous studies have examined this effect.[10,11] This is important to note in the direction of future ankle treatments. When using this garment, it may be best utilized to direct treatments to the lateral, medial, or posterior aspects of the ankle as many subjects reported a slight warming sensation on areas of the ankle in direct contact with the garment sleeve. This indicates a possible therapeutic benefit when directing treatments to the areas in contact with the garment.

5.4. Limitations

Several limitations were present in the current study. As aforementioned, the ReBound® Diathermy Unit caused interference of other electrical devices within close proximity. This affected the methodology of the study, in which treatments had to be paused to accurately record the surface temperature using the Iso-Thermex electrothermometer. This limitation is correlated to the choice of surface thermocouple placement, as well. In order to reduce the amount of time treatment was paused, thermocouples were placed only on the anterior aspect of the ankle. The current study was able to evaluate different areas on the sleeve; however, different aspects of the ankle were not evaluated. The researcher involved with performing the placement of the thermocouples had limited experience. However, a placement protocol was in effect and was followed precisely to avoid poor intrarater reliability.

5.5. Recommendations for Future Research

Further research should be performed on the ReBound® Diathermy unit. As previously noted, many subjects reported slight warmth to areas in contact with the garment sleeve. Measuring skin temperatures in these areas may be more difficult, but should be attempted to further evaluate this modality's ability to produce skin temperatures. An ideal evaluation of the ReBound® Diathermy unit would include both skin and intramuscular temperatures to assess the full thermal capabilities of this unit. Research involving injured tissue should be evaluated to determine the effect on healing rate in those individuals who utilize this modality.

5.6. Conclusion

Based on previous research, the ReBound® Diathermy modality has been designated as a moderate heating modality.[10,11] This is the first study that has evaluated the skin temperature thermal changes during this treatment. This modality is not recommended to produce anterior ankle skin temperatures in college-aged males, which correlates well with the goal of using shortwave diathermy. As stated before, shortwave diathermy should bypasses skin and adipose to produce deeper tissue temperatures.[1] Based on previous research that has evaluated deeper tissue temperatures, it is likely tissue temperatures may have been produced out of range of the surface thermocouples. However, without assessing deeper tissue temperatures in the current study, recommendations cannot be made. Another possibility, due to the absence of anterior skin temperatures, is the assumption of lower intramuscular temperatures on the anterior aspect of the foot and ankle when using this garment. This may correlate with the subject self-reports, which indicate the possibility of a thermal response in the lateral, medial, and/or posterior ankle. Those areas are in close proximity to the sleeve. Therefore, the ReBound® Diathermy ankle garment is recommended to provide a safe treatment to the ankle/foot without producing anterior skin temperatures.

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APPENDIX A. MEGAPULSE II AND REBOUND® DIATHERMY SPECIFICATION COMPARISONS[9,28]

Technical Specification	**Megapulse II**	**ReBound®**
Operating Frequency	27.12 MHz	13.56 MHz
Power Requirements	120 VAC, 60 Hz	117 VAC, 47-63 Hz
Output Power	150 W (peak power)	35 W (peak power)
Impedance	50 Ohms	50 Ohms
Duty Cycle	Pulsed	Continuous
Weight	86 lbs	3.5 lbs
Dimensions	34”x16”x16”	11”x 9“x6”
Electrodes	Inductive Field Applicator	Back, Shoulder, and Cylindrical garments

APPENDIX B. REBOUND® DIATHERMY EQUIPMENT

APPENDIX C. REBOUND® DIATHERMY ANKLE GARMENT