THERAPEUTIC ULTRASOUND: PROVIDING AN EDUCATIONAL INTERVENTION ON BEST PRACTICE TECHNIQUES AND THEIR IMPLICATIONS

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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

DOCTOR OF PHILOSOPY

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ABSTRACT

BACKGROUND: Therapeutic ultrasound is a modality that is commonly used in the treatment of musculoskeletal injuries by healthcare professionals throughout the world for both its thermal and non-thermal effects. PURPOSE: This study used an in-person or virtual asynchronous educational intervention to educate and demonstrate best practice techniques to practicing athletic trainers while surveying their usage, perception, confidence, and knowledge regarding the modality. METHODS: Thirty-one athletic trainers completed the educational intervention, including 13 who participated in the in-person session and 18 in the virtual asynchronous session. Qualtrics based surveys occurred immediately before and after each educational intervention and four weeks following the completion of the intervention. RESULTS: Descriptive statistics were performed including means, standard deviation, and frequencies. Repeated measures ANOVA testing was used to compare the pre-educational intervention survey, post-intervention survey and the third follow-up educational intervention survey. A statically significant increase in overall mean US knowledge scores was observed from the pre-educational intervention survey to the post-educational intervention survey. Results from the ANOVA were $F(2, 74) = 11.49$, $p < 0.0001$. The Tukey-Kramer post hoc test revealed significant differences between the pre-educational session and the post-educational session. There was no significance when examining thermal and non-thermal ultrasound usage and perception amongst clinicians using a p-value of ≤ 0.05. CONCLUSION: The educational intervention was effective in increasing thermal and non-thermal ultrasound knowledge, perception, and usage. A feasibility component to this study exists to determine if these educational formats are a viable option for increasing ultrasound knowledge, perception, and usage among athletic trainers in the future.

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LIST OF ABBREVIATIONS

C..Celsius

cm..Centimeters

FDA..US Food and Drug Administration

cm^2 ....Centimeters squared

ERA..Effective Radiating Area

W...Watts

W/cm^2...Watts per centimeters squared

SAI ....Spatial Average Intensity

MHz ....Megahertz

BNR ....Beam Nonuniformity Ratio

cm/s ....Centimeters per second

CE ....Continuing education

Hz...Hertz

ATs...Athletic Trainers

PTs ....Physical Therapists

BOC ....Board of Certifications

NATA ....National Athletic Trainers' Association

1. INTRODUCTION

Therapeutic ultrasound is a deep heating modality that is commonly used to treat musculoskeletal conditions; however, there are many uncontrollable variables that could result in unsuccessful treatment outcomes.[1-15] Ultrasound is defined as inaudible acoustic vibrations at high frequency that may produce either thermal or non-thermal physiological effects.[16] A therapeutic ultrasound treatment outcome, or goal, should be established before the treatment begins. The treatment goal should be temperature dependent, and clinicians must be aware of how the temperature increases within the tissue provoke different physiological responses when setting treatment goals. The use of ultrasound as a therapeutic agent can be effective if the clinician has an understanding of its effects on biologic tissues and of the physical mechanisms by which the ultrasound produces those effects.[17]

1.1. Thermal Ultrasound

Therapeutic ultrasound is classified as a deep-heating modality when used in a continuous, or thermal mode.[18-20] As tissue temperatures increase, several physiological responses are initiated within the targeted tissue. A 1° Celsius (C) increase in tissue temperature is ideal for treating mild inflammation and will also increase the metabolic rate within tissues. An increase of 2° to 3° C decreases muscle spasms and pain, increases blood flow, and reduces chronic inflammation. Obtaining a vigorous heat, which is a tissue temperature greater than 3° C, will increase the viscoelastic properties of collagen so tissues can be stretched much easier.[1,21-25] Regardless of whether or not thermal effects are produced with an ultrasound treatment, non-thermal changes do occur simultaneously with a thermal ultrasound treatment.[26]

1.2. Non-Thermal Ultrasound

Non-thermal ultrasound is desired when treating an acute soft tissue injury where heating should be minimized.[27] A non-thermal ultrasound uses a pulsed mode output that implements an on/off cycle which influences the production of soundwaves throughout a treatment. The individual pulses of ultrasonic waves cause acoustical streaming and cavitation, two unrelated events that are thought to lead to non-thermal effects of ultrasound.[28] Acoustic microstreaming is defined as the unidirectional movement of fluids along the boundaries of the cell membrane which can alter the cell membrane's structure and function, thereby affecting the healing process.[29] Cavitation is a similar phenomenon created by non-thermal ultrasound. Cavitation is the formation of gas bubbles that expand and contract due to ultrasonically induced pressures in the tissue's fluids[26] Like thermal ultrasound, physiological effects do occur during a non-thermal ultrasound session. The non-thermal physiological effects include, but are not limited to, increased cellular diffusion and membrane permeability, as well as fibroblastic activities, such as protein synthesis, that speed up tissue regeneration.[30]

1.3. Variables Affecting Treatment Outcomes

Although there are numerous factors that may affect treatment outcomes, the most common are the variations amongst ultrasound machines and user knowledge on proper treatment parameter settings and techniques. [1-10] Variations amongst machines makes it difficult to obtain the proper temperature increase needed due to the unknown heating rate of a particular ultrasound machine. Multiple studies have been performed in the past comparing several brands of ultrasound machines and the variations amongst their heating rates.[1,2,4,22] Gange et al[4] recently found that the Dynatron Solaris 708© ultrasound machine's heating rates measured at a depth of 1.0 centimeters (cm) were similar to the Omnisound 3000™ machine that Draper et al[22] used;

however, at depths of 1.75 cm and 2.5 cm of tissue depth, the heating rates were quite different amongst the two machines. Most educational textbooks use Draper et al[22] heating rate results as a general guideline for setting paraments for an ultrasound treatment. These guidelines can be misleading to clinicians who have temperature dependent outcome in mind as the heating rate is dependent to each individual ultrasound machine.

A review of US Food and Drug Administration (FDA) guidelines suggests that large variations can exist, both intramanufacturer and intermanufacturer, in effective radiating area (ERA, cm^2) and total power measured in Watts (W), resulting in a variability in spatial average intensity (SAI, W/cm^2).[5] Spatial average intensity is measured in watts/centimeter squared (W/cm^2) and indicates the amount of power, or energy, that will be delivered to the tissue during an ultrasound treatment. The FDA currently does not have any regulatory guidelines for SAI so the accuracy of this dose-determining parameter is unmeasured in each ultrasound unit.[5] A study by Johns et al[11] tested several transducers using the same machine and found that one particular transducer produced an SAI of 50% greater than another transducer tested even though the ultrasound generator parameters were set to 1.2 W/cm^2 at 3.3 Megahertz (MHz) for both transducers. A difference in SAI of 50% would create a 1.5° C difference in tissue temperature rise if using the heating rates reported by Draper et al[22] and proper ultrasound application techniques are followed during a treatment. This much variation could render some ultrasound treatments essentially useless or could potentially cause bodily harm if the tissue temperature were to rise too high.

1.4. Clinician Knowledge and Perception

Knowledge and perception levels of clinicians will often dictate whether ultrasound is used correctly, or at all. Draper[31] stated that correct application of therapeutic ultrasound can aid in the treatment of musculoskeletal injuries, whereas incorrect application may reduce the desired physiological effects or even cause harm. For this reason, it is imperative that a clinician has a strong knowledge base regarding ultrasound's uses and parameters. A study by Schellhase et al[32] surveyed collegiate level athletic trainers on their perceived knowledge and actual knowledge of therapeutic ultrasound concepts. The results determined that collegiate athletic trainers had confidence in their knowledge, but the scores on the actual questions were relatively poor.[32] The questions most poorly understood in this study were in regards to beam nonuniformity ratio (BNR), tissue types that influenced absorption, and the effect of frequencies on heating rates.[32] These results demonstrate the need for more education for clinicians in these areas that can greatly influence ultrasound treatment goals. A study by Chipchase & Trinkle[33] also questioned the ultrasound knowledge of physiotherapists in South Australia where 70% of respondents from this study said they used ultrasound daily. The results conclude that respondents with superior knowledge regarding optimum dosages of ultrasound for various conditions may be more likely to apply appropriate dosages and procure better treatment outcomes.[33] Chipchase and Trickle[33] also surveyed the same group of physiotherapists regarding their perception of the efficacy of ultrasound. They determined that respondents with higher overall knowledge scores reported a higher perception of ultrasound's effectiveness for every listed musculoskeletal condition.[33] It was also noted that higher perceived effectiveness scores were reported by physiotherapists who used ultrasound in more than half of their treatment sessions when compared to the rest of the physiotherapists.[33] These results indicates that physiotherapists who used ultrasound more frequently found it to be most effective.

1.5. Clinician Implications

When preforming an ultrasound, it is important for the clinician to follow best practice techniques which have been established by several research studies.[7,12,13,34-38] These best practice techniques consist of treating an appropriate sized treatment area, using the proper frequency for the target tissue and having the proper transducer speed.

The appropriate ultrasound treatment area size is 2 - 3 times the size of the ERA of the crystal housed inside the ultrasound transducer.[12,34] The ERA is the area of the transducer head that transmits the energy to the tissue and is always smaller than the transducer head.[28] A study by Chan et al[14] suggested that an ultrasound treatment with parameter settings of 3 MHz at 1.0 W/cm² and a treatment area of two times the size of the ERA, had a higher heating rate than an ultrasound treatment with identical parameter settings but an area of four times the size of the ERA ultrasound treatment. This evidence demonstrates that the size of treatment area directly affects tissue heating rates and treating an area larger than two to three times the ERA will likely negatively affect projected clinical outcomes.

Choosing the proper ultrasound frequency is vital because it correlates strongly with heating rates and determines how deep the ultrasound will penetrate. A 1.0 MHz ultrasound frequency heating rate is slower than a 3.0 MHz ultrasound frequency because of several factors. One of these key factors, when pertaining to heating rates, is that during a 1.0 MHz ultrasound treatment, the crystal inside the transducer is deforming at a rate of 1 million times per second whereas, during a 3.0 MHz ultrasound treatment the crystal deforms at a rate of 3 million times per second.[39] Theoretically, this will result in a 3.0 MHz ultrasound treatment heating three times faster than the a 1.0 MHz ultrasound which must be taken into account when setting temperature dependent treatment goals. Equally as important as heating rates when discussing frequency is the depth of the tissue being targeted during the ultrasound treatment. Depth of tissue penetration is not intensity dependent, but frequency dependent.[35] A 1.0 MHz ultrasound treatment may heat tissues approximately 2.3 cm to 5.0 cm deep, and 3.0 MHz may reach tissues 0.8 cm to 1.6 cm deep regardless of the intensity setting.[24] A 1.0 MHz frequency ultrasound is most useful in patients with a high percentage of body fat, and whenever desired effects are needed in deeper structures, such as the soleus, piriformis and hip adductor muscles.[22,29] The 3.0 MHz frequency is ideal for superficial tissues like the plantar fascia, Achilles tendon, and epicondylitis.[29,40] Knowledge of the differences in frequency settings is imperative for reaching specific depths of tissues as well as providing the appropriate duration to reach the proper temperature increase.

The rate at which the transducer is moved during an ultrasound treatment can also impact an ultrasound treatment. It is recommended by many studies that the transducer be moved at a rate of 3 – 4 centimeters per second (cm/s).[7,13,37,38] However, a study by Weaver et al[13] demonstrated that tissue temperature increases were very similar with transducer velocities of 2 – 8 cm/s using the same settings of 1.0 MHz at 1.5 W/cm² for 10 minutes for each treatment. Draper[7] recommends slow strokes at a rate of approximately 3 - 4 cm/sec stating that rapid strokes can cause the clinician to slip into treating a larger treatment area which will affect the desired temperature goal since the treatment area will likely grow larger than the recommended 2 – 3 times the ERA. Using slow transducer movements during an ultrasound treatment will also allow for evenly distributed sound waves throughout the area.[7,39] This range of suggested transducer velocity differences adds yet another variable within ultrasound treatments that potentially could affect the clinical outcome.

1.6. Feasibility and Needs of Continuing Education

Continuing education (CE) for athletic trainers consists of educational activities that maintain or develop the knowledge, skill, performance, and professional relationships needed to provide high-quality patient care.[41] The feasibility of continuing education for athletic trainers can be challenging due to several barriers. Armstrong[42] reported that travel distance and cost of attending a continuing education session are the most prominent barriers why athletic trainers do not attend educational sessions. Travel distance can result in lost work time or having to use personal time off days to attend a CE session. Travel distance will also increase the cost of the continuing education event due to transportation and possible housing. The overall cost of a CE session can be financially challenging for some and may deter them from attending. Other prominent barriers were lack of financial support from employer to pay for CE activities, lack of staff to cover patient care, and lack of time to commit to CE activity.[42] Providing CE activities that are close in proximity, free or low in cost, at a convenient time and are fulling athletic training educational needs may assist in making CE much more feasible for athletic trainers.

Continuing education sessions that are both clinically relevant and interesting may assist in fulfilling athletic trainers' educational needs. Cuppett[43] surveyed athletic trainers in regards to continuing education needs and found that the highest overall level of self-perceived need was in the practice domain of rehabilitation and reconditioning of athletic injuries. This domain includes modalities, such as therapeutic ultrasound, showing that athletic trainers perceive more education is needed in this specific area. Continuing education should attempt to provide practical information that athletic trainers can apply in their daily work.[44] Providing educational topics that are applicable to everyday tasks or issues of athletic trainers will assist in meeting educational needs and make CE much more feasible for most.

To our knowledge, there is little evidence regarding whether proper clinician education on best practice ultrasound treatment techniques improve ultrasound treatment outcomes. Also, there is little evidence pertaining specifically to the educational method being used to deliver the best practice ultrasound treatment techniques educational session.

1.7. Statement of the Problem

Education and research regarding therapeutic ultrasound are inconsistent and often poorly conveyed. The efficacy of therapeutic ultrasound has been challenged in the past and has changed individuals' perception regarding the modality. This may be caused by individuals having very little to no knowledge or education pertaining to therapeutic ultrasound. Proper education and techniques must be available, so the modality is used properly.

1.8. Purpose of the Study

The purpose of this study was to provide best practice ultrasound treatment techniques educational training intervention, both live and virtually asynchronous, to athletic trainers in the state of North Dakota.

1.9. Research Questions and Hypotheses

Q1: What effect does an educational intervention regarding therapeutic ultrasound have on the clinician's knowledge and perception of thermal ultrasound?

H1: The educational intervention will increase the clinician's knowledge and positively impact their perception of thermal ultrasound.

Q2: Will an educational intervention regarding therapeutic ultrasound impact the clinician's knowledge and perception of non-thermal ultrasound?

H2: The educational intervention will increase the clinician's knowledge and positively impact their perception of non-thermal ultrasound.

Q3: Will an educational intervention regarding therapeutic ultrasound change the amount a clinician uses thermal ultrasound?

H3: The educational intervention will increase the amount a clinician uses thermal ultrasound.

Q4: Will an educational intervention regarding therapeutic ultrasound change the amount a clinical uses non-thermal ultrasound?

H4: The educational intervention will increase the amount a clinician uses non-thermal ultrasound.

Q5: Is there a difference in the effectiveness of the in-person educational intervention versus the virtual asynchronous educational intervention?

H5: There will be no difference in the effectiveness of the educational intervention based on the educational delivery method used.

Q6: Is it feasible to provide continuing education units for this study with the education methods and means provided?

H6: It is feasible to provide continuing education units for this study with the education methods and means provided.

1.10. Limitations

1. Our sample for both educational interventions were restricted to North Dakota BOC Certified Athletic Trainers who can attend the educational session; therefore, it is not a full representation of all United States BOC Certified Athletic Trainers.

2. With survey-based research there are expected to be self-report biases.

1.11. Delimitations

1. Using only BOC Certified Athletic Trainers in North Dakota allows for a smaller sample size to gauge if the educational session will be successful on a larger scale.

2. Retired and non-BOC Certified Athletic Training students are excluded.

1.12. Definition of Terms

<u>Ultrasound-</u> an inaudible, acoustic vibration, of high frequency that may produce thermal or nonthermal physiological effects.[29]

<u>Thermal (continuous) Ultrasound-</u> the sound energy remains constant throughout the treatment. The ultrasound energy is being produced 100% of the time.[39]

<u>Non-Thermal (pulsed) Ultrasound-</u> the sound energy is periodically interrupted, with no ultrasound energy being produced during the off period.[39]

<u>Duty Cycle</u>- The percentage of time that ultrasound is being generated over one pulse period.[39]

<u>Effective radiating area (ERA)-</u> the total area of the surface of the transducer that actually produces the sound wave.[39]

<u>Spatial Average Intensity (SAI)</u>- the intensity of the ultrasound beam averaged over the entire area of the tranducer.[39]

<u>Power</u>- total amount of ultrasound energy in the beam that is expressed in watts (W).[39]

Megahertz- one million hertz or one million cycles per second; typically applied to the frequency of electromagnetic waves.[45]

Frequency- the number of cycles or pulses per second[39]

Intensity- a measure of the rate at which energy is being delivered per unit area.[29]

Transducer- also referred to as an applicator or a sound head on an ultrasound machine.[29]

2. REVIEW OF LITERATURE

2.1. Purpose of the Study

The purpose of this study was to assess the feasibility of providing both an in-person and virtual asynchronous educational training intervention regarding best practice ultrasound treatment techniques to athletic trainers in the state of North Dakota.

2.2. Introduction

There are many misconceptions regarding therapeutic ultrasound in the literature which portrays the modality poorly. Education and quality research is lacking in the field of therapeutic ultrasound which has a negative effect on individuals' perception and use of therapeutic ultrasound. More education and demonstration of proper therapeutic ultrasound techniques are needed to provide clinicians with the tools to properly use the modality. Further education and proper use will ensure that therapeutic ultrasound has positive treatment outcomes which provides better outcomes for patients.

2.3. Definition and Prevalence of Therapeutic Ultrasound

At least one type of ultrasound can be found in every healthcare setting throughout the world with uses such as destroying cancerous cells, monitoring fetal development, and diagnosis of and treating musculoskeletal injuries. [29,28] There are two types of ultrasound: therapeutic and diagnostic. The frequency of the soundwave determines which type of ultrasound it is and how it will affect the tissue. Diagnostic ultrasound has been used for over 50 years and its main purpose is to image internal structures such as a fetus during pregnancy.[39] Diagnostic musculoskeletal ultrasound is used to identify pathologies in muscles, tendons, bones, and joints and can aid in the diagnosis of musculoskeletal injuries.[39] Therapeutic ultrasound has been used for therapeutic purposes as a valuable tool in the rehabilitation of many different injuries primarily for the purpose of stimulating the repair of soft-tissue injuries and for relief of pain.[17] The focus of this paper is therapeutic ultrasound. Therapeutic ultrasound consists of inaudible high-frequency mechanical vibrations created when a generator produces electrical energy that is converted to acoustic energy through mechanical deformation of a piezo-electrical crystal located in the transducer.[29]

2.3.1. Frequency of Use

In many countries, therapeutic ultrasound is one of the single most frequently used treatment modalities as well as the most frequently used electrophysical agent.[46] Ultrasound is widely used in many countries including Canada, Australia, Denmark, Finland, New Zealand, Switzerland, the United Kingdom and the United States.[6] Surveys performed in the United Kingdom and Scandinavian countries ascertained that more than 50% of the treatment protocols in private practice used ultrasound.[23] In Canada in 1987, more than 4 million ultrasound treatments were administered along with the expectation of that number rising each year.[47] In the United States, ultrasound is widely used by many healthcare providers on a daily or weekly basis. Wong et al.[48] surveyed 476 physical therapists who were orthopaedic specialists in the Northeast/Mid-Atlantic regions of the United States asking their use and the clinical importance of ultrasound in their practice. Two hundred and seven individuals responded to the survey and 79% of those reported using ultrasound at least once a week, and 45% more than ten times a week.[48]

2.3.2. Ultrasound Indications

Therapeutic ultrasound is widely used and is used on many different types of musculoskeletal conditions. It is used frequently throughout the world because of the several physiological effects it can produce when used properly such as pain relief, wound healing, increasing local blood flow and increasing tendon extensibility when using thermal ultrasound.[49] Wong et al[48] reported 83.6% of respondents indicated they were likely to use ultrasound to decrease soft tissue inflammation, 70.9% to increase tissue extensibility, 68.8% to enhance scar tissue remodeling, 52.5% to increase soft tissue healing, 49.3% to decrease pain, and 35.1% to decrease soft tissue swelling. Other indication of thermal and non-thermal ultrasound can consist of joint contractures, muscle spasms, edema reduction, wound healing and bone fractures.[29,39] Understanding how therapeutic ultrasound interacts with structures within the human body assists in determining when therapeutic ultrasound should be used.

2.4. History of Therapeutic Ultrasound

Therapeutic ultrasound has been studied for over 60 years with each researcher examining a wide array of topics and conditions. The oldest published study that used settings similar to today's therapeutic ultrasound was performed by DeForest et al in 1953.[50] Most of the research before DeForest et al[50] examined ultrasonic energy at soundwaves above 20,000 Hertz (Hz), which is a much lower frequency than that of the current therapeutic ultrasound which ranges from 750,000 – 3,000,000 Hz or 0.75 – 3.3 MHz. In 1939, Pohlman et al[51] demonstrated the therapeutic effects of ultrasonic waves in human tissue and went on to introduce ultrasonic treatments as a routine medical practice. Therefore, the notion of using soundwaves to treat human tissue is relatively old practice.

Many studies completed before 1953 used ultrasonic waves that caused tissue damage or destruction resulting in raising the frequency of the ultrasound to a therapeutic level.[50] DeForest et al[50] examined the effects of therapeutic ultrasound on growing bone using a quartz crystal with a diameter of 2.5 cm and a frequency of 800,000 cycles per second with an output of 5 to 10 Watts on rabbit and dog legs. While using stationary therapeutic ultrasound at these aforementioned settings, DeForest et al[50] concluded that damage can occur to the bone and noted that it should not be applied to growing human bone. Today's therapeutic ultrasound machines have ranges from 750,000 to 3,000,000 cycles per second, or 0.75 to 3 MHz, and range from 0.1 to 10 W, with 0.3 to 5 W being the standard range for treatment dose.[29]

2.4.1. Therapeutic Dosing

Following the advice of DeForest et al[50], many studies were performed to determine a safe therapeutic dose to use therapeutic ultrasound. From 1965-1967, Justus F. Lehmann and his colleagues performed several studies examining the heating effects of therapeutic ultrasound on bone and the tissue surrounding the bone.[52] In 1967, Lehmann et al[52] used human participants and sterilized thermistor needles that were inserted into the quadriceps muscle to read the internal tissue temperature. The researchers then performed a therapeutic ultrasound session with half the participants receiving a 1.0 W/cm^2 intensity reading, while the other half received a 1.5 W/cm^2 intensity for 15 minutes or until the participants felt pain. The temperature was recorded in the tissue at the end of the treatment time. This study by Lehmann et al[52] obtained tissue temperatures in live, human tissue, which in turn, was the beginning of developing safe heating rates to apply while using therapeutic ultrasound on human subjects.

In 1987, ter Haar[35] explained the basic physics of therapeutic ultrasound and theorized an approximate temperature increase in each wavelength of therapeutic ultrasound heated human tissue. The tissue temperature increases were based on a mathematical equation to estimate the temperature rise that may be expected after irradiation with an intensity after a time, in the absence of any cooling mechanism, such as blood flow. Using this mathematical equation, ter Haar,[35] concluded that a 1 MHz therapeutic ultrasound with an intensity of 1.0 W/cm^2 would increase tissue temperatures 0.8˚C per minute during a stationary treatment. In addition, a 3 MHz would increase tissue temperature three times the rate of a 1 MHz treatment equaling 2.4˚C per minute. It is important to note that these results were not data of a research study measuring actual human tissue temperature. However, the mathematical guidelines created by ter Haar[35] and human tissue temperatures collected by Lehmann et al[52] gave researchers the foundation to make tremendous progress into determining appropriate heating rates while using therapeutic ultrasound in vivo on human tissue.

In 1995, Draper et al[12] designed a study using Lehmann et al[52] and ter Haar[35] results as guidelines to examine the actual rate of temperature increase in human muscle. This study was the first *in vivo* study that measured the rate of change in temperature during 3 MHz ultrasound treatments, and at the time of this study there have been no other studies performed comparing heating rates of 1 MHz and 3 MHz.[22] The main purpose of the Draper et al[22] study was to provide evidence for ultrasound treatment dosages. The importance of knowing the treatment dosage is crucial so clinicians can use therapeutic ultrasound to treat the specific condition or injury. Draper et al[22] established heating rates for the 1 and 3 MHz ultrasound which provided clinicians with a blueprint on appropriate dosage. Based on the tissue temperature guidelines provided by Lehmann et al[52], Draper et al[22] concluded the biophysical effects of 1˚C increase (mild heating) accelerates the metabolic rate in tissue. An increase of 2-3˚C (moderate heating) reduces muscle spasm, pain, and chronic inflammation and increases blood flow. Vigorous heat, ≥ 4˚ C decreases visco-elastic properties of collagen and inhibits sympathetic activity. Draper et al.[22] revealed his heating rates were less than what ter Harr[35] predicted. However, ter Harr[35] did not take into account the effects of blood flow and thermal conduction on tissue cooling within his mathematical equations. This mathematical equation by ter Haar[35] concluded that with a 1 MHz therapeutic ultrasound wavelength at 1.0 W/cm^2 intensity, the tissue temperature will raise

0.8˚C per minute during a stationary treatment while a 3 MHz will theoretically increase tissue temperature three times the rate of a 1 MHz treatment equaling 2.4˚C per minute. Draper et al.[22] measured two depths in vivo human tissue using both a 1 and 3 MHz ultrasound while moving the applicator at a rate of 4 cm/s at four different intensities to record their conclusions on heating rates. Draper et al[22] concluded that at a depth of 2.5 cm a 1.0 MHz ultrasound at 1.0 W/cm^2 had a heating rate of 0.16 ˚C per minute which is much lower than ter Haar's[35] estimation of 0.8˚C per minute using a 1 MHz ultrasound frequency. Draper et al's[22] result at a depth of 2.5 cm for a 3 MHz ultrasound at 1.0 W/cm^2 was 0.58 ˚C per minute which again is much lower when compared to ter Haar's[35] estimation of 2.4˚C per minute. Gange et al[4] performed a study with methods similar to Draper et al[22] in 2016 with the exception of using a different ultrasound machine, slightly different tissue depths and only performing a 3 MHz ultrasound. Using ultrasound parameters of 3 MHz at 1.0 W/cm^2 , Gange et al[4] reported a heating rate of 0.7˚C per minute at 1.0 cm deep which is slightly higher than the Draper et al[22] result of 0.58˚C per minute at 0.8 cm with both heating rates being much lower than ter Haar's[35] mathematical estimation of 2.4˚C per minute at a 3 MHz ultrasound frequency. The main difference amongst these studies[4,22,35] was the methods used. Ter Haar[35] used a mathematical equation that did not take into account the movement of the ultrasound transducer and blood flow in living tissue, whereas, Draper et al[22] and Gange et al[4] performed the ultrasound on live, human participants while moving the transducer at a rate of 2 – 4 centimeters per second.

These guidelines established 25 years ago by Draper et al.[22] are discussed in many of today's textbooks and are still followed by many clinicians today when determining their ultrasound treatment goals. This is problematic because many studies have confirmed large variations in heating rates amongst machines and even individual ultrasound transducers from the same manufacturers. Having a guideline is helpful; however, clinicians must be aware that not all machines have identical heating rates and ultrasound parameter adjustments should occur to account for this variation.

2.5. Components of Ultrasound

An ultrasound machine consists of a generator, crystal, soundhead, and an applicator. The generator produces the electrical current the crystal needs to contract and expand producing soundwaves. The soundwaves are transmitted by propagation through molecular collision and vibration.[35] The molecular collisions produce frictional heat and consequently increases tissue temperature. The crystal, which is a thin (2 - 3 millimeters thick) synthetic ceramic, usually made of lead zirconate or titanite, converts the electrical energy from the generator to acoustic energy.[29] As the energy is passed through the crystal, the crystal expands and contracts which creates the piezoelectric effect. There are two forms of the piezoelectric effect. The first form is the direct piezoelectric effect which is the creation of an electrical voltage across the crystal as it compresses. The second form is the reverse piezoelectric effect which occurs when an alternating current running through the crystal causes the crystal to expand then changes the polarity. Whenever the crystal expands and contracts it vibrates resulting in the mechanical production of high-frequency soundwaves. The soundhead usually consists of a durable stainless-steel plate which is the interface between the crystal and the tissues. The crystal and the soundhead are housed in the applicator which is the piece of hardened plastic that the clinician grasps to provide an ultrasound treatment. If any of these components are damaged or missing, the mechanical effects and thermal effects of ultrasound will not occur, and the ultrasound treatment will be unsuccessful.

2.5.1. Effective Radiating Area

The area of the soundhead that actually produces the ultrasound waves is known as the effective radiating area (ERA).[28,39] The ERA is also known as the surface area where the sound wave is transmitted from the crystal within the soundhead to the tissues of the body.[29] The size of the ERA is determined by the size and vibrational properties of the piezoelectric crystal itself and is always smaller than the cross-sectional area of the end metal end plate.[36] The crystal is always smaller than the soundhead and if the manufacturer states the crystal is the same size of the soundhead it is likely it was not scanned for quality.[29] Clinicians must be aware of the ERA as it compares to the size of the actual soundhead. If the ERA is significantly lower than the size of the soundhead, it will decrease the actual treatment area being heated as the ultrasound beam is produced in the ERA and not in the soundhead itself. The appropriate size of the treatment area should be two to three times the size of the ERA.[53,54] This concept should not be confused with two to three times the size of the soundhead which is a very common mistake while using ultrasound and can affect the results of the ultrasound treatment.[7,29] A study by Chan et al[14] showed that an ultrasound treatment with parameter settings of 3 MHz at 1.0 W/cm² and a treatment area of two times the size of the ERA of 4.5 cm² (5 cm² soundhead), had a higher heating rate (2.1°C±0.4°C/min) than an ultrasound treatment with identical parameter setting but an area of four times the size of the ERA ultrasound treatment (1.2°C/minute). Another study by Miller et al[55] with identical parameters of 3 MHz at 1.0 W/cm² and an area two times the size of the 5 cm² soundhead measured the temperature increases within the middle of the treatment area and its periphery. The middle portion of the treatment obtained a temperature increase of 0.588 °C per minute while the periphery of the treatment area was only an increase of 0.364 °C per minute. In comparison to one another, they did see temperature increases within a smaller area showing that the size of the treatment area is important. However, the heating rates cannot be compared because Chan et al[14] performed the ultrasound treatment on the patellar tendon and Miller et al[55] used the gastrocnemius-soleus complex which are different types of tissue that absorb ultrasound energy differently. Therefore, it is imperative that the ERA size is known by the clinician and that they are not using the size of the soundhead as a reference point for the treatment area size. As Chan et al[14] and Miller et al[55] concluded, a very small change in treatment area size can affect heating rates immensely.

2.5.2. Beam Nonuniformity Ratio

The effective radiating area is the area that contains the ultrasound beam however this beam is not always uniform in intensity. The beam nonuniformity ratio, or the BNR, is an indicator of the variability of intensity within the ultrasound beam.[29,39] The BNR is determined by measuring the ratio between the highest intensity in the beam compared to the average intensity within the beam.[28,29] An optimal BNR would be a ratio of 1:1 which means the average output intensity would be 1.0 W/cm^2 and the highest intensity of the beam would be 1.0 W/cm^2, however, this is not possible.[29] In general, most ultrasound machines produced today have BNR ranges of 2:1 to 6:1. The lower the BNR ratio, the more uniform the energy is dispersed. Ultrasound machines with a BNR ratio of 8:1 or higher can be potentially dangerous to the patient and could damage tissue. Peak intensities of 8.0 W/cm^2 have been shown to damage tissue; therefore, the patient runs a risk of tissue damage if intensities greater than 1.0 W/cm^2 are used on a machine with an 8:1 BNR.[39] The lower the BNR is, the more uniform the ultrasound energy is dispersed thus making it safer to the patient. If energy is not properly dispersed, it may cause a “hot spot”. A “hot spot” is an area at the tissue interface that may become overheated from too much energy being concentrated in one area.[29] These hot spots can result in tissue damage and pain to the patient which is why the BNR is required to be listed on the ultrasound by the U.S. Food and Drug Administration (FDA) Center for Devices and Radiological Health.[56]

2.5.3. Spatial Average Intensity

The spatial average intensity (SAI) describes the amount of energy passing through a unit of area, in this case, the ultrasound soundhead's ERA.[28] Spatial average intensity is measure in watts/centimeter squared (W/cm²) and indicates the amount of power, or energy, that will be delivered to the tissue during an ultrasound treatment. The FDA does not have a regulatory guideline for the SAI even though most clinicians base their treatment dose on this metric.[11] A study be Straub et al[57] tested 66 ultrasound transducers and found that tested SAI values had a large range of -43% to +61% of the digitally displayed value which was W/cm². Johns et al[11] reported when comparing seven transducers that used the same ultrasound machine, one transducer in particular created an SAI of 50% greater than another transducer even though the intensity was set to 1.2 W/cm². This discrepancy would result in difference of 1.5°C total temperature rise difference amongst the two transducers if Draper et al's[22] 3.3 MHz heating rates were applied. Demchak et al[3] also tested the SAI of three transducers using the same ultrasound machine and a 1.2W/cm² intensity and found that transducer A produced a heating rate of 0.32°C, transducer B was 0.31°C, and transducer C had a heating rate of 0.50°C. Each of the studies above have shown there is variability amongst SIA, even while using the same ultrasound machine, which can greatly affect the heating rates amongst ultrasound transducers.

2.5.4. Non-Thermal Effect

Non-thermal ultrasound is preferred when thermal effects are not desired and is generally used in acute injury scenarios. Therapeutically significant non-thermal effects have been identified in soft tissue repair via stimulation of fibroblast activity, which produces an increase in protein synthesis, tissue regeneration, blood flow and bone healing.[58,59] The mechanical effects, or non-thermal effects of ultrasound, consist of cavitation and acoustic microstreaming. Cavitation is the formation of gas-filled bubbles that expand and contract due to the ultrasound energy being applied and can result in stable or unstable cavitation.[28] Stable cavitation occurs when the bubbles compress during the high-pressure peaks of ultrasonic energy followed by expansion of the bubbles during low-pressure troughs. Stable cavitation is the desired outcome when providing an ultrasound treatment. Stable cavitation will result in increased flow in the fluid around these vibrating bubbles and can modify cellular function. Unstable cavitation involves the compression of the bubbles during the high-pressure peaks of ultrasonic energy followed by a collapse, or bursting of the bubble during the trough.[28] Unstable cavitation usually occurs because the intensity of the ultrasound energy is too high which can damage the surrounding tissues. When an ultrasound machine is performing and calibrated properly, unstable cavitation will not occur.

Acoustic microstreaming is the unidirectional movement of fluids along the boundaries of cell membranes resulting from the mechanical pressure wave in an ultrasonic field.[35] Acoustic microstreaming can alter the cell membrane structure and function due to changes in cell membrane permeability to sodium and calcium ions important in the healing process.[39] Non-thermal effects of ultrasound, such as stable cavitation and acoustic microstreaming, are reported to modulate membrane properties, alter cellular proliferation, and produce increases in proteins associated with inflammation and injury repair.[60] Other non-thermal effects include: Increased histamine release, calcium ion influx, increased phagocytic activity of macrophages, increase protein synthesis, increased capillary density of ischemic tissues, tissue regeneration, wound healing, attraction of immune cells, increased fibroblasts and vascular regeneration.[21,61]

2.5.5. Thermal Effects

The amount of energy applied during an ultrasound treatment will determine whether the soundwaves will create mechanical effects or thermal and mechanical effects. This energy is determined by setting the frequency (MHz) and intensity (W/cm^2) on the ultrasound machine. Therapeutic ultrasound has been used extensively, for thermal effects, since 1955 for a variety of conditions such as the treatment of musculoskeletal pain, soft tissue injury, and joint dysfunction, including osteoarthritis, periarthritis, bursitis, and tenosynovitis.[22] More recently, additional applications such as accelerated tissue repair and wound healing, edema reduction, treatment of scar tissue, and phonophoresis have been reported in the literature.[22] Thermal effects are also performed for the treatment of pain, reduction of sub-acute and chronic inflammation and muscle spasms, and stretching of collagenous tissue in joint and connective tissue contractures.[22] The numerous thermal effects that ultrasound produces explains why it is so widely used in the healthcare setting.

The level of thermal effects achieved is based on the amount of energy that is absorbed into the tissue during an ultrasound treatment. Tissues high in protein are denser and will absorb energy much quicker than tissues with lower levels of protein. Dense tissues high in collagen such as bone, cartilage and tendons absorb much more ultrasonic energy than muscle, fat, or blood. Collagen-rich tissues such as tendons, joint menisci, superficial bone, large nerve roots, intermuscular fascia and scar tissue are preferentially heated.[62] Tissues that are fluid filled, such as the fat layer and articular fluid, are relatively transparent to ultrasonic energy.[63] It is imperative to know the collagen content of the target tissue when providing an ultrasound treatment due to the difference in heating rates amongst these tissues. Tissues high in collagen have shown temperature increases of 1.7°C to 2.5°C during a 3.0 MHz continuous ultrasound whereas tissues lower in collagen, such as muscle, will only see temperature increases of 0.8°C to 1.4°C per minute during a 3.0 MHz continuous ultrasound.[14,22,35] These heating rates will impact the amount of time needed to reach the desired temperature increases and produce optimal thermal effects within different tissue types.

The primary advantage of thermal ultrasound over non-acoustic heating modalities such as heat packs, is that collagen-rich tissues such as tendons, muscles, ligaments, joint capsules, joint menisci, intermuscular interfaces, nerve roots, periosteum, and cortical bone, as well as other deep tissues, can be selectively heated to the therapeutic range without causing a significant tissue temperature increase in skin or fat.[35] For thermal effects to be optimal, Weaver et al[13] indicated the tissue temperature must be raised to a level of 40 - 45°C for a minimum of five minutes for most thermal effect to occur. Other sources indicated absolute temperatures are not as imperative but rather the temperature rise above the baseline temperature and each degree of temperature increase producing different physiological responses.[7,21,22] Based on the tissue temperature guidelines provided by Lehmann et al[52], Draper et al[22] concluded the biophysical effects with a 1˚C increase (mild heating) accelerates the metabolic rate in tissue. A 1°C increase assists in treating mild and chronic inflammation by accelerating the local metabolic rate.[14] Cambier et al[23] also concluded that an increase of tissue temperature by 1°C will result in a 13% increase in metabolic rate, which will increase the number of extra nutrients needed to improve conditions for proper healing. An increase of 2-3˚C (moderate heating) reduces muscle spasm, pain, and chronic inflammation and increases blood flow. Vigorous heat, ≥4˚ C, decreases visco-elastic properties of collagen and inhibits sympathetic activity. When the goal is to boost viscoelastic properties of collagen so the tissue can be stretched or scar tissue reduced, vigorous heating, or an increase of greater than 3° C is warranted.[22] An increase of 3° C or greater will make tissue more extensible as long as the stretching of the tissue is done within the proper time window following the ultrasound treatment.

A modality often used before stretching, exercise, or friction massage in an effort to break up adhesions is ultrasound.[22] For this to occur, vigorous heating, which is an increase of 3° C or greater, is needed. Vigorous heating achieved with ultrasound, followed by stretching of tissue, is a very common practice amongst clinicians but is not always performed properly. Stretching or joint mobilization should be performed immediately after the ultrasound treatment because the stretching window stays open for only 5 – 10 minutes after the ultrasound treatment.[29] Draper et al[25] defined the stretching window as the time period of vigorous heating when tissues will undergo the greatest extensibility and elongation. Simultaneously heating and stretching provides the best results for permanent elongation and that the optimal time to stretch the tissue is at the peak of heating.[49] This study performed by Rose et al[49] suggested that a 1.0 MHz ultrasound at 1.5 W/cm^2 achieved a 4° C increase on the gastrocnemius-soleus complex. The tissue temperature raised 4.0° C ± 1.1° C and dropped 1° C in only two minutes, and then dropped another degree Celsius in only 31 seconds. This demonstrates that the most effective time to encourage range of motion and stretching exercises within rigid tissue is actually less than three minutes following ultrasound treatments that raise the temperature greater than 3° C.[49] In another study it was reported that using a 3.0 MHz ultrasound, at 1.5 W/cm^2 on the gastrocnemius-soleus complex raised the tissue temperature 5.3° C above baseline in an average time of six minutes at a depth of 1.2 cm.[25] These findings by Draper et al[25] support when using a 1.0 MHz ultrasound, the stretch must be done within two minutes from the conclusion of the ultrasound and the 3.0 MHz ultrasound must be performed within 3.3 minutes from the conclusion of the ultrasound or the tissue is not at the optimal temperature level for stretching.

For the best clinical results according to the research above, tissue elongation or stretching should occur immediately following an ultrasound treatment.

2.6. Parameters

When providing an ultrasound treatment, the proper parameters must be followed to obtain therapeutic results. Parameters such as the mode, duty cycle, frequency, intensity, and treatment length must all be considered when performing an ultrasound treatment.

2.6.1. Mode and Duty Cycle

The two modes of ultrasound delivery to choose from are continuous or non-thermal or pulsed ultrasound. A duty cycle is another term used when further defining a mode of ultrasound. A duty cycle is defined as the fraction of time during a single pulse period that the ultrasound beam is present and is usually expressed in a percentage.[36] Most ultrasound machines have either a 20% or 50% duty cycle option. A 20% duty cycle will deliver 20% of the energy when compared to a continuous wave which will deliver energy 100% of the time of the treatment. Continuous ultrasound occurs when the sound energy is produced 100% of the time, whereas pulsed ultrasound is when the energy is periodically interrupted with no ultrasound energy being produced.[29] Continuous ultrasound is used primarily for its thermal effects when the goal is to increase tissue temperature when properly applied with specific guidelines.[22] Non-thermal or pulsed ultrasound's main purpose is to achieve non-thermal effects; however, non-thermal effects occur when either mode is used.[39]

2.6.2. Frequency

Frequency of the ultrasound beam determines the depth of penetration into the tissue and is measured in Megahertz (MHz). Typically, 1 MHz ultrasound mode is used for heating tissues 2.5 – 5.0 cm deep, whereas 3.0 MHz is used to heat tissues <2.5 cm deep.[22] The depth of the target tissue should be considered when choosing the frequency. A 1.0 MHz frequency is most useful in patients with higher adipose content and when the target tissue is in deeper structures such as the soleus, piriformis and hip adductor muscles.[22] A 3.0 MHz frequency is absorbed superficially and therefore is ideal for treating plantar fasciitis, patellar tendonitis and epicondylitis.[24,40] Regardless of which frequency is used, both have a distinct effect on the rate of temperature increase.[22]

2.6.3. Intensity

The rate at which these temperature increases occur is dependent on the power and the intensity of the ultrasound beam. Power represents the amount of energy being produced by the ultrasound machine and is measured in Watts (W).[28] Intensity describes the strength of the wave at a given location, or per unit area, and is measured in Watts per centimeter squared (W/cm^2).[28,29,39] There are no definitive guidelines for selecting specific ultrasound intensities; however if the intensity is too high, tissue damage may occur.[22,64] Definitive guidelines are very hard to establish because of the variability amongst ultrasound machines. These variations are observed in many studies in the literature where the same intensities are set but on two different machines.[4,22,24] Draper et al.[22] performed a 3.0 MHz ultrasound treatment at 1.0 W/cm^2 using a Omnisound 3000™ machine and observed an increase of 0.58° C per minute at a depth of 2.5 cm below the skin.[22] A different study with the same parameter settings but using a Dynatron Solaris 708 ultrasound machine, observed an increase of 0.18° C per minute at the same tissue depth.[4] Although the intensity settings were the same in both studies, the variation in the tissue temperature was very large which makes it very difficult to determine the proper intensity for each individual ultrasound treatment.

2.6.4. Treatment Time

Treatment length in time is directly proportional to the set frequency and intensity parameters of an ultrasound treatment. The length of the treatment is decided by the size of the area to be treated, the ultrasound frequency, the intensity in W/cm^2, and the desired tissue temperature increase.[7] It is recommended that the treatment area is no larger than 2 - 3 times the size of the ultrasound head.[29,36,39] If the size of the treatment area is larger than 2 - 3 times the size of the sound head, additional treatment time must be added to achieve the intended treatment goal. When selecting an ultrasound frequency, it is important to remember a 3.0 MHz ultrasound frequency heats up the tissue three times faster than a 1.0 MHz ultrasound treatment which will proportionally decrease the treatment time by one third.[22,25] Ultrasound frequency is only one of the indicators that determines the duration or time of the treatment. A proper treatment time cannot be established until an intensity level is set. Setting a higher intensity in W/cm^2 will result in a shorter treatment time whereas, a lower intensity in W/cm^2 will result in a longer treatment time. However, in one study it was shown that an ultrasound treatment session using 1.0 MHz frequency and an intensity of 1.0 W/cm^2 increased intramuscular tissue to higher temperatures than a 2.0 W/cm^2 intensity at a depth of 4.0 centimeter.[65] Establishing the appropriate treatment time is another factor that can influence an ultrasound treatment's success.

2.7. Clinician Knowledge and Perception

Clinician knowledge and perception are both key factors when determining the success, or failure, of an ultrasound treatment. All athletic trainers (ATs) learn the Commission on Accreditation of Athletic Training Education's Standard 73 which requires that therapeutic modalities be taught within their educational programs; however, each program will have varying levels of how extensively it is taught. Each athletic training student within an educational program is required to meet minimum standards of therapeutic modalities knowledge by graduating with a degree in athletic training and passing the certification exam; however, the retention of knowledge by ATs once they become certified is unclear.[32] A review of literature by Yang et al[66] found that healthcare professionals' knowledge and skill related to emergency care declined within six months to one year after training. These findings suggest that retention of knowledge diminishes over time and interventions must occur to relearn this knowledge.

Interventions to increase or refresh knowledge of therapeutic ultrasound are intended to have a positive effect on the clinician and their ultrasound treatments. Increasing knowledge regarding the best practices of ultrasound requires some level of education. Armijo-Olivo et al[67] surveyed 438 Physical Therapists (PTs) in Alberta, Canada to explore the frequency and patterns of ultrasound use and to investigate beliefs about ultrasound. The researchers asked the PTs their current education level and if they believed their knowledge was adequate. Approximately 65% of respondents with an undergraduate degree believed they had adequate knowledge, versus 52% of graduate students. However, when asked whether their knowledge of ultrasound research evidence was adequate, 37% of undergraduate students felt it was adequate versus 59% of the graduate students.[67] These findings are concerning with there being relatively low percentages when asked about knowledge and research knowledge amongst PTs. As for making decisions on ultrasound parameters or use, 40% of PTs responded that they make their ultrasound decisions based on clinical practice experience, while undergraduate training was 19% and research was 13%. Chipchase and Trickle[33] surveyed physiotherapists in South Australia and concluded that respondents with superior knowledge regarding optimum dosages of ultrasound for various conditions may be more likely to apply appropriate dosages and procure better treatment outcomes. However, when Schellhase et al[32] surveyed collegiate ATs, they found that the ATs had confidence in their knowledge, but the scores of the actual educational questions were relatively poor. The questions most poorly understood in this study were in regards to beam nonuniformity ratio, tissue types that influence absorption, and the effect of frequencies on heating rates.[32] Errors in any of the aforementioned areas can have drastic effects on ultrasound treatments and can change the perception of clinicians on the efficacy of ultrasound. Thirteen of the survey questions in Schellhase et al's[32] study were answered correctly by less than 75% of the respondents. The most missed questions fell into three categories: insufficient parameters, safety concerns, and theory/book knowledge. As analysis during the study on the incorrect answers in the insufficient parameters category pointed to ATs using intensities that are too low and/or durations that were too short.[32] Having insufficient parameter settings will affect the treatment goal which in turn, may make some clinicians perceive that ultrasound does not work but in reality it is because the modality is not being used properly.

The perception of whether ultrasound is a relevant modality is mixed amongst clinicians and researchers. As perception is based on past experience; an indication of physiotherapists' perception of ultrasound's effectiveness in treating a variety of pathologies can further direct clinical research into areas where significant outcomes can be achieved.[33] Chipchase and Trickle[33] asked physiotherapists which musculoskeletal condition they perceived ultrasound was best for and how effective ultrasound is in general. The responses indicated that ultrasound was most effective for chronic muscle tears, chronic scar tissue, acute bursitis, and tendonitis. Also, higher perceived effectiveness scores were reported by physiotherapist who used ultrasound in over half of their treatments when compared to those who rarely used ultrasound.[33] They also believed that ultrasound was more effective when used as an adjunct to the physiotherapy treatment package meaning the use of other treatment methods such as massage and stretching.[33]

These responses indicate that the physiotherapist in general perceive ultrasound works well on certain musculoskeletal and is even more effective when it is used often and in conjunction with other treatment methods. Armijo-Olivo et al[67] also surveyed Canadian PTs on the beliefs about the effectiveness of ultrasound. Most respondents reported that they consider ultrasound moderately to highly effective to achieving specific treatment goals such as acute inflammation (81% of respondents) and improving fibroblast proliferations (59% of respondents).

2.8. In-Person versus Virtual Education Models

Virtual education has been around for numerous years; however, the impact of COVID-19 has increased its use and popularity. In-person education has always been the standard for education but with technological advances virtual learning has become much more prevalent. Austin et al.[68] studied a hybrid in-person versus a virtual simulation and found that resident students desire in-person training and relished the opportunity for hands-on learning and that the virtual education group lacked engaging discussions which were critical for their field of study. Brockman et al.'s[69] research found that students preferred the in-person biology laboratory because it promoted ownership of their work and personal connection with the instructor; however, the aggregated quiz scores between the two educational models provided no significant differences between quiz scores of the two groups. Students did find that the online convenience of a the virtual method was superior to the in-person method.[69] Similarly, Gross et al.[70] stated that when comparing in-person and asynchronous distance community-based trainings there were no significant differences in outcomes. Today, convenience and access to materials at any time to account for an individual's busy schedule appears to be very important to most individuals thus making virtual training in education a relevant option. However, it appears that the personal connections and ownership of one's work are still a key component to in-person learning. Both educational methods appear to have value and are viable options given test scores and perception of both methods appear to be equal.

2.9. Feasibility of Continuing Education Study Needs

Continuing education (CE) can be classified into formal and informal models. Athletic trainers reported that they engage in both formal and informal CE activities to improve their knowledge, clinical skill or abilities, attitudes toward patient care, and patient care itself. [41] Formal CE typically include short courses featuring lectures, seminars, and small group activities. Informal CE includes learning and practicing in a clinical environment and providing patient care which occurs outside of a classroom or lecture hall. Armstrong and Weidner[41] concluded that formal CE was perceived to improve knowledge more than informal CE, whereas informal CE was perceived to improve both clinical skills or abilities and attitudes toward patient care more than formal CE.

Formal and informal continuing education can occur in any environment and is dependent on individual's learning styles. Armstrong and Weidner[42] reported that most athletic trainers preferred professional conferences or seminars as their preferred formal CE method. However, when asked if they preferred in-person or online formal CE formats, most preferred formal online CE activities so they can complete the CE as their schedule allows.[42] Providing continuing education to athletic trainers is challenging due to their unconventional work schedule. Athletic trainers commonly have working hours extending into the late evenings and weekends to provide medical coverage for athletic events.

Providing or participating in a CE activity can be challenging for anyone and there may be several barriers that must be addressed. Armstrong and Weidner[42] concluded that the most commonly reported barriers for athletic trainers were distance of travel, cost of attending and lack of financial support from their employer. These barriers involve a financial and time component with both having potential effects on one's professional and personal life. Providing local, reduced price or free CE events theoretically would eliminate or reduce all or some of these barriers immensely. In contrast, the barriers least important amongst athletic trainers were lack of self-confidence regarding the learning material and not being interested in taking time away from personal or family responsibilities.[42] These barriers involve little to no involvement in cost which seems to be the most common barrier of CE. The results suggest that athletic trainers try to choose formal CE activities that are cost effective, require fewer days of missed work, and can be completed on one's own schedule or close proximity to home.[42] Providing proper CE opportunities to athletic trainers can be challenging due to many of these factors. Providers of continuing education sessions must be aware of the needs and barriers of athletic trainers and do their best to reduce barriers and to accommodate potential participants.

2.10. Conclusion

Therapeutic ultrasound is currently one of the most widely used modalities and is continuously being studied, researched, and critiqued. At times, therapeutic ultrasound is misunderstood or misused because of the lack of knowledge on how it works or what the physiological effects are to the tissue. When DeForest et al[50] began researching therapeutic ultrasound in 1953, they spearheaded the pursuit to educate and demonstrate that ultrasound can benefit the human body and if used properly, can be a very beneficial modality for clinical use.

3. METHODS

3.1. Purpose of the Study

The purpose of this study was to assess the feasibility of providing athletic trainers in the state of North Dakota an educational training intervention pertaining to best practice ultrasound treatment techniques which will be in either a live in-person or virtual asynchronous educational training intervention format.

3.2. Introduction

Education regarding therapeutic ultrasound is lacking in many areas of the healthcare world. This lack of education has created research outcomes that have added a negative connotation to the modality and its efficacy. Proper techniques and how to set up a therapeutic ultrasound session are areas where most mistakes are made by clinicians and researchers. More education and demonstration of proper techniques would help eliminate these mistakes and provide better outcomes for patients receiving therapeutic ultrasound.

3.3. Research Design

A series of surveys were conducted online via Qualtrics. A pretest, posttest design with an educational intervention was used. One specific goal of the survey is to evaluate the overall effectiveness of the educational intervention and compare differences amongst the in-person versus virtual intervention methods if any were present. Another goal of the survey was to better understand how and when the clinicians used therapeutic ultrasound and what their overall knowledge and perception was of thermal and non-thermal therapeutic ultrasound.

3.3.1. Participants

Active Board of Certifications (BOC) Certified Athletic Trainers (ATs) from North Dakota who were 18 years of age or older and could read and write in English were recruited for this study. Exclusion criteria included – non-BOC certified students or retired ATs. There was a total of 116 North Dakota BOC certified athletic trainers' participants recruited via email from a compiled list created by the National Athletic Trainers' Association (NATA). The NATA was responsible for dispersion of the recruitment emails which were sent every two days for 14 days totaling eight total emails sent to all North Dakota BOC certified athletic trainers. The study was delimited to North Dakota athletic trainers to ensure that they could attend the in-person session if they selected that option. A convenience sample was used due to the athletic trainers' schedules and geographical location, so the participants were able to self-select their intervention type. Compensation consisted of a random drawing for 25 - $20 Amazon gift cards that each participant was entered into upon completion of the final follow-up survey. Also, one (1) BOC continuing education unit was provided upon completion of the educational intervention.

3.3.2. Instrumentation

A 26-item survey (see Appendix A) was developed to assess clinician perception, confidence, and knowledge as there were no previous instruments developed. The survey contained eight demographics questions, five ultrasound confidence questions, two ultrasound perception questions and eleven ultrasound knowledge questions. Demographics consisted of biological sex, age, primary work setting, years of experience as a BOC Certified Athletic Trainer, highest degree earned, amount of continuing education on ultrasound, frequency of thermal ultrasound use, and frequency of non-thermal ultrasound use. Using a 10-point Likert scale with 1 being not confident at all and 10 being extremely confident, the ultrasound confidence questions inquired about how willing they are to use thermal and non-thermal ultrasound in the present time given their current knowledge, how confident they are in choosing the proper thermal and non-thermal ultrasound parameters and confidence in applying proper ultrasound application techniques. A 10-point Likert was used as it appears to be used often in survey research regarding US. Perception questions consisted of how they perceived the efficacy of thermal and non-thermal ultrasound and their perception on the effectiveness of an educational session regarding ultrasound best practices on improving the clinician's techniques. A 3-point Likert scale containing the wording of *effective*, *somewhat effective*, or *not effective* were used for the perception questions which again is a commonly used scale in US surveys. The eleven knowledge questions consisted of multiple-choice questions pertaining to physiological response of thermal and non-thermal ultrasound, appropriate ultrasound treatment area size, choosing the appropriate ultrasound frequency, and the appropriate ultrasound transducer rate. The survey was evaluated for content validity through three content experts. Their feedback was positive, and they all agreed that the survey was a valid instrument to measure US perception, confidence, usage and knowledge. Additionally, two athletic trainers completed the survey by using a think aloud to ensure participant understanding. The think aloud method is a technique that while the reader is reading the survey out loud, they are also verbalizing their thoughts aloud as well. Both ATs responded that the survey was easy to follow, read and comprehend.

3.3.3. Procedures

Participants were provided an opportunity to ask any questions regarding participation in the study and then completed the informed consent. Once informed consent was completed, participants choose to partake in the live or virtual education intervention. A pre-test survey via Qualtrics was completed prior to the in-person and virtual asynchronous educational interventions. It was accessible via a website address or a QR code at the beginning of PowerPoint presentation (See Appendix B).

The live education intervention took place at the FargoDome in Fargo, North Dakota and was approximately one-hour in length. The live intervention consisted of a presentation of the perception and knowledge of ultrasound, thermal and non-thermal therapeutic ultrasound, machine variability, and best practice research pertaining to ultrasound techniques. This portion of the intervention took approximately 35 minutes which included a lecture-based presentation. The presentation was created by accumulating high quality research articles that were associated with the best practices of therapeutic ultrasound. Active learning strategies and checks for understanding were incorporated into the one-hour session. Following the presentation, approximately 15-minutes of the intervention was a visual demonstration of best practice ultrasound techniques. This visual demonstration consisted of properly setting up ultrasound treatment parameters, achieving an appropriate treatment area size, and performing the proper ultrasound transducer head speed. The final 5 – 10 minutes of the overall educational intervention were used for questions pertaining to any of the presented material or the survey. The virtual educational intervention portion was pre-recorded on a PowerPoint and was offered asynchronously. The virtual intervention followed the same format as the in-person intervention with the exception that participants were asked to submit questions via email instead of verbally. There were no emailed questions or comments following either session.

At the conclusion of each of the educational interventions, participants completed the initial post-session survey online via Qualtrics. A website address or a QR code was available at the end of the PowerPoint presentation. Four weeks following the completion of the education intervention, a follow-up educational intervention survey was sent out via email for participants to complete again online via Qualtrics. Reminder emails for the follow-up educational session survey were sent weekly for four consecutive weeks to promote completion. Participants were entered into a drawing for 25 - $20 Amazon gift cards on completion of the follow-up educational intervention survey. Participants were also awarded one (1) BOC continuing education unit upon completion of the one hour live and virtual educational interventions.

This study was approved by the North Dakota State University Institutional Review Board (see Appendix C).

3.3.4. Data Analysis

Descriptive statistics were performed including means, standard deviation, and frequencies. A repeated measures ANOVA was used to compare the means of the pre-educational survey, post-educational survey, and the follow-up educational survey. Pair sample t-tests were also performed to compare two separate variables amongst the pre-educational survey, post-educational survey, and the follow-up educational survey. Cohens d was also used to measure the differences in the effect size between all three survey types. Qualitative open-ended responses regarding thermal and non-thermal ultrasound usage were evaluated by consensual coding. All analyses were completed using SPSS (Version 29.0.0.0).

4. MANUSCRIPT 1

4.1. Introduction

Therapeutic ultrasound is a deep heating modality that when used properly, will produce thermal effects in soft tissues. These thermal increases will create several physiological changes within the tissue which is believed to create a conducive healing environment. A 1° Celsius (C) increase in tissue temperature is ideal for treating mild inflammation and will also increase the metabolic rate within tissues. An increase of 2° to 3° C decreases muscle spasms and pain, increases blood flow, and reduces chronic inflammation. Obtaining a vigorous heat, which is a tissue temperature greater than 3° C, will increase the viscoelastic properties of collagen so tissues can be stretched much easier as well as inhibits sympathetic activity.[1,21-25] Establishing a tissue temperature goal prior to a therapeutic ultrasound treatment is important but several factors must be accounted for to achieve this goal.

Proper application of therapeutic ultrasound can aid in treatment of musculoskeletal injuries, whereas incorrect application may reduce the desired physiological effects or even cause harm.[31] When setting temperature goals, choosing settings, and applying a thermal ultrasound treatment, the clinician must have a strong educational background and knowledge of best practices. Many factors have been suggested to play a part in effective transmission of ultrasound to targeted tissues, including but not limited to, the size of the treatment area, ultrasound frequency, transducer movement rate and intensity parameters.[7,13,14,23,34,37,38,71-78] Clinicians must rely on their education, experience and best practice techniques to set and meet their ultrasound treatment goals.

Proper formal education and continuing education are vitally important for all healthcare providers. Athletic trainers (ATs) who have graduated from an accredited Athletic Training

Education Program have met the Commission on Accreditation of Athletic Training Education (CAATE) Standard 73 which requires Athletic Training Education Programs to provide education on therapeutic modalities which includes US, however; the retention of knowledge by ATs once they become certified are unclear.[32] A review of literature in healthcare professionals found that knowledge and skill related to emergency care begins to decline within six months to one year after active life support formal training.[66] Active life support training is done every two years and can also be a form of continuing education. Healthcare providers must continue their learning throughout their careers to learn new information, retain previously learned information and to stay current on best practices. A well-rounded education in therapeutic ultrasound can create positive patient outcomes which will create a positive perception of the modality as well. Schellhase et al. concluded ATs had confidence in their knowledge of therapeutic ultrasound concepts, but scores on the actual knowledge questions were relatively poor whereas, Chipchase et al. concluded that ultrasound was perceived to be most effective when used in combination with other techniques.[32,33] Therefore, the aim of this study was to examine if providing a therapeutic ultrasound educational session to athletic trainers would increase their knowledge and perception of thermal therapeutic ultrasound.

4.2. Methods

4.2.1. Research Design

A pretest-posttest design with an educational intervention was used to collect data. Participants could complete an in-person or virtual asynchronous educational intervention. The goal of the survey data was to provide insight on athletic trainers' confidence and perception of thermal ultrasound.

4.2.2. Participants

Thirty-one English writing and speaking, active Board of Certifications (BOC) Certified Athletic Trainers (ATs) from North Dakota that were at least 18 years of age, volunteered for this study. Non-BOC certified students and retired ATs were excluded from the study. The study was delimited to only athletic trainers in North Dakota so they could attend the in-person educational intervention if chosen for that session. A total of 31 participants participated in the study (see Table 1). Two individuals contacted the researchers for information on the virtual asynchronous intervention but did not complete any of the surveys or the educational intervention. One hundred and sixteen North Dakota BOC ATs were sent invitations to the study and only 31 participated which is a 26.7% participation rate. Table 2 provides a description of the sample.

Table 1: In-Person vs Virtual-Asynchronous Educational Intervention Participants

Educational Intervention Type	Frequency	Percent	Cumulative Frequency	Cumulative Percent
In-person	13	41.94	13	41.94
Virtual-asynchronous	18	58.06	31	100

Table 2: Demographics

Biological Sex	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Male	12	38.71	12	38.71
Female	19	61.29	31	100

Age Range	Frequency	Percent	Cumulative Frequency	Cumulative Percent
18-29	19	61.29	19	61.29
30-39	10	32.26	29	93.55
50-59	1	3.23	30	96.77
60+	1	3.23	31	100

Table 2: Demographics (cont.)

Primary Work Setting	Frequency	Percent	Cumulative Frequency	Cumulative Percent
College or university	11	35.48	11	35.48
Secondary school	17	54.84	28	90.32
Clinic & hospital	2	6.45	30	96.77
Professional sports	1	3.23	31	100

Years of Experience	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0-9	24	77.42	24	77.42
10-19	5	16.13	29	93.55
20-29	1	3.23	30	96.77
30-39	1	3.23	31	100

Highest Education	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Bachelors degree	15	48.39	15	48.39
Professional Masters degree in AT	5	16.13	20	64.52
Professional Masters degree in other	2	6.45	22	70.97
Masters degree	7	22.58	29	93.55
Doctoral degree	2	6.45	31	100

Thermal US Usage	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Once a day	1	3.23	1	3.23
Bi-weekly	1	3.23	2	6.45
Weekly	4	12.9	6	19.35
Bi-monthly	3	9.68	9	29.03
Monthly	5	16.13	14	45.16
Never	17	54.84	31	100

Non-Thermal Usage	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Bi-weekly	1	3.33	1	3.33
Weekly	1	3.33	2	6.67
Bi-monthly	4	13.33	6	20
Monthly	5	16.67	11	36.67
Never	19	63.33	30	100

Table 2: Demographics (cont.)

US Continuing Education Hours	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0 hours	15	48.39	15	48.39
5-10 hours	15	48.39	30	96.77
16-20 hours	1	3.23	31	100

4.2.3. Instrumentation

A 26-item survey (see Appendix A) was used to examine ATs confidence, perception, and knowledge of thermal and non-thermal ultrasound. The survey included the following: eight demographic questions consisting of biological sex, age, primary work setting, years of experience as a BOC certified athletic trainer, highest educational degree earned, frequency of thermal and non-thermal ultrasound use, and the amount of time spent on continuing education pertaining to thermal and non-thermal ultrasound.

Five confidence questions, which used a 10-point Likert scale with 1 being not confident at all and 10 being extremely confident, asked how confident they are regarding applying thermal and non-thermal ultrasound with their current ultrasound knowledge, their confidence in choosing the proper parameters, and properly applying ultrasound for both thermal and non-thermal treatments. The two perception questions asked how each athletic trainer perceived the efficacy of both thermal and non-thermal ultrasound and whether they thought an educational intervention regarding best practices would improve their ultrasound knowledge and application. The perception questions were answered by a 3-point Likert scale with response choices of: *Not effective*, *somewhat effective*, and *effective*. Likert scales of these varieties were used as they are commonly used in US survey research.

The remaining 11 knowledge questions were all multiple-choice questions regarding physiological responses caused by thermal and non-thermal ultrasound and how to choose the appropriate ultrasound treatment area size, transducer speed, and ultrasound frequency. Three content experts evaluated the survey for content validity and changes were made based on their feedback. Additionally, two other individuals used the think aloud method while completing the survey to evaluate clarity and understanding.

4.2.4. Procedures

An informed consent form was available to all participants who accessed each survey. All participants had the opportunity to ask any questions throughout the entirety of the study. Once all questions and informed consents were completed, participants self-selected into either the in-person or virtual asynchronous educational intervention group. A convenience sample was used for educational intervention type based on the athletic trainer's availability and geographical location. A pre-test, post-test, and a follow-up survey were completed before, immediately after the educational intervention, and four weeks following both educational intervention types.

The educational intervention consisted of a lecture-based presentation of machine variability and best practice research associated with ultrasound parameters and techniques. The lecture-based presentation was developed using pertinent research articles from reputable sources to reinforce therapeutic ultrasound best practice techniques. This portion of the intervention lasted approximately 35 minutes. Participants were engaged in active learning strategies such as reflecting after each major topic and a visual demonstration with discussion on the information provided in the lecture. Checks for understanding throughout the intervention were also made by the presenter by getting verbal or visual confirmation from participants that they understood. Following the 35-minute lecture-based presentation, a 15-minute ultrasound demonstration session occurred. This demonstration showed how to properly set up the ultrasound parameters and how to use best practice techniques while applying ultrasound such as transducer head speed and determining treatment area size and was performed only by the presenter. The final 5 – 10 minutes were used to answer any questions related to the survey, lecture, and demonstration portion of the educational intervention.

The in-person session took place at a university in the upper Midwest while the virtual asynchronous session was pre-recorded using a PowerPoint. It followed the same format mentioned above with the exception that questions were emailed to the researcher following the educational intervention instead of being verbally asked. Additionally, the ultrasound demonstration during the virtual session was a pre-recorded video that entailed the same content. The combined overall time for each session was approximately 60 minutes in length. If the participants completed the educational education session, they were awarded one (1) BOC continuing education unit.

At the conclusion of each educational intervention, participants were provided a website address or QR code to access the post-educational intervention survey. This survey contained the same content as the previous pre-educational intervention survey. Four weeks following the educational intervention, an email containing the link for the follow-up survey was sent. This survey contained the same content as the previous two surveys. Reminder emails were sent once a week for four weeks to encourage completion of the study. If participants completed the follow-up survey, they were placed into the random drawing for 25 - $20 Amazon gift cards.

This study and its contents were approved by the North Dakota State University Institutional Review Board (See Appendix C).

4.2.5. Data Analysis

Descriptive analyses were completed on all data sets using SPSS (Version 29.0.0.0). Means of knowledge scores were used to observe if the educational intervention influenced knowledge scores on the pre-intervention, post-intervention, and follow-up intervention survey knowledge questions. A repeated measures Analysis of Variance (ANOVA) with a Tukey-Kramer post hoc test was used to compare the mean ultrasound knowledge scores to educational session types and times. A paired-samples T-test with an alpha level of 0.05 was used to examine the clinician's perception of thermal ultrasound. Lastly, open-ended questions were manually coded and placed into theme groups based on their responses. The responses were then totaled to see how many responses were in each group.

4.3. Results

A statically significant increase ($p \leq 0.05$ alpha level) in mean overall knowledge scores was observed from the pre-educational intervention survey to the post-educational intervention survey (See Table 3). Thermal US knowledge means for each intervention are reported in Table 4. Results from the ANOVA were $F(2, 74) = 11.49$, $p < 0.0001$ (See Table 5). The Tukey-Kramer post hoc test revealed significant differences between the pre-educational session and the post-educational session, and the post-educational session and the follow-up educational session as seen on Table 6.

Table 3: Participant's Overall Mean Knowledge Scores

Survey Session	Mean Score	Standard Deviation
Pre-educational intervention	7.06	±1.68
Post-educational intervention	9.14	±1.63
Follow-up educational intervention	7.95	±1.50

Table 4: Thermal US Knowledge Scores

Survey Session	Mean Score	Standard Deviation
Thermal pre-educational session	1.42	±0.62
Thermal post-educational session	1.62	±0.62
Thermal follow-up educational session	1.60	±0.50

Table 5: Repeated Measures ANOVA - Time as the DV

Effect	Num DF	Den DF	F Value	Pr > F
Session type (In-person, virtual asynchronous)	1	74	1.28	0.2624
Time (Pre, post, follow-up survey)	2	74	11.49	<.0001
Session type*time	2	74	0.16	0.8497

Table 6: Tukey-Kramer

Survey Type	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
Pre vs post-educational session	-2.0841	0.4353	74	-4.79	<.0001	<.0001
Pre vs follow-up educational session	-0.9079	0.4828	74	-1.88	0.064	0.152
Post vs follow-up educational session	1.1762	0.4878	74	2.41	0.0184	0.0477

There was no significant statistical difference noted among the clinician perception of thermal US from pre to post or during the follow-up. Means for clinician's perception on thermal ultrasound recorded during each session can be seen in Table 7. Paired samples T-test results for pre-intervention perception levels compared to post-intervention perception levels were $t(28) = -1.19$, $p = 0.12$, d = 0.94 whereas pre-intervention levels compared to follow-up intervention levels were $t(19) = -0.83$, $p = 0.21$, d = 0.81.

The perception scores in this study were not significantly significant, however; most participants thought thermal ultrasound was effective or somewhat effective overall. Sixty-one percent of respondents chose "somewhat effective" in the pre-educational session survey. However, the perception fell to 46% in the post-survey as there was a large shift in perception to the "effective" category. Less than eight percent of respondents stated thermal ultrasound was "not effective" in both the pre- and post-survey. Post intervention, over 70% of participants believed that thermal ultrasound was either "somewhat effective" or "effective" showing the perception of thermal ultrasound is relatively high amongst athletic trainers. The highest mean perception scores were noted in the post-educational intervention survey.

Table 7: Perception on Effectiveness of Thermal US

Pre-Educational Intervention Survey	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Not Effective	2	6.45	2	6.45
Somewhat Effective	19	61.29	21	67.74
Effective	10	32.26	31	100

Post-Educational Intervention Survey	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Not Effective	2	7.14	2	7.14
Somewhat Effective	13	46.43	15	53.57
Effective	13	46.43	28	100

Follow-Up Educational Intervention Survey	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Not Effective	0	0	0	0
Somewhat Effective	12	60	12	60
Effective	8	40	20	100

4.3.1. Open-Ended Questions

Data from the open-ended questions regarding US use revealed five common themes. These themes can be found in Table 8 with a definition and frequency of times they were reported. The first theme was that they did not have a machine which was reported 22 times. The second theme was preferred to use other modalities. One responded stated, “I believe there are more effective ways to get thermal temperature raises in tissue”. The third theme reported was time constraint. In fact, one response was “My setting is not ideal for US due to time constraints”. The fourth theme that occurred four times was cost associated with the unit. One participant stated, “I do not have the financial resources to purchase a US machine”. The last theme that arose was lack of research. Participants described, “I learned evidence in graduate school over the inefficiency of thermal US in heating soft tissues”.

Table 8: Participant Responses on Why They Do Not Use Thermal US

Response Category	n
Do not have access to US machine	22
Prefer other modalities	6
Time constraints	6
Financial costs	4
Lack of research	1

4.4. Discussion

This study investigated if an educational intervention would increase athletic trainers' knowledge and perception on thermal therapeutic ultrasound. A statistically significant difference was found amongst the pre, post, and follow-up mean knowledge and perception scores, however; the mean scores were not significant from the pre-intervention to the follow-up scores. These results demonstrate that the perception and knowledge of thermal ultrasound did increase immediately. However, participants did not retain the information.

When examining knowledge score means, the follow-up survey scores were very similar to the pre-survey scores for thermal ultrasound knowledge. This would indicate that the information conveyed during the educational intervention was not retained. These results are consistent with Yang et al.'s[66] results which found that healthcare professionals' emergency care knowledge and skill declined within six months to a year after being presented with the information. As noted above, the mean knowledge scores were the highest immediately following the educational intervention which supports the concept that the educational intervention was effective in the short term. Armijo-Olivo et al[67] reported only 65% of undergraduate physical therapist (PTs) and 59% of graduate PTs in their study believed they had adequate ultrasound knowledge which also demonstrates that more formal thermal ultrasound education is needed to improve knowledge of thermal ultrasound.

Four weeks following our educational intervention knowledge scores returned to around pre-educational intervention scores concluding that the knowledge was not well retained. Increasing knowledge retention can be done by engaging participants senses.[79] Some examples of active learning strategies that may help in the future include reflecting on the subject once presented with the information, providing multiple, diverse training sessions, and person journaling pertaining to thermal US. During or after an educational session, participants could be asked to reflect on the knowledge learned. Personal reflection can be done in writing or verbally, or a combination of both methods.[80,81] A knowledge reflection session can be included in future research to help increase retention. Another option to aid in knowledge retention could be personal journaling.[82] Asking participants to journal the knowledge they gained or by documenting their thermal US usage and treatment outcomes may also assist in their knowledge retention thus leading to higher perception rates of thermal US. A virtual or in-person educational intervention choice was provided to the participants in the study. Providing different types of follow-up interventions in the future may help with knowledge retention.

Perception of thermal ultrasound in the medical community is mixed. There are many clinicians that perceive it to be effective while some believe it is not effective. Chipchase and Trickle[33] questioned physiotherapists and found the those who used ultrasound more often had higher US perception scores and they also believed it was more effective when used along with other modalities. The results of the current study suggested a slight increase in thermal US perception scores indicating that when ATs are provided with an educational intervention regarding best practice thermal ultrasound techniques their perception levels of thermal ultrasound can be influenced. A positive or negative perception of thermal US can impact the usage of the modality. Knowledge and clinical skills can also dictate the usage of thermal ultrasound. Several studies have concluded that clinicians who use US often have higher perception levels and knowledge scores.[67,83,84] The results of the study suggested that there were differences between pre to post session knowledge but knowledge returned to baseline during the follow-up.

One limitation to this study was the small sample size. The small sample size made it difficult to use advanced statistical methods. Also, using only BOC Certified Athletic Trainers within our region was a limitation and therefore makes it challenging to generalize the findings. We chose to limit the size of the recruiting region of participating ATs to make it feasible for them to attend the in-person educational intervention if they so choose. However, future studies may consider using ATs from multiple regions.

Recommendations for future research would be possible providing a blended course option, performing the study a different time of year, expanding the regional area of AT recruitment, and offering the in-person educational intervention during a convention or meeting.

In summary, the participants did improve their knowledge regarding thermal therapeutic ultrasound when compared to their pre-educational intervention survey scores. However, the knowledge did not appear to be retained as their four-week follow-up educational intervention survey scores were like their pre-educational intervention survey scores. Similarly, the thermal ultrasound perception survey scores were at their highest in the post-educational intervention survey scores showing that receiving an education intervention with best practice research can increase perception. Although none of these scores showed statistical significance, there was an increase in the means marking improvement when incorporating an educational intervention regardless of if it was in-person or virtually asynchronous.

5. MANUSCRIPT 2

5.1. Introduction

Non-thermal ultrasound is a type of therapeutic ultrasound that is not as commonly used as thermal ultrasound, but research has suggested it has benefits with promotion of healing at the cellular level[60,85,86]. Non-thermal, or pulsed ultrasound, differs from a 100% thermal ultrasound as ultrasound is only produced a certain percentage of the time causing a pulsing effect within the cells and their membranes. The clinical application of therapeutic ultrasound has evolved over the past several decades, from being used exclusively as a thermal modality to being employed for its non-thermal effects, particularly in tissue repair and wound healing.[6,67] Non-thermal ultrasound is commonly used for stimulation of tissue repair, reduction of edema and treatment of trigger point for pain management.[22] Clinicians do state that ultrasound is used to accomplish heating within deep tissue. However, there is a common belief that heating alone cannot account for the clinical effects, especially when ultrasound is delivered at a non-thermal setting.[60]

Non-thermal ultrasound is thought to create many effects within the cells but the two most common phenomena that occur are acoustic microstreaming and cavitation. Dyson and Suckling suggested that non-thermal effects of ultrasound, including cavitation and acoustic microstreaming, are more important in the treatment of soft tissue lesions than are thermal effects.[87] Cavitation is defined as the physical forces of the sound waves on microenvironmental gases within fluid and occurs when gas-filled bubbles expand and compress because of ultrasonically induced pressure changes in tissue fluids, with a resulting increase in flow in the surrounding fluid.[60,88] Acoustic microstreaming is defined as the physical forces of the sound wave that provide a driving force capable of displacing ions and small molecules.[86] Effects of cavitation and microstreaming that have been demonstrated include stimulation of fibroblastic repair and collagen synthesis, tissue repair and bone healing.[58,89-92] Both phenomena are thought to create positive physiological changes within the cells that may assist in healing if the non-thermal ultrasound is set up properly and applied correctly. If non-thermal ultrasound is properly applied it is of considerable medical significance for it can be used to stimulate tissue repair, sometimes quite spectacularly.[85] Therefore, education and proper knowledge of non-thermal ultrasound is much needed in the medical community.

Non-thermal ultrasound is not commonly used due to the lack of supporting research and the limited knowledge of this modality. Therefore, it is not often discussed or taught in depth in many educational lectures. To date, we were unable to find any studies that examined the knowledge and perception of non-thermal ultrasound, and it is unclear if it is being taught in the education setting. Therefore, the goal of this study is to examine if providing therapeutic ultrasound educational intervention to athletic trainers would increase their knowledge and perception of non-thermal ultrasound. A secondary goal of this study was to see if there was a difference between offering a virtual versus an in-person educational session.

5.2. Methods

5.2.1. Research Design

A pre-test, post-test survey design with an educational intervention was used. The goals of the surveys were to understand the usage of ultrasound by athletic trainers and if there were any noticeable differences between the in-person and virtual asynchronous educational interventions.

5.2.2. Participants

Participants were at least 18 years of age, English writing and speaking active Board of Certifications (BOC) Certified Athletic Trainers (ATs) from an upper Midwest state. Participants were excluded if they were retired ATs or non-BOC certified students. The National Athletic Trainers Association (NATA) sent recruitment emails to all 116 North Dakota BOC certified athletic trainers within their database every two days for 14 days. A total of 31 out of 116 participants volunteered for the study totaling a 26.7% participation rate (See Table 9). Two potential participants requested information on the virtual asynchronous educational intervention but did not complete any part of the study. The participants self-selected which type of educational intervention they participated in based on their personal schedule and preferences. If the participants completed the one-hour educational intervention, they received one (1) BOC continuing education (CE) unit for their time. Upon completion of the final post-post survey, participants were included in a random drawing consisting of 20 - $25 Amazon gift cards as a means of compensation for participating in this study.

Table 9: Demographics (Reprinted from Table 2, Chapter 4)

Biological Sex	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Male	12	38.71	12	38.71
Female	19	61.29	31	100

Age Range	Frequency	Percent	Cumulative Frequency	Cumulative Percent
18-29	19	61.29	19	61.29
30-39	10	32.26	29	93.55
50-59	1	3.23	30	96.77
60+	1	3.23	31	100

Table 9: Demographics (cont.)

Primary Work Setting	Frequency	Percent	Cumulative Frequency	Cumulative Percent
College or university	11	35.48	11	35.48
Secondary school	17	54.84	28	90.32
Clinic & hospital	2	6.45	30	96.77
Professional sports	1	3.23	31	100

Years of Experience	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0-9	24	77.42	24	77.42
10-19	5	16.13	29	93.55
20-29	1	3.23	30	96.77
30-39	1	3.23	31	100

Highest Education	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Bachelors degree	15	48.39	15	48.39
Professional Masters degree in AT	5	16.13	20	64.52
Professional Masters degree in other	2	6.45	22	70.97
Masters degree	7	22.58	29	93.55
Doctoral degree	2	6.45	31	100

Thermal US Usage	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Once a day	1	3.23	1	3.23
Bi-weekly	1	3.23	2	6.45
Weekly	4	12.9	6	19.35
Bi-monthly	3	9.68	9	29.03
Monthly	5	16.13	14	45.16
Never	17	54.84	31	100

Non-Thermal Usage	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Bi-weekly	1	3.33	1	3.33
Weekly	1	3.33	2	6.67
Bi-monthly	4	13.33	6	20
Monthly	5	16.67	11	36.67
Never	19	63.33	30	100

US Continuing Education Hours	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0 hours	15	48.39	15	48.39
5-10 hours	15	48.39	30	96.77
16-20 hours	1	3.23	31	100

5.2.3. Instrumentation

A survey consisting of 26 items was used to assess the clinical knowledge and perception of therapeutic ultrasound. There were eight demographic questions, five ultrasound confidence questions, two perception questions and eleven multiple choice knowledge questions. Demographic information collected included biological sex, age, primary work setting, years of experience as a BOC Certified Athletic Trainer, highest degree earned, amount of CE related to ultrasound, frequency of thermal ultrasound use, and frequency of non-thermal ultrasound use. The five confidence questions were evaluated using a 10-point Likert scale with 1 being not confident at all and 10 being extremely confident. A 10-point Likert scale was used in the study as it appears to be the most common scale when assessing confidence in US survey research. The confidence questions asked how confident the clinicians were on using thermal and non-thermal ultrasound with their current knowledge, choosing the proper parameters and application methods of both thermal and non-thermal ultrasound. A 3-point Likert scale was used to evaluate clinicians' perception of thermal and non-thermal ultrasound and used *effective*, *somewhat effective*, or *not effective* as options to choose from for each question. A 3-point Likert scale was used to gauge perception as it is commonly used to assess perception in US survey research. These questions were how the clinician perceived the efficacy of thermal and non-thermal ultrasound and how effective an educational intervention pertaining to therapeutic ultrasound best practices may be on improving how they administer ultrasound. There were eleven multiple choice knowledge questions used to access the knowledge of each participant. Questions asked about physiological responses of thermal and non-thermal ultrasound, the appropriate treatment area size, the recommended transducer head speed, and choosing the correct ultrasound frequency for a treatment. Three content experts evaluated the survey for content validity while two other experts used a think aloud method to ensure the survey content was understood by participants in this study. Modifications were made to the survey based on the experts' feedback.

5.2.4. Procedures

An opportunity for participants to ask any questions or provide comments was available before the study began. Participants completed an informed consent form and then choose whether they would participate in the live educational intervention or the virtual asynchronous educational intervention. A QR code or website address for the pre-test survey was available on the PowerPoint presentation immediately before the educational intervention began.

The one-hour in length live educational intervention occurred at a university in the upper Midwest and consisted of a lecture-based presentation using PowerPoint, a visual demonstration, and question and answer session. The lecture-based presentation occurred first and was approximately 35 minutes in length. This presentation was created with material from an extensive search for quality articles pertaining to therapeutic ultrasound. Checks for understanding using group reflection after key points and visual demonstration of skills discussed in the lecture. Active learning strategies such as verbal and visual understanding queues from the participants were used throughout the educational intervention. Following the lecture-based presentation, a 15-minute visual demonstration on ultrasound best practices was performed by the presenter as the participants observed. This visual demonstration consisted of properly setting up an ultrasound treatment, selecting the proper parameters, creating a proper treatment area size, and using the correct ultrasound transducer head speed while executing the treatment. The final 5 – 10 minutes was used for any question, comments, or concerns from the participants. The virtual intervention followed the exact format of the live intervention but was pre-recorded on a voice PowerPoint and was offered asynchronously. The only exception was that participants partaking in the virtual intervention would email questions or comments to the researchers following the educational intervention. There were no emails received with questions or comments from either educational intervention type.

Immediately following the conclusion of the live and virtual educational interventions, a website address and QR code were available for the participants to choose from to complete the post-session survey. A follow-up survey was emailed to all participants four weeks following the completion of the educational intervention. This follow-up survey was completed on Qualtrics and had the same format and questions as the pre and post intervention surveys. Emails were sent weekly for four consecutive weeks to promote completion of the follow-up survey. If participants completed the follow-up survey, they were entered into a random drawing for 25 - $20 Amazon gift cards.

This study and its contents were approved by the North Dakota State University Institutional Review Board.

5.2.5. Data Analysis

Means of knowledge scores were used to examine if the educational intervention influenced knowledge scores on the pre-intervention, post-intervention, and follow-up intervention survey knowledge questions. Descriptive statistics were used and completed in SPSS Version 29. Additionally, a repeated measures Analysis or Variance (ANOVA) with a Tukey-Kramer post hoc test were used to compare mean ultrasound knowledge scores to each educational session ($\alpha \leq 0.05$). Paired-samples t-tests with a 0.05 alpha level were used to examine the clinician's perception of non-thermal ultrasound. Open ended questions were evaluated using consensual analysis then grouped into themes where a quantitative value was given to indicate the number of responses.

5.3. Results

A statistical difference was found in the overall knowledge scores when comparing the pre-educational intervention survey to the post-educational intervention survey scores (See Table 10). Results from the ANOVA were $F(2, 74) = 11.49$, $p < 0.0001$ (See Table 11). The Tukey-Kramer post hoc test revealed significant differences between the pre-educational session and the post-educational session, and the post-educational session and the follow-up educational session (See Table 12).

Specific to non-thermal US knowledge means can be found in Table 13. The pre-intervention survey was 1.42±0.62, post-intervention survey was 1.62±0.62, and the follow-up intervention survey were 1.60±0.50.

Table 10: Participant's Overall Mean Knowledge Scores (Reprinted from Table 3, Chapter 4)

Survey Session	Mean Score	Standard Deviation
Pre-educational intervention	7.06	±1.68
Post-educational intervention	9.14	±1.63
Post-post-educational intervention	7.95	±1.50

Table 11: Repeated Measures ANOVA-Time as the DV (Reprinted from Table 5, Chapter 4)

Effect	Num DF	Den DF	F Value	Pr > F
Session type (In-person, virtual asynchronous)	1	74	1.28	0.2624
Time (Pre, post, follow-up survey)	2	74	11.49	<.0001
Session type*time	2	74	0.16	0.8497

Table 12: Tukey-Kramer (Reprinted from Table 6, Chapter 4)

Survey Type	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
Pre vs post-educational session	-2.0841	0.4353	74	-4.79	<.0001	<.0001
Pre vs follow-up educational session	-0.9079	0.4828	74	-1.88	0.064	0.152
Post vs follow-up educational session	1.1762	0.4878	74	2.41	0.0184	0.0477

Table 13: Non-Thermal US Knowledge Scores

Survey Session	Mean Score	Standard Deviation
Non-thermal pre-educational session	1.32	±0.60
Non-thermal post-educational session	1.55	±0.57
Non-thermal follow-up educational session	1.50	±0.69

Clinician perception means and paired t-test results revealed no statistically significant differences in clinician's perception on non-thermal ultrasound following the educational intervention when compared to the pre-intervention means. Descriptive means for clinician's perception on non-thermal ultrasound can be found in Table 14. Paired samples t-test results for pre-intervention perception levels compared to post-intervention perception levels were $t(28) = -1.57$, $p = 0.64$, d = 0.83 whereas pre-intervention levels compared to follow-up intervention levels were $t(19) = -1.93$, $p = 0.35$, d = 0.81.

Table 14: Participant's Perception of Non-Thermal US

Survey Session	Mean Score	Standard Deviation
Pre-educational intervention	2.13	±0.51
Post-educational intervention	2.36	±0.62
Follow-up educational intervention	2.35	±0.49

Less than eight percent of respondents stated non-thermal ultrasound was "not effective" in both the pre-and post-survey (See Table 15). Under 50% of participants believed that non-thermal ultrasound was either "somewhat effective" or "effective" suggesting the perception of non-thermal ultrasound is relatively low amongst ATs. The highest mean perception scores were noted in the post-educational intervention survey. This again indicates that when ATs are provided with an educational intervention regarding best practice non-thermal ultrasound techniques, their perception slightly increases immediately following the educational intervention.

Table 15: Perception of Effectiveness of Non-Thermal US

Pre-Educational Intervention Survey	Frequency	%	Cumulative Frequency	Cumulative Percent
Not Effective	2	6.67	2	6.67
Somewhat Effective	22	73.33	24	80
Effective	6	20	30	100

Post-Educational Intervention Survey	Frequency	%	Cumulative Frequency	Cumulative Percent
Not Effective	2	7.14	2	7.14
Somewhat Effective	14	50	16	57.14
Effective	12	42.86	28	100

Follow-Up Educational Survey	Frequency	%	Cumulative Frequency	Cumulative Percent
Not Effective	0	0	0	0
Somewhat Effective	13	65	13	65
Effective	7	35	20	100

5.3.1. Open-Ended Questions

If a participant answered that they did not use non-thermal US at all in our survey they were then asked an open-ended question as to why they did not use it. Five themes emerged from the questions with the most common response was they did not have access to a US machine, followed by they preferred other modalities over US and then time constraints (See Table 16 for full list and frequencies). A participant stated, “The effects of non-thermal US are not well supported, and I believe there are more effective methods to get the same results”. Another agreed with the statement and wrote “I don’t really use US and the non-thermal effects are not well supported”. Time constraints was a common answer as well with one participant commenting “I don’t use non-thermal US mostly due to time constraints based on the among of athletes I have". Interestingly, lack of knowledge was suggested by five participants. In fact, one participant stated, "I did not know enough about it before this PowerPoint" while another wrote, "I never think of it and don't know how to use it properly". Four participants noted they did not have the financial resources to purchase a US machine thus affecting their ability to use non-thermal US. Not having the proper knowledge of a modality and not having access to a US machine can have a great effect on usage and perception of non-thermal US.

Table 16: Participant Responses on Why They Do Not Use Non-Thermal US

Response Category	n
Do not have access to US machine	22
Prefer other modalities	11
Time constraints	7
Lack of knowledge	5
Financial costs	4

5.4. Discussion

This study investigated if an educational intervention would increase athletic trainers' knowledge and perception on non-thermal therapeutic ultrasound. When comparing the pre, post, and follow-up survey mean knowledge and perception scores a statistical significance was found between the pre and post surveys. These results demonstrate that following an educational intervention containing best practice research, ATs perception and knowledge of non-thermal, and ultrasound in general, did increase.

Follow-up survey score means were like the pre-survey scores for non-thermal ultrasound knowledge indicating that the information from the educational intervention was not well retained. Schellhase et al.[32] noted that every athletic training education student must meet minimum standards of therapeutic modality knowledge before they can graduate; however, the retention of this knowledge once they become certified is unclear. Similarly in this study, mean knowledge score results were the highest on the post-educational intervention demonstrating that the participants did learn some of the material but retained it for a short time frame. Schellhase et al.[32] also noted that collegiate ATs had confidence in their ultrasound knowledge, but the scores to their actual educational questions were low suggesting that more formal non-thermal ultrasound education is needed to improve overall knowledge in ATs.

Our follow-up survey knowledge scores indicated that the knowledge was not well retained four weeks following the educational intervention. Potential ways to increase knowledge retention regarding non-thermal US include reflecting on the non-thermal US, providing multiple, diverse training sessions, and personal journaling on non-thermal US. These strategies can help engage the participant's sense and increase learning. Reflective writing provides an opportunity for the participants to document their thoughts or knowledge they learned during the educational intervention.[80,81] This type of reflection could be included in our study in the future. We provided the participants with the choice of what type of educational intervention they preferred for this study. Providing different types of follow-up interventions in the future may assist in increasing knowledge retention. Encouraging personal journaling for the participants may be another strategy to improve knowledge retention.[82] By simply journaling personal thoughts and experiences regarding non-thermal US may improve knowledge retention amongst learning in future research.

The lack of education and research pertaining to non-thermal ultrasound has altered the perception of some clinicians over the years. Many clinicians do not use non-thermal ultrasound because they perceive it to be ineffective or they simply do not have the proper educational background due to the small amount of time spent on non-thermal US. However, Armijo-Olivo et al[67] surveyed Canadian physical therapists (PTs) and found that 81% of respondents perceived ultrasound to be effective for treatment of acute inflammation and 59% perceived it to improve fibroblastic proliferations, both indications for non-thermal ultrasound use. There were no statistically significant changes in mean perception scores between survey sessions in this study. However, less than eight percent of respondents stated non-thermal ultrasound was “not effective” in both the pre-and post-survey. Comments regarding non-thermal ultrasound were “I did not know enough about it before this PowerPoint” and “I never think of it and don’t know how to use it properly”. Other participant comments regarding non-thermal US were “The effects of non-thermal ultrasound are not well supported, and I believe there are more effective methods to get the same results” and “I don’t really use ultrasound and the non-thermal effects are not well supported”. Under 50% of participants believed that non-thermal ultrasound was either “somewhat effective” or “effective” suggesting the perception of non-thermal ultrasound effectiveness is relatively low amongst ATs. However, the highest mean scores were noted following the educational session which suggest that when ATs are provided with an educational intervention regarding best practice non-thermal ultrasound techniques, their perception increases immediately following the educational intervention.

Many factors can impact the usage of any type of modality with perception being a large factor. Other factors may include confidence levels, access, and knowledge of non-thermal ultrasound. Higher confidence scores, perception levels and knowledge scores have been observed amongst clinicians who use US often in several studies.[67,83,84]

This study also examined the effectiveness of each educational intervention type, in-person vs virtual asynchronous. Multiple studies using both in-person and asynchronous distance-based training have been reported to have no significant difference in outcomes amongst educational intervention types.[70,93,94] These results were consistent with our study which revealed no statistically significant differences in knowledge and perception scores amongst ATs participating in an in-person or virtual asynchronous educational intervention. We provided two educational intervention options to our participants and ultimately allowed them to choose which educational intervention they prefer. Armstrong and Weidner[42] concluded that ATs chose formal methods of continuing education (CE) that were cost effective, required fewer days of missed work, and can be completed on one's own schedule or in close proximately of their home. By providing both types of interventions for this study we were hopeful it would increase participation and accommodate ATs' busy and unorthodox schedules.

Armstrong and Weidner[42] determined the most commonly reported barriers of CE among ATs were the cost of attendance, distance to travel, and the lack of financial assistance from their employer. One barrier that can be removed by using virtual learning is distance to travel and possibility of financial need. We offered the educational intervention at no cost to the participants and even provided an opportunity to win a $20 Amazon gift card. The participants also received one (1) BOC continuing education unit at no cost if they finished the one-hour educational intervention. Travel costs were eliminated by offering a virtual asynchronous educational intervention. This study suggests that virtual learning may be a viable option to help alleviate barriers and still provide educational trainings for ATs.

Our main limitation in the study was the small sample size. A small sample size makes it difficult to find any powerful statistical significances. This study delimited to ATs in a specific upper Midwest state so the results may not be transferable to other regions. Therefore, future studies may consider other regions or recruiting from additional areas.

Further recommendations for future research could be providing a blended course option or having the study available at a different time of year. Additionally, offering the intervention during a professional convention or state or regional meeting could expand the training's reach.

expansion of AT recruitment and offering the in-person educational intervention during a professional convention or state or regional meeting.

In summary, the participants did improve their knowledge regarding non-thermal therapeutic ultrasound when compared to their pre-educational intervention survey scores, but the knowledge did not appear to be well retained. Perception of non-thermal ultrasound increased immediately following the educational intervention demonstrating that an education intervention with best practice research can increase perception of non-thermal ultrasound. Nonetheless, there was an increase in the overall knowledge and perception means marking improvement when incorporating an in-person or virtual asynchronous educational intervention with best practice research pertaining to non-thermal ultrasound.

6. SUMMARY AND RECOMMENDATIONS

6.1. Summary

The purpose of this study was to provide athletic trainers an educational training intervention pertaining to best practice ultrasound treatment techniques which will be in either a live, in-person or virtual asynchronous educational training intervention format. This study used quantitative and qualitative measures to examine the knowledge, usage, and perceptions of both thermal and non-thermal ultrasound. The educational intervention was successful in raising US knowledge levels immediately following the educational intervention, but retention of the knowledge was poor. Usage and perception of thermal and non-thermal US did increase slightly post-educational intervention but returned to pre-educational intervention levels with the follow-up survey. Feedback from participants in this study showed that many did not have access to a US machine which can directly impact usage, perception, and knowledge. The results for each research question will be discussed below.

6.1.1. Research Question One

What effect does an educational intervention regarding therapeutic ultrasound have on the clinician's knowledge and perception of thermal ultrasound? The educational intervention had a positive effect on knowledge and perception of thermal ultrasound. Mean knowledge scores had the largest increased immediately following the educational intervention demonstrating it was effective (See Table 3 in Chapter 4). A statically significant increase in overall mean US knowledge scores was observed from the pre-educational intervention survey to the post-educational intervention survey. Results from the ANOVA were $F(2, 74) = 11.49$, $p < 0.0001$ (See Table 5 in Chapter 4). The Tukey-Kramer post hoc test revealed significant differences between the pre-educational session and the post-educational session (See Table 6 in

Chapter 4). Knowledge scores specific to thermal US followed the same pattern confirming the educational intervention was effective in increasing thermal US knowledge (See Table 4 in Chapter 4). However, results from the follow-up survey completed four weeks following the educational intervention showed that knowledge scores had returned close to pre-educational intervention levels exhibiting that the overall knowledge and thermal US knowledge was not well retained.

Perception levels of thermal ultrasound had a small, but not significant increase with each survey demonstrating the participants continued to perceive thermal US as a viable treatment option (See Table 7 in Chapter 4). This also indicates that the educational intervention provided the participants with the necessary information and research needed to increase their perception of the modality.

6.1.2. Research Question Two

Will an educational intervention regarding therapeutic ultrasound impact the clinician's knowledge and perception of non-thermal ultrasound? Overall US knowledge and knowledge specific to non-thermal ultrasound slightly increased following the educational intervention again demonstrating the educational intervention was successful at increasing overall and non-thermal US knowledge (See Table 13 in Chapter 5). A statically significant increase in overall mean US knowledge scores was observed from the pre-educational intervention survey to the post-educational intervention survey. Results from the ANOVA were $F(2, 74) = 11.49$, $p < 0.0001$ (See Table 11 in Chapter 5). The Tukey-Kramer post hoc test revealed significant differences between the pre-educational session and the post-educational session (See Table 12 in Chapter 5).

Participant perception of non-thermal US had a slight increase from pre-educational intervention levels again exhibiting that the information provided during the educational intervention was effective at increasing the participant's perception of non-thermal US (See Table 14 in Chapter 5). Although the increase was not statistically significant, improvements were made in mean non-thermal perception scores.

6.1.3. Research Question Three

Will an educational intervention regarding therapeutic ultrasound change the amount a clinician uses thermal ultrasound? Usage of thermal US did significantly change amongst the participants in this study demonstrating the educational intervention did not influence thermal US usage. Many of the participants never use thermal US, however; many did not have access to a US machine. A small shift was observed from the pre- to post-educational intervention with some "Never" responses changing to "Monthly" showing that some participants did change their usage after the educational intervention (See Table 17). Providing access to US and more education regarding thermal US is needed to help increase usage of thermal US in the future.

Table 17: Thermal US Usage

Frequency	Once a day	Bi-Weekly	Weekly	Bi-Monthly	Monthly	Never
Pre-educational intervention	1	1	4	3	5	17
	3.23%	3.23%	12.90%	9.68%	16.13%	54.84%
Post-educational intervention	1	1	3	3	7	14
	3.45%	3.45%	10.34%	10.34%	24.14%	48.28%
Follow-up-educational intervention	0	2	3	5	2	8
	0%	10%	15%	25%	10%	40%

6.1.4. Research Question Four

Will an educational intervention regarding therapeutic ultrasound change the amount a clinical uses non-thermal ultrasound? Like thermal US usage, non-thermal US usage did not significantly change among participants and the chosen responses were linear amongst educational interventions (See Table 18). The "Never" option was the most frequently chosen option among participants; however, many of them stated they did not have access to a US machine. Another common theme was that they did not have the knowledge or know how to set up non-thermal US which can decrease the usage of the modality. Many other factors can influence the usage of non-thermal US, but more education and research are needed in the future.

Table 18: Non-Thermal US Usage

Frequency	Bi-Weekly	Weekly	Bi-Monthly	Monthly	Never
Pre-educational intervention	1	1	4	5	19
	3.33%	3.33%	13.33%	16.67%	63.33%
Post-educational intervention	3	0	3	5	18
	10.34%	0%	10.34%	17.24%	62.07%
Follow-up-educational intervention	1	1	2	4	12
	5%	5%	10%	20%	60%

6.1.5. Research Question Five

Is there a difference in the effectiveness of the in-person educational intervention versus the virtual asynchronous educational intervention? No statistically significant differences in mean knowledge scores amongst ATs participating in the in-person versus virtual asynchronous educational intervention were found (See Table 5 in Chapter 4). However, mean knowledge scores were higher in the in-person educational intervention group when comparing the two groups. Mean knowledge scores for the in-person educational intervention can be found on Table 19 and the virtual asynchronous means are found in Table 20.

Table 19: In-Person Mean Knowledge Scores

Survey Session	Mean Score	Standard Deviation
Pre-educational intervention	7.15	±1.56
Post-educational intervention	9.38	±1.82
Follow-up educational intervention	8.33	±1.56

Table 20: Virtual Asynchronous Mean Knowledge Scores

Survey Session	Mean Score	Standard Deviation
Pre-educational intervention	7.00	±1.76
Post-educational intervention	8.94	±1.43
Follow-up educational intervention	7.64	±1.37

6.1.6. Research Question Six

Is it feasibility to provide continuing education for this study with the education methods and means provided? Yes, we do believe that this method was feasible as a continuing educational option for ATs. Overall mean scores did significantly increase following both educational intervention types indicating that the educational delivery was effective. Armstrong and Weidner[42] determined the most commonly reported barriers of CE among ATs were the cost of attendance, distance to travel, and the lack of financial assistance from their employer. This study eliminated all the common barriers mentioned above by providing free attendance and a virtual option which eliminates any travel distance. To add more incentive, we offered one (1) free BOC CEU and a chance to win a $20 Amazon gift card. To make this study even more feasible in the future, more in-person educational interventions could be offered several times a year and the virtual option could be available year-round. This would allow participants to choose what educational option and the time of year that works best for them to participate in the study.

6.2. Recommendations

Recommendations for future research would be increasing the recruitment area, offering more educational sessions, and incorporating learning retention techniques. The main limitation in this study was the sample size. Increasing the recruitment area and offering a larger window for educational sessions should help increase the sample size in the future. Our recruitment area was limited to allow the in-person educational sessions to be available to most participants if that was the educational intervention they chose. The virtual asynchronous option allows for participation anywhere in the world and can be done at the participant's leisure and could be offered for a longer timeframe. The in-person session could be performed at local, state, or national conferences, which would also help with recruitment numbers and increasing the sample size.

Results from this study concluded that overall mean knowledge scores significantly increased following the educational sessions. However, the follow-up survey knowledge mean scores decreased back to pre-educational session means exhibiting the knowledge was not well retained by the participants. Retention strategies such as personal journaling, topic reflection, and providing multiple, diverse breakout sessions could be instilled in future research to aid in knowledge retention.

6.3. Conclusion

In conclusion, both educational intervention types were effective at increasing knowledge immediately following the educational session. However, follow-up survey knowledge mean scores indicated that the knowledge was not retained well by the participants. Perception of both thermal and non-thermal increased following both educational intervention types again, signifying that the educational intervention was effective in conveying knowledge and increasing perception of US. Interestingly, knowledge and perception scores increased but usage of thermal and non-thermal US did not increase. However, when participants were asked why they did not use thermal or non-thermal US, many of their answers specified that they did not have access to a US machine. As for the two different intervention types, neither delivery method was superior to the other statistically. Providing continuing education with the means and methods available in this study appears to be feasible. Some minor adjustments and continuing to offer the educational sessions free of charge makes this study quite feasible. In the future, a larger sample size, offering more educational opportunities, and improving knowledge retention would all be great methodological additions to improve this study.

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APPENDIX A. SURVEY

Therapeutic Ultrasound Knowledge and Perception

Start of Block: Consent Form

Consent Form
Please read the consent form carefully. By clicking on to the next page, you are consenting to participate in this research study.

Health, Nutrition, and Exercise Science
1340 Administration Drive
Fargo, ND 58108-6050
701-231-7474

Therapeutic Ultrasound: Best Practice Techniques and Their Implications

This study is being conducted by: Mr. Michael Kjellerson, Ph.D. candidate in the Health, Nutrition, and Exercise Science department at North Dakota State University and Dr. Shannon David, Associate Professor, Professional Athletic Training Program Director at North Dakota State University.

Key Information about this study:

This consent form is designed to inform you about the study you are being asked to participate in. Here you will find a brief summary about the study; however you can find more detailed information later on in the form.

o We are conducting a research project to assess and understand individuals' perception and knowledge of therapeutic ultrasound. It is our hope, that with this research, we will learn more about individuals understanding of therapeutic ultrasound and if an educational session is beneficial to the participants.

o Must be a active Board of Certifications (BOC) Certified Athletic Trainers (ATs) from North Dakota who is 18 years of age or older and can read and write in English.

o Non-BOC certified students or retired ATs are excluded from the study.

o The risk of participating in this study is minimal. It is not possible to identify all potential risks in research procedures, but we have taken reasonable safeguards to minimize any known risks.

o By taking part in this research, you may not get any benefit from being in this study. Benefits to others and/or society are likely to include advancement of knowledge, and/or growth as a professional. Data collected from the survey will also be used to better improve educational focus of therapeutic ultrasound and its best practices.

Page 1 of 18

o This survey should take approximately 15 - 20 minutes to complete. A 60-minute educational session will then occur at the time you are assigned to. Four weeks following the educational session, you will be sent an email with a link to complete the survey again. The total time commitment for the study in its entirety will be approximately 90 – 100 minutes in length.

o There is no monetary compensation for this study, however one (1) BOC continuing education unit will be provided upon completion of the educational session.

o We will keep private all research records that identify you. You will not be identified in these written materials. We may publish the results of the study; however, we will keep your name and other identifying information private.

Why am I being asked to take part in this study?

You are being asked to take part in this study because you are a BOC Certified Athletic Trainer. We are conducting a research project to assess and understand individuals' perception and knowledge of therapeutic ultrasound. It is our hope, that with this research, we will learn more about individuals understanding of therapeutic ultrasound and if an educational session is beneficial to the participants.

What will I be asked to do?

Because you chose to volunteer for this study, you are invited to take part in our research project. Your participation is entirely voluntary, and you may change your mind or quit participating at any time, with no penalty to you. You are being asked to complete a survey on your understanding of therapeutic ultrasound related topics and complete one 60-minute educational session. This survey will take approximately 15 - 20 minutes to complete the questions regarding your knowledge, confidence, and perception of therapeutic ultrasound. There will be two surveys, one before the educational session and one four weeks following the educational session totaling 30 - 40 minutes of survey time. The 60-minute educational session will occur only once and will be in-person or virtual.

What are the risks and discomforts?

There is minimal risk involved in this study. It is not possible to identify all potential risks in research; however, reasonable safeguards have been taken to minimize known risks. If new findings develop during the course of the research which may change your willingness to participate, we will tell you about these findings.

What are the expected benefits of this research?

Individual Benefits: By taking part in this research, you may not get any benefit from being in this study. Data collected from the survey will also be used to better improve educational focus of therapeutic ultrasound and its best practices.

Societal Benefits: Benefits to others and/or society are likely to include advancement of knowledge, and/or growth as a professional.

Do I have to take part in this study?
Your participation in this research is your choice. If you decide to participate in the study, you may change your mind and stop participating at any time without penalty or loss of benefits to which you are already entitled.

Will it cost me anything to participate?
There is no cost associated with participation in this study.

What are the alternatives to being in this study?
Instead of being in this research, you may choose not to participate.

Who will have access to my information and how will my information be used?
Only the investigators of this study will have access to the information you submit. We will keep private all research records that identify you. Your information will be combined with information from other people taking part in this study, we will write about the combined information that we have gathered. You will not be identified in these written materials. We may publish the results of the study; however, we will keep your name and other identifying information private.

Can my participation in the study end early?
Your participation is entirely voluntary, and you may change your mind or voluntarily withdraw at any time, with no penalty to you.

Will I receive any compensation for participating in the study?
There is no monetary compensation for this study, however one (1) BOC continuing education unit will be provided upon completion of the educational session.

What happens if I am injured because of the study?
If you are injured during the course of this study, you should contact Michael Kjellerson at 701-730-2030. Treatment for the injury will be available including first aid, emergency treatment, and follow-up care as needed. Payment for this treatment must be provided by you and your third party payer (such as health insurance or Medicaid). This does not mean that you are releasing or waiving any legal right you might have against the researcher or NDSU as a result of you participation in this research.

What if I have questions?
Before you decide whether you'd like to participate in this study, please ask any questions that come to mind now. Later, if you have questions about the study, you can contact Michael Kjellerson at 701-730-2030 or michael.kjellerson@ndsu.edu, or Shannon David at 701-231-5686 or shannon.david@ndsu.edu.

What are my rights as a research participant?
You have rights as a research participant. All research with human participants is reviewed by a committee called the Institutional Review Board (IRB) which works to protect your rights and welfare. If you have questions about your rights, an unresolved question, a concern or complaint

about this research you may contact the IRB office at 701.231.8995, toll-free at 855-800-6717 or via email (ndsu.irb@ndsu.edu).

Documentation of Informed Consent:
You are freely making a decision whether to be in this research study. Signing this form means that:
1. You have read and understood this consent form
2. You have had your questions answered, and
3. You have decided to be in the study.

You will be given a copy of this consent form to keep.

By clicking on to the next page, you are consenting to participate in this research study.

Therapeutic ultrasound best practices consent form

End of Block: Consent Form

Start of Block: Directions

Directions Dear Participant, Our names are Mr. Michael Kjellerson, Ph.D. candidate in the Health Nutrition and Exercise Science at North Dakota State University and Dr. Shannon David, associate professor and program director at North Dakota State University. We are conducting a research project to assess and understand Athletic Trainers' use, confidence, perception, and knowledge of therapeutic ultrasound and its best practices. You are invited to take part in our research project. Your participation is entirely voluntary, and you may change your mind or quit participating at any time, with no penalty to you.

You are being asked to complete a survey on your use, confidence, perception, and knowledge of therapeutic ultrasound. This survey should take 15 to 20 minutes to complete. It is entirely electronic and will be returned to the data collection team automatically. Please read and answer each question carefully.

End of Block: Directions

Start of Block: Question Block

Question 1 What is your biological sex?

- ◯ Male (1)
- ◯ Female (2)
- ◯ Prefer not to say (3)

Question 2 What is your age?

- ◯ 18-29 years (1)
- ◯ 30-39 years (2)
- ◯ 40-49 years (3)
- ◯ 50-59 years (4)
- ◯ 60+ years (5)

Question 3 What is your primary work setting?

- ◯ College/University (1)
- ◯ Secondary School (2)
- ◯ Clinic and Hospital (3)
- ◯ Professional Sports (4)
- ◯ Emerging Setting ie. performing arts, public safety, military, occupational health. etc.. (5)

Question 4 How many years have you been a BOC Certified Athletic Trainer?

- ◯ 0-9 years (1)
- ◯ 10-19 years (2)
- ◯ 20-29 years (3)
- ◯ 30-39 years (4)
- ◯ 40-49 years (5)
- ◯ 50+ years (6)

Question 5 What is your highest educational degree earned?

- ◯ Bachelors Degree (1)
- ◯ Professional Masters Degree in AT (2)
- ◯ Professional Masters Degree in other area (3)
- ◯ Masters Degree (4)
- ◯ Doctoral Degree (5)
- ◯ Clinical Degree ie. DAT (6)

Question 6 Approximately how many continuing education hours, or any additional training outside of your formal education, have you completed on therapeutic ultrasound?

- ◯ 0 hours (1)
- ◯ 1-5 hours (2)
- ◯ 6-10 hours (3)
- ◯ 11-15 hours (4)
- ◯ 16-20 hours (5)
- ◯ 20+ hours (6)

Page Break

Question 7 The following questions are to examine your general use and confidence in thermal and non-thermal therapeutic ultrasound. Please choose the most appropriate answer.

How often do you use **thermal** ultrasound in your practice?

○ Once a Day (1)

○ Bi-Weekly (2)

○ Weekly (3)

○ Bi-Monthly (4)

○ Monthly (5)

○ Never (6)

Skip To: 7A If The following questions are to examine your general use and confidence in thermal and non-thermal... = Never

Skip To: Question 8 If The following questions are to examine your general use and confidence in thermal and non-thermal... = Once a Day

Skip To: Question 8 If The following questions are to examine your general use and confidence in thermal and non-thermal... = Bi-Weekly

Skip To: Question 8 If The following questions are to examine your general use and confidence in thermal and non-thermal... = Weekly

Skip To: Question 8 If The following questions are to examine your general use and confidence in thermal and non-thermal... = Monthly

Skip To: Question 8 If The following questions are to examine your general use and confidence in thermal and non-thermal... = Bi-Monthly

---

7A Please explain why you do not use **thermal** ultrasound?

____

Question 8 How often do you use **non-thermal** ultrasound in your practice?

- ◯ Once a Day (1)
- ◯ Bi-Weekly (2)
- ◯ Weekly (3)
- ◯ Bi-Monthly (4)
- ◯ Monthly (5)
- ◯ Never (6)

Skip To: 8A If How often do you use non-thermal ultrasound in your practice? = Never
Skip To: Question 9 If How often do you use non-thermal ultrasound in your practice? = Once a Day
Skip To: Question 9 If How often do you use non-thermal ultrasound in your practice? = Bi-Weekly
Skip To: Question 9 If How often do you use non-thermal ultrasound in your practice? = Weekly
Skip To: Question 9 If How often do you use non-thermal ultrasound in your practice? = Bi-Monthly
Skip To: Question 9 If How often do you use non-thermal ultrasound in your practice? = Monthly

8A Please explain why you do not use **non-thermal** ultrasound?

____

Page Break

Question 9 On a scale of 1-10, 1 being not confident at all and 10 being extremely confident, how confident are you in effectively using **thermal** therapeutic ultrasound with your current education/knowledge?

____

Question 10 On a scale of 1-10, 1 being not confident at all and 10 being extremely confident, how confident are you on choosing the proper **thermal** ultrasound parameters for a specific musculoskeletal injury/condition?

____

Page Break

Question 11 On a scale of 1-10, 1 being not confident at all and 10 being extremely confident, how confident are you in effectively using **non-thermal** therapeutic ultrasound with your current education/knowledge?

____

Question 12 On a scale of 1-10, 1 being not confident at all and 10 being extremely confident, how confident are you on choosing the proper **non-thermal** ultrasound parameters for a specific musculoskeletal injury/condition?

____

Page Break

Question 13 On a scale of 1-10, 1 being not confident at all and 10 being extremely confident, how confident are you on performing proper application techniques of therapeutic ultrasound?

____

Page Break

Question 14 The following questions are to examine your perception on the effectiveness of thermal and non-thermal therapeutic ultrasound. Please choose the most appropriate answer.

What is your perception on the following statements?

	Perception		
	Not Effective (1)	Somewhat Effective (2)	Effective (3)
How effective is thermal ultrasound in treating musculoskeletal injuries/conditions? (1)	○	○	○
How effective is non-thermal ultrasound in treating musculoskeletal injuries/conditions? (2)	○	○	○

Question 15 What is your perception on the following statement?

	Perception		
	Not Effective (1)	Somewhat Effective (2)	Effective (3)
How effective will an educational session focusing on best practice therapeutic ultrasound techniques be to you as a clinician and how you administer ultrasound? (1)	○	○	○

Page Break

Question 16 The following questions are intended to test your knowledge within various areas of therapeutic ultrasound. Please choose the most appropriate answer.

Based on the literature, what is the appropriate rate of speed while moving the ultrasound transducer head?

- ○ 1 - 2 centimeters per second (1)
- ○ 3 - 4 centimeters per second (2)
- ○ 7 - 9 centimeters per second (3)
- ○ 10 - 12 centimeters per second (4)

Question 17 What is the appropriate treatment area size when performing an ultrasound treatment according to the literature?

- ○ 1 - 2 times the size of the Effective Radiating Area (ERA) (1)
- ○ 3 - 4 times the size of the Effective Radiating Area (ERA) (2)
- ○ 5 - 7 times the size of the soundhead (3)
- ○ 3 - 4 times the size of the soundhead (4)

Question 18 What degree of tissue temperature increase above baseline should be obtained if the clinician wants to increase the viscoelastic properties of a tissue?

- ○ 1 - 2 Degree Celsius increase (1)
- ○ 3 - 4 Degree Celsius increase (2)
- ○ 5 - 6 Degree Celsius increase (3)
- ○ 7 - 8 Degree Celsius increase (4)

Question 19 What is the main determinant when choosing the frequency setting of an therapeutic ultrasound treatment?

- ◯ The Effective Radiating Area (ERA) of the ultrasound head (1)
- ◯ Rate of tissue temperature increase needed to achieve a treatment goal (2)
- ◯ The Beam Nonuniformity Ratio (BNR) of the ultrasound machine (3)
- ◯ The depth of the target tissue wishing to treat (4)

Question 20 What therapeutic ultrasound setting is most likely to influence whether a treatment is thermal or non-thermal?

- ◯ Intensity (1)
- ◯ Duty cycle (on/off time) (2)
- ◯ Duration (3)
- ◯ Frequency (4)

Question 21 Which muscular structure below warrants an ultrasound frequency of 3 Megahertz (MHz) during a therapeutic ultrasound treatment?

- ◯ Biceps Femoris (1)
- ◯ Soleus (2)
- ◯ Gluteus Maximus (3)
- ◯ Rhomboid Major (4)

Question 22 Which structure below warrants an ultrasound frequency of 1 Megahertz (MHz) during a therapeutic ultrasound treatment?

- ○ Plantar Fascia (1)
- ○ Medial Epicondyle of the Elbow (2)
- ○ Piriformis (3)
- ○ Gastrocnemius (4)

Page Break

Question 23 What therapeutic ultrasound setting has the ***largest effect*** on a **thermal** ultrasound's outcome when considering tissue temperature increases?

- ◯ Intensity (1)
- ◯ Duty rate/cycle (On/off time) (2)
- ◯ Duration (3)
- ◯ Choosing the size of the ultrasound head (4)

Question 24 What condition below is an indication for the use of **thermal** therapeutic ultrasound?

- ◯ An acute ankle sprain (1 day post injury) (1)
- ◯ Total joint replacement (performed 3 years ago) (2)
- ◯ Diabetic ulcers with decreased sensation (1 week) (3)
- ◯ Hamstring strain (2 weeks ago) (4)

Page Break

Question 25 What therapeutic ultrasound setting dictates the percentage of energy that is delivered to the tissue during a **non-thermal** ultrasound treatment?

○ Intensity (1)

○ Duty rate/cycle (On/off time) (2)

○ Duration (3)

○ Choosing the size of the ultrasound head (4)

Question 26 What condition below is the best indication for the use of **non-thermal** therapeutic ultrasound according to the best evidence available?

○ An acute ankle lateral sprain (1)

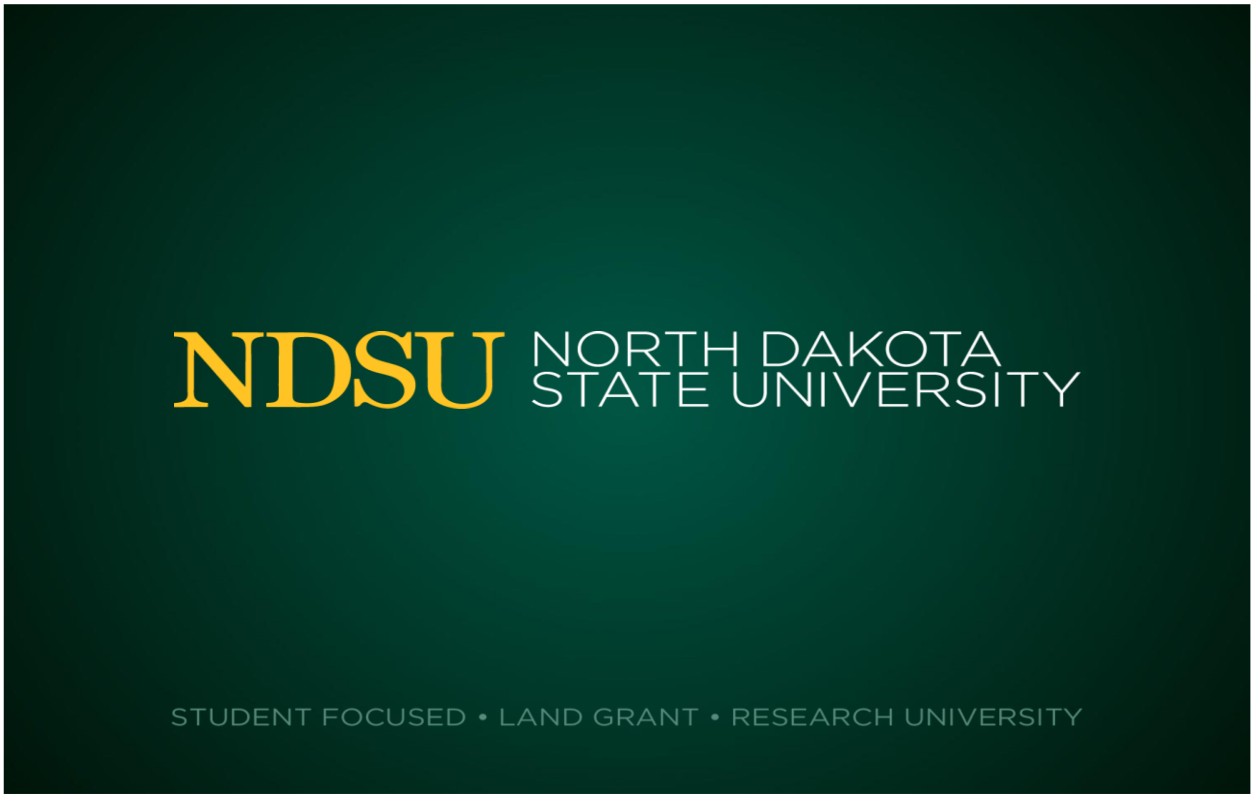
○ Chronic hamstring strain (2)

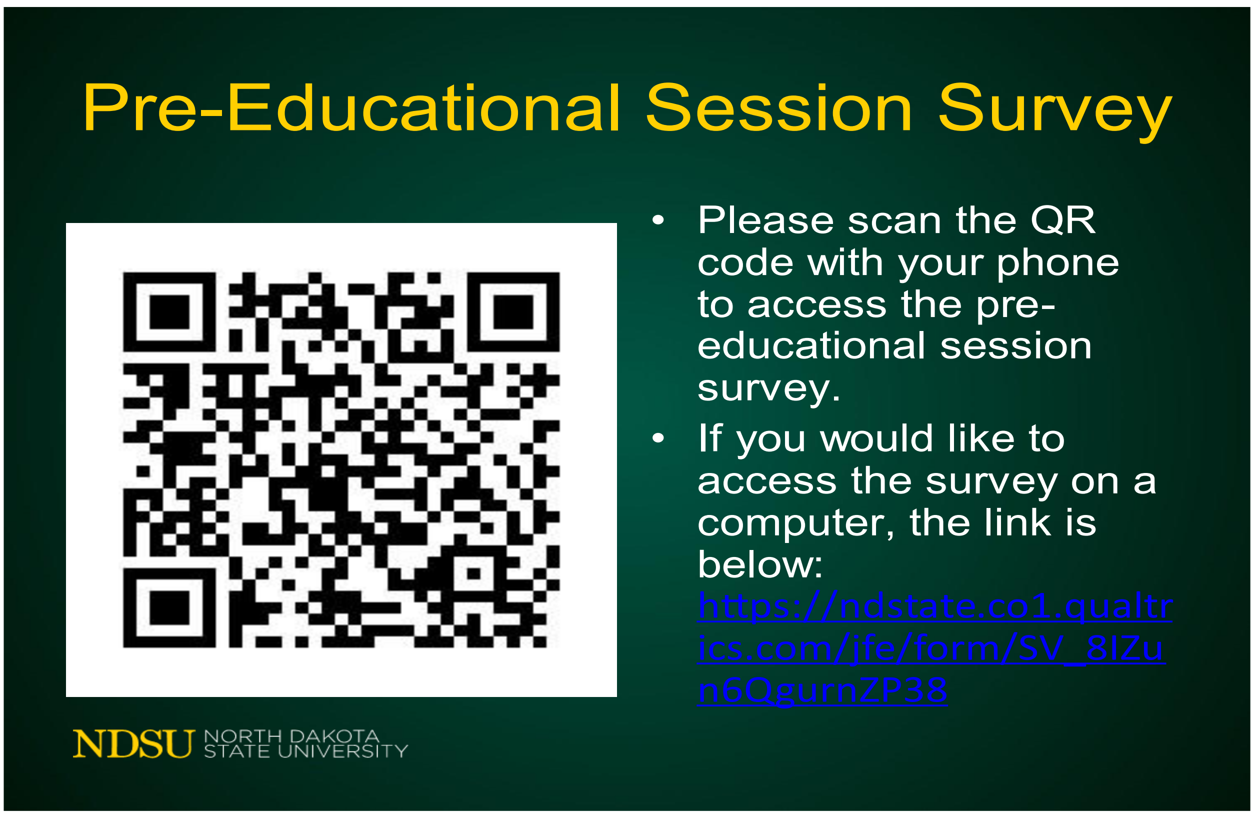
○ Elbow lateral epicondylitis (3)

○ Ganglion cyst on the wrist (4)

End of Block: Question Block

APPENDIX B. EDUCATIONAL INTERVENTION POWERPOINT





Therapeutic Ultrasound

Providing an Educational Intervention on Best Practice Techniques and Their Implications

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Objectives

- Interpret clinician knowledge and perception of therapeutic ultrasound.
- Classify the differences between thermal and non - thermal ultrasound.
- Explain the variation of heating rates amongst therapeutic ultrasound machines.
- Evaluate multiple variables that may affect therapeutic ultrasound (US) outcomes.
- Executing best practice techniques for therapeutic ultrasound.

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CLINICIAN KNOWLEDGE AND PERCEPTION OF THERAPEUTIC ULTRASOUND

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Clinicians Knowledge of Therapeutic Ultrasound

- US knowledge and perception levels of clinicians will often dictate whether US is used correctly, or if at all.
- Draper[1] stated that correct application of therapeutic ultrasound can aid in the treatment of musculoskeletal injuries, whereas incorrect application may reduce the desired physiological effects or even cause harm.

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Clinicians Knowledge of Therapeutic Ultrasound

- In 2015, Schellhase et al[2] surveyed collegiate level ATs on their perceived knowledge and actual knowledge.
  - Results revealed that ATs had confidence in their knowledge, but the actual scores were relatively low.
- In 2003, Chipchase et al[3] questioned physiotherapists in South Australia where 70% said they used US daily.
  - Results concluded that those with superior knowledge regarding optimum dosages were more likely to apply appropriate dosages and have better treatment outcomes.

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Clinicians Perception of Therapeutic Ultrasound

- Chipchase et al[10] also asked the same group of physiotherapists about their perception of the efficacy of US.
  - They determined respondents with higher overall knowledge scores reported a higher perceived US effectiveness on every musculoskeletal condition listed.
  - It was also concluded that higher perceived US effectiveness was reported by physiotherapists who used US in more than half of their treatment sessions.

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THERMAL VS NON-THERMAL THERAPEUTIC ULTRASOUND

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Thermal vs Non-Thermal US

- **Thermal US**
  - US energy is created 100% of the time throughout the treatment.
  - Used in post acute and chronic injuries/ailments.
- **Non-Thermal US**
  - US energy is dosed using an on/off cycle, energy is not present 100% of the time.
  - Used primarily in acute injuries but can also be used in post -acute and chronic injuries/ailments.

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Non-Thermal US

- Ultrasound energy is created via a pulsed mode that uses an on/off or duty cycle, so energy is only present a certain percentage of the time.
  – Most machines have a 10%, 20% and 50% duty cycle.
- Non-thermal US is commonly used in acute injuries with much of the research focusing on acute lateral ankle sprains.

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Non-Thermal US

- The pulsing created by non -thermal ultrasound waves creates acoustic microstreaming and cavitation.
  – Acoustic microstreaming is a unidirectional movement of fluids along the boundaries of the cell membrane which can alter the cell membrane's structure and function.
  – Cavitation is the formation of gas bubbles that expand and contract due to ultrasonic pressures again creating changes at a cellular level.

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Thermal Ultrasound
Mild Heating

- 1˚C tissue temperature increase (Mild heating) [4–7]
  - Increase metabolic rate
  - Reduces mild inflammation
  - Treats hematomas

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Thermal Ultrasound

- Every thermal US treatment should be performed with a goal in mind. These goals should be tissue temperature dependent.

- Mild heating = 1˚C ↑ of Tissue Temp.
- Moderate heating = 2˚- 3˚C ↑ of Tissue Temp.
- Vigorous heating = 4˚C ↑ of Tissue Temp.

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Thermal Ultrasound Moderate Heating

- 2 - 3˚C tissue temperature increase (Moderate heating) [4–7]
  - Reduce pain
  - Reduce muscle spasm
  - Reduce chronic inflammation
  - Increase blood flow
  - Treats trigger points

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Thermal Ultrasound Vigorous Heating

- 4˚C tissue temperature increase (Vigorous heating) [4–7]
  - Increases viscoelastic properties of tissue*
  - Scar tissue reduction*
  - Inhibits sympathetic activity

* Much more effective with IMMEDIATE stretch or mobilization (Stretching window)

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HEATING RATES AND THERAPEUTIC ULTRASOUND MACHINE VARIABILITY

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Therapeutic US Heating Rates

- Textbook recommendations chart showing heating rates per minute based on Omnisound 3000 US machine.[4-7]

Intensity	1 MHz	3 MHz
0.5	0.04°C	0.3°C
1.0	0.2°C	0.6°C
1.5	0.3°C	0.9°C
2.0	0.4°C	1.4°C

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Variations in Heating Rates Amongst US Machines

- In order to reach these specific tissue temperature goals, we must know the correct heating rates of each US machine.

- However, The FDA currently has no regulatory guidelines on the spatial average intensity (SAI) setting. The regulations pertain to the accuracy of the timer and the total displayed power vs actual energy produce, but a ±20% error band is permitted.

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Variations in Heating Rates Amongst US Machines

- Merrick et al.[11] examined heating rates amongst the Omnisound 3000C, Dynatron 950 and Excel Ultra III ultrasound machines.
- 3MHz at 1.5 W/cm^2 for 10 minutes. Thermocouples were at a 1.6 cm depth
  - The Omnisound's heating rate = ~1.0 C˚/min
  - The Dynatron 950's heating rate = ~0.4 C˚/min
  - The Excel Ultra III's heating rate = ~0.41 C˚/min

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Variations in Heating Rates Amongst US Machines

- Demchak et al.[12] researched heating rates amongst 3 different Omnisound 3000 ultrasound machines.

- 1MHz at 1.2 W/cm² for 10 minutes. Thermocouples were at a 3 cm depth
- Omnisound A's heating rate = ~0.32 C˚/min*
- Omnisound B's heating rate = ~0.31 C˚/min*
- Omnisound C's heating rate = ~0.5 C˚/min*

*Averages at the greatest tissue temperature increase

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THERAPEUTIC ULTRASOUND SETTINGS THAT IMPACT OUTCOMES: FREQUENCY

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Therapeutic US Frequency

- Frequency of the US determines the depth of penetration and is measured in Megahertz (MHz).

- **Frequency should be depth dependent, not temperature dependent.**

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1 MHz US Frequency

- The 1 MHz frequency is used for heating tissues ~ 2.5 – 5cm deep.[4]

- Tissues located approximately at these depths include:[4]
  - Piriformis
  - Soleus
  - Hip Adductors

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3 MHz US Frequency

- The 3 MHz frequency is used for heating any tissues less than 2.5 cm deep.[4]
- Tissues located approximately at these depths include:[13, 14]
  - Plantar Fascia
  - Patellar Tendon
  - Elbow Epicondyles

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THERAPEUTIC ULTRASOUND SETTINGS THAT IMPACT OUTCOMES: INTENSITY

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Therapeutic US Intensity

- Intensity of an US treatment dictates the amount of energy being delivered by the US beam and is measured in Watts per centimeter squared (W/cm^2).
- **Intensity should be temperature dependent, not depth dependent!**

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Therapeutic US Intensity

- There are no definitive guidelines for selecting US intensities, however if the intensity is too high, tissue damage may occur.[4,15]
- Many studies have proven that US machines, even the same brand, produce different heating rates at the same intensity settings.[11-13,16]

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THERAPEUTIC ULTRASOUND SETTINGS THAT IMPACT OUTCOMES: TREATMENT TIME

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Therapeutic US Treatment Time

- The length of the treatment is decided by the size of the area to be treated, the ultrasound frequency, the intensity in W/cm2, and the desired tissue temperature increase.[17]
  - A lower intensity will require a longer treatment time.
  - 3 MHz heats up 3 times faster than 1 MHz so the treatment time is shorter with a 3 MHz US.[4,18]
  - A treatment area larger than 2 -3 times the effective radiating area (ERA) of the soundhead will require a longer treatment time.

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THERAPEUTIC ULTRASOUND SETTINGS THAT IMPACT OUTCOMES: TREATMENT AREA

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Therapeutic US Recommended Treatment Area

- It is recommended that the treatment area is no larger than 2 – 3 times larger than the size of the effective radiating area (ERA) of the soundhead.[7,19,20]

- Chan et al[21] found that a treatment size 2 times the size of the ERA had a higher heating rate than 4 times the size of the ERA demonstrating that treatment area will impact the outcome of your treatment.

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THERAPEUTIC ULTRASOUND SETTINGS THAT IMPACT OUTCOMES: ULTRASOUND TRANSDUCER HEAD SPEED

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Therapeutic US Recommended Transducer Speed

- It is recommended by many studies that the transducer be moved at a rate of 3 – 4 centimeters per second (cm/s).[17,22-24]
- However, a study by Weaver et al[22] demonstrated that tissue temperature increases were very similar with transducer velocities of 2 – 8 cm/s using the same settings for each treatment.

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Therapeutic US Recommended Transducer Speed

- Draper[17] recommends slow strokes at a rate of approximately 3 – 4 cm/sec stating that rapid strokes can cause the clinician to slip into treating a larger treatment area which will affect the desired temperature goal since the area will likely be larger than the recommended 2 – 3 times the ERA.

- Using slow transducer movements during an ultrasound treatment will also allow for evenly distributed sound waves throughout the area.[17,20]

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DEMONSTRATION OF BEST PRACTICE TECHNIQUES FOR THERAPEUTIC ULTRASOUND

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Therapeutic Ultrasound Set Up

- **Choose US frequency** – depth dependent, not temperature dependent!
- **Choose US intensity** – temperature dependent, not depth dependent.
- **Choose US treatment area** – 2 to 3 times the size of the ERA.
- **Choose US treatment time** – dependent on frequency, intensity, and treatment area.
- **Appropriate transducer speed** – The majority of research suggest a rate of 3 – 4 cm/second.

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Therapeutic Ultrasound Set Up - Frequency

- Choosing US frequency
  - Determine the tissue depth
  - 1 MHz frequency should be chosen for tissues between 2.5 and 5 cm (~ 1 – 2 inches).
    - Glutes, piriformis, soleus, hamstrings, quad.
  - 3 MHz frequency should be chosen for tissues less than 2.5 cm deep.
    - Plantar fascia, elbow condyles, gastrocnemius, patellar/quad tendon, paraspinals, rhomboids.

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Therapeutic Ultrasound Set Up - Intensity

- Choosing US intensity
  - There are no definitive guidelines for selecting US intensities, however if the intensity is too high, tissue damage may occur.[4,15]
  - It is suggested that clinicians follow general heating rate guidelines.
  - That doesn't help me set a proper US intensity! Do what ATs do best, improvise!

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Therapeutic Ultrasound Set Up - Treatment Area

- The appropriate ultrasound treatment area size is 2 - 3 times the size of the ERA of the crystal housed inside the ultrasound transducer.[25,26]

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Therapeutic Ultrasound Set Up - Treatment Time

- Choose US treatment time
  - Dependent on US frequency – 3MHz heats up 3 times fast so require 1/3 less treatment time than 1 MHz US treatments.
  - Dependent on US intensity – ↑ intensity have ↑ rate of temperature increase which ↓ the needed treatment time and vice versa.
  - Treatment area – if going outside of the recommended 2 – 3 times ERA more time should be added.

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Therapeutic Ultrasound Set Up - US Transducer Speed

- It is recommended by many studies that the transducer be moved at a rate of 3 – 4 centimeters per second (cm/s).[17,22-24]

- Use of a metronome can be a useful tool.

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Therapeutic US Recommended Treatment Area

- It is recommended that the treatment area is no larger than 2 – 3 times larger than the size of the effective radiating area (ERA) of the soundhead.[7,19,20]

- Chan et al[21] found that a treatment size 2 times the size of the ERA had a higher heating rate than 4 times the size of the ERA demonstrating that treatment area will impact the outcome of your treatment.

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Exit Survey

- Please scan the QR code to access the exit survey.
- If you would like to access the survey on a computer, the link is below: https://ndstate.co1.qualtrics.com/jfe/form/SV_8lZun6QgurnZP38
- A final survey will be emailed to you in approximately 4 weeks. All surveys must be completed to be entered into the Amazon gift card drawing

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APPENDIX C. IRB APPROVAL LETTER

04/24/2023

Dr. Shannon
Lyn David
Misialek
Health,
Nutrition &
Exercise

Re: IRB Determination of Exempt Human Subjects Research:
Protocol #IRB0004650, “Therapeutic Ultrasound: Best Practice and Their Implications”

NDSU Co-investigator(s) and research team:

- Shannon Lyn David Misialek
- Michael C Kjellerson

Approval Date: 04/24/2023
Expiration Date: 04/23/2026
Study site(s): Research will be performed on the NDSU campus for the in-person session. The online session will be done online asynchronously.
Funding Source:
The above referenced human subjects research project has been determined exempt (category 1) in accordance with federal regulations (Code of Federal Regulations, Title 45, Part 46, *Protection of Human Subjects*).

Please also note the following:

- The study must be conducted as described in the approved protocol.
- Changes to this protocol must be approved prior to initiating, unless the changes are necessary to eliminate an immediate hazard to subjects.
- Promptly report adverse events, unanticipated problems involving risks to subjects or others, or protocol deviations related to this project.

Thank you for your cooperation with NDSU IRB procedures. Best wishes for a successful study.

NDSU has an approved FederalWide Assurance with the Department of Health and Human Services: FWA00002439.

APPENDIX D. CONSENT FORM

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Health, Nutrition, and Exercise Science
1340 Administration Drive
Fargo, ND 58108-6050
701-231-7474

Therapeutic Ultrasound: Best Practice Techniques and Their Implications

This study is being conducted by: Mr. Michael Kjellerson, Ph.D. candidate in the Health, Nutrition, and Exercise Science department at North Dakota State University and Dr. Shannon David, Associate Professor, Professional Athletic Training Program Director at North Dakota State University.

Key Information about this study:

This consent form is designed to inform you about the study you are being asked in which to participate. This consent form is also available on the first page of the survey on Qualtrics. It reads "Please read the consent form carefully. By clicking on to the next page, you are consenting to participate in this research study."

Below you will find a brief summary about the study; however, you can find more detailed information later on in the form.

- We are conducting a research project to assess and understand individuals' use, confidence, perception and knowledge of therapeutic ultrasound. It is our hope, that with this research, we will learn more about individuals understanding of therapeutic ultrasound and if an educational session is beneficial to the participants.
    - Must be an active Board of Certifications (BOC) Certified Athletic Trainers (ATs) from North Dakota who is 18 years of age or older and can read and write in English.
    - Non-BOC certified students or retired ATs are excluded from the study.
    - The risk of participating in this study is minimal. It is not possible to identify all potential risks in research procedures, but we have taken reasonable safeguards to minimize any known risks.
    - Benefits to others and/or society are likely to include advancement of knowledge, and/or growth as a professional. Data collected from the survey will also be used to better improve the educational focus of therapeutic ultrasound and its best practices.
    - The time commitment is approximately 10 – 15 minutes to complete the survey, which will occur three times totaling a time of 30 – 45 minutes. One 60-minute educational session will occur between the first two surveys. The final survey will occur approximately four weeks following the educational session. The total time commitment will be approximately 90 – 105 minutes in length.

- By taking part in this research, you are included in a random drawing for a $20 Amazon gift card upon completion of the final survey. Also, one (1) BOC continuing education unit will be provided upon completion of the educational session.
- We will keep private all research records that identify you. You will not be identified in these written materials. We may publish the results of the study; however, we will keep your name and other identifying information private.

Why am I being asked to take part in this study?

You are being asked to take part in this study because you are an Athletic Trainer. We are conducting a research project to assess and understand individuals' perception and knowledge of therapeutic ultrasound. It is our hope that with this research, we will learn more about individuals understanding of therapeutic ultrasound and if an educational session is beneficial to the participants.

What will I be asked to do?

Because you chose to volunteer for this study, you are invited to take part in our research project. Your participation is entirely voluntary, and you may change your mind or quit participating at any time, with no penalty to you. You are being asked to complete a survey on your understanding of therapeutic ultrasound related topics and complete one 60-minute educational session. This survey will take approximately 10 - 15 minutes to complete the questions regarding your knowledge, confidence, and perception of therapeutic ultrasound. There will be three surveys, one before the educational session, one following the educational session, and one four weeks following the educational session totaling 30 - 40 minutes. The educational session will occur only once and will be in-person or virtual.

What are the risks and discomforts?

There is minimal risk involved in this study. It is not possible to identify all potential risks in research; however, reasonable safeguards have been taken to minimize known risks. If new findings develop during the course of the research, which may change your willingness to participate, we will tell you about these findings.

What are the expected benefits of this research?

Individual Benefits: By taking part in this research, you may not get any benefit from being in this study. Data collected from the survey will also be used to better improve the educational focus of therapeutic ultrasound and its best practices.

Societal Benefits: Benefits to others and/or society are likely to include advancement of knowledge, and/or growth as a professional**.**

Do I have to take part in this study?

Your participation in this research is your choice. If you decide to participate in the study, you may change your mind and stop participating at any time without penalty or loss of benefits to which you are already entitled.

Will it cost me anything to participate?

There is no cost associated with participation in this study.

What are the alternatives to being in this study?

Instead of being in this research, you may choose not to participate.

Who will have access to my information and how will my information be used?

Only the investigators of this study will have access to the information you submit. We will keep private all research records that identify you. Your information will be combined with information from other people taking part in this study, we will write about the combined information that we have gathered. You will not be identified in these written materials. We may publish the results of the study; however, we will keep your name and other identifying information private.

Can my participation in the study end early?
Your participation is entirely voluntary, and you may change your mind or quit participating at any time, with no penalty to you. However, you will be taken out of the drawing for the Amazon gift card.

Will I receive any compensation for participating in the study?
By taking part in this research, you are included in a random drawing for a $20 Amazon gift card upon completion of the study. Also, one (1) BOC continuing education unit will be provided upon completion of the educational session.

What if I have questions?
Before you decide whether you'd like to participate in this study, please ask any questions that come to mind now. Later, if you have questions about the study, you can contact Michael Kjellerson at ###-###-#### or michael.kjellerson@ndsu.edu, or Shannon David at 701-231-5686 or shannon.david@ndsu.edu.

What are my rights as a research participant?
You have rights as a research participant. All research with human participants is reviewed by a committee called the *Institutional Review Board (IRB)* which works to protect your rights and welfare. If you have questions about your rights, an unresolved question, a concern, or complaint about this research you may contact the IRB office at 701.231.8995, toll-free at 855-800-6717 or via email (ndsu.irb@ndsu.edu).

Documentation of Informed Consent:
You are freely making a decision whether to be in this research study. By clicking on to the second page of the survey you are consenting to participate in this research study, meaning that:

1. you have read and understood this consent form
2. you have had your questions answered, and
3. you have decided to be in the study.