CONTINUING EDUCATION
for Physical Therapists

EVIDENCE-BASED APPLICATION OF THERAPEUTIC ULTRASOUND

PDH Academy Course #PT-1707 | 2 CE HOURS

Course Abstract

This course examines the evidence behind the use of ultrasound in therapeutic settings. It covers pain, inflammation, soft tissue compliance, wound care, and phonophoresis.

NOTE: Links provided within the course material are for informational purposes only. No endorsement of processes or products is intended or implied.

Approvals

To view the states that approve and accept our courses, visit www.pdhtherapy.com/physical-therapy/.

Target Audience & Prerequisites

PT, PTA – no prerequisites

Learning Objectives

By the end of this course, learners will:

- ❑ Recall indications and contraindications for ultrasound
- ❑ Recognize parameters and basic terms associated with ultrasound
- ❑ Identify elements of ultrasound delivery
- ❑ Distinguish between evidence-based principles pertaining to each of the clinical applications of electrical stimulation

Timed Topic Outline

I. History & Principles of Ultrasound (5 minutes)
II. Physiology of Ultrasound (5 minutes)
III. Ultrasound Parameters and Basic Terms (30 minutes)
IV. Ultrasound Delivery (10 minutes)
V. Evidence-based Treatment (60 minutes)
Pain, Inflammation, and Soft Tissue Compliance;
Wound Care; Phonophoresis
VI. References and Exam (10 minutes)

Delivery Method

Correspondence/internet self-study with a provider-graded multiple choice final exam. *To earn continuing education credit for this course, you must achieve a passing score of 80% on the final exam.*

Cancellation

In the unlikely event that a self-study course is temporarily unavailable, already-enrolled participants will be notified by email. A notification will also be posted on the relevant pages of our website.

Customers who cancel orders within five business days of the order date receive a full refund. Cancellations can be made by phone at (888) 564-9098 or email at support@pdhacademy.com.

Accessibility and/or Special Needs Concerns?

Contact customer service by phone at (888)564-9098 or email at support@pdhacademy.com.

Course Author Bio and Disclosure

Dawn T. Gulick, PT, PhD, ATC, CSCS, is a Professor of Physical Therapy at Widener University in Chester Pennsylvania. She has been teaching for over 20 years. Her areas of expertise are orthopedics, sports medicine, modalities, and medical screening. As a clinician, she has owned a private orthopedic/sports medicine practice. She also provides athletic training services from the middle school to elite Olympic/Paralympic level. As a member of the Olympic Sports Medicine Society, Dr. Gulick has provided medical coverage at numerous national and international events. As a scholar, Dr. Gulick is the author of 4 books (*Ortho Notes, Screening Notes, Sport Notes, Mobilization Notes*), 4 book chapters, and over 50 peer-reviewed publications, and has made over 100 professional and civic presentations. She is the developer of a mobile app called iOrtho+ (Apple, Android, & PC versions), and the owner of a provisional patent.

Dr. Gulick earned a Bachelor of Science in Athletic Training from Lock Haven University (Lock Haven, PA), a Master of Physical Therapy from Emory University (Atlanta, GA), and a Doctorate of Philosophy in Exercise Physiology from Temple University (Philadelphia, PA). She is an AMBUCS scholar and a member of Phi Kappa Phi Honor Society. As a licensed physical therapist, she has direct access authorization. She also is a certified strength and conditioning specialist.

Dawn T. Gulick sells iOrtho+, a mobile app, through Therapeutic Articulations LLC; receives royalties as an author with F. A. Davis Publishing; and received a stipend as the author of this course. She has no other relevant financial or nonfinancial relationships to disclose.

History & Principles of Ultrasound

Ultrasound waves are the result of a (reverse) piezoelectric effect: when a voltage is applied in given direction, the crystal will contract and when the voltage is reversed, the crystal expands. This contraction and expansion of the crystal produces an ultrasound wave (figure 1).

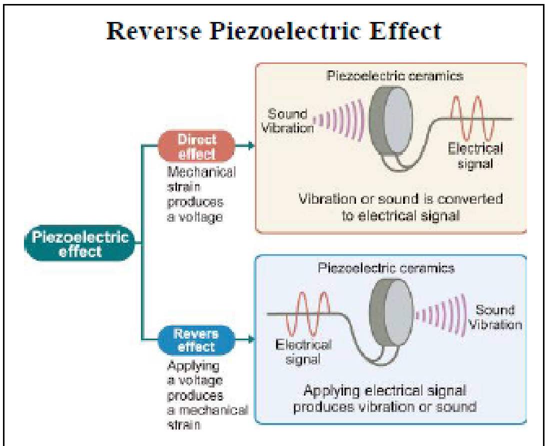


Figure 1

The application of ultrasound came to the forefront during World War II via the use of sonar systems to navigate submarines. The realization that high intensity ultrasound waves could be used for heating and healing led to the clinical application in the 1940s.

Ultrasound is a modality that is used in a variety of ways, determined by the frequency of the waves. Low frequency diagnostic ultrasound is used for imaging of internal structures. Therapeutic ultrasound is used for soft tissue interventions. High frequency destructive ultrasound is used for tissue irradiation, i.e. lithotripsy.

The focus of this course is on therapeutic ultrasound. This is one of the most commonly used modalities in clinical practice.

Physiology of Ultrasound

The biophysical effects of ultrasound can be identified as either thermal or non-thermal.

Thermal effects are the result of the absorption and attenuation of the sound waves in the tissues. As ultrasound waves are absorbed by the tissue, the vibrational energy is converted to heat. With the absorption, the waves are attenuated, i.e. reduced in amplitude as a function of the distance traveled through the tissue. Table 1 displays the absorption and penetration of ultrasound waves based on the tissue medium.

Table 1: Absorption & Penetration of Ultrasound Waves by Tissue		
Tissue	Absorption	Penetration
Water	1 dB	1200 dB
Blood	23-60 dB	20-52 dB
Fat	390 dB	4 dB
Muscle	663 dB	2 dB
Nerve	1193 dB	1 dB

This is important because the type of tissue being treated will influence the intensity needed for a given treatment. Intensity will be addressed is one of the treatment parameters later in the course. The physiologic influences of thermal ultrasound include:

- Increased tissue temperature
- Increased collagen extensibility
- Increased blood flow
- Increased enzymatic activity
- Decreased muscle guarding
- Increased nerve conduction velocity
- Increased pain threshold

Non-thermal effects are the result of cavitation, microstreaming, and acoustic streaming. Cavitational effects result from the vibration of the tissue causing microscopic bubbles to form, which transmit the vibrations to stimulate cell membranes. This stimulation appears to enhance the cell-repair effects of the inflammatory response. Other mechanical (non-thermal) effects include degranulation of mast cells to cause histamine release, increased phagocytic activity, increased macrophage activity, increased protein synthesis, and wound contraction (Cameron, 2003; Prentice, 2012).

Common clinical uses of therapeutic ultrasound include muscle guarding and pain control, tissue extensibility, trigger point management, wound healing and debridement, fracture repair, enhanced tendon and ligament healing (-itis), and resorption of calcium deposits, hematomas, and drug transmission (Cameron, 2003; Prentice, 2012).

On the other hand, contraindications for US include:

- Malignancy, TB, & hemophilia
- Genitals, brain, eyes, pacemaker, carotid sinus
- Pregnancy
- Epiphyseal plates
- Ischemic areas, peripheral vascular disease, thrombus
- Area of compromised sensation
- Over the spinal cord after a laminectomy

Furthermore, there are a number of conditions on which we do not completely understand the effect of US. These are areas we should treat with caution:

- Metal plates
- Screws
- Rods
- Gortex tubes

For many years, joint arthroplasties were also included as a contraindication for US. But in 2007, Gulick, Nevulis, Fagnani, Long and Morris put a hip replacement in a pig. They performed serial CT-scans of the hip after each set of 10 US treatments, for a total of five CT-scans over 50 US treatments. The treatment parameters were 1-MHz frequency with a 5 cm^2 transducer at 1.5 W/cm^2 using overlapping circles in a 3x-ERA for 10 minutes. In summary, there was no disruption of the methyl methacrylate at any of the Gruen Zones. Thermistors placed next to the hip implant permitted the collection of temperature data. The authors concluded that neither the thermal nor mechanical influence of US had a deleterious effect on a hip arthroplasty.

Ultrasound Parameters and Basic Terms

The literature suggests that terms and application techniques that were taught in the classroom are often forgotten after a little time in clinical practice. Many clinicians do not have the time to keep up with all the literature nor the ability to access a vast array of journals containing the information. Thus, this course will review the treatment parameters as well as discuss the clinical relevance.

Conduction mediums are at the center of one such clinical decision. Water is considered to be the gold standard for conduction and lends itself to the treatment of irregular contours very well (Cameron, 2003). For example, feet and hands with undulations in the tissue surface can be challenging to maintain consistent contact with the US transducer. Rendering treatment underwater can mitigate this issue (figure 2). However, a study by Draper, Sunderland, Kirkendall, and Ricard (1993) compared underwater US to that administered with topical gel (n=20). The researchers performed both treatments at 1.5 W/cm^2 for 10 minutes. The transducer was moved at 4 cm/sec and the muscular tissue temperature was measured with a thermistor 3 cm below the skin surface. The results are displayed in table 2:

Underwater Ultrasound

Figure 2

Table 2: Gel vs. Underwater Ultrasound Tissue Temperature Increase		
Condition	Temperature Increase	Percent Temperature Increase
Gel	4.8°C	13.9%
Underwater	2.1°C	6%

Although the frequency of US was not indicated, these results reveal a significantly greater magnitude of tissue heating with gel as compared to underwater. However, there were two other parameters not disclosed in the literature: the temperature of the water and the distance of the transducer from the skin when underwater. Both of these items could have had an impact on the results. One should consider the temperature of the water when using it as a medium. Subacute treatments may warrant using cold water for a non-thermal effect versus chronic injuries where deep heating is desirable should use warm/hot water. When underwater, the distance of the transducer from the skin need only be enough to create a thin layer for transmission of the sound waves. There are no known studies exploring the dissipation of sound waves when underwater to make a more specific recommendation.

Nonetheless, not all irregular surfaces are conducive to being placed underwater. If the anatomic contour is irregular but cannot be placed underwater, another option is to use a gel pad (figure 3). Draper, Edvalson, Knight, Eggett, and Shurtz (2010) studied the use of full and half-thicken gel pads on the human Achilles tendon (n=48). Thermocouples were placed 1 cm deep into the Achilles tendon to monitor temperature increase with 1 cm and 2 cm thick gel pads compared to gel. All treatments were with 3-MHz US for 10 minutes at 1.0 W/cm². The results demonstrated the following temperature increases:

Ultrasound with Gel Pad

Figure 3

- US Gel = 13.3° C
- 1 cm Gel Pad = 9.3° C
- 2 cm Gel Pad = 6.5° C

The conclusion was the thinner gel pad was more conducive to tissue heating.

Typical US is delivered with ultrasonic gel or lotion. Transmission of the sound waves through the gel/lotion has been estimated to be 90-96% of water transmission (Cameron, 2003). Commercial devices are available to heat the US gel but the therapeutic effects are questionable. The warmth of the gel is certainly more comfortable for the patient. Despite storing the gel at room temperature (~70°F), the gel always feels cold to the patient when skin temperature is approximately 92°F. However, heating the gel results in a decrease in viscosity and makes it harder to keep the gel contained, i.e. it slides off the skin when the slightest of curvature is present. So heating US gel is not always desirable. There is one important point that should not go unstated about US gel. Spratt, Levine, and Tillman (2014) inspected the clinical therapeutic US equipment for bacterial contamination. They reported 52.7% of the tips of US gel bottles tested positive for non-specific bacterial contamination and 3.6% were positive for MRSA. In 14.5% of the US gels, there was non-specific bacteria. Moreover, 35.5% of the US transducers were contaminated with bacteria. Based on this data, clinicians are strongly recommended disinfection of the US transducers between clinical treatments and avoiding touching the tip of the US gel to the patient during application.

The use of other conductive mediums has also been explored. Flex-All® is one such medium. Draper and Anderson (2004) conducted a study to determine if Flex-All® conducted US waves. Flex-All® is a substance containing menthol (alcohol obtained from the oil of peppermint plants), an anesthetic used to depress cutaneous sensory receptors. When mixed in a 3:1 US gel to Flex-All® concoction, the following treatments were performed:

- 1-MHz x 10 min @ 1.25 w/cm² with gel
- 1-MHz x 10 min @ 1.25 w/cm² with Flex-All®
- 3-MHz x 5 min @ 1.42 w/cm² with gel
- 3-MHz x 5 min @ 1.42 w/cm² with Flex-All®

The outcome measures were the tissue temperature at 2 and 4 cm depth. The results were no difference in tissue temperature with gel versus Flex-All®. Thus, the conclusion was 25% Flex-All® combined with 75% US gel was capable of providing pain-relieving effects with the added benefit of deep heating.

Effective radiating area (ERA) is defined as the area of the transducer over which the energy radiates. ERA more directly indicates the size of the crystal found within the transducer and does not always equal the size of the transducer head. The fact that the size of the transducer does not always correlate with the size of the ERA is not always taken into consideration when applying ultrasound to the treatment area. A study by John, Straub, and Howard (2007) inspected the mean measured ERA relative to the transducer surface area. The reported versus measure ERA and the ERA to transducer size percentage is displayed in table 3.

Table 3: Reported vs. Measured Ultrasound ERA by Device				
3-MHz Transducer	**Measurement**	**ERA Area (cm^2)**	**Percentage**	**ERA Percent to Transducer Surface Area**
Chattanooga	Reported Measured	4.00 4.89	+ 22.2%	48%
Dynatron	Reported Measured	5.00 4.83	- 3.4%	45%
Mettler	Reported Measured	5.00 5.64	+ 12.8%	85%
Omnisound	Reported Measured	4.50 4.56	+ 1.3%	65%
Rich-Mar	Reported Measured	5.00 4.55	- 9%	65%
XLTEK	Reported Measured	5.00 5.56	+ 11.2%	79%

Other studies have also compared the size of the transducers to reported ERA (Johns, Staub, & Howard, 2007). It is important to emphasize transducer size is important when matching it to the body part being treated but it is the ERA that determines the area emitting US waves. Since the treatment area should not be more than two to four times the size of the ERA, if the transducer is 10 cm^2 but the ERA is 8 cm^2, the clinician could be misguided into thinking that a 20 cm^2 to 40 cm^2 area could be treated with this transducer. In actuality, based on the ERA, the treatment area should be no greater than a 16 cm^2 to 32 cm^2 area.

Chudliegh, Schulthies, Draper, and Myrer (1997) compared the muscle temperature rise with 1-MHz ultrasound on treatment sizes of two and six times the effective radiating area of the transducer. Temperature increased by 3.4°C and 1.1°C for the two and six ERA treatments, respectively. This is a very significant difference if the treatment expectation were to be tissue heating. Thus, treatment could be ineffective if spread over too large an area. The ultrasound may not provide adequate heating when the sound waves are dispersed over too wide an area for too short a period of time. It is incumbent upon the clinician to know the limitations of the US unit being used. All units provide manufacturer labeling detailing ERA and BNR (to be discussed below).

Frequency, measured in Hertz, is the number of compression and rarefaction cycles per unit of time of the crystal found within the transducer (Cameron, 2003). The frequency is inversely related to the depth of tissue penetration (figure 4). In other words, an increase in the frequency of 1-MHz to 3-MHz decreases the depth of tissue penetration from 5 cm to 2.5 cm, respectively. Despite being a well-known relationship, a study by Wong, Schumann, Townsend, and Phelps (2007) of 457 licensed physical therapists with orthopedic clinical specializations revealed this information may not be as wide-spread as one thinks. Of the 203 respondents, 6% erroneously reported 3-MHz would be the treatment of choice for deep tissue pathologies in which pain, inflammation, swelling, and tissue extensibility are desired. Likewise, 15% erroneously indicated a 1-MHz frequency should be used for superficial pathologies. Based on the current literature, there is ample evidence to support the use of 1-MHz frequency ultrasound to target up to 5 cm in depth, while 3-MHz frequency will target more superficial tissue at 2.5 cm (Chan et al, 1998; Draper et al, 1995; Draper & Ricard, 1995). Knowledge of the depth of the tissue being targeted and the frequency required to reach that tissue depth will certainly enhance therapeutic ultrasound effectiveness (figure 5).

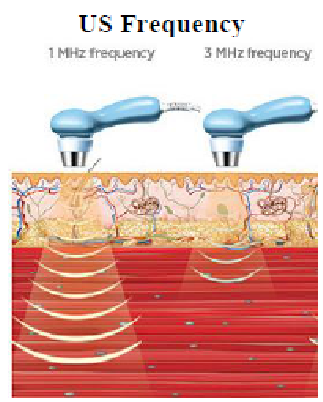


Figure 4

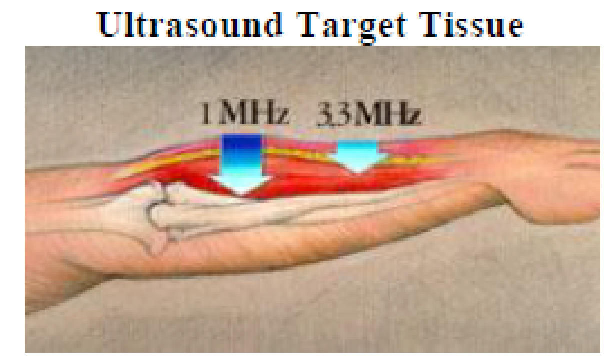


Figure 5

Beam non-uniformity ratio (BNR) is the ratio of the spatial peak intensity to the spatial average intensity (Cameron, 2003). For clarification purposes, the spatial average intensity is the intensity selected by the clinician (0.5 W/cm^2 to 3.0 W/cm^2) on the treating device. Because of the somewhat irregular crystal formation resulting in irregular energy output, the ultrasound can reach a peak intensity much greater than the average intensity during ultrasound application. Transducers BNRs can range between 2:1 and 6:1, with most being in the 5:1 - 6:1 span. If the BNR is listed as 5:1 and the intensity chosen by the therapist is 1 W/cm^2, there is the opportunity for the spatial peak to reach upwards of 5 W/cm^2 during treatment. This generally is not a problem at an intensity of 1 W/cm^2. However, at 2.5 W/cm^2, peaks of 12.5 W/cm^2 are possible. At 10 W/cm^2, the patient will experience intense spikes that are often painful. This was evidenced in a study by Young, Kimura, and Gulick (1999). They examined the output of four different US units with a hydrophone. The intensity was standardized at 1.5 W/cm^2 and the output was mapped across the US head (figure 6). Despite the machines being calibrated, the measures were significantly different across units. Some units with a high BNR (5:1) had significant "hot spots" whereas others with lower BNRs (2.1) had a more uniformed heating. Thus, a machine with a high BNR will adversely affect the clinician's ability to employ an intensity to achieve vigorous heating of a tissue.

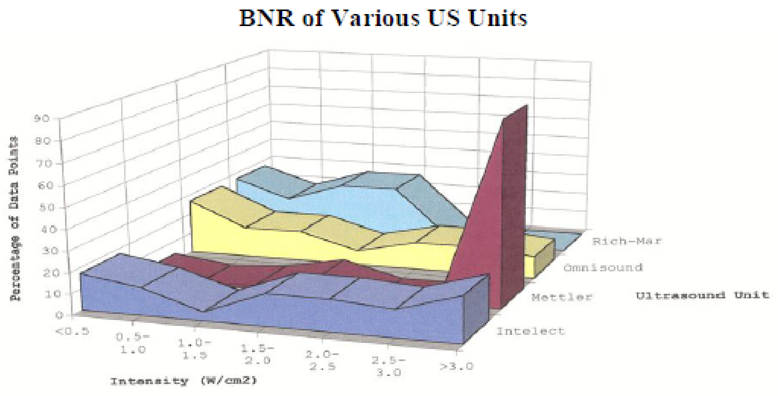


Figure 6

Duty cycle is the proportion of the total treatment time that the ultrasound is on and the transducer is emitting energy. A continuous ultrasound, or 100% duty cycle, is the uninterrupted transmission of sound waves over the time of the treatment (figure 7, top). Continuous ultrasound is the treatment of choice to achieve thermal effects of tissue two to five centimeters below the skin. Pulsed ultrasound (figure 7, bottom) tends to be used as a non-thermal application that may vary from a 1:5 on time to total time ratio (20% duty cycle) to a 1:2 ratio (50% duty cycle). In other words, for a 1:5 duty cycle, for every second the US waves are transmitting, there is a corresponding 4 second off time. Thus, the ratio of 1 second on to 5 seconds total time equals a 1:5 ratio or 20% duty cycle. It is a common error to think duty cycle is on time:off time but as one can see from the calculations below, this is inaccurate:

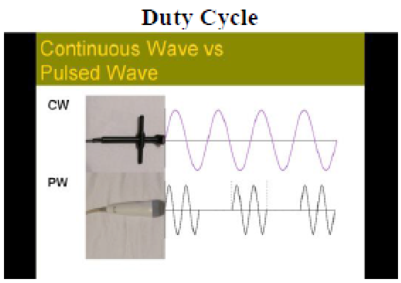


Figure 7

- If on time is 5 seconds, off time is 10 seconds, total treatment time is 15 seconds

  CORRECT: Duty Cycle = On time:Total time = 5:15 = 1:3 = 33%

  INCORRECT: Duty Cycle = On time:Off time = 5:10 = 1:2 = 50%

Although it is possible to use a very high intensity with a pulsed US treatment and achieve a heating effect, generally, a pulsed treatment is used for the mechanical properties of stimulating cellular and molecular effects.

Finally, ***intensity*** was briefly addressed with respect to BNR but it deserves more attention as a key parameter in an efficacious US treatment, i.e. tissue heating and treatment duration. Intensity is measured in watts per square centimeter (W/cm^2). Draper, Castel, and Castel (1995) explored the heating effect of US by placing thermistors (needles with thermometers) in the gastroc/soleus complex at given depths. The temperatures were monitored over a defined treatment duration across various intensities. As a result of this work, Draper et al was able to generate a predictive equation for tissue heating.

These equations were the first in the US literature to quantify the magnitude of the tissue heating. So let's put this information to a practical application. If a clinician is treating an individual with a 1-MHz US unit at 2 W/cm^2 for 10 minutes, s/he would expect a 4°C temperature increase. This is based on the following calculation:

0.2 x 2.0 W/cm^2 x 10 minutes = 4.0 °C increase in tissue temperature

1-MHz Frequency

0.2 x Intensity (in W/cm2) x treatment time in minutes = Degrees C of Temperature Increase

So a clinician would expect it to take 10 minutes to achieve a 4.0°C tissue temperature.

Now let's look at a similar application using a 3-MHz frequency for a more superficial tissue. If a clinician treated an individual for 8 minutes at 1.5 W/cm^2, one would expect a 4.2°C tissue temperature increase. This is based on the following calculation:

0.6 x 1.5 W/cm^2 x 5 minutes = 4.2 °C increase in tissue temperature

3-MHz Frequency

0.6 x Intensity (in W/cm2) x treatment time in minutes = Degrees C of Temperature Increase

As previously discussed, 3-MHz US may not penetrate as deep as 1-MHz US but it heats three times faster.

One should keep two things in mind as you use this data clinically: 1) the study was done using an OmniSound US unit (BNR < 2.9:1) and is not necessarily generalizable to all units and 2) the time needed to achieve the heating reflects the minimal treatment duration. In other words, it is the time it takes to "get" to that temperature. If the desire is to attain therapeutic heating to increase tissue viscoelasticity, one should consider continuing US treatment beyond this minimum to maintain the heating for a therapeutic intervention, i.e. stretching, soft tissue mobilization, etc.

In 2012, Prentice reported this data in a slightly different way (table 4).

Table 4: Calculation for Tissue Heating Effects		
	1-MHz	3-MHz
Intensity (W/cm^2)	Rate of Temperature Increase C/min	Rate of Temperature Increase C/min
0.5	0.04 C	0.3 C
1	0.2 C	0.6 C
1.5	0.3 C	0.9 C
2	0.4 C	1.4 C

Again, this table provides guidance for treatment parameters. But more important than any "formula" is what the patient reports. As a clinician, it is not uncommon to hear a colleague say, "today I am going to treat your injury with a deep heating modality called US. You are not going to feel anything, but…." The question is why? If the desired response is tissue heating, why wouldn't a patient feel heat? As a clinician, given the variability of the different US units, one needs to think about patient response. One should use the "formula" as it was intended: a guideline. Then, adjust the intensity to achieve the desired goal: mild, moderate, or vigorous heating as defined by 1°C, 2°-3°C, or 4°C tissue temperature increases, respectively.

Table 5: Classification of Tissue Heating		
Effect	Temperature Increase	Application
Non-Thermal	None	Acute edema
Mild Thermal	1 degree C	Subacute injury, hematoma
Moderate Thermal	2-3 degrees C	Inflammation, pain, MTrP
Vigorous Thermal	4 degrees C	Collagen elongation

As indicated above in table 5, increasing tissue temperature to 4°C above baseline can increase the viscoelastic properties of collagen, allowing for greater tissue extensibility (Draper & Rocard, 1995). However, there is a finite amount of time in which the tissue temperature will remain elevated. Later in this course, we will discuss the evidence supporting this limited "therapeutic window." To maximize the opportunity, one should incorporate stretching "into" the US treatment and not wait until the US application is complete to begin stretching. For example, imagine performing a 3-MHz US treatment to the lateral epicondyle. Perhaps, the first 5-minutes of US is rendered with the forearm supported on the table. The next 5-minutes would then be performed with the elbow extended, forearm pronated, and wrist flexed to put the involved tissues on a stretch. Additional stretching of the tissue or eccentric strengthening activities, could be completed immediately following the ultrasound treatment, taking advantage of the increased tissue temperature and viscoelastic properties afforded by the heat (Chan et al, 1998; Draper & Ricard, 1995; Prentice, 2012).

While discussing the effect of time and intensity on heating, it would also be valuable to consider the methodology when heating is not desired, i.e. sub-acute injuries where pain and edema management employ mechanical effects. To minimize the heating effect to emphasize the mechanical properties of US, one has several options: reduce the intensity, reduce the time, increase the size of the treatment area, or use a duty cycle.

In reducing the intensity, the same formulas can be applied. For example, let's use the 1-MHz example at 2 W/cm^2 for 10 minutes we referenced above. Remember we estimated a 4°C temperature increase based on the following calculation:

0.2 x 2.0 W/cm^2 x 10 minutes = 4.0 °C increase

So, option #1 is to reduce the intensity: 0.2 x 1.0 W/cm^2 x 10 minutes = 2.0 °C increase

If a 2°C temperature increase is still too high, option #2, a reduction in time could also be considered: 0.2 x 1.0 W/cm^2 x 8 minutes = 1.6 °C increase.

If mild heating of 1°C was all that was desired, option #3 would be to increase the treatment area from 2x ERA to 3x ERA. This would effectively dissipate some of the heating effect over a larger area.

Finally, option #4 would be to use the duty cycle. This would involve taking the estimated temperature increase and multiplying by the percentage of the duty cycle to achieve the desired temperature increase. For example (back to the 1-MHz example): 0.2 x 2.0 W/cm^2 x 10 minutes = 4.0 °C increase could be pulsed at 50% to achieve a 2°C increase or 25% to achieve a 1.0 °C increase.

Ultrasound Delivery

Now that we have reviewed the parameters involved in the implementation of US, let's look at the psychomotor skill of delivering the US intervention.

Despite selecting appropriate parameters for treatment, there are numerous ways a clinician can negate an effective treatment. We have all seen clinicians move an US transducer across a patient's back like it is a race track. Is it any wonder there is no heating when a clinician is moving the transducer at 5-6 inches per second over the entire lumbar spine measuring 10-12 times ERA? Therefore, when generalizations are made about the effectiveness of US, one needs to consider the techniques used to render the modality. This includes three important components: optimal speed of transducer movement, type of strokes (longitudinal vs circular), and transducer contact with the skin.

First, the optimal speed has been reported to be 3-4 cm per second (Prentice, 2012). Moving faster than that would most likely result in a reduction of tissue heating.

Second, the choice between longitudinal versus circular strokes is sometime dictated by the anatomic region. However, given the high BNR of some US units, circular strokes aid in the "washing out" of some hot spots on the crystals. Whereas, longitudinal strokes would keep a crystal hot spot traversing the same tissue repeatedly.

Third is the transducer contact with the skin. Many clinicians rock or wobble the transducer on the skin which results in loss of contact and the failure of US wave transmission. A study by Kimura, Gulick, Shelly, and Ziskin (1998) examined the influence of the angle of US application with two US different US units. The study analyzed 60°, 70°, 80°, and 90° angles of application. Table 6 reveals the dependent variable (angle of the transducer to the skin surface) effect on the tissue temperature increase. As the transducer tilt goes from 90° (the transducer surface parallel to the skin) to a 60° tilt, the temperature increase significantly declines. Of course, small tilts of the soundhead to "scoop" up the ultrasound gel may have little to no impact on tissue heating but the frequent to constant "rocking" of the soundhead may significantly compromise treatment outcomes.

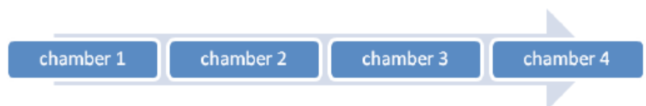
Table 6: Transducer Angle Relative to Tissue Heating over Time

Time (min)	Device	Mean °C Heating @ 90°	Mean °C Heating @ 80°	Mean °C Heating @ 70°	Mean °C Heating @ 60°
1	Excel	0.475	0.375	0.350	0.050
	Mettler	0.525	0.650	0.275	0.200
2	Excel	0.475	0.400	0.450	0.075
	Mettler	0.600	1.100	0.450	0.250
3	Excel	0.500	0.475	0.525	0.150
	Mettler	0.725	1.375	0.400	0.375
4	Excel	0.625	0.625	0.675	0.200
	Mettler	1.175	1.675	0.875	0.475
5	Excel	0.800	0.825	0.900	0.225
	Mettler	1.475	1.025	1.150	0.650

Many clinicians see US administration as an incredibly boring modality. While one may have some very pleasant conversations with patients when administering an US treatment, there is nothing incredibly exciting about actual process. Clinicians appeared to be relieved of this task when Richmar introduced the "hands-free US device" (figure 8). It was compromised of an "auto-transducer" that systematically transmitted a wave of ultrasound as through a 14 cm² transducer with four 3.5 cm² chambers as follows… 1,2,3,4,1,2,3,4, etc:

Hands-Free Ultrasound Device

Figure 8



In essence the four chambers mimicked the movement of the transducer. The effectiveness of this device was studied by Gulick (2009, 2010). The study involved the use of thermistors in the gastroc/soleus complex at depths of 2, 3, 4, and 5 cm. The US treatment was rendered with a 1-MHz frequency using the standard transducer and the hands-free transducer in random order. The treatment was at 1.5 W/cm² for 10 minutes. Tissue temperature was measured at each depth every 30-seconds. Table 7 summarizes the tissue temperature change and figures 9 to 12 graph the temperature changes over time:

Table 7: 1-MHz Hands-free vs. Hammer Transducer Tissue Temperature Change				
Tissue Depth	**Mode**	**Baseline Temp**	**Final Temp**	**Temp Change**
2 cm	Hands-Free	34.85°C	35.60°C	+0.75°C
	Manual	34.85°C	35.58°C	+0.73°C
3 cm	Hands-Free	35.43°C	35.36°C	-0.07°C
	Manual	35.41°C	35.37°C	-0.04°C
4 cm	Hands-Free	35.65°C	35.34°C	-0.31°C
	Manual	35.57°C	35.56°C	-0.01°C
5 cm	Hands-Free	36.65°C	36.46°C	-0.19°C
	Manual	36.55°C	37.27°C	+0.72°C

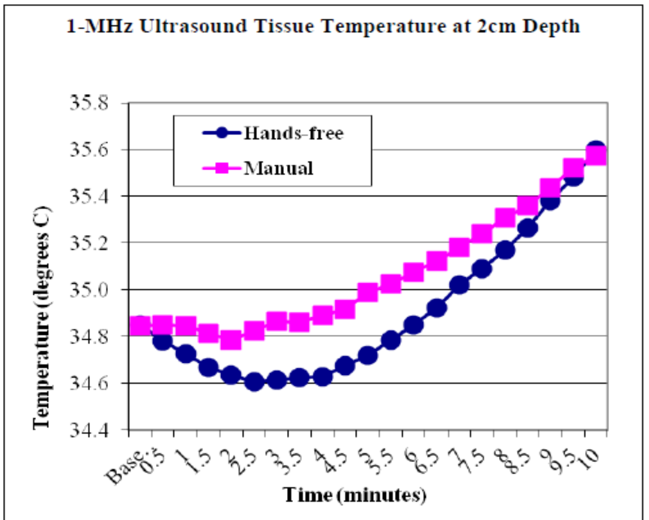


Figure 9

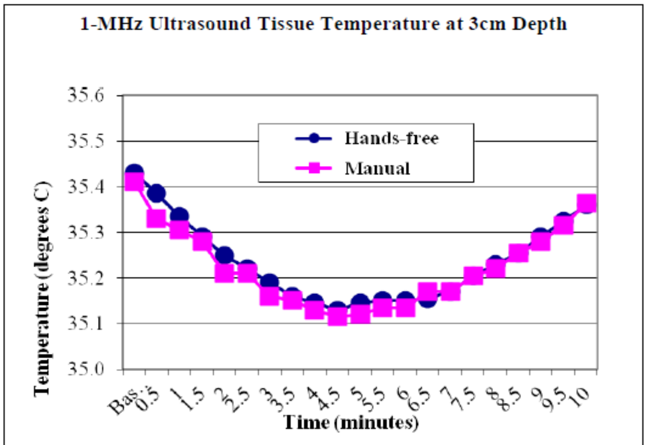


Figure 10

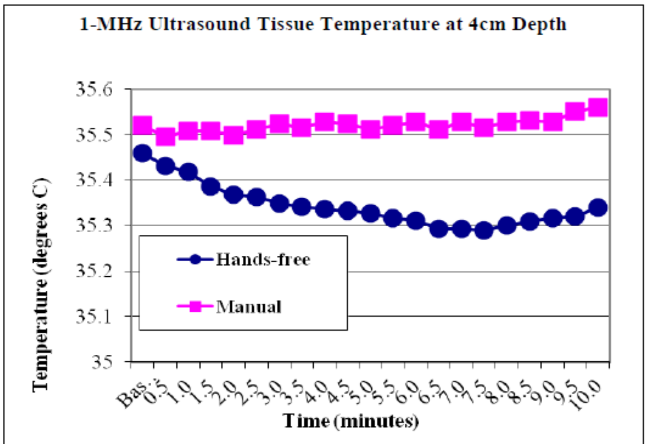


Figure 11

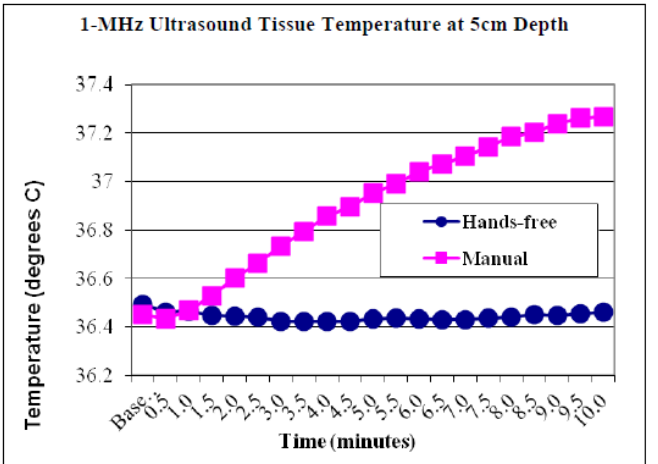


Figure 12

As one can see, despite an expected 3°C temperature increase with the given treatment protocol, this did not occur. Since neither the auto-sound or manual hammer transducer increased tissue temperature, could the 5.5:1 BNR of this unit have played a role? Gulick (2010) also studied the 3-MHz frequency of this unit and mode in a similar methodology. For the 3-MHz frequency there was significant heating with both modes but not to the magnitude expected. At both the 1-cm and 2-cm tissue depth the manual transducer resulted in more significant heating than the hands-free transducer. The results for the 3-MHz frequency are summarized in table 8 and figure 13 and 14:

Table 8: 3-MHz Hands-free vs. Hammer Transducer Tissue Temperature Change				
Tissue Depth	**Mode**	**Baseline Temp**	**Final Temp**	**Temp Change**
1 cm	Hands-Free	33.6°C	38.7°C	+5.1°C
	Manual	33.4°C	40.1°C	+6.7°C
2 cm	Hands-Free	34.9°C	36.4°C	+1.5°C
	Manual	34.4°C	38.4°C	+4.0°C

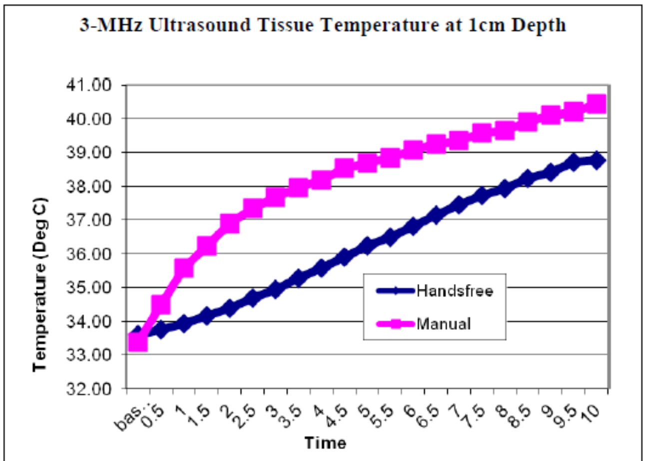


Figure 13

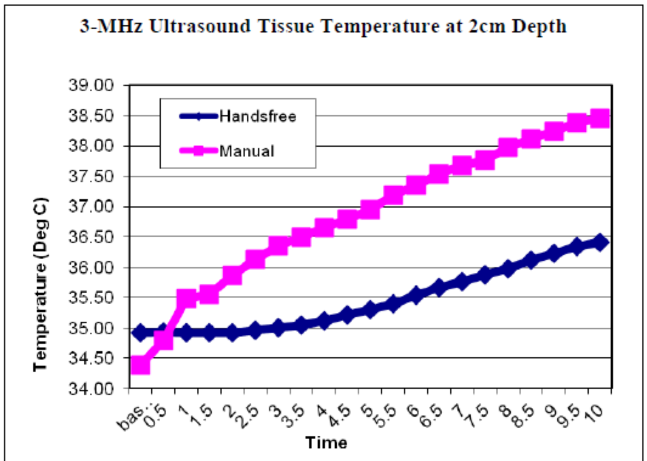


Figure 14

Unfortunately, although the concept of a hands-free mode of US transmission may be very attractive, the actual application did not prove to be therapeutic in either of these studies.

Evidence-based Treatment

So now that the parameters involved in an US treatment have been vetted, it is time to discuss the literature associated with the various modes of treatment: pain, inflammation, soft tissue compliance, wound care, and phonophoresis.

Pain, Inflammation, and Soft Tissue Compliance

Over the years, there have been numerous studies with US. A very significant percentage of the studies have found it to be ineffective.

For example, a Cochrane Review by van den Bekerom, van der Windt, ter Riet, van der Heijden, and Bouter (2011) on therapeutic US for acute ankle sprains found US to be unsuccessful for management of pain, swelling, functional disability, or range of motion. Table 9 reveals the parameters of some of the studies in the Cochrane Review:

Table 9: Summary of Cochrane Review – Acute Ankle Sprains (2011)		
Parameters	**Results**	**Authors**
Continuous 1.5 W/cm^2 x 4-10 treatments	No significant difference	Makuloluwe, 1977
Pulsed 0.25 W/cm^2 x 2 min x 3 treatments	No significant difference	Nyanzi, 1999
Pulsed 3MHz at 0.35-0.5 W/cm^2 x 2-3 min x 4 treatments	No significant difference	Oakland, 1993
Continuous 0.5 W/cm^2 x 5-10 min x 2 wks	No significant difference	Van Lelieveld, 1979
Pulsed 3MHz at 0.25-0.5 W/cm^2 x 10 min x 6 treatments	No significant difference	Zammit, 2005

Although the goal for acute ankle sprains would be the management of pain and/or edema, most of the parameters studied were so short or the intensity so low, it was probably not worth performing. A few years later, another Cochrane Review was published (Verhagen, 2013). Over 600 participants were compared across multiple studies using pulsed and continuous US. There were few beneficial effects in "overall improvement, pain, or the ability to bear weight." The researcher reported two to four week follow up suggested most participants would recover regardless of treatment. Perhaps acute ankle sprains are simply not the population for which US should be used.

Another Cochrane Review on US for chronic low back pain (2014) by Ebadi, Henschke, Nakhostin Ansari, Fallah, and van Tulder revealed more capricious outcomes (table 10). In these cases, the desired effect would be therapeutic heating. In the studies below, tissue temperature increases of 1.2° to 4°C would have been expected. Some reported improvement, some did not. All three studies by Durmus used suitable methodology to achieve a 2° to 3°C temperature increase with comparative groups not receiving US.

Table 10: Summary of Cochrane Review – Chronic Low Back Pain (2014)

Parameters	Results	Authors
1-MHz at 1.5-2.5 W/cm^2 x 5-10 min x 6 treatments + therapeutic exercise vs Exercise alone	No significant difference	Mohseni-Bandpei, 2006
1.2 W/cm^2 x 5 min x 10 treatments + therapeutic exercise vs control	No significant difference in VAS	Grubisic, 2006
1-MHz at 1.5 W/cm^2 x 10 treatments + therapeutic exercise vs Sham US + exercise	No significant difference	Ebadi, 2012
1.5 W/cm^2 x 10 min x 18 treatments + therapeutic exercise vs Exercise alone	Improvement with US	Durmus, 2013
1-MHz at 1 W/cm^2 x 10 min + therapeutic exercise vs Exercise alone	Improvement with US	Durmus, 2010a
Hot pack, US (1 W/cm^2 x 10 min) + therapeutic exercise vs Hot pack, sham + exercise	Improvement with US	Durmus, 2010b
1-MHz @ 1.5 W/cm^2 x 10 treatments vs Sham	No significant difference	Ansari, 2006

In a different usage for US, Rahmann (2007) investigated the effect on calcific tendinitis. Twenty-six patients received US treatments at 1.0-1.5 W/cm^2. After 10 treatments, all patients were painfree with increased range of motion. In addition, 24 of the 26 radiographs showed no calculi after treatment. Ebenbichler (1999) delivered pulsed US treatments at 2.5 W/cm^2 for 15 minutes to 32 patients with calcific tendinitis. Sham treatments were rendered to 29 patients. After 24 treatments, the calcium deposit of six patients was completely gone, nine had a 50% reduction, and 17 had no change. Kachewar and Kulkarni (2013) theorized US increases blood flow and metabolism. The release of chemokines would stimulate the accumulation of mononuclear cells to accelerate the disruption of apatite-like microcrystals. Migrating macrophages phagocytize the calcified particles.

The effect of US on myofascial trigger points (MTrP) has also been studied (Aguilera et al, 2009). The researchers compared three treatments (n=66). Group #1 received 90 seconds of manual compression, group #2 received 2 minutes of 1-MHz pulsed US at 1 W/cm^2, and group #3 received 5 minutes of sham US. The outcome measures included active range of motion, basal electrical activity (BEA) of the upper trapezius, and pain pressure threshold (PPT). The results revealed an immediate decrease in BEA with both the manual compression and US. The manual compression group also improved in cervical motion.

Likewise, Kim, Yang, Lee and Toon (2014) examined two distinct forms of 1-MHz US (n=41). One group received "conventional" US using a transducer with a 20 cm^2 ERA over a 40 cm^2 treatment area. The transducer was moved at 2.5 cm/sec at an intensity of 1 W/cm^2 for 5 minutes. The other group received a very unique form of US: high-power pain threshold (HPPT). This treatment utilized static US (an unusual methodology) to patient threshold for 4-5 seconds and then the intensity was reduced by 50% for 15 seconds. This was repeated three times. Both groups were treated twice per week for four weeks. The outcome measures were a visual analogue scale (VAS), PPT, and cervical range of motion (ROM). The results displayed in table 11 reveal similar responses to both interventions. It is interesting that the conventional US would have resulted in approximately a 2.5°C increase in tissue temperature but the HPPT US would have primarily had mechanical effect (no significant heating).

Table 11: Summary of Conventional vs HPPT Ultrasound

		Base	1 wk	2 wk	3 wk	4 wk
VAS	US	5.34	4.63	4.37	3.82	2.84
	HP	6.27	5.11	4.80	4.05	3.36
PPT	US	2.13	2.04	2.20	2.23	2.35
	HP	2.08	2.12	2.30	2.25	2.50
ROM	US	18.65	19.32	20.91	20.82	24.21
	HP	18.65	20.08	20.24	22.74	23.02

Draper, Mahaffey, Kaiser, Eggett, and Jarmin (2010) confirmed the positive influence of thermal US on MTrP. They randomly assigned 26 patients to 3-MHz US or sham. Using a 7 cm^2 US transducer, a 1.4W/cm^2 was administered for five minutes over a 2x ERA (14 cm^2). Two treatments were performed over two weeks. The results of the PPT with a dolorimeter were:

Immediate effect: Sham 0.64 ↑ vs US 2.65 ↑

Residual effect: sham 0.93 ↑ vs US 2.09 ↑

Thus, thermal US with an estimated 5°C tissue temperature increase was effective in reducing MTrP discomfort and stiffness.

Another study looked at the influence of US on pain in degenerative musculoskeletal diseases (Muftiv & Miladinovic, 2013). Two groups were assessed for pain level with a visual analogue scale (VAS). They were treated 10 times with 1-MHz US. The first group received 8 minutes of US at 0.4 W/cm^2 and the second group received 4 minutes of 0.8 W/cm^2. VAS of the first group improved by 3.97 and that of the second group by 4.74, however, the difference was not statistically significant. This should not be a surprise since the parameters used for each group should have yielded identical increases in tissue temperature:

Group 1: 0.2 x 0.4 W/cm^2 x 8 minutes => approximately 0.64°C tissue temperature increase

Group 2: 0.2 x 0.8 W/cm^2 x 4 minutes => approximately 0.64°C tissue temperature increase

Two studies by Ulus et al (2012) and Cakir et al (2014) explored the ability of US to manage pain in patients with osteoarthritis (OA). Ulus et al treated all 42 patients with bilateral knee replacements with hot packs, interferential electrical stimulation, and exercise. Half of the patients also received US five times per week for three weeks. The 1-MHz US treatment intensity was 1.0 W/cm^2 for 10 minutes. The outcome measures were VAS, Western Ontario and McMaster University Osteoarthritis Index (WOMAC), 50 meter walk speed, Lequesne Index, and Hospital Anxiety and Depression Scale. They all improved for all patients, i.e. there was no difference in the groups that did or did not receive US. Likewise, in the study by Cakir et al, 60 patients with OA were randomized into three groups: continuous 1-MHz US at 1 W/cm^2, pulsed 1-MHz US at 1 W/cm^2 at a 1:4 duty cycle, and sham US. All were treated five times per week for two weeks. The outcome measures included the WOMAC, stiffness, function, VAS, and 20-meter walk time. Again, all groups showed improvement but there was no difference between them. Thus, neither study demonstrated an enhanced benefit of US. Give the number of modalities in the study by Ulus et al, it is challenging to ascertain which one(s) would be responsible for an improvement in the outcome measures. But when the only modality was US in the Cakir et al study, it is becomes clear that US does not appear to benefit OA. The attributes of US really don't lend themselves to the treatment of OA. US may increase tissue temperature, blood flow, collagen extensibility, and enzymatic activity but none of these physiologic features are likely to reverse OA.

To the contrary, the identified physiologic effects of US should benefit myofascial pain. Ilter et al (2015) randomly assigned 60 patients into one of three treatment groups: continuous 3-MHz US at 1 W/cm^2, pulsed US at a 50% duty cycle, and control. Treatment was rendered five days per week for two weeks. Outcome measures included VAS at rest, VAS with activity, Neck Pain and Disability Scale, Beck Depression Scale, and Nottingham Health Profile. All measures were performed at baseline, after treatment, and at the sixth and twelfth week. The continuous US group showed significant improvement in VAS at rest only. The authors concluded continuous US was more efficient in reducing pain at rest but all participants also received hot packs for 10 minutes, as well as stretching and range of motion exercises. Furthermore, participants were permitted to take the analgesic, paracetamol, as needed. Unfortunately, these uncontrolled variables negate the ability to draw meaningful conclusions.

As in the above study, US is a modality often applied with hot packs. Many clinicians opt to use moist heat as a precursor to ultrasound (US) treatment with the rationale of heating the superficial tissue to enhance the deep heating of US. Draper et al (1998) investigated the combination of a hot pack with US as compared to a room temperature pack with US. The hot or room temperature packs were applied for 15-minutes prior to a 10-minute 1-MHz US treatment at 1.5 W/cm^2. Thermistors recorded tissue temperature at one and three centimeters below the skin surface. Table 12 summarizes the tissue temperature changes at the two depths:

Table 12: Tissue Temperature Changes by Treatment at a Given Depth

Depth	Hot Pack Temp	Room Temp Pack	Ultrasound	Total Temp Increase
1 cm	+ 3.83		+ 0.61	+ 4.40
1 cm		+ 0.15	+ 3.50	+ 3.65
3 cm	+ 0.74		+ 3.68	+ 4.42
3 cm		- 0.26	+ 3.85	+ 3.59

At both the 1- and 3-cm depth, the combination of the hot pack and US resulted in a 0.75°C and 0.83°C increase, respectively. Therefore, the hot pack and US have an additive effect on intramuscular temperature but the magnitude of each component may be different due to a tissue temperature plateau. To help clarify this additive effect, Benjaboonyanupap, Paungmali, and Pirunsan (2015) examined the sequence of the hot pack (HP) and US treatments on upper trapezius trigger points. All subjects (n=30) received both HP + US and US + HP. The outcome data included tissue blood flow, pressure pain threshold, supra-thermal threshold, and VAS. Data was collected at baseline, immediately after treatment, after 30 minutes and after 60 minutes. Blood flow and pressure pain threshold significantly increased in both sequences but VAS and supra-thermal threshold improved more in the HP + US group.

Increased tissue temperature and blood flow are important elements to enhance tissue compliance. The effects of US on ROM and stretch pain were studied by Morishita et al (2014). Subjects (n=15) performed all three interventions: US, sham US, and control. US treatment used a continuous 3-MHz frequency at 1.0 W/cm² for 10 minutes. Dependent data included ROM, VAS, and skin surface temperature. ROM and skin surface temperature was significantly higher for the US treatment. These values remained higher for 20 minutes after the US intervention. Not only is it valuable to confirm the potential changes in soft tissue but it is essential to know how long the changes to the tissue manifest. Since US should never be rendered in isolation, it is important to recognize the duration of time in which the tissue temperature remains at a therapeutic level.

Draper and Ricard (1995) coined the term "stretching window" to describe the period of time in which the tissue temperature is elevated and conducive to responding in a positive way to stretching. Draper and Ricard embarked on an interesting methodology to calculate the rate of temperature decay. To do so, they inserted thermistors 1.2 cm into the triceps surae of 20 subjects. They then administered a 3-MHz US treatment at 1.5 W/cm² until the tissue increased at least 5°C. The rate at which the temperature dropped was recorded at 30-second intervals. The results were a significant nonlinear relationship between time and temperature decay. With the mean baseline temperature of 33.8°C and the peak temperature of 39.1°C, the rate of temperature decay was as follows (figure 15):

Rate of Temperature Decay After Thermal 3-MHz US
• After 1:20 minutes the tissue temperature dropped 1°C
• After 3:22 minutes the tissue temperature dropped 2°C
• After 5:50 minutes the tissue temperature dropped 3°C
• After 9:13 minutes the tissue temperature dropped 4°C
• After 14:55 minutes the tissue temperature dropped 5°C
• By 18:00 minutes the tissue temperature dropped 5.3°C & was back to baseline
Figure 15

Thus, one can see, a clinician has less than 3.5 minutes to capitalize on the enhanced viscoelastic properties resulting from the elevated tissue temperature. Hence, the rationale for stretching during the US treatment and continuing into the period immediately after treatment to take advantage of the desirable effects. Unfortunately, many clinicians wait until the conclusion of the US treatment to begin soft tissue interventions and many are distracted by other tasks after the US treatment which waste the precious time prior to temperature decay. Knowledge of the physiology associated with the US treatment can result in superior outcomes for your patients.

Wound Care

Enhanced blood flow, tissue heating and enzymatic activity are not limited to the application of soft tissue extensibility. Olvaie, Rad, Elahifar, Garkaz, and Mahsa (2013) demonstrated these attributes could be applied to wound healing as well. In addition to the standard multilayer compression bandaging, non-adherent dressing, and regular debridement, 90 patients with chronic wounds were randomly assigned to one of three groups:

Group 1: Standard care

Group 2: High-frequency US (HFU) = 1-3-MHz frequency at 0.5-1.0 W/cm² x 5-10 minutes

Group 3: Non-contact low-frequency US (NCLFU) = 40 kHz frequency at 0.1-0.8 W/cm² x 4-10 minutes

Treatment was provided three times per week for three months (or until the wound was healed). The results were statistically significant (table 13).

Table 13: Wound Healing with Ultrasound			
	Initial Wound Size	Wound Size at 4 month	Average Healing Time
Standard Care	9.60 cm²	4.28 cm²	8.50 months
HFU	9.86 cm²	3.23 cm²	6.86 months
NCLFU	10.01 cm²	2.72 cm²	6.65 months

In addition to the enhanced healing, edema and pain rating score were also significantly better for the US groups over that of just standard care. The boosted healing time represents improved quality of life and substantial savings in health care costs.

Although Cullum and Liu (2017) acknowledged the significant burden venous leg ulcers can place on the healthcare system, their Cochrane Review called into question 10 of the 11 studies that met their criteria. They searched for randomized controlled trials which included ultrasound and non-ultrasound comparisons (usual care or sham). They eliminated studies due to lack of blinding, imprecision, or perceived bias and concluded it is uncertain whether US improves healing of venous leg ulcers.

Phonophoresis

The first attempts to use ultrasonic waves to aid the penetration of drugs into the skin tissue dates back to the 1950's (Graj-Szczypiorowska, Zajac, Skalska-Izdebska, 2007). Despite wide usage, there is a dearth of objective research methods and reliable scientific verification for its efficacy. The medications used with phonophoresis include diclofenac, dexamethasone, hydrocortisone, lidocaine, and dimethylsulfoxide (DMSO). The following overview of phonophoresis studies examine the impact on signs and symptoms associated with various pathologies as well as the presence of medication in the tissue.

Ay, Dogan, Evcik, and Baser (2011) performed a randomized double-blinded study comparing diclofenac phonophoresis, ultrasound, and placebo US to myofascial trigger points (n=60). The 1-MHz US treatments were administered for 10 minutes per day, five days per week over three weeks at an intensity of 1.5 W/cm². All groups also performed a neck exercise program. The outcome measures were VAS, ROM, number of trigger points, PPT, and the Neck Disability Index (NDI). There were statistically significant improvements in pain severity, number of trigger points, PPT, ROM and NDI scores both in phonophoresis and in US groups. Given that phonophoresis was not found to be superior to US and no measurements were taken to assess the transmission of diclofenac, one cannot conclude if any medication was transmitted. Nonetheless, Rosim, Barbieri, Lancas, and Mazzer (2005) did use high performance liquid chromatography to quantify phoresing of diclofenac. Fourteen individuals were each treated with either US followed by the application of diclofenac gel or sham US followed by diclofenac gel. Plasma diclofenac mass was measured at one, two, and three hours post treatment. The diclofenac mass was found to be significantly higher after US at one and two hours post treatment but not at three hours post treatment (table 14).

Table 14: Diclofenac Mass after US vs. Sham US

	1 hour	2 hour	3 hour
Ultrasound	0.0987 microg/mL	0.0724 microg/mL	0.0864 microg/mL
Sham	0.0389 microg/mL	0.0529 microg/mL	0.0683 microg/mL

Although the technique utilized in this study was not the typical methodology for phonophoresis, it did demonstrate that US enhanced the percutaneous penetration of topical diclofenac gel.

Dexamethasone sodium phosphate, a corticosteroid, is another drug used in phonophoresis. Akinbo, Aiyejusunle, Akinyemi, Anesegun, and Danesi (2007) compared phonophoresis and iontophoresis with dexamethasone on patients with knee osteoarthritis (n=50). The phonophoresis was delivered with 1-MHz US for five minutes. The iontophoresis treatment was rendered for 10 minutes. The outcome measures were the Western Ontario and McMaster University Osteoarthritis Index (WOMAC), 20-meter ambulatory time, and knee ROM. After 10 treatments over two weeks, all measures were found to have improved. However, there was no difference between the groups. Given the intensity for neither treatment was reported, it is challenging to know if the parameters were appropriate for transmission of the dexamethasone.

Darrow, Schulthiesm Draper, Ricard, and Measom (1999) also studied dexamethasone transmission with phonophoresis but they measured the quantity transmitted to the tissue not the signs and symptoms associated with a specific pathology. They administered dexamethasone with US and via sham US for 10 minutes using a 1-MHz frequency at 1.0 W/cm² over a 2xERA (n=40). Blood draws were taken pre-treatment, post-treatment, and 15 and 30 minutes after treatment. There was no significant amount of serum dexamethasone found in the blood draws. Thus, the researchers concluded a more appropriate medium and US parameters need to be determined for dexamethasone phonophoresis.

To that end, Saliba, Mistry, Perrin, Gieck, and Weltman (2007) used a novel approach to the transmission of dexamethasone. They applied two grams of 0.33% dexamethasone cream to a 10-cm² area of the anterior forearm and then donned an occluded dressing (Tegaderm) for 30 minutes before the ultrasound and sham treatments were bestowed. The US treatments were 1.0 W/cm² pulsed at 50% with a 3-MHz frequency for five minutes. The outcome measure was serum samples drawn before, immediately post treatment, and at 2, 4, 6, 8, and 10 hours post treatment. Using this technique the rate of appearance and total concentration of dexamethasone in the serum was greater after phonophoresis than after sham ultrasound. Because the sham US only resulted in a trace change in serum dexamethasone, the massaging effect of the sham US treatment did not influence the transmission of the drug. The researchers attributed the saturation of the skin prior to the US with the success of transmission. By using each subject in both treatments, they served as their own control for variations such as age, skin type, and hydration. The researchers suggested clinicians re-think the method in which phonophoresis is performed. They recommended additional research into the duration of drug occlusion prior to US treatment.

Hydrocortisone is a corticosteroid used to manage the signs and symptoms of inflammation. Kuntz, Griffiths, Rankin, Armstrong, and McLoughlin (2006) administered both sham and phonophoresis treatments to 12 individuals. The phonophoresis included 10% hydrocortisone gel at 1.0 W/cm² for 7 minutes with a 1-MHz frequency. The sound head was 5 cm² and the standardized templated area was 10 cm² (2xERA). The outcome measure was cortisol concentrations in the biopsied vastus lateralis muscle.

The result was no significant difference in muscle cortisol concentration between phonophoresis and sham treatments. The authors entertained the notion that the cortisol could have been absorbed in the extracellular environment of the muscle and redistributed through uptake by the surrounding vasculature. However, Bare et al (1996) observed no significant difference in serum cortisol concentrations after a 10% hydrocortisone phonophoresis treatment similar to the parameters used in the current study.

Lidocaine is an anesthetic commonly used for pain relief. Ebrahimi, Abbasnia, Motealleh, Kooroshfard, Kamali, and Ghaffaninezhad (2012) compared the pulsed and continuous modes of phonophoresis on sensory blockage (as measured by two-point discrimination). Individuals were randomly assigned to one of three groups: pulsed US with lidocaine, continuous US with lidocaine, and sham US with lidocaine (n=93). It appeared the lidocaine gel was applied to the skin for 5 minutes prior to the administration of the US treatment. However the duration of the US treatment was not disclosed. It is possible the US treatment was 5 minutes. The US applied was at a frequency of 1-MHz and an intensity of 1 W/cm^2. The pulsed mode was at a duty cycle of 1:4 and the treatment area was 3xERA. The pulsed US with topical lidocaine gel induced greater anesthetic effect compared with continuous US with topical lidocaine gel and lidocaine application alone. The authors stated the mechanical properties of pulsed US appear to be responsible for greater drug penetration. Without clarity on the duration of the application, the results are difficult to apply clinically.

The aforementioned authors did provide a rich discussion on the physiological rationale for pulsed US. They attributed the improved transdermal permeation to the "augmented fluidity of intercellular lipids due to thermal or mechanical stress, enlargement of intercellular spaces and the creation of permanent/transient holes within corneocytes and keratinocytes." It appears the mechanical properties of pulsed US, such as cavitation, microstreaming, and micromassage, are responsible for drug penetration. Frenkel (2008) stated that "acoustic cavitation may be defined as the growth, oscillation, and collapse of small stabilized gas bubbles under the influence of the varying pressure field of a sound wave in a fluid medium." It may be the most important of all the non-thermal ultrasound mechanisms. Under normal circumstances, the stratum corneum acts as a barrier to drug penetration. However, the oscillation of gas bubbles may disrupt and disorganize the lipid bilayers of the stratum corneum to enhance perfusion via the ducts of the sweat glands and the hair follicles in the skin (Mitragotri et al, 1995; Haar, 2007; Ogura et al, 2008).

The aim of a study by Silveira, Victor, Schefer, Silva, Streck, Paula, and Pinho (2010) was to evaluate the effects on the pulsed US with gel-dimethylsulfoxide (DMSO) in the parameters of muscular damage and oxidative stress. They divided 36 Wistar rats into six groups:

1. uninjured sham
2. injured without treatment
3. injured and treated with gel-saline
4. injured and treated with gel-DMSO (15mg/kg)
5. injured and treated with pulsed US with gel-saline
6. injured and treated with pulsed US with gel-DMSO

The pulsed US was delivered via a 1-MHz frequency at 0.8 W/cm^2 for 6 minutes at 2, 12, 24, 48, 72, 96, and 120 hours post muscle trauma. Creatine kinase and acid phosphatase activity was used as markers of skeletal muscle damage. Superoxide anion, protein carbonyls, superoxide dismutase (SOD) and catalase (CAT) activity was used as indicators of oxidative stress. Based on the changes of these markers with the six treatments, the researchers reported DMSO was effective in the reduction of the muscular lesion as well as the oxidative stress but only when delivered with pulsed US.

In summary of phonophoresis, there is research to support the ability to transmit various substances through the stratum corneum with the aid of pulsed US. The theory proposed is the augmentation of the lipid bilayer may create temporary cavities through corneocytes and keratinocytes to enhance skin permeability. It appears this is best achieved through mechanical properties of pulsed US. It is not completely clear why the continuous mode of US is not as effective. Perhaps the heating of the tissue is a deterrent to drug transmission. Furthermore, the ideal parameters for the pulsed US (frequency, intensity, duty cycle, treatment duration) have not been identified.

Conclusion

This course has revealed a plethora of research challenging the efficacy of therapeutic ultrasound for the treatment of a wide variety of conditions. The research has divulged conditions for which US can mitigate signs and symptoms and those that seem to be less useful.

The take home messages from this course can be summarized as follows:

1. the clinician most know the condition for which the treatment is being applied and the target tissue involved
2. the clinician must know the limitations of the US unit, i.e. BNR, ERA
3. the clinician must select treatment parameters consistent with the goal(s), i.e. frequency, intensity, duration of treatment
4. the clinician must implement proper technique in administered US, i.e. speed and contact of the transducer

If the clinician heeds these recommendations, the likelihood of an effective treatment will be notably enhanced.

Images

Figure 1 https://www.honda-el.co.jp/ufile/library/1386_file.jpg

Figure 2 http://www.hsiehtherapies.com/CustomImages/Underwater_ultrasound_treatment.jpg

Figure 3 http://cdnll.coneinstruments.com/images/xxl/AquaflexGelPad_a.jpg

Figure 5 http://www.bing.com/images/searchview=detailV2&ccid=SDrlRh9e&id=8AEB8B001ABCC733FA9BB3FA19C5D4B32566C4A4&thid=OIP.SDrlRh9ezsbKg781iUQMlADNBq&q=1+mhz+vs+3+mhz+ultrasound+depth&simid=608000094514384036&selectedIndex=2&ajaxhist=0

Figure 7 http://www.ultrasoundregistryreview.com/SPI/images/zxx12.jpg

References

1. Akinbo SR, Aiyejusunle CB, Akinyemi OA, Adesegun SA, Danesi MA. Comparison of the therapeutic efficacy of phonophoresis and iontophoresis using dexamethasone sodium phosphate in the management of patients with knee osteoarthritis. Nigerian Postgraduate Medical Journal. 2007;14(3):190-194
2. Alexander LD, Gilman DR, Brown DR, Brown JL, Houghton PE. Exposure to low amounts of ultrasound energy does not improve soft tissue shoulder pathology: a systematic review. Physical Therapy. 2010;90(1):14-25.
3. Ay S, Dogan SK, Evcik D, Baser OC. Comparison the efficacy of phonophoresis and ultrasound therapy in myofascial pain syndrome. Rheumatology International. 2011;31(9):1203-1208
4. Baker KG, Robertson VJ, Duck FA. A review of therapeutic ultrasound: biophysical effects. Physical Therapy. 2001;81(7):1351-1358.
5. Bare AC, McAnaw MB, Pritchard AE, et al. Phonophoretic delivery of 10% hydrocortisone through the epidermis of humans as determined by serum cortisol concentrations. Physical Therapy. 1996;76:738–749.
6. Benjaboonyanupap D, Paungmali A, Pirunsan U. Effect of therapeutic sequence of hot pack and ultrasound on physiological response over trigger point of upper trapezius. Asian Journal of Sports Medicine. 2015;6(3):323806
7. Cakir S, Hepguler S, Ozturk C, Isleten B, Atamaz FC. Efficiency of therapeutic ultrasound for the management of knee osteoarthritis: a randomized, controlled, and double-blinded study. American Journal of Physical Medicine & Rehabilitation. 2014;93(5):405-412
8. Cameron M. Physical Agents in Rehabilitation: From Research to Practice. 2nd ed. St. Louis, MO: Saunders; 2003.
9. Chan AK, Myrer JW, Measom GJ, Draper DO. Temperature changes in human patellar tendon in response to therapeutic ultrasound. Journal of Athletic Training. 1998;33(2):130-135.
10. Chudliegh D, Schulthies SS, Draper DO, Myrer JW. Muscle temperature rise with 1-MHz ultrasound in treatment sizes of 2 and 6 times the effective radiating area of the transducer. Master's Thesis, Brigham Young University, July 1997
11. Cochran Review by van den Bekerom M, van der Windt D, ter Riet G, van der Heijden G, Bouter LM, Therapeutic ultrasound for acute ankle sprains 2011

12. Cullum N, Liu Z. Therapeutic ultrasound for venous leg ulcers. The Cochrane Database of Systemic Reviews. 2017 May 15;5: CD001180
13. Darrow H, Schulthies S, Draper D, Ricard M, Measom GJ. Serum dexamethasone levels after Decadron phonophoresis. Journal of Athletic Training. 1999 Oct-Dec; 34(4): 338-341
14. Draper DO, Anderson, 2004 US with Flex-All® (3:1 ratio)
15. Draper DO, Castel JC, Castel D. Rate of temperature increase in human muscle during 1-MHz and 3-MHz continuous ultrasound. Journal of Orthopedic Sports Physical Therapy. Oct 1995;22(4):142-150.
16. Draper DO, Edvalson C, Knight KL, Eggett D, Shurtz J. Temperature increases in the human Achilles tendon during ultrasound treatments with commercial ultrasound gel and full-thickness and half-thickness gel pads. Journal of Athletic Training. 2010;45(4):333-337.
17. Draper DO, Harris ST, Schulthies S, Durranr E, Knight KL, Ricard M. Therapeutic ultrasound versus sham ultrasound for the management of patients with knee osteoarthritis: a randomized double-blinded controlled clinical study. International Journal of Rheumatic Diseases. 2012;15(2):197-206
18. Draper DO, Harris ST, Schulthies S, Durranr E, Knight KL, Ricard M. Hot pack and 1-MHz ultrasound treatments have an additive effect on muscle temperature increase. Journal of Athletic Training. 1998;33(1):21-24
19. Draper DO, Mahaffey C, Kaiser D, Eggett D, Jarmin J. Thermal ultrasound decreases tissue stiffness of trigger points in upper trapezius muscles. Physiotherapy theory and practice 2010 Apr 22; 26(3): 167-72
20. Draper DO, Ricard MD. Rate of temperature decay in human muscle following 3-MHz ultrasound: the stretching window revealed. Journal of Athletic Training 1995;30(4):304-307.
21. Draper DO, Schulthies S, Sorvisto P, Hautala AM. Temperature changes in deep muscles of humans during ice and ultrasound therapies: an in vivo study. Journal of Orthopedic and Sports Physical Therapy. 1995;21(3):153-157.
22. Draper DO, Sunderland S, Kirkendall DT, Ricard M. A comparison of temperature rise in human calf muscles following applications of underwater and topical gel ultrasound. JOSPT. 1993;17(5):247-251
23. Ebadi S, Henschke N, Nakhostin Ansari N, Fallah E, van Tulder MW. Therapeutic ultrasound for chronic low-back pain (Review). Cochrane Collaboration 2014
24. Ebrahimi S, Abbasnia K, Motealleh A, Kooroshfard N, Kamali F, Ghaffarinezhad F. Effect of lidocaine phonophoresis on sensory blockade: pulsed or continuous mode of therapeutic ultrasound? Physiotherapy. 2012;98(1):57-63
25. Frenkel V. Ultrasound mediated delivery of drugs and genes to solid tumors. Advanced Drug Delivery Review 2008;60:1193–208.
26. Goraj-Szczypiorowska B, Zajac L, Sklska-Izdebska R. Evaluation of factors influencing the quality and efficacy of ultrasound and phonophoresis treatment. Ortopedia Traumatologia Rehabilitacja. 2007;9(5):449-458
27. Gulick DT. Comparison of tissue heating between manual and hands-free ultrasound techniques using a 1-MHz frequency. Orthopedic Physical Therapy Practice. 2009;21(4):135-139
28. Gulick DT. Comparison of tissue heating between manual and hands-free ultrasound techniques - 3-MHz. Physiotherapy Theory and Practice. 2010;26(2):100-106
29. Haar GT. Therapeutic applications of ultrasound. Prog Biophys Mol Biol 2007;93:111–29.
30. Ilter L, Dilek B, Batmaz I, Ulu MA, Sariyildiz MA, Nas K, Cevik R. Efficacy of pulsed and continuous therapeutic ultrasound in myofascial pain syndrome: a randomized controlled study. American Journal of Physical Medicine & Rehabilitation. 2015;94(7):547-554
31. Johns LD, Straub SJ, Howard SM. Variability in effective radiating area and output power of new ultrasound transducers at 3-MHz. Journal of Athletic Training. 2007;42(1):22-28.
32. Johns LD. Nonthermal effects of therapeutic ultrasound: the frequency resonance hypothesis. Journal of Athletic Training. 2002;37(3):293-299.
33. Kachewar SG, Kulkarni DS. Calcific Tendinitis of the Rotator Cuff. Journal of Clinical & Diagnostic Research. 2013;7:1482-1485
34. Kimura IF, Gulick DT, Shelly L, Ziskin M, Effects of Two Ultrasound Machines & Angle of Application on the Temperature of Tissue Mimicking Material, Journal of Orthopedic and Sports Physical Therapy, Jan 1998; 27(1):27-31
35. Knight CA, Rutledge CR, Cox ME, Acosta M, Hall SJ. Effect of superficial heat, deep heat, and active exercise warm-up on the extensibility of the plantar flexors. Physical Therapy. 2001;81(6):1206-1214.
36. Kuntz AR, Griffiths CM, Rankin JM, Armstrong CW, McLoughlin TJ. Cortisol Concentrations in Human Skeletal Muscle After Phonophoresis With 10% Hydrocortisone Gel. Journal of Athletic Training 2006;41(3):321–324

37. Kurtaiş Gürsel Y, Ulus Y, Bilgic A, Dincer G, van der Heijden G. Adding ultrasound in the management of soft tissue disorders of the shoulder: a randomized placebo-controlled trial. Physical Therapy. 2004;84(4):336-343.

38. Mitragotri S, Edvards DA, Blankschtein D. A mechanistic study of ultrasonically-enhanced transdermal drug delivery. Journal of Pharmacy & Science 1995;84:697–706.

39. Morishita K, Karasuno H, Yokoi Y, Morozumi K, Ogihara H, Ito T, Hanaoka M, Fujiwara T, Fujimoto T, Abe K. Effects of therapeutic ultrasound on range of motion and stretch pain. Journal of Physical Therapy Science. 2014;26(5):711-715

40. Muftic M, Miladinovic K. Therapeutic ultrasound and pain in degenerative diseases of musculoskeletal system. Acta Informatica Medica. 2013;21(3):170-172

41. Ogura M, Paliwal S, Mitragotri S. Low-frequency sonophoresis: current status and future prospects. Advanced Drug Delivery Review 2008;60:1218–23.

42. Olyaie M, Rad FS, Elahifar MA, Garkaz A, Mahsa G. High frequency and noncontact low-frequency ultrasound therapy for venous ulcer treatment: a randomized, controlled study. Ostomy/Wound Management. 2013;59(8):14-20

43. Philadelphia Panel evidence-based clinical practice guidelines on selected rehabilitation interventions for shoulder pain. Physical Therapy. 2001;81(10):1719-1730.

44. Philadelphia Panel evidence-based clinical practice guidelines on selected rehabilitation interventions for neck pain. Physical Therapy 2001;81(10):1701-1717.

45. Philadelphia Panel evidence-based clinical practice guidelines on selected rehabilitation interventions for knee pain. Physical Therapy. 2001;81(10):1675-1700.

46. Philadelphia Panel evidence-based clinical practice guidelines on selected rehabilitation interventions for low back pain. Physical Therapy. 2001;81(10):1641-1674.

47. Philadelphia Panel evidence-based clinical practice guidelines on selected rehabilitation interventions: overview and methodology. Physical Therapy 2001;81(10):1629-1640.

48. Prentice WE. Therapeutic Modalities for Rehabilitation, 4th ed. McGraw-Hill Publishing. 2012

49. Rim GC, Barbieri CH, Lancas FM, Mazzer N. Diclofenac phonophoresis in human volunteers. Ultrasound in Medicine & Biology. 2005;31(3):337-343

50. Robertson VJ, Baker KG. A review of therapeutic ultrasound: effectiveness studies. Physical Therapy. 2001;81(7):1339-1350.

51. Rose S, Draper DO, Schulthies SS, Durrant E. The stretching window part two: rate of thermal decay in deep muscle following 1-MHz ultrasound. Journal of Athletic Training. 1996;31(2):139-143.

52. Saliba S, Mistry DJ, Perrin DH, Gieck J, Weltman A. Phonophoresis & the Absorption of Dexamethasone in the Presence of an Occlusive Dressing. JAT. 2007;42(3):349–354

53. Santamato A, Solfrizzi V, Panza F, et al. Short-term effects of high-intensity laser therapy versus ultrasound therapy in the treatment of people with subacromial impingement syndrome: a randomized clinical trial. Physical Therapy. 2009;89(7):643-652.

54. Silveira PC, Victor EG, Schefer D, Silva LA, Streck EL, Paula MM, Pinho RA. Effects of therapeutic pulsed ultrasound and dimethylsulfoxide (DMSO) phonophoresis on parameters of oxidative stress in traumatized muscle. Ultrasound in Medicine & Biology. 2010;36(1):44-50

55. Spratt HG, Levine D, Tillman L. Physical therapy clinic therapeutic ultrasound equipment as a source for bacterial contamination. Physiotherapy Theory and Practice. 2014;30(7)

56. Sreeraj SR, Bharati B, Ipseeta R. A review on ultrasound parameters and methods of application in transdermal drug delivery. Osteoarthritis and Cartilage. 2015

57. Verhagen EA. What does therapeutic ultrasound add to recovery from acute ankle sprain? A review. Clinical Journal of Sports Medicine. 2013;23(1):84-85

58. Wong RA, Schumann B, Townsend R, Phelps CA. A survey of therapeutic ultrasound use by physical therapists who are orthopaedic certified specialists. Physical Therapy. 2007;87(8):986-994.

59. Young, R., Kimura, I.F., Gulick, D.T., Accuracy of Intensity Output, Beam Nonuniformity Ratio, & Effective Radiating Area of Four Therapeutic Ultrasound Machines, Poster presentation NATA Annual Conference, June 1999 (abstract published in NATA Journal, April-June 1999, volume 34, number 2, page S-69).

EVIDENCE-BASED APPLICATION OF THERAPEUTIC ULTRASOUND

(2 CE Hours)

FINAL EXAM

1. **All of the following are indications for therapeutic ultrasound EXCEPT _______.**
   a. Collagen extensibility
   b. Increased blood flow
   c. Increased muscle strength
   d. Pain relief

2. **Which of the following are NOT contraindications for therapeutic ultrasound?**
   a. Epiphyseal plates
   b. Joint arthroplasty
   c. Malignancy
   d. Pregnancy

3. **Which of the following is TRUE about ultrasound coupling mediums?**
   a. Flex-All at a 3:1 ratio can be an effective medium
   b. Heating US gel increases conductivity
   c. Thicker gel pads result in increased tissue heating
   d. Underwater intensity should be lower

4. **The recommended treatment area is _______ times ERA.**
   a. 2 - 3
   b. 4 - 6
   c. 5 - 7
   d. 8 - 10

5. **Ultrasound to a sprained finger would best be administered using which of the following conditions?**
   a. 2 cm2 or 5 cm2 transducer with gel
   b. 2 cm2 or 5 cm2 transducer underwater
   c. 5 cm2 or 10 cm2 transducer with gel
   d. 5 cm2 or 10 cm2 transducer underwater

6. **Frequency of therapeutic ultrasound is measured in:**
   a. cm2
   b. degrees C
   c. MHz
   d. w/cm2

7. **If an ultrasound unit has a BNR of 6:1, you could expect spikes of _______ intensity when performing a treatment at 1.8 W/cm2.**
   a. 0.3 W/cm2
   b. 3 MHz
   c. 10. 8 W/cm2
   d. 10.8 MHz

8. **A 3-MHz US treatment is rendered for 10 minutes and yields a 4°C tissue temperature increase. Which of the following pulsed parameters would effectively reduce the thermal effects to 1°C?**
   a. 10%
   b. 25%
   c. 30%
   d. 50%

9. **When performing ultrasound, it is recommended to _______.**
   a. Hold the soundhead still under the water
   b. Move the soundhead at 3-4 cm/sec in circular strokes
   c. Move the soundhead at 3-4 cm/sec in longitudinal strokes
   d. Move the soundhead at 4-6 inch/sec in longitudinal strokes

10. **A Cochrane Review by van den Bekerom, van der Windt, ter Riet, van der Heijden, and Bouter (2011) on therapeutic ultrasound (US) for acute ankle sprains found _______.**
    a. US to be successful for management of pain, swelling, functional disability, and range of motion
    b. US to be successful for management of functional disability and range of motion, but unsuccessful for management of pain and swelling
    c. US to be successful for management of pain and swelling, but unsuccessful for management of functional disability and range of motion
    d. US to be unsuccessful for management of pain, swelling, functional disability, or range of motion

11. **Based on the research of Draper et al, the temperature decay after ultrasound affords you approximately _______ until the temperature drops about 2°C.**
    a. 1.5 minutes
    b. 3.5 minutes
    c. 10 minutes
    d. 15 minutes

12. **Betty Boop has limited knee extension due to soft tissue shortening. You positioned her prone for an US treatment to the hamstrings. If the goal is to improve knee extension ROM, stretching of the knee should occur _______.**
    a. During the administration of ultrasound only
    b. During & immediately after the administration of ultrasound
    c. Immediately before the administration of ultrasound
    d. Immediately before & during the administration of ultrasound

13. **Olvaie, Rad, Elahifar, Garkaz, and Mahsa (2013) considered ultrasound (US) as applied to wound healing. 90 patients with chronic wounds were randomly assigned to one of three groups: standard care (multilayer compression bandaging, non-adherent dressing, and regular debridement), high-frequency US, or non-contact low-frequency US. They found that _______.**
    a. In addition to the enhanced healing, edema and pain rating score were also significantly better for the standard care groups over that of US
    b. In addition to the enhanced healing, edema and pain rating score were also significantly better for the US groups over that of just standard care
    c. US groups displayed a longer average healing time than standard care
    d. US groups displayed larger wound sizes after 4 months than standard care

14. **Which of the following medications is used in phonophoresis to provide pain relief?**
    a. Dexamethasone
    b. Dimethylsulfoxide
    c. Lidocaine
    d. Methyl nicotinate

15. **In summary of phonophoresis, _______.**
    a. No research to date has supported the efficacy of US
    b. Research to date demonstrates that continuous and pulsed modes of US are equally effective
    c. There is research to support the ability to transmit various substances through the stratum corneum with the aid of continuous US; the pulsed mode of US is not as effective.
    d. There is research to support the ability to transmit various substances through the stratum corneum with the aid of pulsed US; the continuous mode of US is not as effective

ANSWER SHEET

First Name: ______________________ Last Name: ______________________ Date: __________

Address: ____ City: ______________________

State: ______________________ ZIP: ____________ Country ______________________

Phone: ______________________ Email: ____

License/certification # and issuing state/organization ______________________________

Clinical Fellow: Supervisor name and license/certification # ______________________________

Graduate Student: University name and expected graduation date ______________________________

** See instructions on the cover page to submit your exams and pay for your course.

By submitting this final exam for grading, I hereby certify that I have spent the required time to study this course material and that I have personally completed each module/session of instruction.

Evidence-Based Electrical Stimulation
Final Exam

1. Ⓐ Ⓑ Ⓒ Ⓓ	4. Ⓐ Ⓑ Ⓒ Ⓓ	7. Ⓐ Ⓑ Ⓒ Ⓓ	10. Ⓐ Ⓑ Ⓒ Ⓓ	13. Ⓐ Ⓑ Ⓒ Ⓓ
2. Ⓐ Ⓑ Ⓒ Ⓓ	5. Ⓐ Ⓑ Ⓒ Ⓓ	8. Ⓐ Ⓑ Ⓒ Ⓓ	11. Ⓐ Ⓑ Ⓒ Ⓓ	14. Ⓐ Ⓑ Ⓒ Ⓓ
3. Ⓐ Ⓑ Ⓒ Ⓓ	6. Ⓐ Ⓑ Ⓒ Ⓓ	9. Ⓐ Ⓑ Ⓒ Ⓓ	12. Ⓐ Ⓑ Ⓒ Ⓓ	15. Ⓐ Ⓑ Ⓒ Ⓓ

Accessibility and/or special needs concerns?
Contact customer service by phone at (888) 564-9098
or email at support@pdhacademy.com.

Refund and general policies are available online at
http://pdhacademy.com/policies/

Evidence-Based Application of Therapeutic Ultrasound

(2 CE HOURS)

COURSE EVALUATION

Learner Name: ______________________________

	Disagree				Agree	
Orientation was thorough and clear	1	2	3	4	5	
Instructional personnel disclosures were readily available and clearly stated	1	2	3	4	5	
Learning objectives were clearly stated	1	2	3	4	5	
Completion requirements were clearly stated	1	2	3	4	5	
Content was well-organized	1	2	3	4	5	
Content was at or above entry-level knowledge	1	2	3	4	5	
Content was substantiated through use of references, footnotes, etc.	1	2	3	4	5	
Content reflected stated learning objectives	1	2	3	4	5	
Exam assessed stated learning objectives	1	2	3	4	5	
Exam was graded promptly	1	2	3	4	5	
Satisfied with learning experience	1	2	3	4	5	
Satisfied with customer service (if applicable)	1	2	3	4	5	n/a

What suggestions do you have to improve this program, if any?

____

____

What educational needs do you currently have?

____

____

What other courses or topics are of interest to you?

____

____