WHITE PAPER

The Gel-Shot: An Improvement in Ultrasound Coupling Media

Draper DO, Wells A, Rigby JH: Brigham Young University, Provo, UT 84602 (Dec. 2013)

Therapeutic ultrasound is inaudible, acoustic vibrations of high frequency that produce thermal and/or nonthermal physiologic effects. It is a valuable tool in the rehabilitation of many different injuries, primarily for the purpose of stimulating the repair of soft tissue injuries and relieving pain.[14] Ultrasound has advantages over nonacoustic heating modalities, such as whirlpools and hot packs. It can heat deep tissues high in collagen, such as tendons, muscles, ligaments and joint capsules, without the possibility of overheating tissue surfaces.

ULTRASOUND COUPLANTS

Transmission of ultrasound only occurs through a medium and does not pass through air or the skin. Optimal ultrasound use requires that a coupling medium be placed between the skin and the ultrasound transducer. Transmission of ultrasound energy through one material to another is dependent on the physical properties of these materials. Thus, careful selection of the preparations used for ultrasound transmission is required. Some commercially prepared gels, lotions, water, mineral oil and glycerin are effective coupling agents for ultrasound.[4,5,10,17,20] The three most commonly used ultrasound couplants are gels, for direct application; water, for the immersion technique; and 1-2cm thick gel pads, for use over bony surfaces.[14]

Direct Application

Commercially available, water soluble ultrasound gel is by far the most common coupling agent used for direct contact ultrasound application.[14,17] A layer of gel is applied to the treatment area in sufficient amounts to maintain good contact and lubrication between the soundhead and the skin. How much gel should be used is a question many clinicians have had for years. Some report using “generous amounts” whereas others suggest that a thin layer be placed between the soundhead and the skin.[14]

Water Immersion Technique

Water is a great coupling medium, but it is not suited for surface application because it will not stay in place like gel. There are, however, some instances where you might want to use the underwater technique. The immersion technique is recommended if the area to be treated is smaller than the diameter of the available soundhead or if the treatment area is irregular with boney prominences. With the immersion technique, a plastic container is filled with warm tap water. The ultrasound head is held 0.5 cm away from the skin and the soundhead is slowly moved.

The Gel Pad Technique

If the treatment area is irregular but cannot be immersed in water, you can use the gel pad as a medium. A gel pad resembles a gel-filled clear hockey puck. A few studies have been performed on the efficacy of gel pads. Two studies suggest that ultrasound gel pads are as effective as ultrasound gel.[13,16] In another study,[7] two thicknesses of the gel pad were tested against ultrasound gel. The two thicknesses were the traditional 2 cm thick pad and the 1 cm thick pad. Ultrasound using the 1cm gel pad heated the tissue 1/3 higher than the 2 cm gel pad, however the gel still heated the tissue the highest. With this in mind, Rich Mar developed the gel shot.

THE GEL-SHOT

The gel shot is a small disk (3 mm thick) that comes in 2, 5 and 10 cm^2 sizes (Figure 1). With an adapter that is attached to the soundhead, the gel shot fits firmly on the face plate of the ultrasound head. As stated earlier, many therapists either use too much gel, or not enough, thus the distance between the skin and the soundhead is not consistent. Consequently, the dosage of ultrasound is compromised. The gel shot is 3 mm thick providing optimal coupling between the soundhead and the skin. This results in a consistent dosage of ultrasound to the treatment site.

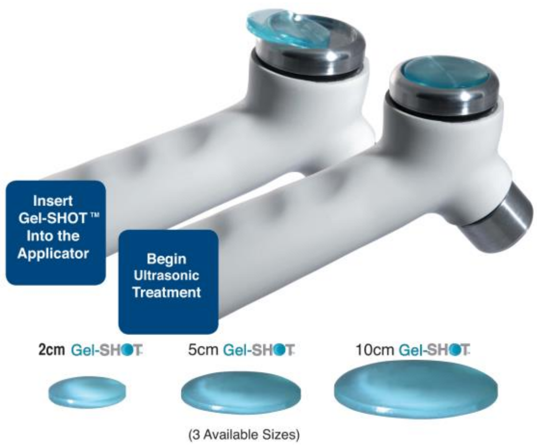

Figure 1. The gel shot in 2, 5 and 10 cm sizes.

RESEARCH ON THE GEL SHOT

We wanted to know how the gel shot compared with ultrasound gel as a couplant. We surmised that the best couplant would deliver more ultrasound energy to the tissue which would result in higher tissue temperatures. Therefore, the purpose of our study was to assess the effectiveness of the gel shot as a coupling medium compared to ultrasound gel, by measuring tissue temperature changes in the triceps surae muscle during a 10 minute ultrasound treatment.

TWO STUDIES (laboratory and clinical)

In order to determine whether ultrasound gel or the gel shot was the most effective couplant, two studies were required. The first (laboratory study) required application of the couplant to a horizontal surface (the posterior surface of the calf). Under these closely controlled conditions, the ultrasound gel would not run down the muscle, but would generally stay in place. There would be minimal scooping of the gel to keep it under the soundhead. This would show a head to head comparison of the coupling mediums.

The second study (clinical study) would test the gels in a typical treatment environment. For this, the ultrasound gel and gel shot would be applied to the medial side of the calf muscle. This gravity dependent position would cause the gel to run somewhat while the gel shot would stay in place. In this setting, the clinician would be scooping the gel back onto the treatment site several times. This lifting of the soundhead off of the tissue would hypothesize to result in a lower temperature increase.[17]

METHODS

The same technique developed by DD over 20 years ago was used to measure deep muscle temperatures.[6,8,9,11] We used a 2 x 2 x 20 repeated measures crossover design for temperature heating. The dependent variable was tissue temperature of the triceps surae muscle group measured to the nearest 0.1°C. The independent variables were 2 levels of treatment groups (gel shot and ultrasound gel), 2 levels of ultrasound frequency (1 and 3 MHz) and time. Time was measured at pretreatment baseline and, then, at 30 second intervals during the 10 minute treatment (20 points).

Participants

We recruited 38 participants for our study (M = 22 , F = 15, age = 23.1 ± 3.6 yrs, height = 69.8 ± 4.2, weight = 172.1 ± 42.0). Each subject was screened for disqualifying conditions that included pregnancy, infection, fever, or injury to the triceps surae area in the past 2 months. During the study, all participants were fully compliant, and we did not have to terminate a treatment because no subject reported pain during the treatment. All participants provided written, informed consent, and the study was approved by Brigham Young University's Institutional Review Board.

Instruments

Implantable IT-21 thermocouples (Physitemp Instruments Inc, Clifton, NJ) were plugged into an electrothermometer (Iso-Thermix; Columbus Instruments, Columbus, OH) to instantaneously record tissue temperatures. The reliability and validity of the IT-21 thermocouples and Iso-Thermix electrothermometer have been described previously.[12,15] We used a musculoskeletal imaging ultrasound (LOGIQ 5P; General Electric Company, Fairfield, CT) to verify the depth that each thermocouple was placed. The ultrasound device was manufactured by Rich-Mar (Chattanooga, TN). The two couplants we used were the gel shot (Rich-Mar, Chattanooga, TN) and ultrasound transmission gel (Parker Laboratories, Fairfield, NJ).

Procedures

Participants were instructed to refrain from exercise for at least 2 hours before testing. Each subject wore shorts for the treatments and reported to the modalities laboratory at Brigham Young University. Participants were randomly assigned to receive either 1 or 3 MHz ultrasound treatments throughout their participation in the study. We used a random draw to determine which couplant was to be used first and 48 hours later. Participants lay prone on a treatment table. The calf muscle served as the target tissue. A small carpenter square was used to measure perpendicularly from an already marked line on the posterior skin surface to a 2 or 3 cm (actual depth = 1.9 ± 0.1 or 2.9 ± 0.1 cm) posterior to anterior distance on the medial side of the calf for the 3 or 1 MHz treatments, respectively. A dot was placed on the skin on the medial side of the triceps surae at 3 cm distance.

The skin over the target tissue was prepared using an iodine swab and wiped clean using an isopropyl alcohol preparation pad. A 20-gauge 1.88 in (2.54 cm) catheter (BD Medical, Franklin Lakes, NJ) was inserted at the desired depth into the medial aspect of the triceps surae. The depth of the catheter insertion was verified to be within 0.2 cm of the desired depth using the musculoskeletal imaging ultrasound (Figure 2). Next, we inserted one IT-21 thermocouple via the catheter. We slowly removed the catheter, leaving the thermocouple intact (Figure 3). The catheter was removed to expose the end of the thermocouple so that proper intramuscular temperature could be obtained. If not removed, the catheter would have covered the thermocouple and interfered with its ability to properly measure tissue temperature. The thermocouple was secured to the skin with clear medical tape; it was attached to an Iso-Thermix electrothermometer and set to measure tissue temperature every 30 seconds. Baseline temperature was recorded and reached when the temperature did not change more than 0.5° C over a 1 minute period.

Figure 2. Verification of thermocouple depth via musculoskeletal imaging ultrasound

Figure 3. Insertion of thermocouple via the catheter

Ultrasound Treatment

Order of treatments was determined by a random draw. One-half of the subjects had the ultrasound gel treatment first followed by the gel shot 48 hours later. The other half had the gel shot first followed by the gel 48 hours later. After the baseline temperature was reached, we began the ultrasound treatment. For the 1 MHz treatment, the following parameters were used: continuous mode, 1.5 W/cm^2, 10 minutes. For the 3 MHz treatment, the following parameters were used: continuous mode, 1.0 W/cm^2, 10 minutes. Each treatment involved treating an area 2 times the size of the soundhead at a speed of about 4 cm/sec. For the gel treatment, about 5 ml of ultrasound gel was applied to the site (once at the start of the treatment and a second allocation of gel was applied midway through the treatment) (Figure 4). During the treatment the soundhead was lifted off the skin to scoop the gel back onto the treatment area. This happened about once per minute. Methods for the gel shot treatment were identical except that scooping of the gel was not needed. After the 10 minute treatment, the thermocouples were taken out, the area cleansed and a band-aid was applied to the treatment site.

Statistical Analysis

For all data, tissue temperature change was calculated as the difference between measured temperatures minus baseline. For both studies, we used a repeated measure ANOVA to determine statistical differences between the gel shot and ultrasound gel over the course of the ultrasound treatment. Different analyses were performed for each frequency.

Figure 4. Ultrasound treatment (treating an area 2 times the size of the soundhead at a speed of about 4 cm/sec) using ultrasound gel.

RESULTS
Laboratory setting
1 MHz

On average, the gel shot produced a 3.9 ± 1.4° C temperature increase, while the ultrasound gel treatment produced a 2.6 ± 1.1° C temperature increase. The gel shot produced temperatures 33.5% higher than the gel technique (Figure 5). The gel shot significantly allowed for an increase in temperature at a greater rate than the ultrasound gel ($F_{20,\ 181}$ = 1.65, P=0.045).

3 MHz

On average, the gel shot produced a 4.5 ± 1.2° C temperature increase, while the ultrasound gel treatment produced a 4.1 ± 1.4° C temperature increase. The gel shot produced temperatures 9.3% higher than the gel technique (Figure 6). The gel shot did not significantly increase tissue temperature at a greater rate than the ultrasound gel ($F_{20,\ 180}$ = 0.67, P=0.85).

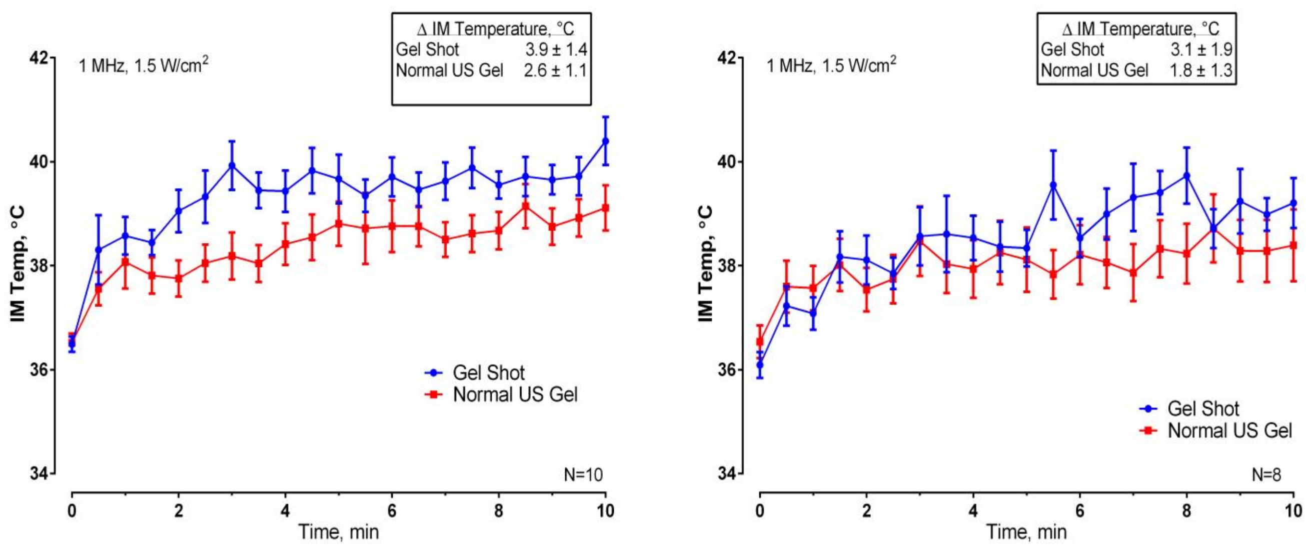

Figure 5. Increase of intramuscular temperature during 1 MHz ultrasound treatment for laboratory (left) and clinical (right) studies.

Clinical setting

1 MHz

On average, the gel shot produced a 3.1 ± 1.8° C temperature increase, while the ultrasound gel treatment produced a 1.9 ± 1.3° C temperature increase. The gel shot produced temperatures 40.5% higher than the gel technique (Figure 5). The gel shot significantly allowed for a greater average tissue temperature ($F_{1,7} = 16.71$, $P = 0.0046$) and increased rate of heating compared to ultrasound gel ($F_{20,140} = 2.75$, $P = 0.0003$).

3 MHz

On average, the gel shot produced a 5.8 ± 1.3° C temperature increase, while the ultrasound gel treatment produced a 5.2 ± 0.9° C temperature increase. The gel shot produced temperatures 11.0% higher than the gel technique (Figure 6). The gel shot did not significantly increase tissue temperature at a greater rate than the ultrasound gel ($F_{20,180} = 0.67$, $P=0.85$).

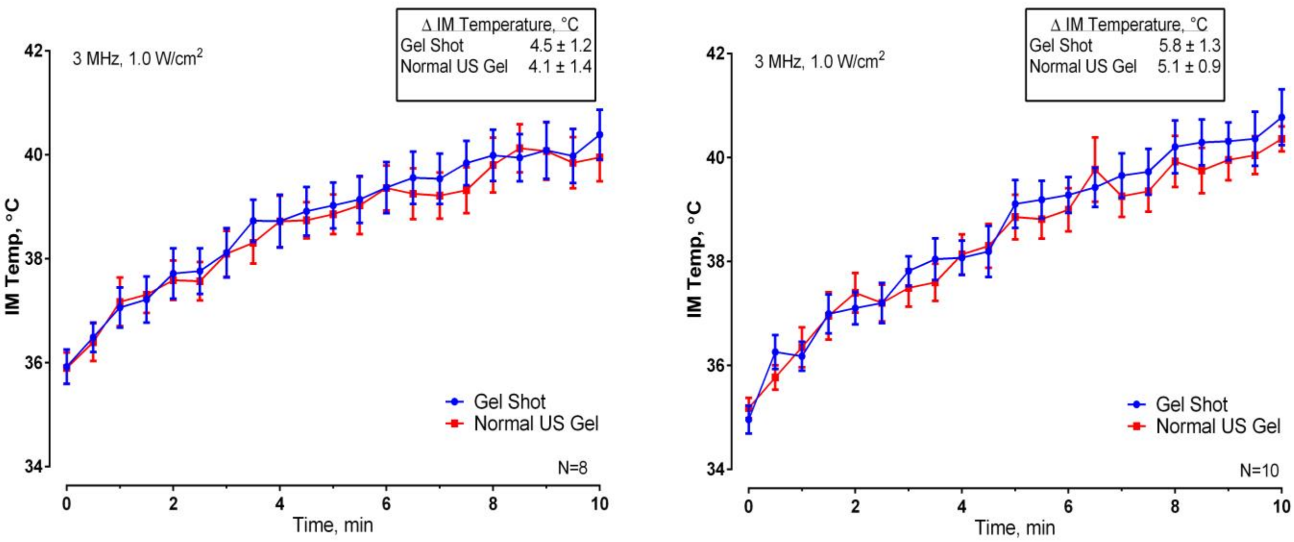

Figure 6. Increase of intramuscular temperature during 3 MHz ultrasound treatment for laboratory (left) and clinical (right) studies.

DISCUSSION

There have been several studies that tested the effectiveness of ultrasound couplants.[1-5,7,10,18-20] However, we are the first to test the effectiveness of the gel shot as an ultrasound couplant. We have shown that the gel shot is superior to ultrasound gel at increasing tissue temperature. We believe there are 4 main reasons for this. First, the gel shot produces an even medium over the tissue. The gel application is not uniform, due to the soundhead pushing gel out of the way of treated tissues. The gel shot is uniform and never changes in shape or consistency. Second, there are no air bubbles in the gel shot, which can lead to cavitation and impeding of the ultrasound beam. Third, the gel shot is always the same thickness (3 mm). This produces uniform coupling throughout the treatment. The gel might start at 3 mm thickness, but that is easily decreased as the soundhead puts pressure on the gel. Fourth, the gel shot stays in place on the soundhead for 100% of the treatment. The gel is constantly pushed out of the way, thus requiring the clinician to lift the soundhead from the target tissue and "scoop" the gel back on the soundhead. We hypothesize that this act would reduce the amount of heat to the area.

Cameron and Monroe[4] used a 5 mm thickness of medium in a study used to determine the best ultrasound couplant. She stated that a layer as thin as 0.5 mm can be used clinically. They are of the opinion that changes in the thickness of the layer do not affect how well the medium works as a couplant. We disagree with this premise. We feel that the consistent 3 mm thick gel shot contributed to it being a more effective couplant than the ultrasound gel.

BENEFITS OF THE GEL-SHOT

-The Gel-Shot is sterile. It comes individually wrapped in a hermetically sealed blister pack, therefore eliminating bacteria. Ultrasound gel comes in a bottle, the tip of which is often placed on the skin. The tip of the gel bottle can be a breeding ground for bacteria and ultrasound heads that are not wiped clean can have gel infested bacteria on them.

-There is no mess with the Gel-Shot. Patients will no longer have cold and messy ultrasound gel running all over them and their clothes. Therapists will no longer have to clean up the area with towels. There will be no messy soundheads after treatment which shortens applicator life.

-The Gel-Shot allows for a 360° treatment application. Ultrasound gel will run when placed in a gravity dependent position. The gel shot can be applied to any surface in any gravity dependent position while not losing any of the couplant.

-The Gel-Shot is inexpensive, less than 30 cents per shot. By the time freight is considered in the equation, ultrasound gel can be more expensive.

-The Gel-Shot treatment area maintains its size, allowing for proper treatment of 2 times the size of the soundhead. Because ultrasound gel spreads out, the treatment area gets bigger as the clinician goes out of the recommended treatment area to capture escaping gel.

-Due to the all of the above qualities listed, the gel shot will certainly produce better efficiency and better outcomes than ultrasound treatments using a gel medium.

REFERENCES

1. Ashton DF, Draper DO, Myrer JW. Temperature rise in human muscle during ultrasound treatments using flex-all as a coupling agent. *J Athl Train.* 1998;33(2):136-140.

2. Bishop S, Draper DO, Knight KL, Feland BJ, Eggett D. Human tissue-temperature rise during ultrasound treatments with the aquaflex gel pad. *J Athl Train.* 2004;39(2):126-131.

3. Cage SA, Rupp KA, Castel JC, Saliba EN, Hertel J, Saliba SA. Relative acoustic transmission of topical preparations used with therapeutic ultrasound. *Arch Phys Med Rehabil.* 2013;94(11):2126-2130.

4. Cameron MH, Monroe LG. Relative transmission of ultrasound by media customarily used for phonophoresis. *Phys Ther.* 1992;72(2):142-148.

5. Docker MF, Foulkes DJ, Patrick MK. Ultrasound couplants for physiotherapy. *Physiotherapy.* 1982;68(4):124-125.

6. Draper DO, Castel JC, Castel D. Rate of temperature increase in human muscle during 1 MHz and 3 MHz continuous ultrasound. *J Orthop Sports Phys Ther.* 1995;22(4):142-150.

7. Draper DO, Edvalson CG, 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. *J Athl Train.* 2010;45(4):333-337.

8. Draper DO, Hawkes AR, Johnson AW, Diede MT, Rigby JH. Muscle heating with Megapulse II shortwave diathermy and ReBound diathermy. *J Athl Train.* 2013;48(4):477-482.
9. Draper DO, Sunderland S. Examination of the law of grotthus-draper: does ultrasound penetrate subcutaneous fat in humans? *J Athl Train.* 1993;28(3):246-250.
10. Griffin JE. Transmissiveness of ultrasound through tap water, glycerin, and mineral oil. *Phys Ther.* 1980;60(8):1010-1016.
11. Hawkes AR, Draper DO, Johnson AW, Diede MT, Rigby JH. Heating capacity of rebound shortwave diathermy and moist hot packs at superficial depths. *J Athl Train.* 2013;48(4):471-476.
12. Jutte LS, Knight KL, Long BC, Hawkins JR, Schulthies SS, Dalley EB. The Uncertainty (Validity and Reliability) of Three electrothermometers in Therapeutic Modality Research. *J Athl Train.* 2005;40(3):207-210.
13. Klucinec B, Scheidler M, Denegar C, Domholdt E, Burgess S. Transmissivity of coupling agents used to deliver ultrasound through indirect methods. *The Journal Of Orthopaedic And Sports Physical Therapy.* 2000;30(5):263-269.
14. Knight K, Draper D. *Therapeutic modalities: the art and science.* 2nd ed. Baltimore: Lippincott Williams & Wilkins; 2013.
15. Long BC, Jutte LS, Knight KL. Response of thermocouples interfaced to electrothermometers when immersed in 5 water bath temperatures. *J Athl Train.* 2010;45(4):338-343.
16. Merrick MA, Mihalyov MR, Roethemeier JL, Cordova ML, Ingersoll CD. A comparison of intramuscular temperatures during ultrasound treatments with coupling gel or gel pads. *The Journal Of Orthopaedic And Sports Physical Therapy.* 2002;32(5):216-220.
17. Michlovitz SL, Bellew J, Nolan T. *Modalities for Therapeutic Intervention.* 5th ed. Philadelphia, PA: FA David; 2012.
18. Myrer JW, Measom GJ, Fellingham GW. Intramuscular temperature rises with topical analgesics used as coupling agents during therapeutic ultrasound. *J Athl Train.* 2001;36(1):20-26.
19. Rigby J, Dye S, Draper D. A comparison of Biogreeze mixure o 100% ulrasound gel as a coupling medium duing therapeutic ultasound. *Ath Train & Sports Healthcare.* 2014;6(1).
20. Warren CG, Koblanski JN, Sigelmann RA. Ultrasound coupling media: their relative transmissivity. *Arch Phys Med Rehabil.* 1976;57(5):218-222.