Use of Pulsed Shortwave Diathermy and Joint Mobilization to Increase Ankle Range of Motion in the Presence of Surgical Implanted Metal: A Case Series

Cindy Seiger, PT, MS[1]
David O. Draper, EdD, ATC,L[2]

Study Design: Case series.
Background: Traditionally, all forms of diathermy have been contraindicated over metal implants. There is a lack of research-based evidence for harm regarding the use of pulsed shortwave diathermy (PSWD) over orthopaedic metal implants. Because PSWD is an effective modality for deep heating, we investigated whether ankle range of motion (ROM) could improve with the cautious use of PSWD and joint mobilizations, despite orthopaedic metal implants being in the treatment field.
Case Descriptions: Four subjects presented with decreased ankle ROM due to extensive fractures from traumatic injuries. All subjects were postsurgical, with several internal fixation devices. Subjects previously received rehabilitation therapy involving joint mobilizations, therapeutic exercises, moist heat, and ice, but continued to lack 15° to 23° of ankle dorsiflexion. The Human Subjects Review Board of Brigham Young University approved the methods of this case series. Subjects gave written informed consent. Initial dorsiflexion active ROM for each patient was –3°, 0°, 8°, and 5°, respectively. Treatment regime consisted of PSWD to the ankle for 20 minutes at 27.12 MHz, 800 pps, 400 microseconds (48 W). Immediately after PSWD, mobilizations were administered to the joints of the ankle and foot. Ice was applied posttreatment.
Outcomes: Dorsiflexion improved 15°, 15°, 10°, and 14°, respectively, after 8 or 13 visits. All patients returned to normal activities with functional ROM in all planes. Follow-up 4 to 6 weeks later indicated that the subjects maintained 78% to 100% of their dorsiflexion. No discomfort, pain, or burning was reported during or after treatment. No negative effects were reported during the short-term follow-up.
Discussion: When applied with appropriate caution, we propose PSWD (48 W) may be an appropriate adjunct to joint mobilizations to increase ROM in peripheral joints, despite implanted metal. We continue to advise caution when applying diathermy with machines other than the Megapulse II. Further research is needed to determine the safety parameters of other diathermy machines. As a final caution, we advise that diathermy not be used in the presence of a cardiac pacemaker or neurostimulator. *J Orthop Sports Phys Ther 2006;36(9):669-677.* doi:10.2519/jospt.2006.2198

Key Words: *heat, internal fixation, modalities, physical agents, shortwave diathermy*

[1] *Clinical Assistant Professor, Department of Physical and Occupational Therapy, Idaho State University, Pocatello, ID.*
[2] *Professor, Department of Exercise Sciences, Brigham Young University, Provo, UT.*
This series was approved by the Brigham Young University Human Subjects Review Board.
Address correspondence to Cindy Seiger, Idaho State University, Box 8045, Portacello, ID 83201. E-mail: seigcind@isu.edu

The use of heat to treat injury and disease has been historically documented. Traditionally, heat has been applied in the form of heated air or water. Heat decreases muscle spasm and pain, along with increasing blood flow and collagen extensibility.[25] In rehabilitation the most common form of heat application is a moist heat pack. Other forms of heat used in rehabilitation include paraffin wax, heated whirlpool, ultrasound, and diathermy.[5,10,11,15,35,39,43,47,51]

Diathermy has been used to apply heat for treatment of different types of injuries, including chronic pelvic inflammation,[3] adhesive capsulitis,[18] low back pain,[52] myofascial trigger points,[32,48] osteoarthritis,[19] and ankle and foot sprains.[38] Diathermy has also been used in postsurgical ankle rehabilitation.[44] Preliminary research has indicated that pulsed shortwave diathermy (PSWD) (48 W) heats deep tissue (depth, 3-5 cm) to approximately a 4°C temperature increase.[10] According to Lehmann,[25] a temperature increase of 4°C is necessary to increase collagen extensibility and inhibit sympathetic activity.

CASE REPORT

Current practice recommendations indicate diathermy should not be applied over joints with metal implants because of the possibility of causing tissue damage.[22,43,47,50] This recommendation of contraindication appears to be based on ''common sense'' and consensus rather than evidence-based practice because of the effect on the metal in pacemakers and neurostimulators.[47,50]

There is a lack of research on the effects or safety of PSWD in the presence of orthopedic metal implants. Early work indicated that the use of shortwave fields do not heat metal within phantom loads simulating human tissue except when the metal acted as a shunt for a ''pathway of low resistance'' when compared to the surrounding tissue.[12,45] This pathway decreased the resistance and created an area for the electromagnetic field to concentrate. The metal only acted as a pathway when a rod-shaped metal implant was placed directly perpendicular to the field or a thin metal wire was in the field. The longer the shunt the more concentrated the field became and the greater the risk of burns increased.[12,45] The heating in this situation occurred at the ends of the metal and not along the entire metal piece. It was concluded that shortwave diathermy could safely be applied in the presence of metal as long as radiographic images were available to enable the diathermy to be aligned in a way that was not perpendicular to the main axis of the metal implant.[12,45]

Since its discovery, diathermy has been recognized as an alternative to infrared energy for heating deep tissue.[32,52] There are 2 types of diathermy: microwave and shortwave. Shortwave diathermy has become more predominate due to the higher risk of injury when using microwave radiation. The more commonly used moist heat packs effectively heat to a depth of only 1 cm below the skin surface,[9] whereas PSWD has been shown to produce a 4°C temperature increase at a depth of 3 to 5 cm.[7,10,36] Ultrasound is also used to heat to a depth of 3 to 5 cm, but the treatment area is small (3-10 cm^2), while the diathermy treatment area is much larger (150-200 cm^2).[14] Thus, diathermy is advantageous for larger treatment areas. Diathermy may also be applied over a thin layer of clothing, while ultrasound requires the use of a coupling gel directly in contact with the skin.[14]

In conjunction with heat, joint mobilizations are used to increase collagen extensibility and improve joint physiologic and accessory movements.[17,18,20,30] Research indicates that joint mobilizations improve range of motion (ROM) when joint stiffness is present.[19,33] For patient comfort and to minimize posttreatment soreness, it is valuable to increase the temperature of the area to be mobilized.[20]

Both authors have used PSWD in clinical situations to apply deep heat to joints with decreased ROM after an immobilization period. PSWD was chosen for these patients because of the size of the area to be heated and the depth of the targeted tissues. This application, in conjunction with joint mobilizations, has been an effective treatment regimen for these patients. Because of the anecdotal results that occurred in patients without metal implants, we investigated whether ankle ROM would improve with the cautious use of deep heat (PSWD) and joint mobilizations despite orthopedic metal implants being in the treatment field. The purpose of this case series is to describe the treatment protocol used in 4 patients with metal implants due to an open reduction and internal fixation (ORIF) surgery after traumatic injury. The difference with this protocol from other protocols is the addition of PSWD prior to joint mobilizations.

CASE DESCRIPTIONS

History

A summary of each patient history is presented in Table 1. All patients were referred separately to this research institution by associates of the patients who had knowledge of the research being conducted. All inquired of and attended the research institution due to significantly decreased ROM in 1 ankle joint, which limited daily and recreational activities. Patients were excluded if they had a compromised peripheral vascular system, decreased sensation in the affected area, pregnancy, or implanted pacemaker or neurostimulator. The Brigham Young University Human Subjects Review Board approved the methods used for this case series and all patients signed an informed consent form. This consent form included a warning about the possibility of burns due to excessive heating. Each patient presented copies of their most recent radiographs to ensure that the diathermy field would not be applied perpendicular to the long axis of the metal implant.

The patients (3 female, 1 male) ranged in age from 22 to 48 years. All patients sustained their injuries from traumatic accidents. All received surgery to internally fixate the bones of the talocrural joint. We obtained radiographic images for all of the patients to determine the placement of the metal implants (Figure1).

Patient 1 sustained a Pilon fracture with talar dislocation during a motor vehicle accident. Because of the severity of the injury, patient 1 was advised by the surgeon that an amputation might be required due to a sustained decreased arterial blood supply to the foot. Patient 1 refused amputation but, instead, opted for surgery receiving a total of 18 metal implants. During the surgery, the arterial and venous vascular network was repaired and the patient had no further vascular complications.

TABLE 1. Patient history.

	Patient 1	Patient 2	Patient 3	Patient 4
Age (y)	48	39	37	22
Sex	Female	Female	Female	Male
Affected ankle	Left	Right	Left	Right
Mechanism of injury	Auto accident	Auto accident	Fall due to obstacle	Sporting accident
Time since injury	4 mo	18 y	2 y	7 mo
Type of injury	Pilon fracture with talar dislocation	Fractured talus	Fractured medial malleolus	Fractured tibia, dislocated talus
Type of internal fixation	18 pieces including 2 plates and 16 screws	1 screw, 1 pin	2 screws	1 plate, 2 permanent screws, 2 biodegradable screws
Previous physical therapy*	Yes	Yes	Yes	Yes

* Physical therapy included moist heat/ice pack, ultrasound, joint mobilizations, stretching, therapeutic exercises for strength and range of motion, and balance re-education.

Patient 2 was involved in a motor vehicle accident fracturing her talar trochlea and lateral malleolus. During surgery, patient 2 had the uppermost portion of her talar dome removed due to the fracture site and had 1 screw implanted. Patient 3 fractured the left medial malleolus due to a sudden eversion of the foot when stepping into a hole in the ground while walking around a campground at night. Surgery repaired the fracture with the implantation of 2 screws. Patient 4 dislocated the talus and fractured the tibia when hit during a rugby match with his foot planted on the ground. His fractures were repaired with 1 plate and 2 screws.

Each patient had attended physical therapy after surgery. During their physical therapy sessions, each received moist heat/cold packs, hot whirlpool, ultrasound to the scar site, passive and active stretching, joint mobilizations, therapeutic exercises for strengthening and ROM, and balance re-education. While the therapeutic exercises and balance re-education were slightly different for each patient, all received the moist heat/cold packs, hot whirlpool, ultrasound, stretching, and joint mobilizations. It is unclear which joint mobilizations were applied to each patient or the skill of the therapist who applied the mobilizations. All patients were told by their orthopedic surgeons that no further gains would occur in their ankle ROM.

Examination

All patients presented to the facility with altered gait and patient 1 was unable to heel strike during gait. Upon testing, all demonstrated decreased ankle ROM and muscle strength, altered single-leg balance, tenderness to palpation, and occasional joint pain. None of the patients demonstrated edema on palpation or visual inspection of the ankle or foot.

The movements measured were dorsiflexion and plantar flexion of the talocrural joint and inversion/adduction and eversion/abduction of the subtalar and forefoot regions. Active range of motion (AROM) was tested in the non–weight-bearing position of long sitting. In this position, neutral was considered to be when the foot was at a 90° angle to the tibia. In this position, we considered normal dorsiflexion AROM to be 15° to 20°, plantar flexion 40° to 50°, inversion/adduction 30° to 35°, and eversion/abduction 20° to 30° from neutral.[2,28,40] During the initial examination, the patients lacked 15° to 23° of dorsiflexion.

The same therapist obtained all AROM measurements using a 10.16-cm, plastic, 360° universal goniometer (scale marked in 1° increments).[4,13,29,42,53] The bony landmarks used for dorsiflexion and plantar flexion measurement were the lateral midlines of the fibula and the fifth metatarsal. The bony landmarks used for inversion/adduction and eversion/abduction measurement were the tibial crest, anterior midline of the talocrural joint, and the anterior midline of the second metatarsal. These landmarks were standardized for each patient to ensure reliability and validity of the measurement.[13] The same goniometer was

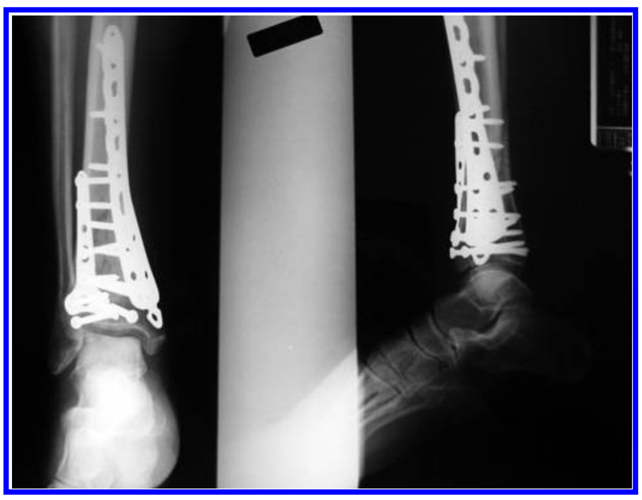

FIGURE 1. Radiographs of the ankle of patient 1 showing 18 metal implants.

CASE REPORT

used for all measurements to limit error due to differences between goniometers. However, no masking of the goniometer was used during the measurements.

Despite the limitations and inherent errors in using a goniometer for measurement, we considered a deficit of greater than 5°, compared to the unaffected ankle AROM, to be a clinically meaningful limitation and a gain of 5° after treatment to be a meaningful improvement. Five degrees of change was chosen as the lower limit because of the inherent errors in the ROM measurements[53] and the total AROM available in each plane of movement.

Manual muscle testing (MMT) was performed in the long-sitting position. It was graded on a 5-point scale.[21] We observed weakness in all planes of the injured ankles for all of the patients when compared to the uninjured extremities (Table 2).

Intervention

A treatment protocol of PSWD, followed by joint mobilizations and concluding with a crushed-ice pack, was initiated after the initial examination. During each treatment session, AROM was obtained prior to the PSWD and after the joint mobilizations, but before ice pack application. Subjects were instructed not to begin additional home exercise programs other than those in which they were participating at the time of the start of the intervention. They were instructed not to begin any new exercises/activities or change or discontinue any current exercises/activities.

The PSWD (Megapulse II; Accelerated Care Plus, Reno, NV) was applied to the anteromedial and anterolateral talocrural joint line for 20 minutes at a delta-T setting of 4 (27.12 MHz; 400 microseconds; 800 pps; 48 W). Because diathermy was applied at the site of the metal implants, all patients were asked prior to the application of the PSWD to inform the therapist of any sensations during the diathermy session. They were also asked during the PSWD application to describe how their ankle felt and if they could feel any heat or other ''unusual'' sensation. None of the patients stated they felt pain or burning sensations, but all felt a mild vibration sensation. This mild vibration sensation diminished after the first 2 to 3 minutes and only occurred during 1 or 2 of the treatment sessions. Upon the completion of each 20-minute diathermy session, the therapist noted the ankle was warm to the touch.

Each application of PSWD was immediately followed by joint mobilizations to the ankle and foot joints for a total of 6 to 10 minutes. The total amount of joint mobilizations applied depended upon each patient's tolerance. The joint mobilizations used included Maitland grades III and IV and static glide techniques.[20,30] To improve dorsiflexion and plantar flexion, sustained posterior and anterior glides (grade IV) with distraction were applied at the end of the physiologic range for each patient. Grade III and IV oscillatory mobilizations were applied to the other joints of the foot. Each sustained or oscillatory mobilization was performed for a minimum of 30 seconds with 3 repetitions. Because of the decreased talar dome of the right talus for patient 2, plantar flexion was not emphasized during joint mobilizations due to the possibility of increasing ankle instability. A crushed-ice pack was applied for 10 to 15 minutes following the postmeasurements. The intervention was applied 2 to 3 times per week for 3 weeks, then 1 to 2 times per week for 2 weeks.

Patient 1 received a total of 13 treatment sessions while the other patients received a total of 8 sessions. Final AROM measurements were obtained at the end of the 8th or 13th treatment session (Table 2). Patient 1 received 13 treatments for 2 reasons: the substantial loss of AROM that was present on the initial examination, and the improvement that took place over the course of the 8 initial treatment sessions. So, the patient agreed to see if her AROM would continue to improve over the course of an additional 5 treatment sessions.

Follow-up measurements were obtained within 1 to 3 months of the final treatment session. During this follow-up, patient 1 maintained 100%, patient 2 maintained 87%, patient 3 maintained 78%, and patient 4 maintained 79% of the AROM they achieved by their final session. A second follow-up was conducted approximately 1 year after the final session via telephone. At this time, we were only able to contact 3 of the 4 subjects. Patient 4 had moved and we were unable to determine his new contact information. During this follow-up, the 3 available patients stated that they felt they had maintained their AROM and continued to participate in their usual activities without difficulty. None of the patients stated that they had noticed any adverse effects after the cessation of the treatment.

Approximately 5 months following the last treatment session, patient 1 underwent surgery to remove all of the metal implants but did not receive any follow-up physical therapy. After the metal was removed, the surgeon stated that he was unable to detect any damage to the metal, nor was there damage to the surrounding tissue from the heating process. Patient 1 returned 3 months after the metal implants were removed for additional PSWD and joint mobilization treatments. Upon AROM measurements, it was noted there was a significant decrease in dorsiflexion. This may have occurred because the patient was placed in a fixed walking boot for 6 weeks after the removal surgery. The AROM measurements at this time were 7° dorsiflexion, 40° plantar flexion, 28° eversion/abduction, and 30° inversion/

TABLE 2. Active range of motion measurements at initial, discharge, and follow-up.

	Initial	Discharge	Follow-up (1 mo)
Patient 1			
AROM: DF	–3°	12°	12°
AROM: PF	26°	50°	44°
AROM: Abd	8°	40°	32°
AROM: Add	9°	36°	30°
Tenderness to palpation	At scar site: moderate	At scar site: minimum	
MMT	4/5 DF, PF, Abd, Add	5–/5 DF, PF, Abd, Add	
Accessory movement	Moderate hypomobile all ankle and foot joints	Minimal talocrural hypomobility	
Patient 2			
AROM: DF	0°	15°	13°
AROM: PF	55°	60°	55°
AROM: Abd	9°	30°	39°
AROM: Add	14°	38°	20°
Tenderness to palpation	At scar site: minimum	At scar site: minimum	
MMT	5–/5 DF, PF; 4–/5 Abd, Add	5/5 DF, PF, Abd, Add	
Accessory movement	Moderate hypermobile talocrural plantar flexion; moderate hypomobile all other foot and ankle joints	Hypermobile talocrural plantar flexion	
Patient 3			
AROM: DF	8°	18°	14°
AROM: PF	38°	60°	50°
AROM: Abd	24°	30°	30°
AROM: Add	35°	45°	40°
Tenderness to palpation	At scar site: minimum	At scar site: minimum	
MMT	4/5 DF, PF, Abd, Add	5/5 DF, PF, Abd, Add	
Accessory movement	Moderate hypomobile all ankle and foot joints	Minimal talocrural hypomobility	
Patient 4*			
AROM: DF	5°	19°	15°
AROM: PF	35°	58°	55°
AROM: Abd	18°	35°	28°
AROM: Add	38°	44°	38°
Tenderness to palpation	At scar site and along extensor hallucis longus insertion moderate	Extensor hallucis longus insertion moderate	
MMT	5/5 DF, PF, Abd, Add; 2/5 extension of first toe	5/5 DF, PF, Abd, Add; 3/5 extension of first toe	
Accessory movement	Moderate hypomobile all ankle and foot joints	Hypomobile first MTP and IP joints	

Abbreviations: Abd, eversion/abduction; Add, inversion/adduction; AROM, active range of motion; DF, dorsiflexion; IP, interphalangeal; MMT, manual muscle test; MTP, metatarsophalangeal; PF, plantar flexion.
* Patient 4 sprained injured ankle 1 week prior to follow-up measurements.

adduction. A total of 4 treatment sessions (2 times per week for 2 weeks) with the same treatment protocol were given at this time.

Outcomes

At the end of the 8 or 13 sessions, all patients achieved AROM to within 5° of the unaffected ankle measurements (Table 2). Overall, dorsiflexion improved 15°, 15°, 10°, and 14°, and plantar flexion improved 24°, 5°, 22°, 23°, respectively (Figure 2A-B). Inversion/adduction and eversion/abduction also showed similar improvements (Figure 2C-D). During the follow-up AROM measurements 1 to 3 months later, subjects maintained dorsiflexion to within 75% of their final measurements.

Because of the severity of the injury and the substantial loss of dorsiflexion, patient 1 was treated for a total of 13 visits. At the end of the initial 8 treatment sessions, patient 1 had obtained 10° dorsiflexion, 41° plantar flexion, 27° inversion/adduction, and 31° eversion/abduction. After the additional 5 treatment sessions, patient 1 achieved 12° dorsiflexion, 50° plantar flexion, 36° inversion/adduction, and 40° eversion/abduction (Table 2). After the metal implants were removed, patient 1 achieved 15° dorsiflexion, 50° plantar flexion, 31° inversion/adduction, and 33° eversion/abduction. The inversion/adduction and eversion/abduction motions did not return to the AROM that was obtained after the 13 original sessions.

CASE REPORT

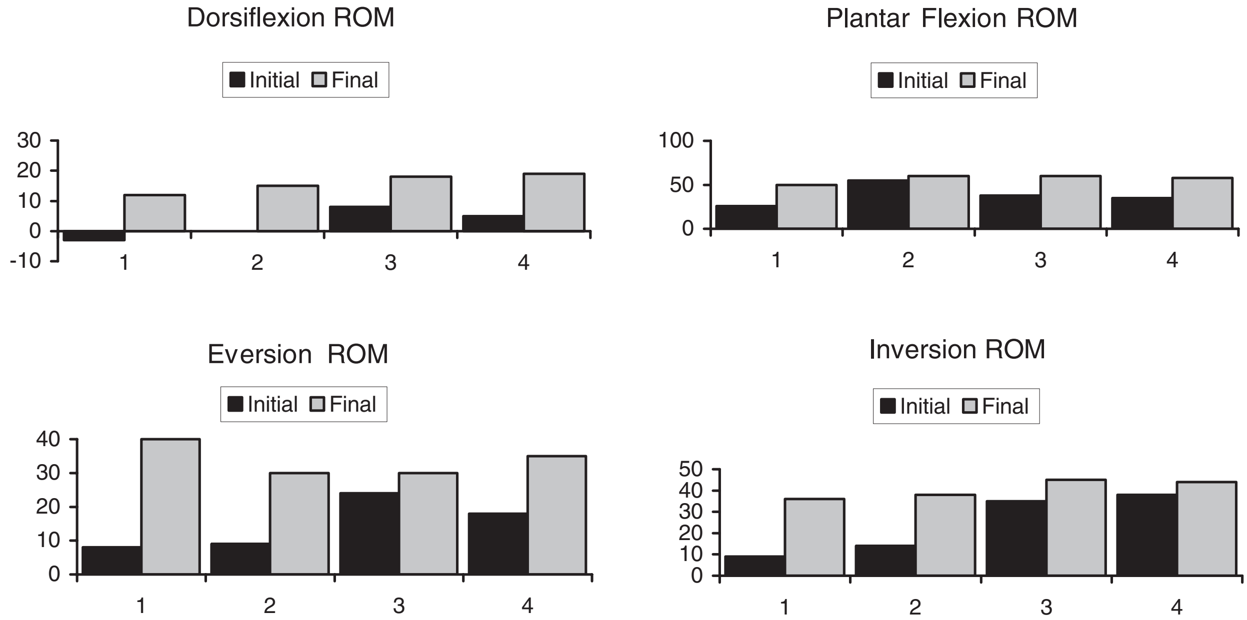

FIGURE 2. Initial and final active range of motion (AROM) in degrees for each of the 4 patients.

DISCUSSION

The most dramatic change in AROM occurred in dorsiflexion for patient 1, with an improvement of 18° over the 13 initial and 4 follow-up treatment sessions. All patients returned to normal activities with equivalent bilateral dorsiflexion, plantar flexion, inversion/adduction, and eversion/abduction. Subjects also stated they had returned to their previous daily and recreational activities, including sports, hiking, and running. They demonstrated an overall improvement in gait and balance after their AROM increased.

Fractures of the ankle joint have high complication rates including posttraumatic arthritis and osteonecrosis of the talar neck in association with joint stiffness, pain, and loss of function.[49] We suspect that all of these patients will have the long-term effect of posttraumatic arthritis but, at the time of this study, none of the patients presented with osteonecrosis of the talus.

The length of time since the injury for patient 2 (18 years) and patient 3 (2 years) was of concern because of the damage to the cartilage of the joints and possible adhesions of the nearby tendon sheaths and affected joint capsules.[23] We were concerned that mature scar tissue could affect the outcomes of patients 2 and 3. The resulting increase in AROM suggests that the greater elapsed time did not have a major effect on the outcomes. Patients 1 and 4 presented for treatment less than a year from their initial injury; thus, their scar tissue had not fully matured and we were not as concerned about adhesions and contractures.

Using PSWD produces heat similar to using a continuous setting.[14,35,46] It was thought that PSWD only produced athermal effects on tissues, but research has determined that higher levels of pulse repetition rate, pulse duration, and pulse power can increase both tissue temperature and the thermal sensation.[35] Because of the generation of heat, the vascular system increases the blood flow to the area to regulate tissue temperature.[1,16,41] The greater amounts of heat cause a larger vascular response, which in turn tends to prevent tissue damage.[1,16,41]

Traditionally, all diathermy has been contraindicated over areas with metal implants,[31,43,47] acute injury,[47] active inflammatory disease,[47] ischemic or anesthetic areas,[47] over eyes and gonads,[47] pregnancy (for the patient or therapist),[6,27,37,47] malignant tissue,[47] and on a patient with an implanted pacemaker, neurostimulator, or defibrillator.[31,47,50] A literature search for the effects of shortwave diathermy over orthopedic metal was conducted. This literature search indicated that any form of metal implant is generally contraindicated for shortwave diathermy.[22] However, there was no research evidence to indicate whether the use of PSWD over orthopedic metal was safe or not. According to Shields et al,[47] the contraindication of diathermy over metal appears to be based on a ''common sense'' approach and they have suggested that future research should address the lack of information on the use of PSWD in the presence of metal implants. This issue of safety was also discussed with several ''experts'' in the field of electrotherapy. The consensus was that there is a lack of research on how PSWD affects orthopedic metal implants. There continues to be an agreement that any form of diathermy should not be used in the presence of pacemakers or neurostimulators.

However, a preliminary investigation by one of the authors has indicated that a low-watt PSWD application did not increase the temperature of the metal or the tissues around the metal to a level that would produce injury.[8] This preliminary investigation[8] reported a 25° improvement in elbow extension in 1 patient after 6 sessions of PSWD and joint mobilizations. Of particular interest was the fact that surgical removal of the implants 4 weeks following the intervention indicated no apparent adverse effect of PSWD according to the surgeon's observations. Another investigation indicates that the tissue within the PSWD thermal field increases up to approximately 40°C.[14] This tissue temperature increase is below the 45°C level that can result in damage to collagen and protein structures.[24]

Mobilizations of the ankle and foot joints were used because of their effectiveness in improving AROM.[20,30] Passive stretching was not performed because it does not improve ankle ROM after an ankle fracture with immobilization or maintain muscle length.[34,39] Joint mobilizations were performed immediately following the application of the PSWD. This is because the heat dissipates rapidly due to the thermal conduction away from the site from the vascular system.[14,35,46] It has been determined that the temperature rise in skeletal muscle due to PSWD decreases rapidly within the first 10 minutes after the diathermy application is completed.[10]

For these 4 individuals, we applied diathermy using the Megapulse II diathermy machine. It uses an induction method to transfer the electromagnetic energy to the tissues. Because we only used the Megapulse II machine, we cannot generalize our results to other diathermy machines because other machines have different specific absorption rates and heat the subcutaneous fat and muscle differently.[26] These different absorption rates are due to the wave frequency used, the overall output, and the differences in electromagnetic shielding of the machine to directionally focus the wave field.[26]

The PSWD in these cases was applied to the anteromedial and anterolateral talocrural joint line for 20 minutes at a delta-T setting of 4 (27.12 MHz, 400 microseconds; 800 pps). These parameters generate a total energy amount of 48 W. Because we used these specific parameter settings, we cannot generalize our findings to other parameters that may be used in other machines. Further research on the specific parameters for other diathermy machines needs to be completed.

Limitations of this case series include lack of a blinding of the goniometric measurements, a lack of blinding of the subjects to their treatment condition, the effect of the relative skill of the therapist with application of joint mobilizations, and a lack of control group to determine cause and effect.

The patients included in this case series were referred to this institution because of a long-term, significant decrease in active and passive ankle ROM that was present after rehabilitation. To determine the full implications of this case series, additional research is needed to determine the effectiveness of this protocol using a greater number of subjects involved in a randomized experiment with a control group with outcome measures including ROM, pain, edema, and function. Further research methods need to include a blinding of the therapist to experiment group and of the goniometric measurements.

Research on the safety of this protocol also needs to be completed. This future research needs to focus on the temperature rises in the different types of metal implants that are used in orthopedic surgery. It is unclear whether plates will heat differently from screws and pins or how the different types of metal used will be affected. Additional research should examine how the tissue around the metal implants is affected.

Because additional research needs to be completed, we would advise caution when applying PSWD over orthopedic metal implants in the peripheral joints. We advise against using PSWD in patients with compromised peripheral vascular system or altered sensation. PSWD should only be applied over patients with normal sensation in the area being treated, due to the thermal effect that is generated, to allow the patient to feel if heating is excessive. A final caution: we continue to advise that diathermy be contraindicated in the presence of cardiac pacemakers and neurostimulators.

REFERENCES

1. Abramson DI, Mitchell RE, Tuck S, Jr., Bell Y, Zayas AM. Changes in blood flow, oxygen uptake and tissue temperatures produced by the topical application of wet heat. *Arch Phys Med Rehabil*. 1961;42:305-318.
2. Baggett BD, Young G. Ankle joint dorsiflexion. Establishment of a normal range. *J Am Podiatr Med Assoc*. 1993;83:251-254.
3. Balogun JA, Okonofua FE. Management of chronic pelvic inflammatory disease with shortwave diathermy. A case report. *Phys Ther*. 1988;68:1541-1545.
4. Boone DC, Azen SP, Lin CM, Spence C, Baron C, Lee L. Reliability of goniometric measurements. *Phys Ther*. 1978;58:1355-1390.
5. Brown M, Baker RD. Effect of pulsed short wave diathermy on skeletal muscle injury in rabbits. *Phys Ther*. 1987;67:208-214.
6. Brown-Woodman PD, Hadley JA, Waterhouse J, Webster WS. Teratogenic effects of exposure to radiofrequency radiation (27.12 MHz) from a shortwave diathermy unit. *Ind Health*. 1988;26:1-10.
7. Chapman CE. Can the use of physical modalities for pain control be rationalized by the research evidence? *Can J Physiol Pharmacol*. 1991;69:704-712.
8. Draper DO, Castel JC, Castel D. Low-watt pulsed shortwave diathermy and metal-plate fixation of the elbow. *Athl Ther Today*. 2004;September:27-31.

CASE REPORT

9. Draper DO, Harris ST, Schulthies S, Durrant E, Knight KL, Ricard M. Hot-pack and 1-MHz ultrasound treatments have an additive effect on muscle temperature increase. *J Athl Train*. 1998;33:21-24.
10. Draper DO, Knight K, Fujiwara T, Castel JC. Temperature change in human muscle during and after pulsed short-wave diathermy. *J Orthop Sports Phys Ther*. 1999;29:13-18; discussion 19-22.
11. Draper DO, Miner L, Knight KL, Ricard MD. The carry-over effects of diathermy and stretching in developing hamstring flexibility. *J Athl Train*. 2002;37:37-42.
12. Ducker HG. The effects of metal on short-wave field distribution. *Physiotherapy*. 1968;54:244-246.
13. Gajdosik RL, Bohannon RW. Clinical measurement of range of motion. Review of goniometry emphasizing reliability and validity. *Phys Ther*. 1987;67:1867-1872.
14. Garrett CL, Draper DO, Knight KL. Heat distribution in the lower leg from pulsed short-wave diathermy and ultrasound treatments. *J Athl Train*. 2000;35:50-55.
15. Goats GC. Pulsed electromagnetic (short-wave) energy therapy. *Br J Sports Med*. 1989;23:213-216.
16. Greenberg RS. The effects of hot packs and exercise on local blood flow. *Phys Ther*. 1972;52:273-278.
17. Greenman PE. *Principles of Manual Medicine*. 2nd ed. Baltimore, MD: Williams & Wilkins; 1996.
18. Guler-Uysal F, Kozanoglu E. Comparison of the early response to two methods of rehabilitation in adhesive capsulitis. *Swiss Med Wkly*. 2004;134:353-358.
19. Jan MH, Lai JS. The effects of physiotherapy on osteoarthritic knees of females. *J Formos Med Assoc*. 1991;90:1008-1013.
20. Kaltenborn FM. *Manual Mobilization of the Joints: The Kaltenborn Method of Joint Examination and Treatment*. 6th ed. Oslo, Norway: Olaf Norlis Bokhandel; 2002.
21. Kendall F, McCreary EK, Provance PG. *Muscles: Testing and Function*. Baltimore, MD: Williams & Wilkins; 1993.
22. Kitchen S, Partridge C. Review of shortwave diathermy continuous and pulsed patterns. *Physiotherapy*. 1992;78:243-252.
23. Leadbetter WB, Buckwalter JA, Gordon SL. *American Orthopaedic Society for Sports Medicine Symposium. Sports-Induced Inflammation: Clinical and Basic Science Concepts*. Park Ridge, IL: American Academy of Orthopaedic Surgeons; 1990.
24. Lehmann JF, deLateur BJ. Therapeutic heat. In: Lehmann JF, ed. *Therapeutic Heat and Cold*. Baltimore, MD: Williams & Wilkins; 1990.
25. Lehmann JF, Masock AJ, Warren CG, Koblanski JN. Effect of therapeutic temperatures on tendon extensibility. *Arch Phys Med Rehabil*. 1970;51:481-487.
26. Lehmann JF, McDougall JA, Guy AW, Warren CG, Esselman PC. Heating patterns produced by shortwave diathermy applicators in tissue substitute models. *Arch Phys Med Rehabil*. 1983;64:575-577.
27. Lerman Y, Jacubovich R, Green MS. Pregnancy outcome following exposure to shortwaves among female physiotherapists in Israel. *Am J Ind Med*. 2001;39:499-504.
28. Lindsjo U, Danckwardt-Lilliestrom G, Sahlstedt B. Measurement of the motion range in the loaded ankle. *Clin Orthop Relat Res*. 1985;Oct:68-71.
29. Low JL. The reliability of joint measurement. *Physiotherapy*. 1976;62:227-229.
30. Maitland GD. *Peripheral Manipulation*. 3rd ed. Oxford, UK: Butterworth-Heinemann; 1991.
31. Martin CJ, McCallum HM, Heaton B. An evaluation of radiofrequency exposure from therapeutic diathermy equipment in the light of current recommendations. *Clin Phys Physiol Meas*. 1990;11:53-63.
32. McCray RE, Patton NJ. Pain relief at trigger points: a comparison of moist heat and shortwave diathermy. *J Orthop Sports Phys Ther*. 1984;5:175-178.
33. Michlovitz SL, Harris BA, Watkins MP. Therapy interventions for improving joint range of motion: A systematic review. *J Hand Ther*. 2004;17:118-131.
34. Moseley AM, Herbert RD, Nightingale EJ, et al. Passive stretching does not enhance outcomes in patients with plantarflexion contracture after cast immobilization for ankle fracture: a randomized controlled trial. *Arch Phys Med Rehabil*. 2005;86:1118-1126.
35. Murray CC, Kitchen S. Effect of pulse repetition rate on the perception of thermal sensation with pulsed shortwave diathermy. *Physiother Res Int*. 2000;5:73-84.
36. Oosterveld FG, Rasker JJ, Jacobs JW, Overmars HJ. The effect of local heat and cold therapy on the intraarticular and skin surface temperature of the knee. *Arthritis Rheum*. 1992;35:146-151.
37. Ouellet-Hellstrom R, Stewart WF. Miscarriages among female physical therapists who report using radio- and microwave-frequency electromagnetic radiation. *Am J Epidemiol*. 1993;138:775-786.
38. Pasila M, Visuri T, Sundholm A. Pulsating shortwave diathermy: value in treatment of recent ankle and foot sprains. *Arch Phys Med Rehabil*. 1978;59:383-386.
39. Peres SE, Draper DO, Knight KL, Ricard MD. Pulsed shortwave diathermy and prolonged long-duration stretching increase dorsiflexion range of motion more than identical stretching without diathermy. *J Athl Train*. 2002;37:43-50.
40. Reese NB, Bandy WD. *Joint Range of Motion and Muscle Length Testing*. Philadelphia, PA: W.B. Saunders Co; 2002.
41. Reid RW, Foley JM, Prior BM, Weingand KW, Meyer RA. Mild topical heat increases popliteal blood flow as measured by MRI. *Med Sci Sports Exerc*. 1999;31:S208.
42. Rothstein JM, Miller PJ, Roettger RF. Goniometric reliability in a clinical setting. Elbow and knee measurements. *Phys Ther*. 1983;63:1611-1615.
43. Ruggera PS, Witters DM, von Maltzahn G, Bassen HI. In vitro assessment of tissue heating near metallic medical implants by exposure to pulsed radio frequency diathermy. *Phys Med Biol*. 2003;48:2919-2928.
44. Santiesteban AJ, Grant C. Post-surgical effect of pulsed shortwave therapy. *J Am Podiatr Med Assoc*. 1985;75:306-309.
45. Scott BO. The effects of metal on short-wave field distribution. *Ann Phys Med*. 1953;1:238-244.
46. Sekins KM, Lehmann JF, Esselman P, et al. Local muscle blood flow and temperature responses to 915MHz diathermy as simultaneously measured and numerically predicted. *Arch Phys Med Rehabil*. 1984;65:1-7.
47. Shields N, O'Hare H, Gormley J. Contra-indications to shortwave diathermy: survey of Irish physiotherapists. *Physiotherapy*. 2004;90:42-53.
48. Talaat AM, el-Dibany MM, el-Garf A. Physical therapy in the management of myofacial pain dysfunction syndrome. *Ann Otol Rhinol Laryngol*. 1986;95:225-228.
49. Vallier HA, Nork SE, Barei DP, Benirschke SK, Sangeorzan BJ. Talar neck fractures: results and outcomes. *J Bone Joint Surg Am*. 2004;86-A:1616-1624.
50. Valtonen EJ, Lilius HG, Tiula E. Disturbances in the function of cardiac pacemaker caused by short wave and microwave diathermies and pulsed high frequency current. *Ann Chir Gynaecol Fenn*. 1975;64:284-287.

51. Vanharanta H. Effect of short-wave diathermy on mobility and radiological stage of the knee in the development of experimental osteoarthritis. *Am J Phys Med*. 1982;61:59-65.
52. Wagstaff P, Wagstaff S, Downey M. A pilot study to compare the efficacy of continuous and pulsed magnetic energy (short-wave diathermy) on the relief of low back pain. *Physiotherapy*. 1986;72:563-566.
53. Youdas JW, Bogard CL, Suman VJ. Reliability of goniometric measurements and visual estimates of ankle joint active range of motion obtained in a clinical setting. *Arch Phys Med Rehabil*. 1993;74:1113-1118.

This article has been cited by:

1. Arash Babaei-Ghazani, Banafsheh Shahrami, Ehsan Fallah, Tannaz Ahadi, Bijan Forough, Safoora Ebadi. 2020. Continuous shortwave diathermy with exercise reduces pain and improves function in Lateral Epicondylitis more than sham diathermy: A randomized controlled trial. *Journal of Bodywork and Movement Therapies* **24**:1, 69-76. [Crossref]
2. Caizhong Xie, Xiangzhe Li, Lu Fang, Tong Wang. 2019. Effects of Athermal Shortwave Diathermy Treatment on Somatosensory Evoked Potentials and Motor Evoked Potentials in Rats With Spinal Cord Injury. *SPINE* **44**:13, E749-E758. [Crossref]
3. Joel Frontera, Amy Cao. Cancer Pain and Physical Modalities 427-432. [Crossref]
4. Camila Prochnow Goulart, Gabriela Otto, Natália Lima, Morgana Neves, Ana Tereza Bittencourt Guimarães, Gladson Ricardo Flor Bertolini. 2018. Efeitos adversos da eletrotermofototerapia em clínicas da cidade de Cascavel - PR. *Fisioterapia e Pesquisa* **25**:4, 382-387. [Crossref]
5. Binoy Kumaran, Anthony Herbland, Tim Watson. 2017. Continuous-mode 448 kHz capacitive resistive monopolar radiofrequency induces greater deep blood flow changes compared to pulsed mode shortwave: a crossover study in healthy adults. *European Journal of Physiotherapy* **19**:3, 137-146. [Crossref]
6. Michelle Kaye Grover, David O. Draper. 2017. Ultrasound, Stretching, and Joint Mobilizations for Restoring Limited Abduction of the Thumb. *Athletic Training & Sports Health Care* **9**:3, 133-137. [Crossref]
7. Jennifer Ostrowski, Claire Ely, Haley Evans, Diana Bocklund. 2016. Comparison of Pulsed Shortwave Diathermy and Continuous Shortwave Diathermy Devices. *Athletic Training & Sports Health Care* **8**:1, 18-26. [Crossref]
8. Binoy Kumaran, Tim Watson. 2015. Radiofrequency-based treatment in therapy-related clinical practice – a narrative review. Part II: chronic conditions. *Physical Therapy Reviews* **20**:5-6, 325-343. [Crossref]
9. Gang Wang, Yiming Xu, Lina Zhang, Dongmei Ye, Xianxuan Feng, Tengfei Fu, Yuehong Bai. 2015. Enhancement of Apoptosis by Titanium Alloy Internal Fixations during Microwave Treatments for Fractures: An Animal Study. *PLOS ONE* **10**:7, e0132046. [Crossref]
10. Dongmei Ye, Yiming Xu, Gang Wang, Xianxuan Feng, Tengfei Fu, Han Zhang, Lan Jiang, Yuehong Bai. 2015. Thermal effects of 2450 MHz microwave exposure near a titanium alloy plate implanted in rabbit limbs. *Bioelectromagnetics* **36**:4, 309-318. [Crossref]
11. Sebastian F Baumbach, Mareen Brumann, Jakob Binder, Wolf Mutschler, Markus Regauer, Hans Polzer. 2014. The influence of knee position on ankle dorsiflexion - a biometric study. *BMC Musculoskeletal Disorders* **15**:1. . [Crossref]
12. David O. Draper. 2014. Pulsed Shortwave Diathermy and Joint Mobilizations for Achieving Normal Elbow Range of Motion After Injury or Surgery With Implanted Metal: A Case Series. *Journal of Athletic Training* **49**:6, 851-855. [Crossref]
13. Eun-Kyung Koh, Jong-Hyuck Weon, Do-Young Jung. 2014. Effect of Direction of Gliding in Tibiofibular Joint on Angle of Active Ankle Dorsiflexion. *Journal of the Korean Society of Physical Medicine* **9**:4, 439-445. [Crossref]
14. Dongmei Ye, Yiming Xu, Tengfei Fu, Han Zhang, Xianxuan Feng, Gang Wang, Lan Jiang, Yuehong Bai. 2013. Low dose of continuous – wave microwave irradiation did not cause temperature increase in muscles tissue adjacent to titanium alloy implants – an animal study. *BMC Musculoskeletal Disorders* **14**:1. . [Crossref]
15. David O. Draper. 2013. Comparison of Shortwave Diathermy and Microwave Diathermy. *International Journal of Athletic Therapy and Training* **18**:6, 13-17. [Crossref]
16. Dongmei Ye, Yiming Xu, Han Zhang, Tengfei Fu, Lan Jiang, Yuehong Bai. 2013. Effects of Low-Dose Microwave on Healing of Fractures with Titanium Alloy Internal Fixation: An Experimental Study in a Rabbit Model. *PLoS ONE* **8**:9, e75756. [Crossref]
17. David O. Draper, Amanda R. Hawkes, A. Wayne Johnson, Mike T. Diede, Justin H. Rigby. 2013. Muscle Heating With Megapulse II Shortwave Diathermy and ReBound Diathermy. *Journal of Athletic Training* **48**:4, 477-482. [Crossref]
18. Tim Watson. Electrotherapy 417-455. [Crossref]
19. Lifei Guo, Nicole J. Kubat, Richard A. Isenberg. 2011. Pulsed radio frequency energy (PRFE) use in human medical applications. *Electromagnetic Biology and Medicine* **30**:1, 21-45. [Crossref]
20. 2010. ELECTROPHYSICAL AGENTS - Contraindications And Precautions: An Evidence-Based Approach To Clinical Decision Making In Physical Therapy. *Physiotherapy Canada* **62**:5, 1-80. [Crossref]
21. David O. Draper. 2010. Ultrasound and Joint Mobilizations for Achieving Normal Wrist Range of Motion After Injury or Surgery: A Case Series. *Journal of Athletic Training* **45**:5, 486-491. [Crossref]
22. Misaki Fujii, Daisuke Suzuki, Eiichi Uchiyama, Takayuki Muraki, Atsushi Teramoto, Mitsuhiro Aoki, Shigenori Miyamoto. 2010. Does distal tibiofibular joint mobilization decrease limitation of ankle dorsiflexion?. *Manual Therapy* **15**:1, 117-121. [Crossref]
23. David O. Draper, Jamie VanPatten. 2010. Shortwave Diathermy and Joint Mobilizations for Postsurgical Restoration of Knee Motion. *Athletic Therapy Today* **15**:1, 39-41. [Crossref]
24. Wayne Johnson, David O. Draper. 2010. Increased Range of Motion and Function in an Individual with Breast Cancer and Necrotizing Fasciitis—Manual Therapy and Pulsed Short-Wave Diathermy Treatment. *Case Reports in Medicine* **2010**, 1-4. [Crossref]
25. David O. Draper, Matt Gage. 2010. Pulsed Shortwave Diathermy and Joint Mobilizations for Restoring Motion in a Patient with Adhesive Capsulitis. *Athletic Training & Sports Health Care* **2**:1, 31-35. [Crossref]
26. Sarah M. Mitchell, Cynthia A. Trowbridge, A. Louise Fincher, Joel T. Cramer. 2008. Effect of diathermy on muscle temperature, electromyography, and mechanomyography. *Muscle & Nerve* **38**:2, 992-1004. [Crossref]
27. W. Jenrich. 2008. Elektrotherapeutische Differenzialtherapie. *Manuelle Medizin* **46**:5, 316-324. [Crossref]
28. Jue-Long Wang, Rai-Chi Chan, He-Hsiung Cheng, Chun-Jen Huang, Yih-Chau Lu, I-Shu Chen, Shiuh-Inn Liu, Shu-Shong Hsu, Hong-Tai Chang, Jong-Khing Huang, Jin-Shyr Chen, Chin-Man Ho, Chung-Ren Jan. 2007. SHORT WAVES-INDUCED ENHANCEMENT

OF PROLIFERATION OF HUMAN CHONDROCYTES: INVOLVEMENT OF EXTRACELLULAR SIGNAL-REGULATED MAP-KINASE (ERK). *Clinical and Experimental Pharmacology and Physiology* **34**:7, 581-585. [Crossref]