PULSED SHORTWAVE THERAPY (PSWT)

Pulsed Shortwave Therapy (PSWT) is a widely used modality in the UK (Al Mandil and Watson 2006), though it is often called Pulsed Electromagnetic Energy (PEME) which is less than fully appropriate in that many modalities come under the heading of PEME, PSWT being only one of them and the use of the term should be avoided. The older term Pulsed Shortwave Diathermy is not really appropriate either in that the modality is not primarily employed as a diathermy (literally 'through heating').

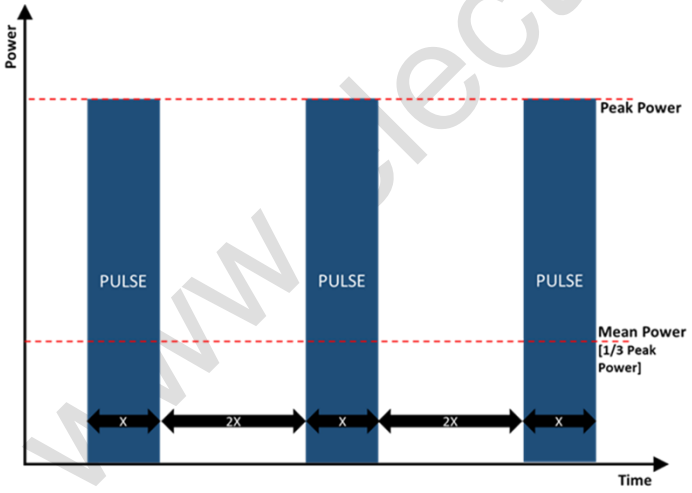
PSWT employs the same operating frequency as traditional SWD ie. 27.12MHz. The output from the machine is pulsed such that the 'on' time is considerably shorter than the 'off' time, thus the mean power delivered to the patient is relatively low even though the peak power (i.e. during the on pulses) can be quite high (typically around 150 – 200 Watts peak power with modern machines, though some still go up to 1000W).

The control offered by the machine will enable the user to vary (a) the mean power delivered to the patient and (b) the pulsing parameters governing the mode of delivery of the energy. It would seem from current research that the ***mean power*** is probably the most important parameter.

The use of Radiofrequency and specifically shortwave treatments in the clinical environment have been usefully reviewed in Kumaran and Watson (2015, 2016) and Al-Mandeel and Watson, 2020)

MAIN MACHINE PARAMETERS

- **Pulse Repetition Rate (Hz or pps)**
  the number of pulses delivered per second
- **Pulse Duration (Width) (microseconds)**
  the duration (time) of each 'ON' phase
- **Power (Peak and Mean)**
  power delivered from the machine (during pulse and averaged)



Relationship between pulse parameters, peak power and mean power

PULSE REPETITION RATE

- Number of pulses delivered per second
- Variable output on most if not all machines
- Can usually select from a range of preset options (depends on machine)
- e.g. Megapulse
  100 / 200 / 400 / 600 / 800 pps

- e.g. Curapulse 403
  26 / 35 / 46 / 62 / 82 / 110 / 150 / 200 / 300 / 400 pps

There is no current evidence that the 'number' of pulses per second is critical – what is important however is that by varying the pulse rate, the mean power delivered to the tissues can be varied.

PULSE DURATION (WIDTH)

This is the **duration** of each 'ON' phase or pulse. The pulse durations are very short – measured in microseconds (millionths of a second). It is a variable parameter on many but not all machines. It is sometimes fixed (most usually on the machines that deliver both pulsed and continuous shortwave energy, and most commonly 'fixed' at 400μs) The term pulse duration is preferable to pulse width (commonly used) as it is a **time** based measurement rather than a size.

Examples of pulse durations in some commonly encountered PSWT machines :
Curapulse 419 - fixed at **400 μs**
Curapulse 403 - **65/82/110/150/200/300/400 μs**
Megapulse - **20 / 40 / 65 / 100 / 200 / 400 μs**

As with the pulse repetition rate, there is no evidence that that actual (absolute) duration of the pulse is important BUT the combination of pulse repetition rate and pulse duration enables the therapist to control the mean power being delivered to the patient and this, it would appear, IS a critical parameter.

SHORTWAVE CYCLES PER PULSE

Due to the high frequency of the machine (just over 27 million cycles a second), even though the individual pulses are of short duration, the number of cycles completed during each pulse (or 'on' phase) remains quite high. The table below illustrates with some examples (the numbers are not actually important – just here to illustrate the point) :

Pulse Duration	*No of cycles completed per pulse*
65 μs	**1,763 cycles**
100 μs	**2,712 cycles**
400 μs	**10,848 cycles**

MARK : SPACE RATIO (DUTY CYCLE)

The energy output of the machine, in short duration pulses, means that the machine if 'off' for a greater proportion of the time than it is 'on'. As an example, if the machine is set to a short duration pulse and utilises a low pulse repetition rate, the following Mark:Space ratio is achieved

Short Pulse (65 μs) : Low Repetition Rate (26 pps)
Machine is 'ON' for about 0.0017 sec per sec (0.17% duty cycle)
Mark:Space Ratio of about 1:590

It can be seen that the amount of time for which the machine is 'on' is a small proportion of the overall treatment time (about 0.17%). Even if the machine is turned up to a high setting, using a long duration pulse, delivered at a high repetition rate, the mark:space ratio illustrates that there remains a substantial 'off' period

Long Pulse (400 μs) : High Repetition Rate (400 pps)
Machine is 'ON' for about 0.16 sec per sec (16% duty cycle)
Mark:Space Ratio of about 1:6

Machine Output

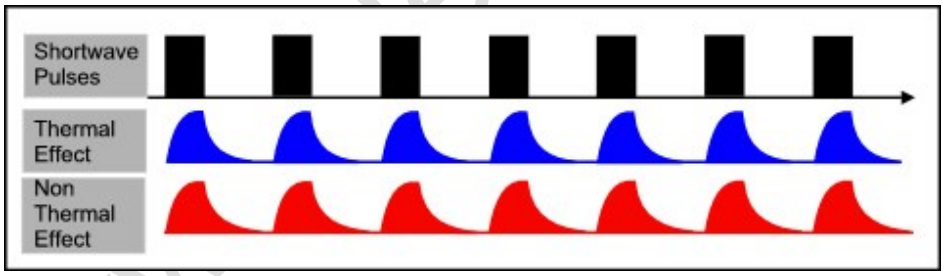
There are two basic types of output from these machines, the **ELECTRIC** field, comparable to the condenser (capacitor) field in traditional SWD & secondly, the **MAGNETIC** field, comparable to inductothermy. Some machines offer the facility to pulse either output, with the magnetic field being delivered via a drum containing a coiled conductor housed in some form of 'monode' or 'drum' applicator (which goes by several different names). Manufacturers include a special screen in the face of the drum to eliminate most, if not all of the electric field. All identified research in which pulsed shortwave has been evaluated has been conducted with the **monode** type applicator. No evidence has been identified that demonstrates a measurable clinical benefit when PSWT is applied using the plate (electrostatic) applicators.

The output of the monode applicator can be thought of as a form of pulsed inductothermy. The pulsed electromagnetic field which is emitted from the applicator will be transmitted through the tissues, and will be absorbed in those of low impedance i.e. the conductors which are tissues like muscle, nerve, those which are highly vascular, tissues in which there is oedema, effusion or recent haematoma.

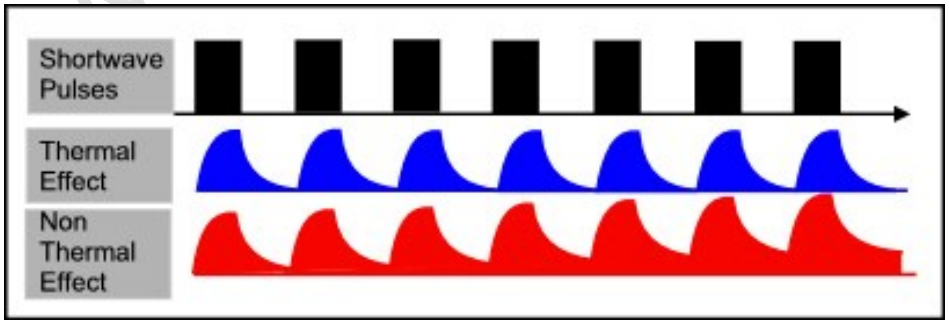
The mean power table that is provided with each machine is the **critical** piece of information when it comes to clinical decision making and patient doses (see later section). The table identifies all the potential combinations of pulse repetition rate and pulse durations, and therefore how the machine can be 'set' to deliver a specific mean power. The tables are **not** interchangeable between models and it is important that the correct table is used for the machine available or else an incorrect clinical dose could be applied.

Tissue Heating

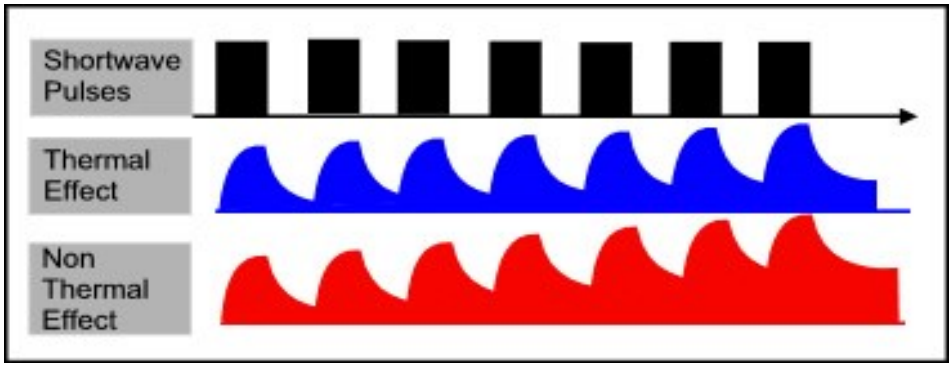
With respect to the effects of pulsed SWD, there is an element of tissue heating which occurs during the `on' pulse, but this is dissipated during the prolonged 'off' phase and therefore, it is possible to give treatment with no NET increase in tissue temperature (loosely termed a .non-thermal' treatment by many therapists – as the tissue is no hotter at the end of the treatment period than it was at the start. Clearly during the delivery of each pulse there will be a (very small) thermal change. In the figures below, (A) demonstrates no accumulation of either thermal or non thermal effects. In (B), the pulses are sufficiently close to generate an accumulative non-thermal effect and in (C) there is an accumulation of both thermal and non thermal effects.



(A) Pulses at sufficient 'distance' – no accumulative effect



(B) Pulses 'closer together' – accumulating non thermal effect, no thermal accumulation



(C) Pulses 'closer still' – accumulation of thermal and non thermal effects

The settings applied on the machine will determine which of these is achieved in a particular treatment, with the **mean power** appearing to be the most critical parameter. The `non thermal' effects of the modality are generally thought to be of greater significance. They appear to accumulate during the treatment time and have a significant effect after a latent period, possibly in the order to 6-8 hours. It is suggested (Hayne 1984, AlMandeel and Watson, 2008) that the energy levels required to produce such an effect in humans is low.

An active research programme has been conducted for several years now relating to the thermal nature of PSWD. It was unclear just what power levels were required to bring about a real tissue heating, and in fact, there has been some opinion that PSWT was a non thermal modality per se. Research has demonstrated that PSWT ***does*** have a thermal component, and real tissue heating can occur under different treatment settings. This is important in that if the modality is to be applied in circumstances where the heating would be inappropriate or contraindicated, it is essential to know the power/energy levels where the thermal effects begins. From the work we have done, it has been shown that a measurable heating effect can be demonstrated at power levels over 5 watts, though on average, it will become apparent at some 11 watts mean power. More recent work by Seiger and Draper (2006) suggests that it may still be safe to apply higher mean power levels than previously thought, even with metal in the tissues.

If a 'non thermal' treatment is the intended outcome of the treatment, it is essential that the mean power applied remains below a level that is likely to induce significant heating effects, and at present, this is taken as being at 5 Watts mean power. If a thermal effect is an intentional outcome of the intervention, then it may be perfectly appropriate to deliver power levels in excess of 5 watts, but if doing so, the therapist must ensure that the precautions are taken as for any other thermal intervention.

EFFECTS OF PULSED SHORTWAVE THERAPY

These can be basically divided into two types - those of the electric field & those of the magnetic field. There appears to be almost no literature/research concerning the effects of pulsing the electric field, & almost all the research reviewed is concerned with the therapeutic effects of the magnetic field. This is not to say that pulsing the electric field has no effect, but that the research evidence for such an effect is lacking. The information which follows relates therefore to the effect of pulsing the magnetic field (i.e. via the drum or monode applicator).

The primary effects of the pulsed magnetic field appears to be at the cell membrane level & is concerned with the transport of ions across the membrane. Some interesting publications have strongly supported the 'non thermal' effects at cell membrane level (Luben 1997, Cleary 1997).

Normal cell membranes exhibit a potential difference due to the relative concentration differences of various ions on either side of the membrane (reviewed in Charman 1990). Of these ions, sodium (Na^+), potassium (K^+), calcium

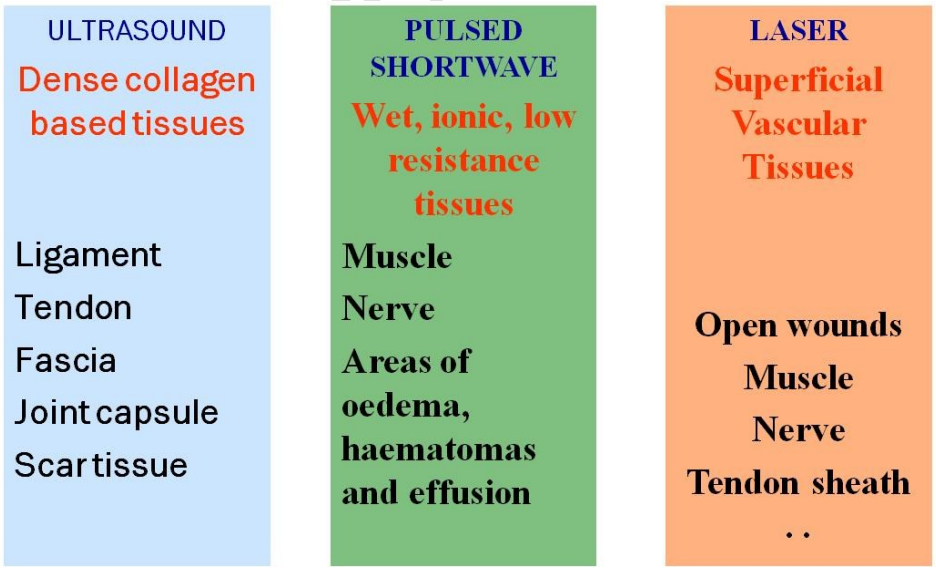
(Ca^{++}), chloride (Cl^{-}), & bicarbonate (HCO_{3-}) are probably the most important. Cell membrane potentials vary according to the cell type, but a typical membrane potential is -70mV, internally negative. It is actively maintained by a series of pumps & gated channels, & cellular energy (ATP) must therefore be utilised to maintain the potential.

A cell involved in the inflammatory process demonstrates a reduced cell membrane potential & consequently, the cell function is disturbed. The altered potential affects ion transport across the membrane, & the resulting ionic imbalance alters cellular osmotic pressures. The application of PSWT to cells affected in this way is claimed to restore the cell membrane potential to their 'normal' values & also restores normal membrane transport & ionic balance. The mechanism by which this effect is brought about is not yet established, but the two theories suggest that this is either a direct ionic transport mechanism or an activation of various pumps (sodium/potassium) by the pulsed energy (Sanseverion 1980). Evidence (Luben & Cleary 1996) supports the contention that the energy is absorbed in the membrane and that via a mechanism of signal transduction, stimulates or enhances intracellular effects.

There appears to be a strong similarity in the mechanism of effect of ultrasound, laser and pulsed shortwave – all three modalities appear to have their primary effect at cell membrane level, with the resulting 'up regulation' of cellular behaviour being the key to the therapeutic effects.

It is claimed that the applied energy has little or no effect on normal cells as `sick' cells respond to lower energy levels than normal cells.

The clinical effects of PSWT are primarily related to the inflammatory and repair phases in musculoskeletal / soft tissues. The effects list is remarkably similar to that of ultrasound and laser therapy – which is not surprising given their probable common mode of action. The key difference in their clinical use relates to WHERE the energy is absorbed rather than the effects achieved. The key differential in tissue absorption is illustrated in the figure below



Research continues with regards both the physiological and clinical effects of pulsed shortwave based therapy. A recent study clearly demonstrated a dose dependant physiological response in healthy subjects (Al Mandeel and Watson, 2010), and an extension to this study, evaluating the response of patients with OA (knee) is in preparation.

Goldin et al (1981) list the following as the primary effects of pulsed SWD:

1) Increased number of white cells, histocytes & fibroblasts in a wound.

2) Improved rate of oedema dispersion.
3) Encourages absorption of heamatoma.
4) Reduction *(resolution)* of the inflammatory process.
5) Prompts a more rapid rate of fibrin fibre orientation & deposition of collagen.
6) Encourages collagen layering at an early stage.
7) Stimulation of osteogenesis.
8) Improved healing of the peripheral & central nervous systems.
*(the claim for CNS healing has **not** been substantiated)*

Papers suggesting that PSWD promotes the ***wound healing*** process include:
Bentall & Eckstein 1975 Wilson 1972, 1974
Wilson & Jagadeesh 1975 Barclay et al 1983.
Seaborne et al 1996 Spielholz et al. (2000) Sheffet et al 2000

Various forms of pulsed electromagnetic fields have been shown to be effective in the stimulation of ***fracture repair*** (as have ultrasound and laser therapies). For those interested in following this up from the literature, the following sample of papers available may provide a useful lead :

Darendeliler, M. A. et al. (1997) Grace, K. L. et al. (1998 Ito, H. and Y. Shirai (2001)
Leisner, S. et al. (2002) Midura, R. J. et al. (2005) Otter, M. W. et al. (1998)
Ryaby, J. T. (1998) Satter Syed, A. et al. (1999) Thawer, H. A. (1999)

The range of clinical applications – in both acute and chronic conditions were recently reviewed (Kumaran and Watson 2015 (acute) and 2016 (chronic). In the acute tissue presentations, the dominant lesions and treatment applications with evidence of benefit (N=30 studies) focused around pain & inflammation together with soft tissue healing and repair. In the chronic studies review (N=90 papers), degenerative joint problems (osteoarthritis), chronic pain and treatment of chronic wounds dominated the literature. The recent review (Al-Mandeel and Watson, 2020) additionally includes material on subacromial impingement; carpal tunnel syndrome; tissue shortening, stiffness & extensibility; low back + neck pain; plantar fasciitis, TMD + numerous others in chronic presentations. In the acute clinical group, beneficial treatments include those for post-operative pain; neck pain; soft tissue injury (primarily ankle) and others.

SUGGESTED TREATMENT DOSES

Due to the wide variety of outputs from the available machines, it is difficult to determine which parameters are most important in dose selection. Numerous fundamental questions have yet to be answered with regards treatment selection such as whether the total energy delivered is significant or whether the mode of delivery is of more importance. It is suggested that the machine parameters are consulted together with the manufacturers information regarding doses (machine output can vary).

In the light of current research, it is suggested that the **minimum energy** required to achieve a therapeutic effect should be utilised. Specific detailed research (clinical & laboratory) is essential for further validation of the treatment which is currently criticised for being unfounded. There is also a strong argument that the ***concentration*** of EM energy is likely to be critical, and it may be at some point in the future that PSWT doses are described more in terms of mean power concentration (W cm^{-2}) rather than just Watts. This would be in keeping with ultrasound and laser therapies.

The general guide below is based on both clinical and research evidence wherever possible.

Acute conditions
Mean power of less than 3 Watts.
More acute the presentation the lower the delivered mean power (i.e. 3 Watts is max for this group).
Using narrower (shorter duration) pulses and a higher the repetition rate may be beneficial.
Time : 10 minutes is probably sufficient

Sub Acute Conditions
Mean power of between 2 and 5 Watts
As the condition becomes less acute, use wider (longer duration) pulses
Time : 10 - 15 mins

Chronic Conditions
Mean power of more than 5 Watts is usually required in order to achieve a reasonable tissue response.

[Be careful with the thermal component as research has shown that at mean powers of about 12 Watts or more, most people can feel some heating effect. If you want to avoid heating, you MUST keep the mean power lower than this. To be safe, better to keep the mean power below 5 Watts at the present time].

Pulses of longer duration are probably of benefit if there is a choice.

Time : 15 – 20 mins. There is no clear evidence of treating for longer than 20 minutes, though this is not 'wrong' per se.

CONTRAINDICATIONS:

- **Pacemakers** (some but not all pacemakers can be adversely influenced by shortwave and pulsed shortwave fields. The current recommendation is that a 3m separation should be maintained between a patient with a pacemaker and an operating shortwave (continuous or pulsed) machine.
- Pregnancy (given the potential adverse effect on the foetus, it is suggested that a patient who is pregnant should not be treated with pulsed shortwave at all.
- Current tissue bleeding (it is fine to apply PSWT soon after an injury so long as in the clinical judgement of the therapist, tissue bleeding has stopped).
- Malignancy (PSWT, like US and Laser has the capacity to increase the rate of division of malignant tissue and therefore it is best avoided. A history of malignancy is not the contraindication (often confused). It is the delivery of the energy to tissue which is malignant, or is considered that it might be thus.)
- Active tuberculosis (no absolute evidence on this, but widely held to be a contraindication)
- Avoid treatment of the abdomen and pelvis during menstruation (precaution rather than a contraindication)
- Severe circulatory compromise or deficit including ischaemic tissue, thrombosis and associated conditions
- Deep X Ray therapy or other ionizing radiations (in the last 6 months) in the region to be treated (historical and assumed rather than actually evidenced)
- Patients who are unable to comprehend the therapists instructions or who are unable to cooperate
- It is considered safe to deliver a low dose (less than 5 Watts mean power) when there is metal in the tissues
- Metal plinths are generally considered acceptable when the applied mean power is less than 5 Watts

PRECAUTIONS

- Avoid active epiphyseal regions in children
- Avoid specialised tissues (e.g. eye and testes)

PHYSIOTHERAPIST SAFETY

In the interest of physiotherapist safety, it is recommended that once the machine has been switched on, the physiotherapist and all other personnel should keep at least ***1 metre*** from the operating machine, leads and electrodes. Pregnant physiotherapists or others with concerns may want to ask a colleague to turn the SWD / PSWD machine on. Almost all modern machines will turn off automatically.

It is recommended that physiotherapists consult the 'Safe Practice with Electrotherapy(Shortwave Therapies)' document (CSP 1997) for further information or the new CSP Electrotherapy Guidance (2006).

ADDITIONAL ISSUES

- It is recommended that other electrotherapy devices, especially electrical stimulation apparatus, are kept at least 2 metres from the PSWT machine.
- The output of some machines (e.g. interferential therapy devices) can be affected by close proximity to an operating SWD / PSWT machine. Departments / physiotherapists should establish the conflicts between their particular SWD / PSWT and electrical stimulation apparatus as these will not be the same for all combinations of equipment.
- It is considered unwise to operate two SWD / PSWT machines simultaneously without maintaining a separation of at least 3 metres.

REFERENCES:

Al Mandeel, M. and Watson, T. (2006)
An evaluative audit of patient records in electrotherapy with specific reference to pulsed shortwave therapy.
Int J Therapy and Rehab.13(9) 414-419

Al Mandeel, M. and Watson, T. (2008)
Shortwave and Pulsed Shortwave Therapies
In: Electrotherapy, Evidence Based Practice (Ch 10).
Editor: T Watson. Published : Elsevier

Al Mandeel and Watson (2010)
The thermal and nonthermal effects of high and low doses of pulsed short wave therapy (PSWT).
Physiotherapy Research International
15(4) :199-211

Al-Mandeel, M.T. Watson (2020).
Pulsed and Continuous Shortwave and Radiofrequency Therapies. Electro Physical Agents: Evidence-Based Practice. T. Watson and E. Nussbaum, Elsevier Health Sciences.

Barclay V, Collier R, Jones A. (1983)
Treatment of various hand injuries by pulsed electromagnetic energy (Diapulse)
Physiotherapy 69(6);186-188

Barker A. et al (1985)
A double blind clinical trial of low power pulsed shortwave therapy.
Physiotherapy 71(12);500-504

Bricknell, R & Watson, T. (1995)
The thermal effects of pulsed shortwave therapy
British Journal of Therapy &
Rehabilitation 2(8);430-434

Cheing, G. L., et al. (2005).
Ice and pulsed electromagnetic field to reduce pain and swelling after distal radius fractures.
J Rehabil Med 37(6): 372-7.

Cleary S (1997)
In vitro studies of the effects of nonthermal radiofrequency and microwave radiation
In : Non Thermal Effects of RF Electromagnetic Fields, ICNIRP

Foley-Nolan et al (1990)
Pulsed high frequency (27MHz) electromagnetic therapy for persistent neck pain.
Orthopaedics 13(4);445-451

Fukuda, T. Y. et al (2011)
Pulsed shortwave treatment in women with knee osteoarthritis: a multicenter, randomized, placebo-controlled clinical trial.
Phys Ther 91(7): 1009-1017.

Goldin J et al (1981)
The effects of Diapulse on the healing of wounds: a double blind randomised controlled trial in man.
British Journal of Plastic Surgery 34;267-270

Hayne C (1984)
Pulsed high frequency energy - its place in physiotherapy.
Physiotherapy 70(12);459-466

Jan, M. H., et al. (2006).
Effects of repetitive shortwave diathermy for reducing synovitis in patients with knee osteoarthritis: an ultrasonographic study.
Phys Ther 86(2): 236-44.

Kallen, B. et al (1992)
Delivery outcomes among physiotherapists in Sweeden: Is non ionising radiation a fetal hazzard.
Physiotherapy 78(1);15-18

Kumaran, B.T. Watson (2015)
Radiofrequency-based treatment in therapy-related clinical practice – a narrative review. Part I: acute conditions Physical Therapy Reviews 20(4): 241

Kumaran, B.T. Watson (2016)
Radiofrequency-based treatment in therapy-related clinical practice – a narrative review. Part II: chronic conditions Physical Therapy Reviews 20(5-6): 325

Luben. R (1997)
Effects of microwave radiation on signal transduction processes of cells in vitro.
Non Thermal Effects of RF Electromagnetic Fields, ICNIRP

Marks, R. and J. van Nguyen (2005).
Pulsed electromagnetic field therapy and osteoarthritis of the knee: Synthesis of the literature.
Int J of Therapy and Rehabilitation 12(8): 347-354.

Martin et al (1991)
Electromagnetic fields from therapeutic diathermy equipment: A review of hazzards & precautions
Physiotherapy 77(1);3-7

Robertson, V. J., et al. (2005).
The effect of heat on tissue extensibility: a comparison of deep and superficial heating.
Arch Phys Med Rehabil 86(4): 819-25.

Sanservino E (1980)
Membrane phenomena & cellular processes under action of pulsating magnetic fields.
Lecture at 2nd Int. Congress Magneto Medicine. Rome. November 1980.

Seiger, C. and D. Draper (2006).
Use of pulsed shortwave diathermy and joint mobilization to increase ankle range of motion in the presence of surgical implanted metal: A case series.
J Orthop Sports Phys Ther 36(9): 669-77.

Shields, N., et al. (2005).
Physiotherapist's perception of risk from electromagnetic fields.
Advances in Physiotherapy 7: 170-175.

Strauch, B. et al. (2006).
Pulsed magnetic field therapy increases tensile strength in a rat Achilles' tendon repair model.
J Hand Surg [Am] 31(7): 1131-5.

Watson, T. (2006).
Electrotherapy and tissue repair.
Sportex-Medicine. 29: 7-13.

Wagstaff, P et al (1986)
A pilot study to compare the efficacy of continuous and pulsed magnetic energy (shortwave diathermy) on the relief of low back pain, Physiotherapy 72(11);563-566

PSWD FOR FRACTURE HEALING

Darendeliler, M. A. et al. (1997).
Effects of static magnetic and pulsed electromagnetic fields on bone healing.
Int J Adult Orthodon Orthognath Surg 12(1): 43-53.

Grace, K. L. et al. (1998).
The effects of pulsed electromagnetism on fresh fracture healing: osteochondral repair in the rat femoral groove.
Orthopedics 21(3): 297-302.

Ito, H. and Y. Shirai (2001).
The efficacy of ununited tibial fracture treatment using pulsing electromagnetic fields: relation to biological activity on nonunion bone ends.
J Nippon Med Sch 68(2): 149-53.

Leisner, S. et al. (2002).
The effect of short-duration, high-intensity electromagnetic pulses on fresh ulnar fractures in rats.
J Vet Med A Physiol Pathol Clin Med 49(1): 33-7.

Midura, R. J. et al. (2005).
Pulsed electromagnetic field treatments enhance the healing of fibular osteotomies.
J Orthop Res 23(5): 1035-46.

Otter, M. W. et al. (1998).
Effects of electromagnetic fields in experimental fracture repair.
Clin Orthop(355 Suppl): S90-104.

Ryaby, J. T. (1998).
Clinical effects of electromagnetic and electric fields on fracture healing.
Clin Orthop(355 Suppl): S205-15.

Satter Syed, A. et al. (1999).
Pulsed electromagnetic fields for the treatment of bone fractures.
Bangladesh Med Res Counc Bull 25(1): 6-10.

Thawer, H. A. (1999).
Pulsed electromagnetic fields for osteogenesis and repair.
Phys-Ther-Rev 4(3): 203-213.