Effect of pulse repetition rate on the perception of thermal sensation with pulsed shortwave diathermy

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ABSTRACT

Background and Purpose. Pulsed shortwave diathermy (PSWD) is a form of therapy commonly used to enhance tissue repair and reduce pain. It is normally considered to be an athermal form of treatment; however, there is some evidence to suggest that thermal effects can arise with adequate dosage. The purpose of this study was to determine the pulse repetition rate (PRR) required to generate a ‘possible’ and ‘definite’ thermal sensation when PSWD was applied to the thigh. Method. Thirty healthy subjects were randomly assigned to placebo or treatment groups. The treatment group was exposed to PSWD at a constant setting of pulse duration (400 µs) and pulse power (190 W) while the PRR was increased from 26 Hz to 400 Hz in 10 increments. Each dose was applied for a period of two minutes. At the end of each application, subjects were asked if they felt a (1) ‘possible’ or (2) ‘definite’ thermal sensation. Skin temperature was measured immediately after each application. Placebo subjects were exposed to PSWD at its lowest settings throughout the experiment (pulse power = 5 W; pulse duration = 65 µs and PRR = 26 Hz). Results. The results showed a significant correlation (p<0.048) between PRR at ‘definite’ thermal sensation and skin temperature post-treatment and PRR at ‘possible’ thermal sensation (p<0.001). Mean skin temperature increased significantly as PRR was increased, from 28.69 (±0.75) °C pre-treatment to 31.14 (±1.04) °C post-treatment, a mean difference of 2.34 °C. Conclusions. These results suggest that PSWD at adequate dosages can generate thermal effects, and that there is a relationship between these thermal effects and the PRR used. These results may have significant implications for the safe use of PSWD in the clinical arena.

Key words: pulse repetition rate, pulsed shortwave diathermy, thermal effects

Introduction

Pulsed shortwave diathermy (PSWD) is widely used in the UK and is one of the most frequently used forms of electrotherapy (Kitchen, 1995; Pope et al., 1995). It is
a form of electromagnetic energy delivered at a frequency of approximately 27.12 MHz, and is delivered to the subject in the form of a train of pulses. There is limited research about the efficacy of PSWD. Wilson (1972) demonstrated a beneficial effect for patients who had sustained an inversion injury of the ankle, particularly in the reduction of pain and also disability. Kaplan and Weinstock (1968) demonstrated that patients receiving PSWD for post-surgical oedema after foot surgery had less pain and less oedema compared to a control group.

In general, PSWD is used for its athermal effects (Kitchen and Partridge, 1995), although the definition or even the existence of athermal effects are the subject of considerable controversy and debate (Hayne, 1984; Kitchen and Dyson, 1996). However, the absorption of electromagnetic energy into tissues will result in thermal changes, although in the case of PSWD these may be imperceptible or ‘micro-thermal’. Therefore, even though during a pulse which exhibits a high peak intensity, instantaneous thermal effects may occur, the treatment will not affect the general temperature of the tissue due to dissipation of heat during the rest period. However, if a pulse is delivered before the thermal effects of a previous pulse are dissipated, it is possible for thermal accumulation to occur. In these instances patients may be able to perceive a definite thermal event.

Several studies have demonstrated that PSWD will, under certain circumstances, produce a heating effect (Erdman, 1960; Silverman and Pendleton, 1968). Morrissey (1966) demonstrated temperature increases at a total dose of 80 W, whereas lower levels of energy did not produce significant heating effects. Erdman (1960) recorded increased skin temperatures of 0.5 °C and 1.5 °C respectively for peak power of 410 W frequency 400 pps and 1025 W frequency 600 pps over the epigastric region in the human subject. More recently, Bricknell and Watson (1995) investigated the effect of pulse power on thermal perception (possible and definite) upon receiving PSWD to the mid-point of the thigh. Pulse frequency and pulse duration were maintained at constant settings of 400 pps and 400 µs respectively. A definite thermal sensation was reported at an average power of 10.88 (±3.22) W.

However these studies were of mixed quality in terms of experimental protocol and detailing of dosage parameters, and their validity is discussed later. These results highlight a number of issues in relation to the safety of PSWD and also show that PSWD is not necessarily the athermal modality it is often claimed to be and can under certain circumstances produce thermal effects.

The purpose of the present study was to establish the pulse repetition rate (PRR) required to generate a perceptible thermal effect using a specific combination of constant pulse duration (400 µs) and pulse power (190 W) settings. The aim of the study was to examine the relationship between thermal sensation and PRR and so has important clinical relevance.

The relationship between PSWD parameters and thermal perception has important implications for the safe and effective use of PSWD. In some clinical situations thermal effects can be contraindicated; for example, impaired thermal sensation at the point of application, or acute inflammation. In many cases, dosage parameters are inadequately quoted by manufacturers and so one aim of this study was to clarify
the dosage of PSWD which will generate a thermal effect. In order to clarify the type
of treatment which is given to patients the parameters should be fully described.
Inadequate detailing of dosage parameters and poorly designed experimental proto-
cols utilized to examine the effects of PSWD have made it almost impossible to com-
pare studies and so concise studies with clearly outlined dosage parameters are
needed urgently. PSWD parameters most frequently quoted include pulse power,
pulse duration and pulse repetition rate. However, as the average power applied is
determined by all three of the above parameters, it is perhaps the most informative
parameter which is unfortunately not often quoted and would facilitate intra-study
comparisons.

**METHOD**

**Study design**

A randomized, controlled, single-blind experimental study design was used to exam-
ine the effect of PRR on thermal perception of PSWD.

**Subjects**

Thirty volunteers (13 male; 17 female) from a student population at King's College
London were recruited for the study. Subjects were not taking any medication, had
suffered no recent injury or illness and were in general good health. Additional
exclusion criteria were those for both thermal and athermal SWD. Subjects were
aware of the study hypothesis as they were required to read, fill in and sign consent
forms explaining the project, listing any contraindications to treatment and guaran-
teeing anonymity. In addition, the purpose of the study was explained verbally to
each subject before testing. However, subjects were unaware as to whether they were
in the treatment or placebo group. Randomization of subjects was achieved by pick-
ing names out of a hat. Fifteen subjects were randomly assigned to each of the
placebo and treatment groups. Permission to carry out the study was obtained from
King's College Ethics Committee.

**Apparatus**

PSWD was administered from a Curapuls 403 machine (Enraf–Norius, Delft,
Netherlands). This is a micro-controlled unit which delivers PSWD therapy by
means of one electrode. Pulse duration, pulse frequency and treatment duration are
all adjustable. The specifications of this apparatus were as follows:

- Frequency 27.12 MHz (±0.6%).
- Pulse duration 65–400 µs (±5%).
- Pulse frequency 26, 35, 46, 62, 82, 110, 150, 200, 300, 400 Hz (±5%).
- Pulse power 0–200 W (±20%).
Mean power 0–32 W (±20%).
Treatment time 0–30 min (±5%).

At each session the machine output was checked by the operator. The same Enraf–Nonius Curapuls 403 shortwave diathermy generator was used on all subjects in each group.

An Edale digital thermometer and probe were used to measure skin surface temperature. Manufacturers’ specifications defined a reliability of ±0.5 °C. A rubber strap was used to affix the thermometer to the treatment area between each two-minute interval. Skin-fold callipers were used to measure body fat percentage. A Mucun thermometer was used to measure room temperature. A single operator (CM) administered the PSWD, questioned the subjects and took skin temperature readings.

Experimental protocol for treatment group

Procedure

Subjects were directed to abstain from physical exercise for at least two hours before PSWD treatment. Upon arrival, subjects sat quietly in the treatment room at a steady temperature for 20 min, screened from the treatment area, in order to standardize subjects’ temperature before the procedure. A full medical history was obtained from each subject, test for skin thermal sensation was performed and percentage body fat was measured as described by Durnin and Wormersely (1974) to ensure that the two groups were not statistically different from each other and could be compared. Room temperature was measured before and after each treatment session to ensure that temperature fluctuations did not affect results.

Skin surface temperature was measured before commencing treatment using a thermometer and probe. A rubber strap rather than sticky tape was used to fix the skin probe in position for temperature measurement. It was reasoned that repeated application and removal of sticky tape might lead to skin sensitization and inflammation which could possibly lead to thermal changes. The thermometer was screened from subjects in order to eliminate any bias and a 90-s cut-off point was used for the skin temperature readings due to slowness in reaching a final temperature reading. A screen was placed over the display unit to ensure that subjects could not see the treatment settings. In addition, the machine was placed on the right-hand side and slightly behind each subject. Subjects were positioned in the half-lying position with a cushion behind them. This position was chosen to ensure that they were comfortable and could remain in this position for up to 40 minutes without moving. In addition, this was an easy position to observe subjects’ faces for any signs of discomfort.

PSWD was applied in two-minute bursts to the mid-point of the right thigh at each PRR assessed. Skin surface temperature was measured and subjects were asked the following two questions:
• Did you think you could feel a change in temperature after the last application? ('possible' thermal sensation)
• Did you definitely feel a change in temperature after the last application? ('definite' thermal sensation)

A note was made of the skin temperature generated at each PRR and the PRR in each case required to generate a (1) 'possible' and (2) 'definite' thermal effect. The sequence of applications was stopped when subjects said they could definitely feel a thermal effect at the point of application.

Dosage

For the treatment group, peak power was kept constant at 190 W and pulse duration was set at 400 µs. A maximum peak power (200 W) was not selected as, in order to obtain this level, the electrode was too close to the skin surface and might have caused a burn. The PRR was increased every two minutes and ranged from 26 Hz to 400 Hz (in 10 increments of two-minute applications).

Experimental protocol for placebo group

Procedure

The protocol was repeated for the placebo group. Again, after each two-minute treatment session, skin surface temperature was measured and subjects were asked if they felt a (1) 'possible' or (2) 'definite' thermal effect at the point of application. Treatment was continued for 10 two-minute 'mock' treatment sessions or stopped if subjects said they could feel a 'definite' thermal effect at the point of application.

Dosage

Peak power (5 W), pulse duration (65 µs) and PRR (26 Hz) were kept at their lowest settings throughout the experiment.

Statistical analysis

A Student's two-sample t-test was used to determine if there was a significant difference in group characteristics between the treatment and placebo groups. The Pearson correlation test was utilized in order to determine if there was a significant correlation between PRR at 'definite' thermal perception and the following variables: age, weight, height, percentage body fat, skin temperature pre-treatment, skin temperature post-treatment, difference in temperature to 'definite' thermal perception, and PRR at 'possible' thermal perception. In addition, the Pearson correlation test was used to assess if there was a significant correlation between PRR at 'possible' thermal sensation and skin temperature post-treatment and change in temperature.
to ‘possible’ thermal sensation. The Mann–Whitney U test was used to determine if mean skin temperature rose significantly with increasing PRR and also whether mean ambient room temperature, pre- and post-treatment sessions for each treatment group, and between groups was significantly different; p<0.05 was judged to be significant.

RESULTS

Subject characteristics

The characteristics of both the placebo and treatment groups are shown in Table 1 and were compared statistically by use of the Student’s two-sample t-test. There was no significant difference between the two groups for any of the parameters assessed and so the two groups could be compared with respect to the effect of PRR on thermal perception.

<table>
<thead>
<tr>
<th>TABLE 1: Characteristics of study subjects (N = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placebo group (N = 15)</td>
</tr>
<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>Height (m)</td>
</tr>
<tr>
<td>Weight (kg)</td>
</tr>
<tr>
<td>Body fat (%)</td>
</tr>
</tbody>
</table>

SD = Standard deviation

Ambient room temperature

The mean ambient room temperature readings for both groups before and after each test session were:

- 23.6 (±0.4) °C (pre-treatment treatment group).
- 24.1 (±0.6) °C (post-treatment treatment group).
- 23.9 (±0.4) °C (pre-treatment placebo group).
- 23.5 (±0.7) °C (post-treatment placebo group).

There was no significant difference between pre- and post-treatment temperature readings in either group nor between treatment and placebo groups.

Experimental group results: active PSWD (N = 15)

Pulse repetition rate

Table 2 summarizes the mean PRRs required to generate a ‘possible’ and ‘definite’ thermal sensation after application of PSWD (at a constant peak power of 190 W
and pulse duration of 400 µs) to the mid-point of the right thigh. ‘Possible’ thermal sensation was recorded at a mean PRR of 183.5 (±92.9) Hz and ‘definite’ thermal sensation was recorded at the higher mean PRR of 278.8 (±108.8) Hz. The majority of subjects (N = 9) indicated a ‘definite’ thermal perception at either 300 Hz (N = 4) or 400 Hz (N = 5). The large standard deviation (SD) observed for mean PRR at ‘definite’ thermal sensation (SD 108.8) is largely due to subject number 15 who indicated a ‘definite’ thermal sensation at 82 Hz; excluding this subject brought the mean SD down to 98.5.

Mean power

As the PRR was increased incrementally whilst keeping pulse duration (400 µs) and peak power (190 W) at a constant setting, the mean power delivered to each subject over the experimental time increased. The mean power required to generate a (1) ‘possible’ and (2) ‘definite’ thermal sensation at the point of application was 13.8 (±7.1) W and 21.2 (±8.3) W respectively. These results are also summarized in Table 2.

<table>
<thead>
<tr>
<th>Thermal sensation</th>
<th>Mean (SD) PRR (Hz)</th>
<th>Mean (SD) power (W)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Possible’ thermal sensation</td>
<td>183.5 (92.9)</td>
<td>13.8 (7.1)</td>
<td>10</td>
</tr>
<tr>
<td>‘Definite’ thermal sensation</td>
<td>278.8 (108.8)</td>
<td>21.2 (8.3)</td>
<td>15</td>
</tr>
</tbody>
</table>

SD = Standard deviation

*Where a ‘possible’ thermal sensation was felt at several consecutive PRRs, the mean PRR was taken.

Skin temperature

Figure 1 summarizes the mean skin temperature measured at each PRR. As can be seen, there is good correlation between PRR and skin temperature (r = 0.517). Mean skin temperature rose steadily from an initial pre-treatment temperature of 28.69 (±0.75) °C to a final temperature measured after the application of PRR at 400 Hz of 31.14 (±1.04) °C, a mean difference in temperature of 2.34 °C. In addition, mean skin temperatures measured at PRR 62 Hz and continuing through to 400 Hz were significantly higher than pre-treatment temperatures. However, at the highest PRR assessed (400 Hz), and hence the highest mean temperature recorded (31.14 (±1.04) °C), the level of significance fell to p<0.047, reflecting the large standard deviation of temperatures at this setting.

Pearson correlation analysis

A correlation analysis was performed to examine how individual subject characteristics and experimental results interrelated. These results are summarized in tables 3 and 4. No significant relationship existed between PRR at ‘definite’ thermal per-
ception and the following variables: age, weight, height, percentage body fat, skin temperature pre-treatment and rise in skin temperature.

Significant relationships were identified between PRR at 'definite' thermal perception and (1) skin temperature post-treatment \( (r = 0.517; p < 0.048) \) and (2) PRR at 'possible' thermal perception \( (r = 0.983; p < 0.001) \). This correlation analysis confirmed an association between PRR and skin temperature and that subjects who reported a 'possible' thermal sensation at a higher PRR tended to be those who reported a 'definite' thermal sensation at a high PRR and vice versa.

Table 4 summarizes the correlation analysis between PRR at 'possible' thermal sensation with (1) skin temperature post-treatment and (2) rise in skin temperature. There was no significant correlation between either of these variables even though the correlation coefficient describing the relationship with skin temperature post-treatment was moderately high \( (r = 0.575) \).

Control group results: non-active PSWD \( (N = 15) \)

Fourteen of the 15 subjects received the minimum dose of peak power \( (5 \text{ W}) \), pulse duration \( (65 \mu\text{s}) \) and PRR \( (26 \text{ Hz}) \) for the full 10 'mock' applications and reported no 'possible' or 'definite' thermal perception. One subject reported a 'possible' thermal sensation after only the fifth 'mock' application and a 'definite' thermal sensation after the sixth 'mock' application. The experiment was stopped at this setting for that particular subject. For all control subjects \( (N = 15) \), application of PSWD at its lowest settings for each of the 'mock' applications did not produce a rise in skin temperature.

\[\text{FIGURE 1: Effect of pulse repetition rate (PRR) on temperature of the mid-thigh after application of pulsed shortwave diathermy (SWD).}\]
DISCUSSION

Shortwave diathermy in both its continuous and pulsed form has been used for some time to treat a wide variety of conditions, including strains and sprains (Wilson, 1972; Kitchen, 1995), joint conditions such as osteoarthritis (Nadasdi, 1960; Vanharanta, 1982) and soft tissue healing (Goldin et al., 1981). Wilson (1972) demonstrated that PSWD treatment improved swelling, pain and disability for patients who had sustained an inversion injury of the ankle, and in separate studies, both Nafasdi (1960) and Vanharanta (1982) demonstrated that PSWD improved chemically induced joint damage in rats and rabbits, respectively.

However, not all research has been able to demonstrate such positive results. McGill (1988) found that PSWD had no significant effect on pain, swelling, amount of analgesia required and time to weightbearing for patients who had sustained an inversion injury of the ankle, and in separate studies, both Nafasdi (1960) and Vanharanta (1982) demonstrated that PSWD improved chemically induced joint damage in rats and rabbits, respectively.

However, not all research has been able to demonstrate such positive results. McGill (1988) found that PSWD had no significant effect on pain, swelling, amount of analgesia required and time to weightbearing for patients who had sustained a lateral ligament sprain of the ankle.

Over the past three decades, PSWD has been researched extensively with respect to clinical efficacy (Kaplan and Weinstock, 1968), the existence of athermal effects (Hayne, 1984) and the production of thermal effects (Erdman, 1960; Morrissey, 1966; Bricknell and Wilson, 1995). However, the research is of mixed quality and often unrepeatable due to incomplete reporting of dosage parameters and poorly detailed experimental protocols. For example, Fenn (1969) described a penetration setting of 4 on the diapulse used to treat chemically induced haematomas in the ears.

\[TABLE 3: Pearson correlation analysis for mean PRR at ‘definite’ thermal sensation and key variables (N = 15)\]

<table>
<thead>
<tr>
<th>Variables</th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>0.433</td>
<td>0.098</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>0.125</td>
<td>0.660</td>
</tr>
<tr>
<td>Height (m)</td>
<td>0.455</td>
<td>0.097</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>0.480</td>
<td>0.143</td>
</tr>
<tr>
<td>Skin temperature (pre-treatment) (°C)</td>
<td>0.392</td>
<td>0.148</td>
</tr>
<tr>
<td>Skin temperature (post-treatment) (°C)</td>
<td>0.517</td>
<td>0.048</td>
</tr>
<tr>
<td>Change in temperature (°C)</td>
<td>0.338</td>
<td>0.228</td>
</tr>
<tr>
<td>PRR at possible thermal sensation (Hz)</td>
<td>0.983</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

PRR = pulse repetition rate; r = Pearson correlation coefficient; p = probability.

\[TABLE 4: Pearson correlation analysis for mean PRR at ‘possible’ thermal sensation and key variables (N = 10)\]

<table>
<thead>
<tr>
<th>Variables</th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin temperature (post-treatment) (°C)</td>
<td>0.575</td>
<td>0.068</td>
</tr>
<tr>
<td>Change in temperature (°C)</td>
<td>0.474</td>
<td>0.152</td>
</tr>
</tbody>
</table>

r = Pearson correlation coefficient; p = probability.

Pulse repetition rate and thermal sensation
of rabbits, and Verrier et al. (1977) defined the SWD dosage used to produce a thermal effect as the 'maximum tolerable dose'. Clearly, there is no agreement on appropriate dosage parameters or the effects of thermal and athermal effects. There is only limited evidence to support the efficacy of PSWD and well-designed trials are needed urgently so that the effects of different treatment parameters can be assessed. The present study hypothesized that PSWD will produce heat if the mean power delivered to a subject is sufficiently high (Silverman and Pendleton, 1968; Bricknell and Wilson, 1995). The aim was to examine the relationship between thermal sensation and PRR, the idea being that energy from the last pulse had not dissipated into the surrounding tissue before the next pulse was delivered (Olivier, 1995).

In this study no relationship between PRR and age, weight, height or body fat was established. The age range of the subjects was low due to selection from a student population (placebo group: 21.33 (±2.6) years; treatment group: 23.93 (±4.5) years). Further studies are needed to examine the effect of PRR on thermal perception using a wider range of ages thus reflecting a standard patient population. The lack of relationship between PRR and percentage body fat may be due to the use of an inductive method rather than the capacitor method of application which has been shown to cause excess heating of fatty tissues (Scott, 1996). The difference between the inductive and capacitor field methods lies in the way energy is introduced into the tissues leading to a different pattern of heating. Thermal effects due to the inductive method are due to magnetically induced eddy currents, where most of the heating occurs in the superficial tissues but not especially in fatty tissues as occurs with the capacitor method of application. A gain, further studies should be carried out to assess the thermal effects of PSWD using the capacitor method.

A significant correlation was demonstrated between PRR at 'definite' thermal perception and skin temperature post-treatment ($p<0.048$) and PRR at 'possible' thermal sensation ($p<0.001$). Bricknell and Watson (1995) also described the same correlations using mean power instead of PRR as the manipulated variable, which indicates the repeatable nature of this research. After each application of PSWD the skin temperature of the treatment area was measured. By the end of the experiment the mean temperature had risen by 2.34 °C to 31.14 (±1.04) °C after application of the highest PRR (400 Hz). This result is in accordance with that of Verrier et al. (1977) who recorded a significant rise in mean temperature of 3.28 °C after application of the 'maximum tolerable' dose using the condenser field technique of application. In addition, Bricknell and Watson (1995) reported that at mean power delivery of 10.88 (±3.32) W, mean skin temperature rose by 2.1 °C after a mean duration of seven minutes. Erdman (1960) also found an increase in skin temperature of 1.5 °C at a PRR of 600 Hz and at six intensity settings (although the detailed parameters of these are unclear or not included).

However, when assessing the validity of these results it is important to consider factors which may affect thermal sensitivity. First, there may be significant differences between injured and non-injured subjects with respect to thermal perception as injured subjects may have increased sensitivity to energy introduced into the tissues. Second, different body areas may have different temperature sensitivities.
Odia and Aigbogun (1988) carried out a study assessing the differences in temperature sensitivity of skin areas (face, forearm and leg). They found that for the face the temperature associated with warmth was significantly lower than for the forearm or leg. This difference in the sensitivities may be based on their differential somatosensory representations and probably also on their different vascularization (Berne and Leavy, 1972). These results suggest that different areas of the body may have different thermal sensitivities and so care should be taken when extrapolating these results to other areas of the body.

In the present study, PRR was increased incrementally while maintaining pulse power (190 W) and pulse duration (400 µs) at constant settings. However, by definition when one of these parameters is altered so is the mean power delivered to the subject. Taking this into consideration the mean powers delivered to each subject required to generate a ‘possible’ and ‘definite’ thermal effect were calculated. The results show that a mean power of 13.76 (±7.06) W and 21.19 (±8.27) W were required to generate a (1) ‘possible’ and (2) ‘definite’ thermal sensations, respectively. In contrast, Bricknell and Watson (1995) reported the mean power required to generate a ‘possible’ and ‘definite’ thermal effect as 6.58 (±3.5) W and 10.88 (±3.32) W, respectively, at a constant setting of pulse duration (400 µs) and PRR (400 Hz). The apparent difference in these two results may be due to the fact that Bricknell and Watson (1995) applied PSWD continuously for a period of up to 30 minutes, increasing peak power every 30 seconds and so thermal accumulation may have occurred thus producing a thermal effect at a lower mean power.

The present study has demonstrated the ability of PSWD to generate thermal effects in healthy tissue. Kloth and Ziskin (1990) suggest that pulsing the output of a SWD apparatus eliminates the heating component associated with continuous SWD. However, the results of this study and those of Bricknell and Watson (1995) indicate that this supposition is incorrect and that the heating capabilities still remain with pulsing, providing the total energy delivered is adequate. These results highlight the importance of clear and known dosage and application considerations for the clinical use of pulsed SWD.

**CONCLUSIONS**

The results of this study indicate that PSWD will produce a ‘definite’ thermal effect if given at a pulse power of 190 W, pulse duration of 400 µs, mean power of 21.19 (±8.27) W whilst steadily increasing the PRR every two minutes to a mean value of 278.8 (±108.8) Hz. The results presented here have important clinical implications for the safe and effective use of PSWD in the clinical arena and provide guidelines for dosage parameters which are not often supplied by manufacturers or adequately described by the vast majority of the current literature in this field. This study could be expanded to include the effect of PRR on thermal sensation in a larger patient population and in other age groups. Thermal sensation could be compared in other areas of the body and other dosage parameters, or combinations of parameters, could be investigated with regards to thermal sensation.
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