Title: Radiofrequency-based treatment in therapy-related clinical practice – A narrative review. Part II: Chronic conditions

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ABSTRACT

Background: Radiofrequency (RF)-based electrophysical agents (EPAs) have been employed in therapy-related clinical practice for several decades. They are used to reduce pain and inflammation and promote tissue healing. Although deemed less popular in current therapy practice, surveys suggest that some of these EPAs are still used reasonably widely.

Objective: To review the evidence for the use of non-invasive low frequency RFs (30 kHz–30 MHz) for treating chronic therapy-related clinical conditions.

Major findings: All relevant peer-reviewed clinical studies published in English, concerning low frequency RFs were sought. Identified literature was stratified as 'acute' and 'chronic' based on their clinical area. The studies on chronic conditions were reviewed for this paper and analysed to assess the volume and scope of current evidence. Out of 120 studies identified, 90 related to chronic conditions. The majority of them (82 studies) employed Shortwave Therapy (SWT) in continuous (CSWT) or pulsed (PSWT) modes. Only eight studies employed frequencies other than shortwave. Overall 67 studies investigated conditions relating to 'pain and inflammation', 16 to 'tissue healing' and seven studies to other less reported conditions.

Conclusions: Evidence favouring and against RF-based EPAs is available. There is moderate evidence favouring the use of SWT (mainly PSWT) in knee osteoarthritis. Some evidence also exists for CSWT in chronic low back pain and PSWT for treating chronic wounds.

Evidence for other conditions is insufficient and conflicting. A general lack of research emphasis in the non-shortwave RF band is evident. Further and wider research in this area is necessary.

KEY WORDS

Chronic conditions; Clinical effects; Electrophysical agents; Non-invasive; Radiofrequency.

INTRODUCTION

Therapeutic use of electrophysical energy has been well-established since the past century, making the treatment using electrophysical agents (EPAs) a key area in the realm of physiotherapy.[1,2] Devices that employ radiofrequency electromagnetic field (RFEMF or simply RF) are a major component of EPAs, the use of which has been reported since the early decades of last century.[3]

The therapeutic effects of RF are mainly linked to their effects on pain relief and tissue repair.[4,5] These effects may be achieved either through thermal or through non-thermal mechanisms, which are essentially dose dependent.[5,6] At higher doses the cardinal effects of RF are heat-related physiological changes triggered by a rise in the tissue temperature.[7-10] At substantially lower doses of RF, a discernible rise in tissue temperature is not achieved,[7,8] but rather the absorption of RF energy in tissues instigate a modulation in cellular activity and alter membrane transport.[5] Although less well understood compared to the thermal effects, the non-thermal effects of RF and the mechanisms underpinning those effects have become more established in the recent years.[11-13]

Even though a key component among the EPAs, RF devices have become less popular lately. The RF frequency ranges presently used in therapy practice have become restricted largely to 30 kHz–30,000 kHz (30 MHz).[14] The drop in popularity of RF-based EPAs has been reciprocated by the evolution and increased popularity of other forms of EPAs such as ultrasound, laser, transcutaneous electrical nerve stimulation (TENS) and interferential therapy (IFT).[15-17] However, it may be argued that this swing towards other non-RF therapies may have been a fashionable shift rather than based on evidence *per se*. The fall in the use of RF-based EPAs is evidenced by the findings from recent surveys and reviews.[14,18] That having been said, a recent audit in the UK has reported that RF-based EPAs such as the pulsed shortwave therapy (PSWT) is still used among about 11% of outpatient clinics in the UK.[17]

In part I[19] of this review published by the same authors, the evidence for RF-based EPAs within the frequency range of 30 kHz–30 MHz used in the treatment of acute therapy-related clinical conditions was presented. The objective of this paper (part II) is to review similar RF-based studies published to date on chronic conditions. In the current literature, apart from the reviews on varying specific conditions and specific RF energy types,[6,20-25] no reviews covering the whole RF literature on chronic conditions could be identified. Hence, to our knowledge this is the first such attempt.

In part I,[19] although beyond the primary remit of the review itself, relevant RF studies performed on laboratory animals were also covered in order to illustrate some key issues. However, unlike in acute conditions, the authors identified only one animal study[26] that evaluated the effects of RF-based therapy that was directly relevant to chronic clinical conditions.

Vanharanta[26] investigated the effect of continuous shortwave therapy (CSWT) on the joint mobility and radiographic changes during the development of osteoarthritis (OA) of the knee joint. The authors developed an experimental model of OA knee by periodically immobilising the knee joints of rabbits. They were then treated with CSWT (55 sessions in 11 weeks, 5 minutes per session) and compared with an identical group of non-treated control rabbits. The groups did not show any significant difference between them post treatment, in terms of joint mobility or radiological changes. A lack of further animal studies relevant to chronic conditions made it difficult to draw a definite comparison with human studies.

METHODS

A detailed account of the methods adopted for this review has been reported previously in part I[19] of this review. While the first part presented the overall search results and a review of the studies (published in English) on RF-based EPAs (30 kHz–30 MHz) conducted on acute conditions, part II aimed to review the identified studies that were conducted on chronic conditions. As detailed in part I,[19] the authors adopted an all-inclusive methodological approach for the purpose of this review; several examples of which are available in the literature.[27-30] This approach is dissimilar to that of a systematic review and does not exclude studies based on their methodological design and/or quality as would be the norm in a systematic review.

The identified studies were stratified on the basis of the frequency of RF used (shortwave, non-shortwave), the study design (clinical trial, cohort study, case study), and their clinical application category [pain and inflammation, tissue healing, others (all other less reported conditions, e.g. – postoperative stiffness of joints)]. For the purpose of this review 'chronic' is considered as conditions older than six weeks. The authors understand that it is problematic to divide studies in to distinct acute and chronic categories as conditions may overlap to a varied extent. However, based on available examples[31,32] the terms 'acute' and 'chronic' are not explicitly defined in the existing literature and any duration used for classifications have been based merely on personal opinion or anecdotal evidence.[33]

The studies employing devices generating RF between 10–30 MHz were considered as shortwave studies, and those employing RF between 30 kHz–10 MHz as non-shortwave studies. The methodological quality of the studies was screened using the Cochrane risk of bias assessment tool[34] where appropriate and scored based on the checklist proposed by Downs and Black[35] for randomised and non-randomised studies.

The Downs and Black checklist is a valid tool[36] containing 27 items concerning the quality of reporting, validity, bias and statistical power of the studies (maximum score of 32; higher the score better the quality). Over the years, several authors have used modified versions of this checklist, mainly by simplifying the ‘item 27’ (originally scored 0–5) that concerns statistical power.[37,38] A similar modified version, scoring item 27 as either ‘zero’ (insufficient power) or ‘one’ (sufficient power) was used in this review. Hence, the maximum score that could be achieved by a study was 28.

RESULTS

The flow of studies through the review is given in Figure 1. Out of the 120 studies that were originally identified[19] on the use of RF-based treatment in therapy practice, a total of 90 (75%) studies investigated chronic conditions. Out of 90, there were 82 (91%) shortwave studies and eight (9%) non-shortwave studies. Sixty-seven studies (74%) were conducted on conditions relating to pain and inflammation and 16 (18%) on conditions relating to tissue healing. A further seven studies (8%) were classed as 'others' and related to a mixture of conditions that were reported relatively rarely (e.g. – postoperative stiffness of joints) (Figure 2).

However, as identified, the authors recognise that it is challenging to classify studies into such distinct clinical categories stated above, given that they may overlap to a varied extent. Clearly there was potential overlap between studies (although more so for the acute studies) that considered pain and inflammation and that considered tissue healing. For the purpose of this review, the allocation of a particular paper into a group was based on the primary outcome(s) as identified by their authors. The full texts were available for all the studies discussed here except for three.[39-41]

Insert Figure 1 here

Insert Figure 2 here

DISCUSSION OF RESULTS

All 90 studies that investigated the effects of RF on chronic clinical conditions are considered in detail in the following sections. The types of RF used, key characteristics including dose parameters (where reported) and the Downs and Black scores are given as tables in their respective sections.

NON-SHORTWAVE STUDIES

Eight studies employed RF between the frequencies 30 kHz–10 MHz for the management of chronic clinical conditions. Five of these studies were clinical trials;[42-46] one cohort study[47] and the remaining two were case studies.[48,49] All eight studies reported conditions giving rise to pain and inflammation. Four were on OA of the knee joint,[44-47] and one each on shoulder pain,[49] temporo-mandibular joint (TMJ) pain and dysfunction,[42] tendinopathy[43] and other chronic pain conditions.[48] The RF employed ranged from 250–500 kHz across all studies, except that by Takahashi and colleagues[47] and the study by Nelson and colleagues[46] where frequencies of 6,000–8,000 kHz (6–8 MHz) were used.

In one of the three randomised controlled trials (RCT) on OA knee, Nelson and colleagues[46] reported a three-fold improvement in VAS pain scores of 15 participants when treated with an active 6.8 MHz pulsed electromagnetic field (PEMF) device [80 (±9) sessions in 42 days, 15 minutes per session] compared with a placebo-treated group of 19 participants. Pain was the only outcome measured in this study, with no follow-up measurements beyond the immediate post treatment phase.

Similarly, Taverner and colleagues[45] used 480 kHz transcutaneous pulsed radiofrequency (TPRF) therapy (single session for 10 minutes) against a placebo-TPRF on 52 participants (in two groups: active and placebo) awaiting total knee replacement (TKR). The study reported a statistically significant reduction in the pain (VAS) scores of active group participants at one and four weeks post treatment compared to the placebo group.

In another clinical trial, Alcidi and colleagues[44] tested 500 kHz RF (five sessions in five days, 20 minutes per session) against TENS (50 Hz, 0.5-millisecond square waves for 20 minutes per session for five days) in 40 patients with OA knee (two groups of 20 each). The RF therapy induced a statistically significant and longer lasting reduction in pain compared to the TENS. However, while a 20-minute treatment is appropriate for RF, it may be too short for TENS to be effective.[2] Also, pain relief with TENS is shown to be prominent during the treatment as opposed to post-treatment.[50]

All three RCTs were small with very short assessment periods and a limited number of outcome measures. None of them employed a true control group, nor did they account for confounding factors such as the use of medication.

Takahashi and colleagues[47] conducted a pilot study on 12 patients presenting with OA knee using an 8 MHz RF applicator (three sessions in three weeks, 20 minutes per session). They demonstrated that 8 MHz RF can be used safely to induce hyperthermia inside the knee joints and obtain significant pain relief. The temperature inside the joint was recorded using an invasive metallic thermocouple that remained *in situ* for the duration of treatment. This could potentially have caused a direct heating of the thermocouple by the RF. It was not possible to determine from the paper whether the researchers had attempted to mediate this effect.

In a mixed case series by Balogh,[48] TPRF therapy was applied to four patients who had suffered lumbar intervertebral disc and other injuries, using conventional TENS electrodes and a 500 kHz RF generator (10 minutes at 1–5 week intervals). Three out of the four patients treated reported significant improvement in self-reported pain and function. However, the treatment protocols were variable for each patient. In a similar study, Taverner and colleagues[49] used RF at 480 kHz (single session of TPRF therapy for up to 12 minutes) to treat a cohort of 13 patients suffering from shoulder pain (15 shoulder joints). Two-thirds of their participants reported pain relief over three months.

Al-Badawi and colleagues[42] achieved a significant reduction in TMJ pain and improvement in mandibular range of movement (ROM) in a double-blinded RCT with 40 participants (two groups of 20 each). The subjects were exposed to either 250 kHz pulsed RF (PRF) or placebo-PRF (six sessions in two weeks, 90 seconds per session), and then followed up for two weeks. The authors concluded that the overall beneficial effect of PRF on TMJ reported pain is a combination of a placebo and true therapeutic effects. This was difficult to be ascertained from these results though, as a true control group was not employed.

In a further study by Costantino and colleagues,[43] the immediate clinical effects on pain obtained by 448 kHz Capacitive Resistive Monopolar RF (CRMRF) therapy were found to be significant yet equivalent to those obtained by cryoultrasound therapy and laser CO_2 therapy. Forty-five athletes suffering from extensor tendinopathy (Achilles, patellar or elbow) were treated in three equal groups, each receiving 12 sessions of one of the three modalities (RF was given for 30 minutes, laser for 15 minutes and cryoultrasound for 20 minutes).

In summary, only a limited number of clinical studies have been published in the non-shortwave RF category. They suggest that RF energy below the frequency of 10 MHz might deliver appreciable therapeutic effects. However, these results should only be considered against their overall methodological quality, several of which were problematic. The paucity of controlled clinical studies and the poor overall methodological quality imply the need for substantially more research in this area. In addition, because of the varied nature of the frequency and dosage parameters used by their authors, any potential range of ideal doses could not be identified. The rationale for frequency and dose selection was also not reported.

Insert Table I here

SHORTWAVE STUDIES

The authors identified 82 clinical studies relating to chronic conditions that employed RF within the shortwave frequency range of 10–30 MHz. All studies used devices delivering energy at the base shortwave frequency of 27.12 MHz either in the continuous (CSWT) or in the pulsed (PSWT) mode. Overall, 59 studies investigated conditions giving rise to pain and inflammation, 16 studies investigated tissue healing and the remaining seven studies examined other less reported conditions such as postoperative stiffness of joints.

STUDIES ON PAIN AND INFLAMMATION

With 59 studies, this is the largest group in terms of the number of studies published. Almost half of them (28 studies) reported the effects of RF-based therapy on arthritis, predominantly OA of the knee joint.[51-78] Twenty-seven of these studies were clinical trials and one cohort experimental study[52] on the effect of CSWT on radio-sodium clearance from the knee joint. A further eight clinical trials[41,79-85] and one cohort study[86] investigated chronic low back pain (LBP), and one clinical trial[87] and five case studies[88-92] investigated various pelvic pain (gynaecological) conditions.

In addition, three clinical trials[93-95] were identified on chronic neck disorders, one clinical trial[96] and one case study[97] each on plantar fasciitis; and one clinical trial[98] and one case study[99] each were identified on chronic shoulder problems. Further, one clinical trial each on TMJ pain,[100] trigger point pain[101] and myofascial pain;[102] and one case study each on Herpes Zoster pain,[103] heel neuroma,[104] avascular necrosis of the femoral head,[105] and multiple cases of pain[106] were also identified. Two recently published clinical trials[39,107] on carpal tunnel syndrome were also included.

Arthritis

As identified, the highest number of studies on the effects of SWT was reported on arthritis, primarily OA of the knee joint. Hamilton and colleagues[51] in their study published in 1959 examined a heterogeneous mix of 62 patients suffering from either rheumatoid arthritis (RA; hands or knees) or OA knee. They reported that CSWT (12 sessions in 4 weeks, 20 minutes per session) improved outcomes of walking and stair climbing among the participants, but not significantly greater than other EPAs, or a placebo-CSWT.

An experimental study by Harris[52] suggested that CSWT exposure (single session for 20 minutes) can improve circulation to the knee joints of people suffering from RA if the condition is quiescent whereas it can be counterproductive if the RA is active. In a later study, Wright[53] gained better long-term improvement with CSWT (18 sessions in 6 weeks, 20 minutes per session) over placebo tablets and placebo injections among 38 patients with OA knee when treated in three different groups. Several studies followed till the early 1990's, where neither CSWT nor PSWT were found to be significantly better than any of the compared treatment methods.[54-61] However, similar to the studies discussed above, none of these earlier trials employed a sufficiently robust methodology. Lack of adequate statistical power and absence of a true control group or long-term follow-ups were common to most of these studies. Nearly all the studies failed to report the SWT dosage parameters adequately (Table II).

More recently, Klaber Moffett and colleagues[62] agreed with the findings of the previous studies, as they found no significant differences between the active, control or placebo groups for self-reported pain and quality of life (QoL) measures of 92 subjects (nine sessions of PSWT in three weeks, 15 minutes per session). This was a well-designed RCT on patients suffering from hip and knee OA. Likewise, two very similar (small) clinical trials[64,65] published in the last decade, which employed four different doses of PSWT (six and nine sessions respectively in two weeks, 20 minutes per session) between them in addition to a placebo dose, reported that there were no significant differences between any of the groups after the intervention.

In contrast, PSWT (10 sessions in two weeks, 15 minutes per session) was shown to improve pain and function at both low and high doses when combined with ultrasound therapy and progressive resistance exercises in the study by Tuzun and colleagues.[63] However, both the groups (20 participants each) had a battery of interventions. In another study by Jan and colleagues,[66] pain and synovial thickness (measured using ultrasonography) were lower in CSWT-treated groups (30 sessions in 8 weeks, 20 minutes per session) compared to a control group regardless of the NSAID consumption. The study had only limited sample (36 participants in three groups) and did not employ a randomised design. Also, the control group participants had significantly less pain at baseline compared to the CSWT group.

Further studies followed, comparing the effects of SWT to spa, ultrasound, ice or exercise therapies. All these studies reported SWT to be either less effective or no better than the comparison groups.[67-69,73] Among these studies, only the trial conducted by Rattanachaiyanont and Kuptniratsaikul[73] employed a well-designed methodology with adequate statistical power. However, even that study employed only female participants and the mean PSWT power dosage used was only 3.2 W, which might be too low for a chronic condition such as OA.

Among the recent studies, Cetin and colleagues[70] suggested that CSWT (24 sessions in 8 weeks, 15 minutes per session) when used with isokinetic exercises reduces pain and augments function among women with OA knee. These findings were contradicted by Akyol and colleagues,[74] who stated that the addition of CSWT (12 sessions in four weeks, 20 minutes per session) to an isokinetic exercise programme brought no further significant benefits in terms of pain and functional QoL. Both studies were small and the results only applied to women of menopausal age group. Unlike these CSWT studies, PSWT delivered at a mean power (MP) of 14.5 W (9 sessions in 3 weeks, either 19 minutes or 38 minutes per session) produced significantly better results compared to a control group in the study by Ovanessian and colleagues.[72]

Consistent with the above results, Fukuda and colleagues published two well-designed RCTs[71,75] on the effects of PSWT on pain and function in women suffering from OA knee. Two doses of PSWT delivering either 17 KJ or 33 KJ of total energy (9 sessions in 3 weeks, 19 or 38 minutes per session respectively) were tested against a placebo group and a control group. Both studies suggested that PSWT produced significantly better clinical outcomes over placebo and control. However, there was no significant difference between the effects produced by the two experimental doses.

In another well-designed multi-centre RCT published recently by Atamaz and colleagues,[76] PSWT (15 sessions in three weeks, 20 minutes per session) was reported to have significantly improved the pain outcomes over a placebo resulting in lower consumption of NSAIDs. The study also had TENS and IFT treated groups, both of which produced similar results over the placebo. There were no significant differences between the three treatment modalities. However, it is not known whether these effects were sustained, as there were no follow-up assessments. Interestingly, similar to the Rattanachaiyanont and Kuptniratsaikul[73] study, the mean PSWT power dose employed was only 3.2 W, which might be too low for a chronic condition such as OA.

Among the two most recent studies identified, Boyaci and colleagues[78] compared the effects of CSWT (10 sessions in two weeks, 20 minutes per session) with those of ultrasound and ketoprofen phonophoresis among 101 women (in three groups) with OA knee. It was reported that all three groups improved significantly in terms of self-reported pain and function, with no significant differences between the groups. In the second smaller pilot study by Teslim and colleagues,[77] CSWT (eight sessions in four weeks, 20 minutes per session) was reported to be more effective in improving the knee ROM and pain compared to PSWT (eight sessions in four weeks, 20 minutes per session) among 24 participants with OA knee (two groups of 12 each). There were no follow-up assessments in either study and neither did they feature control or placebo groups.

Although several of the earlier arthritis studies discussed above lacked robust methodological quality and gave conflicting results, many of the more recently published studies have supported the use of SWT (mainly PSWT) in the management of OA knee. Where reported, the dosage parameters and the overall duration of intervention varied greatly among the studies and the rationale for dose selection was not stated. The durations of intervention varied between single sessions to several weeks in most studies, with an average of 3–6 weeks. No CSWT studies have reported their actual doses employed, apart from merely stating the (subjective) thermal levels of treatment.

For OA knee, based on the evidence a mean PSWT power dose at or above 14.5 W, 8–12 sessions over 4–6 weeks, and 15–20 minutes per session may be necessary for the treatment to be beneficial.

Some of the studies considered here were also covered by systematic reviews published previously. The reader is advised to refer to those reviews[22,23,108,109] for additional information.

Insert Table II here

Low back pain

Among the nine studies on chronic LBP, two large multi-group trials by Gibson and colleagues[81] (12 CSWT sessions in four weeks, session duration not reported) and Sweetman and colleagues[83] (six CSWT sessions in two weeks, 20 minutes per session) reported that CSWT has not been particularly beneficial over exercises, traction, osteopathy or placebo-CSWT. Conversely, two other small clinical trials by Davies and colleagues[80] (CSWT dose parameters not reported) and Wagstaff and colleagues[84] (six PSWT sessions in three weeks, 15 minutes per session) recommended that the effects of both pulsed and continuous SWT were significant in relation to pain relief. The latter also suggested that adding an exercise regime to the intervention, or using dissimilar shortwave pulse patterns did not change the outcome.

Among the later studies, Kerem and Yigiter[82] studied 60 subjects (three groups of 20 participants each) and recommended that both CSWT and PSWT (10 sessions of 20 minutes each) effectively reduced LBP although the effects of PSWT were superior. Similarly, three studies published by the same research group (Shakoor and colleagues)[41,79,86] reported that CSWT (18 sessions in 6 weeks, 15 minutes per session) significantly improved the efficacy of management of chronic LBP. In another recent study by Kim and colleagues,[85] CSWT (single session of treatment, duration not reported) was found to significantly complement manual therapy (nerve mobilisation) in a group of 11 patients with LBP, compared to a similar group treated by manual therapy alone.

The cohort of studies examining the effects of SWT on LBP was much smaller when compared to that of OA knee. The majority of studies employed CSWT and generally favoured its use for the management of LBP. The overall methodological quality of the studies remained low. Grouping issues, lack of follow-up assessments and poor baseline equivalence between the study groups were apparent. Similar to the studies on several other conditions discussed here, the dosage parameters were not fully reported and they remained varied where reported. The rationale for dose selection was not stated, which combined with the lack of dose specific information made it impossible to draw any dose related conclusions. The duration of intervention ranged between single sessions to six weeks in most studies, with an average duration of 3–5 weeks.

Pelvic pain

Studies on pelvic conditions were published as early as 1938, when Waters[92] reported positive responses to CSWT (up to 36 sessions delivered) from 120 gynaecological patients. Subsequently, Burgess[89] reported a study of 50 cases of pelvic sepsis treated by CSWT (12–16 sessions in 4–6 weeks, 30 minutes per session) to obtain intra-vaginal hyperthermia. Patients with gross chronic inflammation appeared to respond satisfactorily to the RF treatment. Later studies included a 71-patient case series of gynaecology patients by Punnonen and colleagues[91] (10–15 PSWT sessions on alternate days) and two small case studies by Balogun and Okonofua[88] (9 CSWT sessions in 3–4 weeks, 25–60 minutes per session) and Lamina and Hanif[90] (15 CSWT sessions in 30 days, 30 minutes per session). All these studies suggested that SWT may be an effective treatment modality for pelvic pain arising from gynaecological conditions.

Only one among the six identified studies in this category was an RCT,[87] where Lamina and colleagues examined 32 subjects (in three groups) suffering from pelvic inflammatory disease and suggested that CSWT (15 sessions in 30 days, 20 minutes per session) showed significant benefit over analgesics and a placebo in reducing pain. This study was low in statistical power and lacked follow-up assessment.

On the whole, with only one RCT identified there is insufficient robust evidence to support the use of SWT for managing chronic pelvic pain secondary to gynaecological disorders.

Neck pain

Three studies (well-designed RCTs) were identified, which studied the effects of PSWT on chronic neck pain. Among them, two studies were based on the same data.[93,95] In the first of the three studies, Foley-Nolan and colleagues[94] demonstrated that PSWT therapy gave better outcomes of pain and neck ROM compared to a placebo. The active group participants wore a PSWT generating soft cervical collar eight hours daily for six weeks. This was a small study with 20 participants (divided in two groups), and without any long-term follow-up assessments.

In a more recent and much larger pragmatic RCT, Dziedzic and colleagues[93] studied 350 patients in three groups (manual therapy, PSWT and control) over 32 weeks (8 PSWT sessions in 6 weeks, 15–20 minutes per session). The study suggested that the addition of either manual therapy or PSWT to 'advice and exercise' did not improve the outcomes. However, being a pragmatic trial, a potential drawback of this study was that it involved 55 different therapists to deliver the intervention, potentially giving rise to reliability issues. Also, the treatment dosage was not fixed across the population, the decision being left to the treating clinician. In a later publication, Lewis and colleagues[95] evaluated the economic outcomes of this study and concluded that the cost-effective intervention was likely to be advice and exercise or manual therapy depending on the economic perspective and preferred outcome, but not PSWT.

Similar to the conditions on pelvic pain, there is insufficient evidence for the use of SWT in the management of chronic neck pain. Although the reported studies were of good methodological quality, no further studies have been identified.

Other conditions with pain and inflammation

Two recent studies were identified on the use of portable PSWT devices in the management of plantar fasciitis.[96,97] Brook and colleagues[96] studied 70 patients placed in two groups (42 active, 28 placebo) and demonstrated a significant reduction of morning pain in the actively-treated group who wore a PSWT device during the night for seven days. However, the study lacked sufficient statistical power and did not perform any follow-up assessments. Similar results were also achieved by Michel in a brief case report with six participants.[97]

Apart from plantar fasciitis, two studies were also identified on the use of SWT in chronic shoulder pain. In a case study published by Ginsberg,[99] PSWT (10 minutes to the shoulder and 10 minutes to the liver) was shown to produce 'impressive clinical results' in the opinion of the author. The study involved 94 patients suffering from shoulder bursitis with calcification. In the second study, which was a more recent clinical trial,[98] 40 cases of shoulder adhesive capsulitis improved significantly with CSWT (10 sessions in 2 weeks, 20 minutes per session), although it was found to be less effective compared to manual therapy (delivered according to the 'Cyriax approach').

In two recently published studies,[39,107] both CSWT and PSWT (15 sessions in 3 weeks, 20 minutes per session) were reported to be effective in the management of mild and moderate carpal tunnel syndrome (CTS) compared to a placebo. Significant improvements were gained in pain, hand function and the electrophysiological measurements. In addition, CSWT was reported to be more effective in reducing symptom severity than either PSWT or placebo.

Among other less reported conditions, Gray and colleagues[100] published a clinical trial on 176 patients with TMJ pain, comparing four active interventions (CSWT, PSWT, laser and ultrasound; 12 sessions in 4 weeks). The CSWT was applied for 10 minutes per session and PSWT 20 minutes per session. All groups reported significant improvement, but without any significant difference between the groups. Myofascial pain (TMJ-related) was shown to improve markedly by CSWT in another trial with 120 patients[102] (three groups: drug therapy, CSWT and ultrasound; 14 sessions of CSWT in 2 weeks, 20 minutes per session). Nonetheless, the effects of ultrasound therapy were superior to that of CSWT. In another brief study[101] on the management of trigger point pain, a single session of CSWT (20 minutes) was found to be more effective than a similar single session treatment with moist heat for reducing tenderness. The result, however, was not statistically significant.

In case studies, SWT was found to be effective in the management of pain associated with Herpes Zoster[103] (daily CSWT sessions of 20 minutes each), heel neuroma[104] (6–12 PSWT sessions in 3–4 weeks, 10–15 minutes per session), and avascular necrosis of the femoral head[105] (PSWT for varying durations). No statistical reporting was done by any of these case studies.

Overall, there is insufficient robust evidence to support the use of SWT in the management of any of the conditions discussed in this section.

Insert Table III here

STUDIES ON TISSUE HEALING

Out of the 16 studies identified in this category, 14 studies (88%) investigated the effects of RF on chronic wounds or chronic ulcers,[110-123] and two on bone healing.[40,124] As identified, all studies employed devices delivering RF energy in pulsed mode at the base shortwave frequency of 27.12 MHz (PSWT). Nine of these studies were case studies,[115-123] one was a cohort study[110] and a further four were clinical trials.[111-114] The case studies reported the effectiveness of PSWT treatment of diabetic foot ulcers,[115,119,123] chronic pressure ulcers,[116,122] chronic lower extremity wounds,[117,120] and venous/microvascular stasis ulcers.[118,121]

In a cohort of 22 patients with pressure ulcers, Itoh and colleagues[110] achieved faster healing when treated by PSWT (30 minutes twice daily) in addition to conventional treatment. Stage II ulcers, which remained unhealed after 3–12 weeks healed completely in 2.33 weeks on average and stage III ulcers unhealed after 8–168 weeks healed completely in 8.85 weeks on average. There was no control group in this study and any statistical analysis of the data was not reported.

Among the clinical trials, Comorosan and colleagues[111] treated 30 elderly patients with pressure ulcers in three separate groups, one of which received PSWT (30 minutes twice daily locally, 20 minutes once daily to the liver). The PSWT group showed much faster improvement (Stage II ulcers healed in 3.28 weeks and Stage III ulcers healed in 4.87 weeks on average) compared to the placebo and control groups that showed poor or no improvement. This trial had numerous methodological limitations including a low sample and absence of validated outcome measures and statistical analysis.

In contrast, Salzberg and colleagues[112] and Kloth and colleagues[114] employed improved methods in their studies although the latter had a fairly small sample. In the first study, a 12-

week PSWT treatment programme was found to significantly accelerate wound healing in spinal cord injured patients with stage II and stage III pressure ulcers.[112] In the second study, four weeks of PSWT (20 sessions, 30 minutes per session) achieved significantly higher (64±15%) healing rate compared to a placebo (-8±24%).[114]

In another small trial, 20 non-ambulatory male patients were treated for four weeks with four different PSWT pulse and field protocols (20 sessions, 20 minutes per session) in a well-controlled double-blinded RCT by Seaborne and colleagues.[113] The study had four groups, each acting as its own control. All groups improved significantly, but no significant difference existed between the groups. The study, however, was low on statistical power.

Among the other studies, Sharp[124] and Comorosan and colleagues[40] reported accelerated bone repair with externally applied PSWT in 16 cases of non-union of fractures and 45 patients with post-traumatic algoneurodystrophies respectively.

While the need for further quality research was evident, the existing studies indicated the potential usefulness of PSWT in facilitating the healing of pressure ulcers. The number of well-designed and adequately controlled studies on tissue healing was fairly low. The majority of studies did not report dosage parameters or the rationale for dose selection. Also, the durations of intervention varied greatly, making it difficult to draw any commonalities between the studies.

Insert Table IV here

STUDIES ON OTHER APPLICATIONS

While the majority of research centred on RF-based therapy for the reduction of pain and inflammation, and several others on tissue healing, a limited number of studies investigated conditions such as post-traumatic/post-surgical stiffness and ROM,[125-129] and vascular disorders.[130,131]

Results of some preliminary investigations on the therapeutic effect of PSWT on ‘intermittent claudication’ were published by Hedenius and colleagues in 1966.[130] In a multi-group study, 18 patients treated with PSWT (372 individual sessions in 62 weeks, 20 minutes per session) showed significantly improved skin temperature and walking tolerance over those who did not receive PSWT. Fair improvement in walking tolerance was also reported by Santoro and colleagues[131] in a small cohort study of 10 participants suffering from peripheral vascular disease (PVD), when treated by CSWT (20 sessions in 4 weeks, 30 minutes per session).

Five case studies[125-129] published by Draper and colleagues demonstrated the clinical effectiveness of PSWT for improving ankle joint ROM[126] (8–13 sessions in 5 weeks, 20 minutes per session), elbow joint ROM[125,129] (4–9 sessions in 2–3 weeks, 20 minutes per session) and symptoms of necrotising fasciitis[128] (12–15 sessions in 6 weeks, 20 minutes per session to each body segment treated); and CSWT (daily sessions for 2 weeks, 20 minutes per session) for improving post-operative ROM in the knee joint.[127] The RF treatment was combined with manual therapy and/or joint mobilisations in all cases. It is suggested that PSWT at thermal doses can be applied safely over areas with metal implants, if delivered with proper technique and caution.[125]

High dose treatments using 38–48 W of energy were employed in all these case studies with the duration of intervention lasting 2–6 weeks. The dose selection was aimed at delivering heat to the tissues thereby raising the tissue temperature by up to 4^{o}C. Nonetheless, proper clinical trials with adequate control, sufficient sample and blinded methods need to be carried out before any conclusions can be drawn.

Insert Table V here

CONCLUSIONS

Evidence favouring and against RF-based EPAs (between 30 kHz–30 MHz) as a treatment modality for chronic therapy-related clinical conditions is available. The majority of the identified studies (91%) were SWT-based, and done on conditions giving rise to pain and inflammation, mainly OA knee and chronic LBP.

Although the review did not employ a cut-off score (Downs and Black) for the methodological quality, the conclusions drawn here are based primarily on the results reported by well-designed studies and the overall weightage of the available evidence. The authors could not determine a clear association between the quality scores achieved by the studies and their reported clinical outcome. While some studies that scored highly (>20) on the Downs and Black scale reported RF to be beneficial, some others reported them to be not beneficial. The same is true also for studies that scored low (<20) on the scale.

Many of the studies published in the earlier decades gave conflicting results on the efficacy of SWT for the management of OA. However, several well-designed and recently published studies have supported the use of SWT in the treatment of OA; mainly in its pulsed form (PSWT). Hence, on the whole there is moderate evidence to support the use of PSWT in OA knee. Apart from OA knee, some evidence also exists favouring the use of CSWT to treat chronic LBP. Sufficient robust evidence does not exist for any other chronic conditions giving rise to pain and inflammation.

For OA knee, based on the available evidence the authors recommend that a mean PSWT power dose at or above 14.5 W, 8–12 sessions over 4–6 weeks, and 15–20 minutes per session may be necessary for the treatment to be beneficial. No recommendations on CSWT dosing can be given for the treatment of LBP based on the available evidence, as the doses were not objectively reported adequately.

Some evidence also exists favouring the use of PSWT to promote the healing of chronic wounds, although the majority of studies identified in this category were case studies. While the need for more quality research was evident, the existing studies indicated the usefulness of PSWT in facilitating the healing of pressure ulcers. Although low in number, all reported clinical trials in this category were reasonably well-designed and favoured the use of PSWT for treating pressure ulcers. However, similar to LBP no recommendations on dosing can be given since the dosage parameters were rarely reported and the durations of intervention varied greatly among the studies.

Since the bulk of the literature centred on applications pertaining to the reduction of pain and inflammation and several others to tissue healing, only a limited number of studies investigated the effects of RF-based therapy on other conditions such as tissue extensibility and ROM. All the identified studies in this area were case studies, and all of them indicated that PSWT may be potentially beneficial for improving ROM in the management of conditions such as post-traumatic stiffness. Nonetheless, proper clinical trials with adequate control, sufficient sample and blinded methods need to be carried out before any recommendations can be made.

Only a limited number of clinical studies have been published in the non-shortwave RF frequency range on chronic conditions. Purely on the basis of the results reported, 448 kHz RF might be beneficial in delivering useful therapeutic effects. However, the paucity of clinical studies and their poor methodological quality suggest there is a need for more research in this area before such therapy can be recommended.

The evidence reported in this review may only be considered against the overall quality of the studies, which was generally lacking. This is somewhat similar to the findings of part I[19] of this review. Lack of robustness and integrity in the methodological designs and poor overall reporting (including the reporting of dosage parameters) made the assessment of results problematic for most studies. Where doses were reported, the rationale for selection was unclear. Many trials also had flaws in their study grouping and did not demonstrate sufficient statistical equivalence between the groups at baseline, where comparisons were made between groups. Several studies either did not have adequate statistical power or failed to report any information relating to statistical power. Furthermore, participant drop-outs were sometimes high, but were not accounted for in the final analysis (no intention-to-treat analysis) as would be expected in a more recent publication. The lack of consistency in reporting and poor methodological quality was particularly evident in the earlier studies. Although both criteria were increasingly met in the more recent studies, proper reporting of the dosage parameters continued to be an issue.

Despite the fact that RF-based EPAs have been used in therapy practice for almost a century, research in this area remains limited. Both the number of studies published on their effects on chronic conditions, and the types of conditions researched are limited. This warrants substantially more research in this area. Nonetheless, the overall numbers are greater than that was identified on the acute conditions in part I.[19] A lack of research emphasis is particularly evident on the non-shortwave RF band, where only a very small number of studies were identified. This warrants particular emphasis in this area especially since EPAs delivering non-shortwave RF are already in clinical use and that the studies published so far have reported encouraging results.

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Figure 1: Flow of studies through the review.

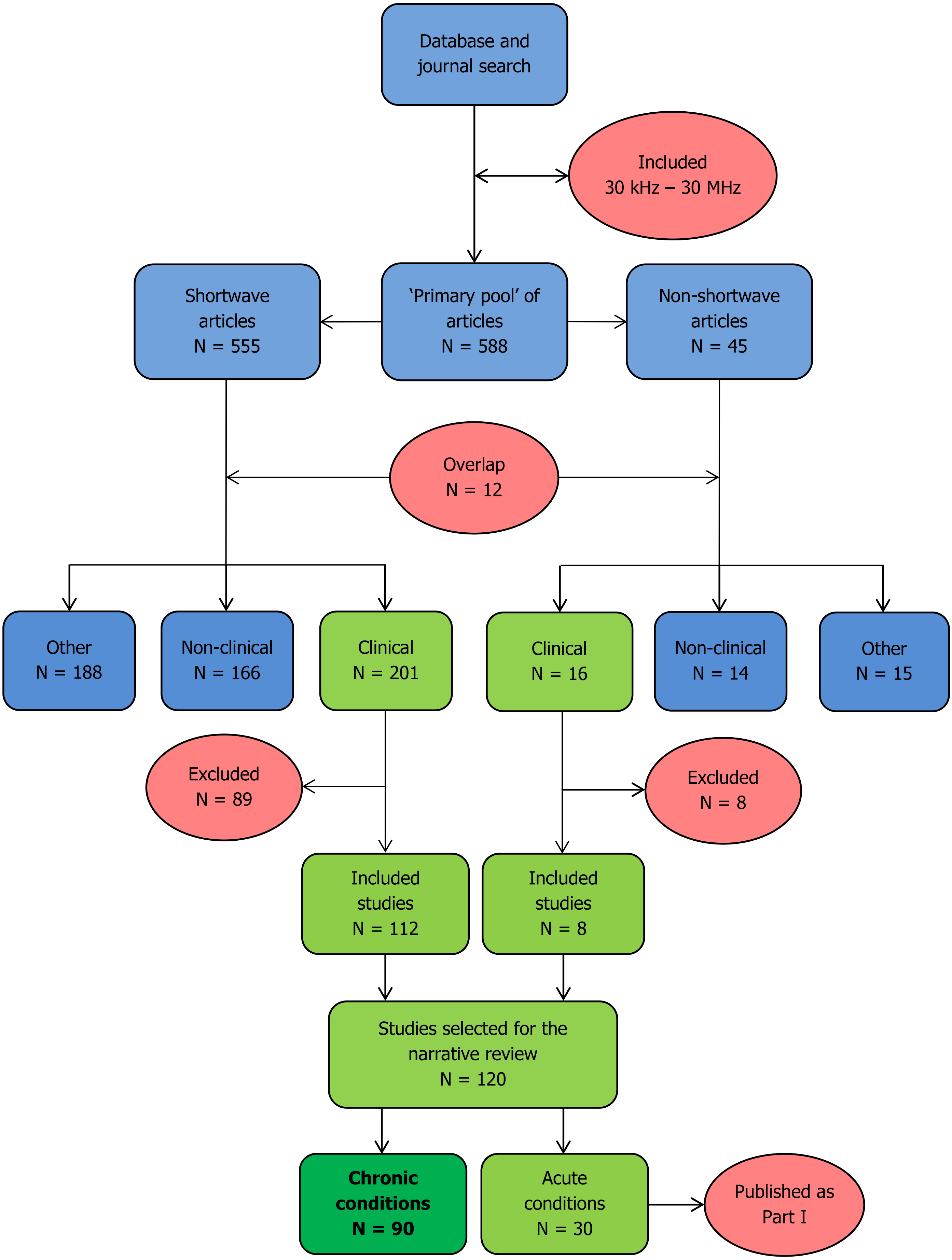

Figure 2: Clinical areas and study types.

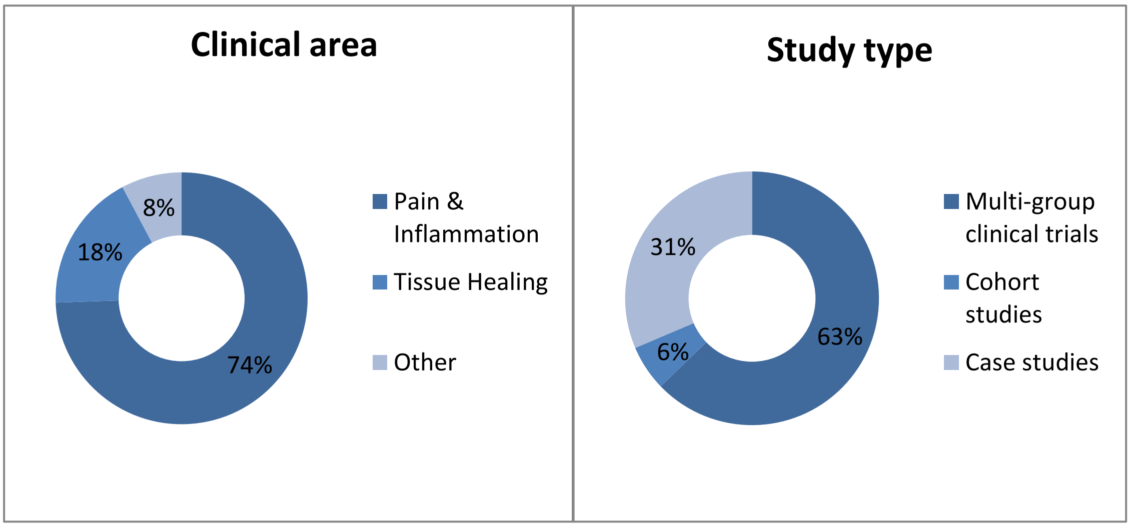

Table 1: Studies in the non-shortwave frequency range.

Study	Diagnostic category	Outcomes measured	Study type, sample size and number of groups	Type of RF used	RF dose parameters					Number and duration of sessions	Did RF improve the outcomes significantly?	Downs and Black score (out of 28)
					CRF Power (W)	PRF						
						PP (W)	PD (µs)	PRR (pps)	MP (W)			
Al-Badawi et al.[42]	TMJ pain and dysfunction	Pain and TMJ function	RCT; 40 subjects; 2 groups	PRF; 0.25 MHz		NR	NR	600	NR	6 (over 2 weeks); 90 sec/session	Yes	21
Costantino et al.[43]	Tendinopathy	Pain	Non-RCT; 45 subjects; 3 groups	CRF; 0.48 MHz	NR					12 (NR); 30 min/session	Yes	15
Alcidi et al.[44]	OA knee	Pain and function	RCT; 42 subjects; 2 groups	CRF; 0.5 MHz	≤30					5 (over 5 days); 20 min/session	Yes	17
Taverner et al.[45]	OA knee	Pain	RCT; 52 subjects; 2 groups	PRF; 0.48 MHz		NR	20,000	2	NR	Single session; 10 min/session	Yes	20
Nelson et al.[46]	OA knee	Pain	RCT; 34 subjects; 2 groups	PRF; 6.8 MHz		NR	7000	1	NR	≤89 (over 42 days); 15 min/session	Yes	25
Takahashi et al.[47]	OA knee	Pain and function	Cohort; 11 subjects (12 knees); 1 group	PRF; 8 MHz		NR	NR	NR	200	3 (over 3 weeks); 20 min/session	Yes	16
Balogh[48]	Back pain, Multiple injuries	Pain	Case series; 4 subjects	PRF; 0.5 MHz		NR	20,000	2	NR	Numerous; 10 min/session	Yes	9
Taverner et al.[49]	Shoulder pain	Pain	Retrospective audit; 13 subjects (15 shoulders)	PRF; 0.48 MHz		NR	20,000/ 10,000	2/5	NR	Single session; ≤12 min/session	Yes	9

RCT – Randomised Controlled Trial; OA – Osteoarthritis; TMJ – Temporo-mandibular Joint; RF – Radiofrequency; CRF – Continuous Radiofrequency; PRF – Pulsed Radiofrequency; PP – Peak power; PD – Pulse duration; PRR – Pulse repetition rate; MP – Mean power; NR – Not reported; NA – Not available to the authors; W – Watts; µs – Microseconds; pps – Pulses per second; min – Minutes.

Table 2: Studies on pain and inflammation (arthritis).

Study	Diagnostic category	Outcomes measured	Study type, sample size and number of groups	Type of RF used	RF dose parameters					Number and duration of sessions	Did RF improve the outcomes significantly?	Downs and Black score (out of 28)
					CSWT Power (W)	PSWT						
						PP (W)	PD (μs)	PRR (pps)	MP (W)			
Hamilton et al.[51]	RA hands/ knee; OA knee	ROM and function	Crossover RCT; 131 subjects; 4 groups	CSWT	NR					12 (over 4 weeks); 20 min/session	Yes	16
Harris[52]	RA knee	Local circulation (Radio-Sodium clearance)	Experimental; 16 subjects; 2 groups	CSWT	NR					Single session; 20 min/session	Yes/No	8
Wright[53]	OA knee	Pain, tenderness, walking time and analgesic intake	RCT; 38 subjects (59 joints); 3 groups	CSWT	NR					18 (over 6 weeks); 20 min/session	Yes	13
Valtonen and Alaranta[54]	OA knee/hip	Level of improvement	RCT; 160 subjects; 2 groups	CSWT	NR					13–14 (over 5 weeks); 15–20 min/session	Yes	10
Clarke et al.[55]	OA knee	Pain, stiffness, tenderness and swelling	RCT; 48 subjects; 3 groups	CSWT	NR					9 (over 3 weeks); NR	No	18
Bansil and Joshi[56]	OA knee	Pain and function	RCT; 60 subjects (100 joints); 2 groups	CSWT	NR					NR; 20 min/session	No	12
Chamberlain et al.[57]	OA knee	Pain, function, ROM, maximum weight lift and endurance	RCT; 42 subjects; 2 groups	CSWT	NR					12 (over 4 weeks; NR	Yes	17
Quirk et al.[58]	OA knee	Pain, function, ROM, exercise endurance and knee girth	RCT; 38 subjects; 3 groups	CSWT	NR					12 (over 4 weeks); 20 min/session	Yes	17
Svarcova et al.[59]	OA knee/hip	Pain and 'therapeutic effect'	Non-RCT; 180 subjects; 3 groups	PSWT		700	NR	NR	NR	10 (over 3 weeks); 4 min/session	Yes	15

Jan and Lai[60]	OA knee	Function and muscle torque	RCT; 61 subjects (94 joints); 4 groups	CSWT	NR					24–69 (over 6–18 weeks); 20 min/session	Yes	15
Sewell et al.[61] (Abstract only)	RA knee	Pain, swelling and function	RCT; 81 subjects; 2 groups	PSWT		NR	65	200 (1:3)	NR	8 (over 4 weeks); 10 min/session	No	NA
Klaber Moffett et al.[62]	OA knee/hip	Pain and function	RCT; 92 subjects; 3 groups	PSWT		NR	NR	82	23	9 (over 3 weeks); 15 min/session	No	19
Tuzun et al.[63]	OA knee	Pain, function, ROM and muscle strength	RCT; 40 subjects; 2 groups	PSWT		1000/ 600	400	20/ 110	8/ 26.4	10 (over 2 weeks); 15 min/session	Yes	15
Callaghan et al.[64]	OA knee	Pain, timed walk, ROM and muscle strength	RCT; 27 subjects; 3 groups	PSWT		125	200/ 400	400	10/20	6 (over 2 weeks); 20 min/session	No	22
Laufer et al.[65]	OA knee	Pain, function, timed walk and stair use	Non-RCT; 103 subjects; 3 groups	PSWT		200	82/ 300	110/ 300	1.8/ 18	9 (over 3 weeks); 20 min/session	No	19
Jan et al.[66]	OA knee	Pain and synovial sac thickness	Non-RCT; 30 subjects (44 joints); 3 groups	CSWT	NR					30 (over ≤8 weeks); 20 min/session	Yes	17
Cantarini et al.[67]	OA knee	Pain, function, QoL and analgesic intake	RCT; 74 subjects; 3 groups	CSWT	NR					10 (over 3 weeks); 15 min/session	No	20
Manhal et al.[68]	OA knee	Pain, deformity and muscle wasting	RCT; 24 subjects; 2 groups	CSWT	NR					6–10 (over 2 weeks); ≤20 min/session	Yes	8
Silva et al.[69]	OA knee	Pain, function, ROM and muscle strength	RCT; 25 subjects; 3 groups	CSWT	NR					10 (over 5 weeks); 20 min/session	No	16
Cetin et al.[70]	OA knee	Pain, function and muscle strength	RCT; 100 subjects (200 joints); 5 groups	CSWT	NR					24 (over 8 weeks); 15 min/session	Yes	20
Fukuda et al.[71]	OA knee	Pain, function and ROM	RCT; 84 subjects; 4 groups	PSWT		250	400	145	14.5	9 (over 3 weeks); 19–38 min/session	Yes	21
Ovanessian et al.[72]	OA knee	Pain, function and ROM	RCT; 42 subjects; 3 groups	PSWT		250	400	145	14.5	9 (over 3 weeks); 19–38 min/session	Yes	17

Rattanachaiyanon-t and Kuptniratsaikul[73]	OA knee	Pain, function, timed walk and stair use	RCT; 113 subjects; 2 groups	PSWT		300	NR	NR	3.2	9 (over 3 weeks); 20 min/session	No	24
Akyol et al.[74]	OA knee	Pain, function, QoL and timed walk	RCT; 40 subjects (80 joints); 2 groups	CSWT	NR					12 (over 4 weeks); 20 min/session	No	21
Fukuda et al.[75]	OA knee	Pain, function and QoL	RCT; 121 subjects; 4 groups	PSWT		250	400	145	14.5	9 (over 3 weeks); 19–38 min/session	Yes	25
Atamaz et al.[76]	OA knee	Pain, function and ROM	RCT; 203 subjects; 6 groups	PSWT		300	NR	NR	3.2	15 (over 3 weeks); 20 min/session	Yes	26
Teslim et al.[77]	OA knee	Pain and ROM	RCT; 24 subjects; 2 groups	CSWT/ PSWT	NR	NR	NR	NR	NR	8 (over 4 weeks); 20 min/session	Yes	17
Boyaci et al.[78]	OA knee	Pain, function and timed walk	RCT; 101 subjects (202 joints); 3 groups	CSWT	NR					10 (over 2 weeks); 20 min/session	Yes	23

RCT – Randomised Controlled Trial; OA – Osteoarthritis; RA – Rheumatoid Arthritis; ROM – Range of Movement; QoL – Quality of Life; RF – Radiofrequency; CSWT – Continuous Shortwave Therapy; PSWT – Pulsed Shortwave Therapy; PP – Peak power; PD – Pulse duration; PRR – Pulse repetition rate; MP – Mean power; NR – Not reported; NA – Not available to the authors; W – Watts; µs – Microseconds; pps – Pulses per second; min – Minutes.

Table 3: Studies on pain and inflammation (All others excluding arthritis).

Study	Diagnostic category	Outcomes measured	Study type, sample size and number of groups	Type of RF used	RF dose parameters					Number and duration of sessions	Did RF improve the outcomes significantly?	Downs and Black score (out of 28)
					CSWT Power (W)	PSWT						
						PP (W)	PD (µs)	PRR (pps)	MP (W)			
Incebiyik et al.[39]	Carpal tunnel syndrome	Pain and function	RCT; 31 subjects (58 joints); 2 groups	CSWT	NA					15 (over 3 weeks); NA	Yes	NA
Shakoor et al.[41]	LBP	Pain	RCT; 102 subjects; 2 groups	CSWT	NA					NA	Yes	NA
Ahmed et al.[79]	LBP	Pain, tenderness and analgesic intake	RCT; 97 subjects; 2 groups	CSWT	NR					18 (over 6 weeks); 15 min/session	Yes	17
Davies et al.[80]	LBP	Pain and flexion ROM	RCT; 43 subjects; 3 groups	CSWT	NR					NR (over 4 weeks); NR	Yes	17
Gibson et al.[81]	LBP	Pain and flexion ROM	RCT; 109 subjects; 3 groups	CSWT	NR					12 (over 6 weeks); NR	No	18
Kerem and Yigiter[82]	LBP	Pain, ROM and muscle strength	Non-RCT (?); 60 subjects; 3 groups	CSWT/ PSWT	NR	300/ 600	4000	200/ 46	240/ 110	10 (NR); 20 min/session	Yes	17
Sweetman et al.[83]	LBP	Clinical outcome	RCT; 400 subjects; 4 groups	CSWT	NR					6 (over 2 weeks); 20 min/session	No	20
Wagstaff et al.[84]	LBP	Pain	RCT; 23 subjects; 3 groups	CSWT/ PSWT	NR	300/ 700	400	200/ 82	23.4/ 23.2	6 (over 3 weeks); 15 min/session	Yes	14
Kim et al.[85]	LBP	Pain, function and knee extensor strength	RCT; 22 subjects; 2 groups	CSWT	50					Single session; NR	Yes	17
Shakoor et al.[86]	LBP	Pain and tenderness	Cohort study; 50 subjects; 1 group	CSWT	NR					18 (over 6 weeks); 15 min/session	Yes	14
Lamina et al.[87]	PID	Pain and inflammation	RCT; 32 subjects; 3 groups	CSWT	≈8.27					15 (over 4 weeks); 20 min/session	Yes	19

Balogun and Okonofua[88]	PID	Pain	Case study; 1 subject	CSWT	NR					9 (over 3 weeks); 25–60 min/session	Yes	7
Burgess[89]	Mixed cases of pelvic sepsis	Pain and treatment outcome	Case series; 50 subjects	CSWT	NR					12–16 (over ≤6 weeks); 30 min/session	Yes	4
Lamina and Hanif[90]	PID	Pain	Case series; 3 subjects	CSWT	NR					15 (over 4 weeks); 30 min/session	Yes	9
Punnonen et al.[91]	Mixed gynaecology and obstetrics cases	Pain and treatment outcome	Case series; 71 subjects	PSWT		300	NR	62	NR	10–15 (over 3–4 weeks); 30 min/session	Yes	6
Waters[92]	Mixed gynaecology and obstetrics cases	Pain and treatment outcome	Case series; 120 subjects	CSWT	NR					≤36 (over ≤4 weeks); ≈15 min/session	Yes	6
Dziedzic et al.[93]	Non-specific neck pain	Pain and function	RCT; 350 subjects; 3 groups	PSWT		NR	NR	NR	≈7.4	8 (over 6 weeks); 20 min/session	Yes	22
Foley-Nolan et al.[94]	Neck pain	Pain and ROM	RCT; 20 subjects; 2 groups	PSWT		NR	60	450	0.001 $5/cm^2$	48 (over 6 weeks); 8 hours/session	Yes	19
Lewis et al.[95]	Non-specific neck pain	Cost effectiveness	RCT; 350 subjects; 3 groups	PSWT		NR	NR	NR	≈7.4	8 (over 6 weeks); 20 min/session	Yes, but not cost effective	22
Brook et al.[96]	Plantar fasciitis	Morning pain	RCT; 70 subjects; 2 groups	PSWT		98×10^{-4}	100	1000	98×10^{-5}	7 (over 1 week); NR	Yes	24
Michel[97]	Plantar fasciitis	Pain and tenderness	Case series; 6 subjects	PSWT		NR	NR	NR	NR	≤215 (over 13–15 weeks); 30 min/session	Yes	7
Guler-Uysal and Kozanoglu[98]	Adhesive capsulitis shoulder	Recovery rate, pain and ROM	RCT; 40 subjects; 2 groups	CSWT	NR					10 (over 2 weeks); 20 min/session	Yes	20
Ginsberg[99]	Calcified bursitis shoulder	Calcium absorption rate	Case series; 94 subjects	PSWT		1025/ NR	65	600/ 400	40/ NR	NR; 20 min/session	Yes	7
Gray et al.[100]	TMJ pain and dysfunction	Pain, 'clinical signs' and mandibular ROM	RCT; 176 subjects; 5 groups	CSWT/ PSWT	NR	NR	60	100	NR	12 (over 4 weeks); 10/20 min/session	Yes	15
McCray and Patton[101]	Trigger points	Pain	RCT; 19 subjects; 2 groups	PSWT		NR	NR	NR	NR	Single session; 20 min/session	Yes	14

Talaat et al.[102]	Myofascial pain syndrome	Pain, tenderness, TMJ noises and ROM	RCT; 120 subjects; 3 groups	CSWT		NR	NR	NR	NR	14 (over 2 weeks); 20 min/session	Yes	10
Allberry et al.[103]	Herpes zoster pain	Pain	Case series; 97 subjects	CSWT		NR	NR	NR	NR	NR; 20 min/session	Yes	7
Shandles et al.[104]	Heel neuroma	Pain	Case series; 317 subjects	PSWT		975/ NR	65	600/ 400	38/ NR	≈6–9 (over ≈3 weeks); 20–30 min/session	Yes	4
Oke et al.[105]	AVN femoral head	Pain and ROM	Case series; 4 subjects	PSWT		200	400	400	32	≈72 (over 4 months); 20 min/session	Yes	7
Taylor[106]	Abscess, neuralgia, neuritis	Pain	Case series; 3 subjects	CSWT		NR	NR	NR	NR	NR; NR	Yes	4
Boyaci et al.[107]	Carpal tunnel syndrome	Pain, function and nerve conduction	RCT; 30 subjects (55 joints); 3 groups	CSWT/ PSWT	NR	NR	400	82	NR	15 (over 3 weeks); 20 min/session	Yes	24

RCT – Randomised Controlled Trial; LBP – Low Back Pain; PID – Pelvic Inflammatory Disease; AVN – Avascular Necrosis; TMJ – Temporo-mandibular Joint; ROM – Range of Movement; RF – Radiofrequency; CSWT – Continuous Shortwave Therapy; PSWT – Pulsed Shortwave Therapy; PP – Peak power; PD – Pulse duration; PRR – Pulse repetition rate; MP – Mean power; NR – Not reported; NA – Not available to the authors; W – Watts; µs – Microseconds; pps – Pulses per second; min – Minutes.

Table 4: Studies on tissue healing.

Study	Diagnostic category	Outcomes measured	Study type, sample size and number of groups	Type of RF used	RF dose parameters					Number and duration of sessions	Did RF improve the outcomes significantly?	Downs and Black score (out of 28)
					CSWT Power (W)	PSWT						
						PP (W)	PD (µs)	PRR (pps)	MP (W)			
Comorosan et al.[40]	Post-traumatic Algoneurodyst-rophies	NA	Cohort; 45 subjects	PSWT		NA	NA	NA	NA	NA; NA	Yes	NA
Itoh et al.[110]	Pressure ulcers	Ulcer size and healing rate	Cohort; 20 subjects (22 ulcers); 1 group	PSWT		975	65	600	38	≤308 (over ≤22 weeks); 30 min/session	Yes	13
Comorosan et al.[111]	Pressure ulcers	Ulcer size and healing rate	RCT; 30 subjects; 3 groups	PSWT		975/ NR	65	600/ 400	38/ NR	≤112 (over ≤8 weeks); 30/20 min/session	Yes	15
Salzberg et al.[112]	Pressure ulcers	Ulcer size and healing rate	RCT; 30 subjects; 2 groups	PSWT		NR	NR	NR	NR	NR (over ≤12 weeks); NR	Yes	20
Seaborne et al.[113]	Pressure ulcers	Ulcer size	RCT; 20 subjects; 4 groups	PSWT		700	400	110/ 20	30.8/ 5.6	20 (over 2 weeks); 20 min/session	Yes	23
Kloth et al.[114]	Pressure ulcers	Ulcer size	RCT; 10 subjects; 2 groups	PSWT		NR	65	600	NR	20 (over 4 weeks); 30 min/session	yes	20
Larsen and Overstreet[115]	Diabetic foot ulcers	Ulcer size and healing rate	Case series; 2 subjects	PSWT		NR	42	1000	NR	NR (over 16–17 weeks); NR	Yes	9
Porreca and Giordano-Jablon[116]	Pressure ulcers	Ulcer size	Case study; 1 subject	PSWT		NR	42	1000	NR	60–420 (1–7 months); 30 min/session	Yes	7
Frykberg et al.[117]	Pressure, diabetic and venous ulcers	Ulcer size	Case series; 4 subjects	PSWT		NR	42	1000	NR	120–240 (over 2–4 months); 30 min/session	Yes	9
Fletcher[118]	Venous ulcer	Pain and ulcer size	Case study; 1 subject	PSWT		NR	42	1000	NR	≈150 (over 6 weeks); 30 min/session	Yes	7

Frykberg et al.[119]	Diabetic foot ulcers	Ulcer size	Case study; 1 subject	PSWT		NR	42	1000	NR	≈200 (over 14 weeks); 30 min/session	Yes	7
Frykberg et al.[120]	Pressure, diabetic and venous ulcers	Ulcer size	Cohort (retrospective audit); 113 subjects; 1 group	PSWT		NR	42	1000	NR	56 (over 4 weeks); 30 min/session	Yes	14
Maier[121]	Cutaneous ulcers of the ankle	Ulcer size	Case series; 2 subjects	PSWT		NR	42	1000	NR	42–392 (over 3–28 weeks); 30 min/session	Yes	8
Conner-Kerr and Isenberg[122]	Pressure ulcers	Ulcer size and healing rate	Cohort (retrospective audit); 89 subjects; 1 group	PSWT		NR	42	1000	NR	56 (over 4 weeks); 30 min/session	Yes	14
Rawe and Vlahovic[123]	Diabetic foot ulcers and venous ulcer	Ulcer size and pain	Case series; 4 subjects	PSWT		NR	NR	1000	NR	21–42 (over 3–6 weeks); 6–8 hours/session	Yes	9
Sharp and Lightwood[124]	Fracture non/delayed union	Healing rate	Case series; 16 subjects	PSWT		NR	NR	NR	NR	NR (over 11–54 weeks); NR	Yes	6

RCT – Randomised Controlled Trial; RF – Radiofrequency; CSWT – Continuous Shortwave Therapy; PSWT – Pulsed Shortwave Therapy; PP – Peak power; PD – Pulse duration; PRR – Pulse repetition rate; MP – Mean power; NR – Not reported; NA – Not available to the authors; W – Watts; µs – Microseconds; pps – Pulses per second; min – Minutes.

Table 5: Studies on other less reported conditions.

Study	Diagnostic category	Outcomes measured	Study type, sample size and number of groups	Type of RF used	RF dose parameters					Number and duration of sessions	Did RF improve the outcomes significantly?	Downs and Black score (out of 28)
					CSWT	PSWT						
					Power (W)	PP (W)	PD (µs)	PRR (pps)	MP (W)			
Draper et al.[125]	Post-traumatic (fracture) stiffness (elbow)	ROM	Case study; 1 subject	PSWT		150	400	800	48	6 (over 2 weeks); 20 min/session	Yes	11
Seiger and Draper[126]	Post-traumatic (fracture) stiffness (ankle)	ROM	Case series; 4 subjects	PSWT		150	400	800	48	8–13 (over 3–5 weeks); 20 min/session	Yes	12
Draper and VanPatten[127]	Post-surgical stiffness (knee)	ROM	Case study; 1 subject	CSWT	35					6 (over 2 weeks); 20 min/session	Yes	11
Johnson and Draper[128]	Fibrosis and adhesions post breast cancer	ROM	Case study; 1 subject	PSWT		150	400	800	48	12–15 (over 6 weeks); 20 min/session	Yes	11
Draper[129]	Post-traumatic/ Post-surgical stiffness (elbow)	ROM	Case series; 6 subjects	PSWT		150	400	800	48	4–6 (over 2 weeks); 20 min/session	Yes	12
Hedenius et al.[130]	Intermittent claudication	Toe skin temperature, walking tolerance, oscillography and calf circumference	Non-RCT; 58 subjects; 5 groups	PSWT		975	65	600	38	372 (over 62 weeks); 20 min/session	Yes	14
Santoro et al.[131]	Arterial peripheral vascular disease	Doppler pressure, Laser Doppler Flowmetry, transcutaneous partial pressure of oxygen and thermistor thermography	Cohort; 10 subjects; 1 group	PSWT		NR	95	7000/ 700	NR	20 (over 4 weeks); 30 (20+10) min/session	Yes	12

RCT – Randomised Controlled Trial; ROM – Range of Movement; RF – Radiofrequency; CSWT – Continuous Shortwave Therapy; PSWT – Pulsed Shortwave Therapy; PP – Peak power; PD – Pulse duration; PRR – Pulse repetition rate; MP – Mean power; NR – Not reported; NA – Not available to the authors; W – Watts; µs – Microseconds; pps – Pulses per second; min – Minutes.