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CONTINUOUS-MODE 448 kHz CAPACITIVE RESISTIVE MONOPOLAR RADIOFREQUENCY INDUCES GREATER DEEP BLOOD FLOW CHANGES COMPARED TO PULSED MODE SHORTWAVE: A CROSSOVER STUDY IN HEALTH ADULTS

KUMARAN B, HERBLAND A, WATSON T. EUR J PHYSIOTHERAPY. DOI: 10.1080/21679169.2017.1316310
Department of Allied Health Professions and Midwifery, School of Health and Social Work, University of Hertfordshire, Hatfield, UK.

INTRODUCTION

Electrophysical agents (EPAs) can reduce pain and inflammation, accelerate tissue healing and improve function (1,2). Several of these benefits relate to thermophysiological responses such as changes to blood flow, muscle tone and tissue compliance induced by tissue hyperthermia (3-6).

The physical nature and metabolic state of tissues can be altered by changes in blood flow and tissue extensibility in patients and in non-clinical situations. In physiotherapy, radiofrequency (RF)-based EPAs are among those that claim to increase blood flow and improve soft tissue compliance, mainly by inducing tissue hyperthermia (9-15). Measures relating to blood flow and tissue compliance closely reflect the body's response when tissues are exposed to heat (16-18).

The RF frequency ranges used in physiotherapy are largely limited to 30 kHz–30 MHz (23–26). Within this range, the main EPA used is shortwave therapy (SWT), which commonly operates at 27.12 MHz, either in continuous (CSWT) or pulsed (PSWT) mode although it is largely limited to PSWT in contemporary practice (25,27). Nonetheless, EPAs employing significantly lower frequency RFs (<1 MHz) have also been reported, such as a capacitive resistive monopolar RF (CRMRF) that employs RF at 448 kHz.

The CRMRF differs from SWT mainly in: the operating frequency and secondly, unlike SWT it cannot be delivered to the tissues through an air gap, needing a coupling medium.

This study aimed to investigate the deep blood flow and tissue extensibility responses to continuous mode CRMRF therapy vs PSWT in asymptomatic adults.

Although CRMRF is a continuous-mode therapy unlike PSWT, comparison of these two EPAs was done on the basis that PSWT is the most relevant comparator to CRMRF in contemporary therapy. Since CRMRF was shown to substantially increase and sustain skin temperature (16), it was hypothesized that similar significant effects may be obtained on deep blood flow and tissue extensibility.

MATERIALS AND METHODS

Crossover study conducted on 17 asymptomatic adults.

Sample and groups. All the participants had normal skin thermal perception and no contra-indications. All attended four experimental conditions: CRMRF high (thermal), CRMRF low (sub/minimally thermal) and CRMRF placebo dose conditions, and a control condition with no intervention. The order of attendance was randomized. Fifteen of them additionally attended a fifth session representing "PSWT high dose" condition to enable a comparison between the two EPAs. Attendance to PSWT condition was not randomized (not truly blinded) although they were only informed that it was another type of RF. The study was approved by the Health and Human Sciences Ethics Committee with Delegated Authority of the University of Hertfordshire.

Apparatus. CRMRF device. The CRMRF at 448 kHz used was an INDIBA® device (Indiba S.A., Barcelona, Spain).

PSWT device. The PSWT at 27.12 MHz used was "a Bosch Ultramed device" (Robert Bosch GmbH, Gottingen, Germany).

Other devices. Blood flow velocity, volume and intensity (2 cm from the skin) were monitored using Doppler ultrasound and tissue extensibility using of sonoelastography. Core temperature was measured with an infra-red tympanic thermometer.

Experimental procedure and data acquisition. Participants were asked to avoid food, beverages and strenuous exercises before the sessions. A minimum gap of 48 h was ensured between sessions. Similar times of the day were chosen for all sessions of a participant. Participants acclimatized for 20 min. Blood flow and sonoelastography measurements were performed pre- and post-intervention.

RF intervention. CRMRF treatment was delivered for 15 min. For CRMRF low, the intensity was maintained at a sub/ minimally-thermal level throughout. For CRMRF placebo, the device output was turned off after the participants reported thermal onset. For the control condition, participants rested on the treatment plinth for 15 min. The nearest available PSWT dose to the mean CRMRF high dose (42.37 W) used in this study was 47 W. Hence, 47 W was delivered for 15 min.

Data analysis. Ultrasound images and sonoelastography were analysed using MATLAB.

All data were analysed using IBM SPSS Statistics. Group data were compared using either two-way repeated measures analysis of variance (ANOVA) or using the non-parametric alternative Friedman's two-way ANOVA by ranks. Statistical significance was set at $p \leq .05$.

RESULTS

All participants completed the treatments. Both types of interventions were well-tolerated, with no adverse events. Mean (SD) treatment doses, room temperature and humidity are reported in Table 1. The study was conducted in thermoneutral conditions.

Blood flow volume. The applied dose influenced the changes in blood flow volume (p=.003). At baseline the groups did not differ significantly, except between the control and placebo groups (p=.009). In the five group analysis, similar result was obtained for the main effect (p<.001). The five groups were not significantly different at baseline (Figure 1)

Within the CRMRF high group, there was a substantial rise in blood flow volume from baseline to post-treatment (p=.001). A significant increase, although less strong was noted also in the CRMRF low group (p=.006). No such changes were noted in the other three groups.

Blood flow intensity. In the four-group analysis, a significant main effect was found at post-treatment (p=.002). Within the CRMRF high group, there was a substantial rise in blood flow intensity from baseline to post-treatment (p=.001). No such changes were noted in the other four groups (Figure 2).

Other results. There were no significant main effects on blood flow velocity and tissue extensibility nor in core temperature, blood pressure or pulse rate under any test condition.

Table 1. Mean (±SD) treatment doses received by the participants in the five experimental groups, and mean (±SD) room temperature and humidity during the experimental sessions.

	CRMRF high	CRMRF low	CRMRF placebo	Control	PSWT
RF dosage in Watts (W)	42.37 (4.64)	18.77 (3.82)	2.79 (1.23)	0	47
Room temperature (°C)	25.12 (1.14)	25.53 (1.11)	2.79 (1.23)	2.79 (1.23)	24.30 (0.56)
Humidity (%)	41.21 (6.38)	41.06 (7.40)	39.68 (6.24)	41.79 (6.50)	32.70 (4.37)

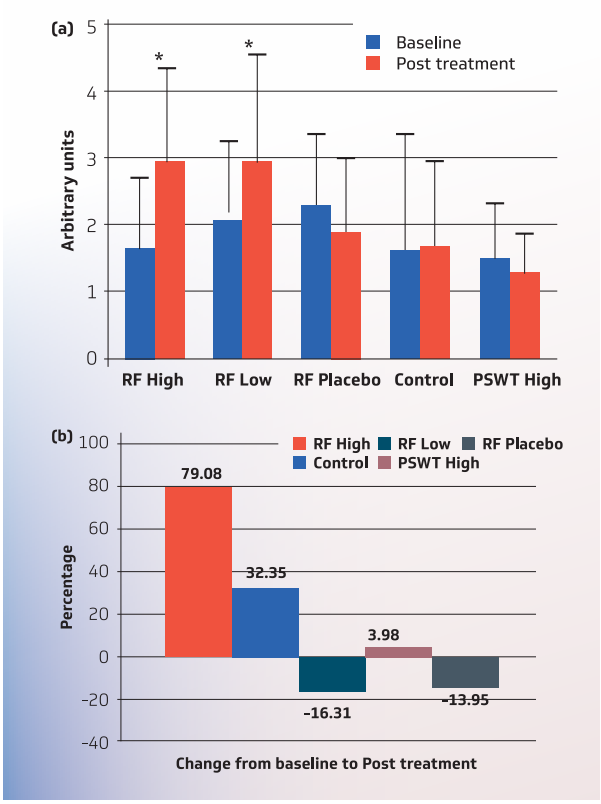

Fig. 1. (a) The mean (±SD) deep blood flow volume responses showing the baseline and post-treatment data from all five groups. The PSWT group results are based on 15 participants, while the other four groups' results are based on 17 participants. Statistically significant differences (at p≤05) when compared to the baseline are indicated by asterisks (*) above the error bars (Friedman's two-way ANOVA). (b) Percentage change of the mean deep blood flow volume from baseline to post-treatment for all five groups. The PSWT group results are based on 15 participants, while the other four groups' results are based on 17 participants.

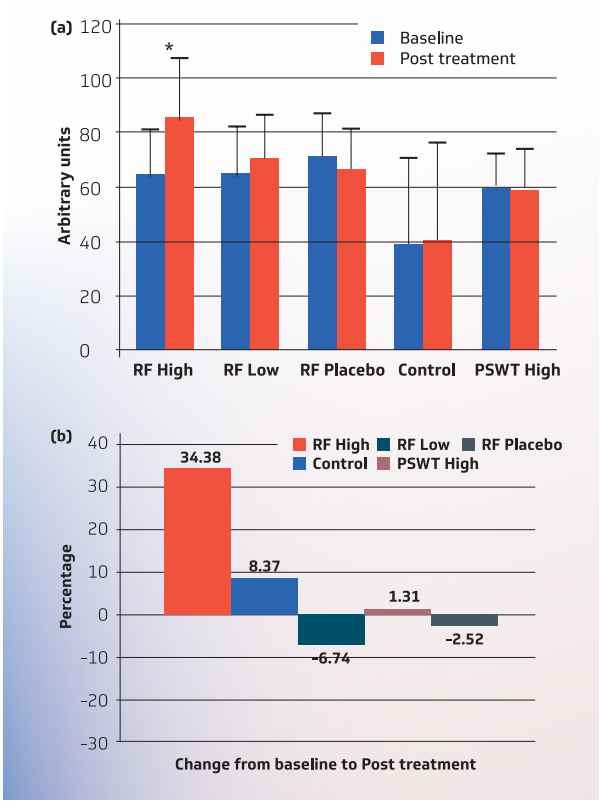

Fig. 2. (a) The mean (±SD) deep blood flow intensity responses showing the baseline and post-treatment data from all five groups. The PSWT group results are based on 15 participants, while the other four groups' results are based on 17 participants. Statistically significant differences (at p≤05) when compared to the baseline are indicated by asterisks (*) above the error bars (Friedman's two-way ANOVA). (b) Percentage change of the mean deep blood flow intensity from baseline to post-treatment for all five groups. The PSWT group results are based on 15 participants, while the other four groups' results are based on 17 participants.

DISCUSSION

There is insufficient evidence on the effects of RF below the shortwave frequency band. Two recent reviews found no clinical studies on acute conditions for frequencies below shortwave (23) and only a limited number on chronic conditions (26).

In the current study in terms of the mode of energy delivery, PSWT may not be directly comparable to CRMRF since the former is pulsed while the latter is continuous. Besides, PSWT is not known to cause extremely high thermophysiological responses. However, the comparisons have been made for the aforementioned reasons.

Past studies have suggested that the differences in blood flow responses secondary to electromagnetic field exposure are mainly due to the differences in their ability to penetrate tissues. RF-based EPAs are proposed to be more penetrative and are anticipated to influence blood flow at various depths (9,12,16) compared to low penetrative infrared radiation that increases cutaneous circulation (34,35).

The significant rise in deep blood flow volume and flow intensity due to the high-dose CRMRF might have been achieved with a potentially modest rise in tissue temperature. This is further vindicated by the rise in blood flow volume even with the low-dose CRMRF where the rise in tissue temperature must have been minimal. This suggests that a substantial rise in tissue temperature may not be required for CRMRF to increase deep blood flow. Thus unlike SWT, CRMRF may be capable of increasing blood flow at depth at substantially lower temperatures. This suggests that CRMRF is potentially capable of inducing a sustained influence on the physiological processes relating to deep blood flow with mechanisms that are either thermal or non-thermal or both.

PSWT may lack any notable non-thermal effect on deep blood flow in absence of significant tissue heating. It appears that a low-dose CRMRF can potentially achieve the same benefits more effectively than PSWT without unduly raising the temperature. Thus the type of applied energy might also be critical beside the temperature change, in deciding the level of tissue response.

There were no significant effects on tissue extensibility, measurements were performed after the blood flow measurements, thus any effect during or immediately after the intervention should have been missed. Besides, participants were healthy adults. People with compromised tissue extensibility, or even asymptomatic with increased tone in their muscles could behave differently.

CONCLUSIONS

A high as well as low dose of CRMRF can significantly enhance blood flow volume at depth, while only the high dose can enhance both the volume and intensity of flow. An equivalent high dose of PSWT failed to show any impact on either parameter. Overall CRMRF induced a significantly more pronounced physiological response out of the two types of RF based EPAs. The deep blood flow velocity, extensibility of tissues, core temperature, blood pressure and pulse rate were not affected by either type of RF treatment.

The more pronounced physiological effects of CRMRF in healthy participants compared to PSWT may be indicative of its potentially greater clinical benefits.

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