Invited lecture/Review

Effects of Capacitive and Resistive Electric Transfer Therapy on Skin Temperature - Literature Review

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Abstract:
Capacitive resistive energy transfer is a form of diathermy with lower frequency, approximately 0.5 MHz. It is used in clinical practice as deep thermotherapy with capacitive and resistive mode. The purpose of the review is to determine the thermal effects of capacitive resistive energy transfer and two modes on tissue temperature in healthy adults. Literature review has been conducted in databases: PubMed, CINAHL and PEDro until the end of 2022. Ten studies were included. Two studies compared capacitive and resistive energy transfer to control and six studies to placebo. In three studies a comparison was made between the capacitive and resistive modes. Capacitive and resistive energy transfer in combination or alone is safe and effective as a form of thermotherapy. Participant's subjective feeling should be that of thermal comfort.

Keywords: Capacitive resistive energy transfer, CRET, Thermal effects, Temperature

Citation: Bec S, Weber D, Vauhnik R. Effects of capacitive and resistive electric transfer therapy on skin temperature – literature review. Proceedings of Socratic Lectures. **2023**, 8; 59-65. https://doi.org/10.55295/PSL.2023.II10

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1. Introduction

Thermotherapy is often used in physiotherapy for relieving pain and inflammation, as well as enhance tissue healing (Cameron, 2018; Kumaran et Watson, 2015). A rise in temperature for 1 °C increased tissue metabolism for 10–15 % (Nadler et al., 2004) and greater rise in temperature (3–4 °C) can also change physical properties of connective tissue, making it more extensible (Cameron, 2018; Kumaran et Watson, 2015). Thermotherapy can be divided into superficial and deep thermotherapy. The most commonly used form of deep thermotherapy is diathermy that uses electromagnetic field from 3 kHz to 3000 MHz (Cameron, 2018; Bryś et al., 2022). The most widely used is short-wave diathermy with 27,12 MHz (Cameron, 2018).

Recently, devices that use lower frequency are becoming available and are used in clinical practice (Kumaran et Watson, 2021. Capacitive and resistive energy transfer (CRET) therapy uses radiofrequency of approximatively 0.5 MHz (Tashiro et al., 2017) and has two treatment modes: capacitive (CAP) and resistive (RES) (Clijsen et al., 2020). The devices have two different active electrodes and a metal plate to close the circuit (Barassi et al., 2022). CAP electrode has a coating layer, that prevents the direct contact of metal to the skin and enables heat generation in superficial water-rich tissue e.g., adipose tissue and lymphatic system (Clijsen et al., 2020). RES electrode doesn't have an insulating layer, so the energy goes directly through the body and generates heat in tissues with less water e.g., bone, joint capsules and tendon (Beltrame et al., 2020; Clijsen et al., 2020).
Two systematic reviews described CRET therapy in rehabilitation and clinical practice and sports (Beltrame et al., 2020; De Sousa-De Sousa et al., 2021), but have not specifically investigated the thermal effects of CRET or the differences between CAP and RES. The purpose of this literature review is to determine effects of CRET and each treatment mode (RES and CAP) on tissue temperature in healthy population.

2. Methods

Literature review has been conducted until the end of the year 2022 in databases: PubMed, CINAHL and PEDro with terms: capacitive resistive, capacitive-resistive, CRET, tecar, radiofrequency therapy, radiofrequency treatment and temperature.
Randomized controlled trials (RCT) in English language that investigated the effects of radiofrequency therapy (frequency up to 0.5 MHz) on skin or tissue temperature in healthy participants were included. Studies on cadavers and animals, or studies that used radiofrequency for aesthetic purposes or ablation were excluded.

3. Results

A total of 10 articles were included (Bito et al., 2020; Bryś et al., 2022; Clijsen et al., 2020; Fousekis et al., 2020; Kumaran et Watson, 2015; Kumaran et Watson, 2018; Tashiro et al., 2017; Yeste-Fabregat et al., 2021; Yokota et al., 2017; Yokota et al., 2018). There was a total of 189 participants. In two studies (Kumaran et Watson, 2018; Yokota et al., 2018) they compared CRET to control and in six studies (Bito et al., 2020; Fousekis et al., 2020; Kumaran et Watson, 2018; Tashiro et al., 2017; Yeste-Fabregat et al., 2021; Yokota et al., 2017) to placebo therapy. Three studies (Bito et al., 2020; Clijsen et al., 2020; Kumaran et Watson, 2015) compared effects of RES and CAP mode of treatment between each other. Six studies had cross-over design (Clijsen et al., 2020; Fousekis et al., 2020; Kumaran et Watson, 2015; Kumaran et Watson, 2018; Tashiro et al., 2017; Yokota et al., 2017).

Table 1: Study characteristics and parameters of treatment.

Author, Year	Sample	Average age ± SD (years)	Experimental condition	Parameters (treatment duration, intensity, plate/active electrode placement)
Yokota et al., 2018	22 M	23.0 ± 1.3	G1: CRET (n = 11)	5 min CAP and 10 min RES Subjective Anterior thigh/posterior thigh
		23.2 ± 2.3	G2: control (n = 11)	
Kumaran et Watson, 2018	7 M 10 W	45.7 ± 5.4	G1: thermal CRET G2: non-thermal CRET G3: placebo CRET G4: control G5: PSWD	5 min CAP and 10 min RES Subjective Calf/anterior thigh
Yeste-Fabregat et al., 2021	32 M	22.8 ± 5.9	G1: CRET (n = 17) G2: placebo CRET (n = 15)	10 min CAP and 15 min RES 40 % peak device power Shin/medial part of calf
Fousekis et al., 2020	10 M	22 ± 3	G1: CRET G2: CRET with Fascia Tools G3: placebo CRET G4: placebo CRET s Fascia Tools	5 min CAP and 10 min RES Subjective Not reported/posterior thigh
Tashiro et al., 2017	13 M	24.5 ± 3.0	G1: CRET G2: thermopack G3: placebo CRET	5 min CAP and 10 min RES Subjective Stomach/lower part of paraspinal muscles
Yokota et al., 2017	8 M 5 W	22.0 ± 0.8	G1: CRET G2: thermopack G3: placebo CRET	5 min CAP and 10 min RES Subjective Anterior thigh/posterior thigh
Bito et al., 2020	27 W	74.6 ± 5.4	G1: CRET (n = 10) G2: thermopack (n = 9) G3: placebo CRET (n = 8)	5 min CAP and 10 min RES Subjective Stomach/thorax posteriorly
Kumaran et Watson, 2015	6 M 9 W	45.1 ± 11.6	G1: RES G2: CAP	Until thermal discomfort Subjective Calf /anterior thigh
Bryś et al., 2022	15 M 15 W	24 ± 1	G1: CAP (n=15) G2: RES (n=15)	10 min each mode (RES and CAP) 35 % → RES: 70 VA, CAP: 69 W Posterior thigh/anterior thigh
Clijsen et al., 2020	6 M 4 W	35.9 ± 10.7	G1: RES G2: CAP G3: placebo CRET	8 min each mode (RES and CAP) Subjective Back in level of scapula/anterior part of forearm

CAP – capacitive, CRET – capacitive resistive energy transfer, G – group, M – men, RES – resistive, SD – standard deviation, W – women

Table 2: Effects of CRET on skin and tissue temperature.

Author, year	Instrument	Results	
		Within group	Comparison between groups
Yokota et al., 2018	Infrared thermometer	↑ ST ($p < 0.05$) immediately after treatment (5.1°C), 15 minutes after (1.9°C) and 30 minutes after (1.7°C) CRET.	↑ ST immediately after and 15 and 30 minutes after CRET in comparison to control ($p < 0.05$)
Kumaran et Watson, 2018	Physiological measurement system	No side effects. ↑ ST ($p < 0.05$) immediately after (power: 42.37 ± 4.64 W) and 20 minutes after CRET.	↑ ST after thermal CRET in comparison to control ($p < 0.05$) and placebo ($p < 0.05$).
Yeste-Fabregat et al., 2021	Thermography	↑ ST immediately after ($p < 0.05$), but not 15 and 30 minutes after CRET.	↑ ST after CRET immediately after in comparison to placebo ($p < 0.05$), but not 15 and 30 minutes after.
Fousekis et al., 2020	Infrared thermometer	↑ ST (10.5 %) immediately after ($p < 0.05$) ↑ ST lasted for 55 minutes after CRET.	↑ ST after CRET in comparison to placebo ($p < 0.05$)
Tashiro et al., 2017	Electronic noninvasive thermometer	Average Δ ↑ in ST: 3.8°C, TT10mm: 3.2°C and TT20mm: 3.6°C immediately after CRET. Average Δ ↑ in ST: 1.6°C, TT10mm: for 2°C and TT20mm: 1.9°C 30 minutes after CRET.	↑ average Δ in ST, TT10mm and TT20mm immediately after and 30 minutes after CRET in comparison to placebo ($p < 0.05$)
Yokota et al., 2017	Electronic noninvasive thermometer	Average Δ ↑ in ST: 2.4°C, TT10mm: 2.3°C and TT20mm: 3.3°C immediately after CRET. Average Δ ↑ in ST: 1.5°C, TT10mm: 1.5°C and TT20mm: 2.3°C 30 minutes after CRET.	↑ average Δ in ST, TT10mm and TT20mm immediately after CRET in comparison to placebo ($p< 0.05$)
Bito et al., 2020	Infrared thermometer	Average Δ ↑ ST: 0.7°C ($p > 0.05$), TT10mm: 2.8°C and TT20mm: 3.6°C ($p < 0.05$) immediately after CRET.	Average Δ in ST ↑ TT10mm and TT20mm immediately after CRET in comparison to placebo ($p<0.05$).
Kumaran et Watson, 2015	Infrared thermometer	No side effects. ↑ ST with RES for 12.7 % ($p < 0.05$) and with CAP for 11.1 % ($p < 0{,}05$) until the feeling of thermal discomfort (power: 32.4 ± 11.8 W for CAP and 81.5 ± 20.1 W for RES). ↑ ST lasted 45 minutes after treatment for RES and CAP ($p < 0.05$).	The temperature at the point of thermal discomfort was the same after RES and CAP, but this threshold was achieved faster after CAP. The temperature dropped faster after CAP. ↑ ST after RES in comparison to CAP after 45 minutes ($p<0.05$).
Bryś et al., 2022	Thermo camera	↑ ST after RES ($p < 0.05$) and CAP ($p < 0.05$) immediately after and 5 and 10 minutes after CRET.	↑ ST immediately after and 5 and 10 minutes after RES in comparison with CAP ($p<0.05$).
Clijsen et al., 2020	Infrared thermography	No side effects. Average Δ ↑ ST after RES for 2.8°C and after CAP for 1 °C (*p* value is not reported).	↑ ST after RES in comparison to placebo ($p<0.05$), but not in comparison to CAP.

CAP – capacitive, CRET – capacitive resistive energy transfer, ↑ - higher, RES – resistive, ST – skin temperature, TT10mm – tissue temperature 10 mm under skin, TT20mm – tissue temperature 20 mm under skin.

In eight studies they used Indiba® device with peak power of 200 W (450 VA) and frequency of 448 kHz. In one study they used Tecar T-Plus Wintecare® (Clijsen et al., 2020) and in one T-CARE TECAR® (Yeste-Fabregat et al., 2021) with peak device power of 300 W and 0.5 MHz frequency. The treated body parts and electrode placement differed between studies. In studies that investigated effects of CRET combining RES and CAP only one study (Yeste-Fabregat et al., 2021) determined a longer treatment time of 25 minute (15 minutes CAP and 10 minutes RES), and the others used almost standardized time of 15 minutes (5 minutes CAP and 10 minutes RES). In most studies the intensity of treatment was set according to participants feeling of thermal comfort. Based on manufacturer's advice a 6 or 7 on scale from 0 to 10 (Kumaran et Watson, 2015; Tashiro et al., 2017). Only two studies (Bryś et al., 2022; Yeste-Fabregat et al., 2021) determined intensity based on percent of peak device power. Parameters of CRET and each mode are summarized in Table 1.

In all studies skin temperature was measured and in three studies (Bito et al., 2020; Tashiro et al., 2017; Yokota et al., 2017) they also measured temperature 10 and 20 millimeters below skin surface. They measured temperature on the treatment area before and right after treatment and 10 (Bryś et al., 2022) to 45 minutes (Kumaran et Watson, 2015) after treatment.

In all studies CRET therapy and each mode (RES and CAP) provided higher skin temperature by the end of the treatment and effects lasted even after the treatment. The rise in the skin temperature was higher in CRET groups as compared to the control and placebo groups. Detailed results are reported in Table 2.

4. Discussion

All studies, except one (Bito et al., 2020) that researched the thermal effects of CRET (5 minutes of CAP and 10 minutes of RES) on superficial tissue, showed skin temperature increase. Bito and colleagues (2020) studied effects on older adults. Older adults have less amount of water in skin and subcutaneous tissue and thinner skin with less vessels (Farage et al., 2007; Lorenzo et al., 2019), which may be the reason they did not see effects on skin temperature. On the other hand, Bito and colleagues (2020) along with Tashiro and colleagues (2017) and Yokota and colleagues (2017) have provided evidence of thermal effects 10 and 20 millimeters under skin surface, which might indicate that thermal effects could be present also in older adults. The rise in skin temperature in the end of the treatment ranged between 2.4°C and 5.1 °C in adults, but only 0.7 °C in older adults. The rise in temperature under skin surface was between 2.8 °C and 3.6 °C in adults and older adults. Higher skin temperature lasted even 30 minutes after the treatment, the difference from before treatment was around 1.5 °C (Tashiro et al., 2017; Yokota et al., 2017). Fousekis and colleagues (2020) reported that higher skin temperature lasted for 55 minutes after treatment. Higher temperature was maintained in deeper tissues as well, around 2 °C 30 minutes after treatment (Tashiro et al., 2017, Yokota et al., 2017). It is important to consider that for these longer lasting effects, the intensity had to be set according to subjective perception of heat in participants. Yeste-Fabregat and colleagues (2021) did see effects on skin temperature immediately after treatment, but not 15 or 30 minutes later. They were the only ones that set the intensity according to 40 % of peak device power. This intensity may have not been enough to get results even if the treatment was longer (25 minutes) than others. Manufacturers of CRET devices advise that level of intensity for should be of thermal comfort around 6 or 7 on scale from 0 to 10 (Kumaran et Watson, 2015).

Both treatment modes (CAP and RES) have been shown to be effective for increasing skin temperature (Bito et al., 2020; Clijsen et al., 2020; Kumaran et Watson, 2015) even for more than 1°C. The increase in the temperature lasted 10 and 45 minutes after the treatment in both modes. When the intensity was set based on participant's perception, there was no difference between the rise in skin temperature between the modes. Changes in the skin temperature were achieved faster with CAP mode, meaning with less power than RES (Clijsen et al., 2020; Kumaran et Watson, 2015). Thermal effect 45 minutes after the treatment was bigger when using RES than CAP mode (Kumaran et Watson, 2015). Results support the developer's claim that RES and CAP modes induce different tissue responses, with CAP having more superficial and RES deeper response, but there is a need for studies that would investigate this with the measurements in deeper tissue.

These differences between CAP and RES modes require caution when comparing effects of treatments done on different body parts and different electrode placement. The amount of heat generated in tissue depends on conductivity, strength of electromagnetic field, size of the electrodes and anthropometric factors (Kumaran et Watson, 2015) as well as the treatment mode. For better comparability, studies should report use power in the treatment and not only participant's subjective perception.

CRET has been shown to be more effective than control immediately after treatment (Yeste-Fabregat et al., 2021; Yokota et al., 2018) and 30 minutes after treatment (Yokota et al., 2018). CRET was more effective in comparison to placebo treatment (Bito et al., 2020; Fousekis et al., 2020; Kumaran et Watson, 2018; Tashiro et al., 2017; Yeste-Fabregat et al., 2021; Yokota et al., 2017), where the skin temperature dropped, because of the cold electrode (Bito et al., 2020). These findings confirm that the increase in tissue temperature is not random or solely from moving the electrode on the skin, but is due to the CRET treatment. Because none of the studies reported any side effects, CRET can be considered as a safe treatment.

5. Conclusion

A fifteen-minute CRET treatment combining RES and CAP mode is safe and effective form of thermotherapy in healthy adults when intensity is set according to subjective perception of thermal comfort. When combining both modalities the thermal effects are superficial and deep. However more research is needed for understanding the effects in the deeper tissue. Further research should focus on how different parameters and participants characteristics affect changes in thermal effects.

Conflicts of Interest: The authors declare no conflict of interest.

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