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Original Article

Effects of capacitive and resistive electric transfer therapy on pain and lumbar muscle stiffness and activity in patients with chronic low back pain

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Abstract. [Purpose] In this study, we investigated the therapeutic effects of capacitive and resistive electric transfer therapy in patients with chronic low back pain. [Participants and Methods] The study included 24 patients with chronic low back pain (12 patients each in the intervention and sham groups). Pain intensity, superficial and deep lumbar multifidus stiffness and maximum forward trunk flexion and associated activation level of the iliocostalis (thoracic and lumbar component) and lumbar multifidus muscles were measured. [Results] Post-intervention pain intensity and muscle stiffness were significantly lower than pre-intervention measurements in the intervention group. However, no between-group difference was observed in the muscle activation level at the end-point of standing trunk flexion. [Conclusion] Our findings highlight a significant therapeutic benefit of capacitive and resistive electric transfer therapy in patients with chronic low back pain and muscle stiffness.
Key words: Capacitive and resistive electric transfer, Elastography, Low back pain

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INTRODUCTION

Capacitive and resistive electric transfer (CRet) therapy has increasingly been reported for the treatment of low back pain (LBP) in recent years. CRet includes two therapeutic modes, capacitive electrode transfer (CET) for deep thermal therapy and resistive electrode transfer (RET) for superficial thermal therapy. The frequency range of CRet (500 Hz) reduces capacitance at the electrode-skin interface, lowering the risk of skin burn associated with traditional deep thermal and superficial thermal therapies. Previous studies reported that among individuals with non-specific LBP, CRet therapy produced vasodilation in deep local tissues and an increase in temperature, with resulting improvements in hemoglobin saturation[1–4)]. These effects of CRet reduce pain and increase range of motion of the lumbar spine. However, the therapeutic effects of CRet for chronic low back pain (CLBP) have not been well examined to date[5)].

Muscle stiffness and the flexion-relaxation phenomenon (FRP) have previously been used as objective indicators of the treatment effects for LBP among patients who have a stiffer lumbar multifidus muscle than healthy individuals[6)]. The FRP specifically refers to the relaxation (i.e., absence of muscle activity) of the thoracolumbar extensor muscles at the point of maximum standing trunk flexion that is observed in 82%–100% of adults without LBP[7)]. By contrast, persisting muscle activity at the point of maximum standing trunk flexion has been reported in adults with CLPB[8–10)]. The FRP is thought to

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reflect the coordination between the passive supporting tissues of the lumbar spine and the active contribution of the flexor and extensor muscles of the trunk, with this coordination being crucial to providing functional stability to the spine[11]. It has been hypothesized that the increased fatiguability and pain of the erector spinae associated with LBP results in decreased spinal stability, causing the observed FRP[12, 13]. In addition, ischemic changes in spinal tissues due to reduced local blood flow and accumulation of muscle byproducts associated with CLBP increases the stiffness of thoracolumbar muscles, further leading to loss of lumbar spine flexibility and a change in the point of maximum standing trunk flexion[3, 14]. Based on this evidence, improving local blood circulation, decreasing muscle stiffness, pain, and muscle fatiguability, and increasing lumbar spine flexibility are therapeutic targets for patients with CLBP, which might normalize activity of the thoracolumbar musculature and, hence, the FRP. As recent studies have reported on the therapeutic benefits of CRet to improve local blood circulation and muscle fatiguability, as well as for pain relief[3, 4], we sought to evaluate the therapeutic effects of CRet therapy in improving pain and muscle stiffness as well as in normalizing muscle activity during maximum standing forward trunk flexion and the FRP among patients with CLBP.

PARTICIPANTS AND METHODS

This was a double-blinded randomized clinical trial. The study group consisted of 24 male patients with CLBP, randomly allocated to either the intervention or sham group (n=12 each). A medical history questionnaire was used to screen for the following exclusion criteria: nerve root compression, disc prolapse, spinal canal stenosis, tumors, spondylolisthesis, LBP with extensive neurological symptoms, and use of painkillers. Patients with LBP with confirmed FRP before the intervention were also excluded[15].

Participants provided informed consent. All methods were performed according to the standards of the Declaration of Helsinki. The study was approved by the ethics committee of the Kanazawa Orthopedic Sports Medicine Clinic (kanazawa-OSMC-2021-004).

CRet, both therapeutic and sham, was applied in a single session to the lower back, for 15 min. The Physio Radio Stim Pro CRET system was used (SAKAI Medical Co., Ltd., Tokyo, Japan). Participants were placed in the prone position on a plinth. A rigid circular electrode (diameter, 60 mm) was used as the active electrode, placed over the lumbar multifidus and erector spinae muscles. A rectangular electrode (dimensions, 150 × 210 mm) was used as the inactive electrode, placed on the abdominal area. Manufacturer-supplied cream was used to maintain conductivity between the electrode and the skin surface. For the sham treatment, electrodes were placed but no CRet treatment was applied. Therapeutic CRet was delivered at a frequency of 500 kHz and consisted of 5-min of CET, followed by 10-min of RET. The intensity was individually set at 6–7 on the following 11-point scale of subjective heat sensation, with anchors at ‘0’ (no heat sensation) and ‘10’ (highest heat sensation tolerable)[2, 4].

The following outcomes were evaluated: LBP intensity, stiffness of the superficial and deep lumbar multifidus, and maximum forward trunk flexion and associated activation level of the iliocostalis (thoracic and lumbar component) and lumbar multifidus muscles.

LBP intensity was evaluated using a 100-mm visual analog scale (VAS), with anchors at ‘0’ (no pain) and ‘100’ (worst possible pain). Muscle stiffness was evaluated by elastography using a B-mode ultrasound apparatus (SSD-3500SV; Fuji Film, Tokyo, Japan) with a linear transducer (scanning frequency, 7.5 MHz). An acoustic coupler (Young’s modulus, 22.6 kPa; EZU- TECPL1, Fuji Film) was placed between the probe and the surface being assessed. Images were recorded over the superficial and deep lumbar multifidus muscles, as per previously described methods[6]. All elastography measurements were performed by an experienced technician. The strain ratio was calculated as the measurement area of the muscle component evaluated (A) divided by the area of the acoustic coupler (B). A strain ratio calculated for the acoustic coupler and a reference material was used to normalize the measured A/B ratio, as previously described[16, 17]. A strain ratio <1 indicated that the muscle was less stiff (i.e., softer) than the reference material.

Muscle activation levels were evaluated using surface electromyogram (EMG) using the active electrode MQ8/16 telemetric EMG system (Kissei Comtec, Nagano, Japan). Disposable Ag/AgCl surface electrodes were used (area, 1 × 1 cm), with an inter-electrode distance of 1 cm. Using previously described methods[18], the electrodes were placed over the thoracic and lumbar components of the iliocostalis lumborum muscle and the lumbar multifidus. The trunk flexion maneuver used to evaluate the muscle activation level (the FRP) was performed from a standardized ‘start’ position, in static standing, with both arms relaxed naturally along the body. The static standing position was held for 4 s to obtain baseline muscle activity levels. Participants were then asked to flex their trunk forward and to hold their maximum flexion position for 4 s, and then to return to the static standing position and to hold this position for 4 s. Three trials of the flexion maneuver were performed, with the average EMG values used for analysis. EMG signals were recorded at the start position and at maximum flexion. EMG were sampled at a 1 KHz frequency. The EMG signals were recorded to a computer for offline processing and analysis (Kine Analyzer, Kissei Comtec, Japan). Signals were bandpass filtered (20–450 Hz), fullwave rectified, and smoothed using the root mean square (RMS) methods. The RMS value for each muscle in the static standing position recorded before the CRet session was set to 1 to normalize values for between-participant analysis. An RMS value for the lumbar multifidus muscle of <1 after the intervention was indicative of a normalization of the FRP (i.e., absence of muscle activity at the point of maximum of standing trunk flexion).

Analyses were performed using SPSS (version 24.0 for Windows; IBM, Tokyo, Japan). Kolmogorov–Smirnov test revealed normal distribution of data. Outcome measures were evaluated before and after the CRet session and compared using a paired t-test analysis. For comparisons between groups, an unpaired t-test was used. The level of significance was set at a p-value <0.05.

RESULTS

There were no differences in the general characteristics of participants between the two groups: intervention (age, 34.3 ± 8.7 years; height, 173.4 ± 4.8 cm; weight, 65.7 ± 6.3 kg) and sham (age, 32.5 ± 7.5 years, height, 175.0 ± 7.8 cm; weight, 66.9 ± 8.2 kg) group. Outcome measures are summarized in Table 1. Post-intervention, LBP intensity and muscle stiffness values were significantly lower than pre-intervention ($p<0.05$). However, there was no between-group difference in the FRP, with no difference in the RMS value of the lumbar multifidus muscle at the end-point of standing trunk flexion ($p>0.05$). There were no changes in measured outcomes, from baseline to post-intervention, for the sham intervention group ($p>0.05$).

DISCUSSION

Our findings support a positive effect of CRet in reducing pain and muscle stiffness among patients with CLBP, but with no immediate effect on increased levels of muscle activation during forward trunk flexion. The measured effects of CRet on LBP in our study group are consistent with those from a previous study[4]. The effect of heat in alleviating LBP has previously been described and includes local vasodilation, for ischemic pain relief[19], and decreased conduction velocity in pain mediating fibers (Aδ and C), increasing the pain threshold[20]. Similarly, a previous study has reported on the decrease in muscle stiffness of the supraspinatus muscle with CRet[21], as we identified for the lumbar musculature. This effect is likely mediated by the deep vasodilation induced by CRet, improving local blood circulation and, thus, decreasing the internal pressure of local tissues caused by an accumulation of fluid and waste byproducts in ischemic tissues[16].

The FRP is mediated by both active (muscles) and passive (ligaments and fascia) spinal tissues[7]. LBP has been associated with dysfunction in the active components, including abnormal muscle activation levels and patterns, as well as increased muscle fatiguability[13]. Although we had hypothesized, a priori, a positive effect of CRet on the FRP, our findings were not supportive of this hypothesis, with no effect of CRet on activation levels of the lumbar extensors during the forward flexion maneuver in our study group. This lack of effect might reflect a contribution of passive spinal tissues to the abnormal FRP observed in patients with CLBP. A previous research has reported on micro-injury to passive spinal tissues with repeated loading or stretching stress, resulting in degeneration and reduced stability of the thoracolumbar fascia[22]. Organoleptic changes in other passive spinal tissues, including the supraspinous ligament and intervertebral capsule, due to continuous or repeated elongation stress caused by reflex activity of the lumbar multifidus and erector spinae muscles, have also been reported[23]. The immediate improvement in muscle stiffness and recovery of muscle fatigue with CRet are thought to reflect its effects on active spinal tissues, with no indications of therapeutic effects for spinal tissue degeneration and reduced spinal stability[1–4]. Studies have reported on the positive therapeutic effect of exercise on the FRP among individuals with LBP[24, 25]. These exercises focus on the coordination between active and passive spinal structures to improve spinal stability and posture control, such as exercises using the Neurac Sling System[25]. Therapeutic effects of exercise are achieved over a longer term period of intervention compared to our single session CRet intervention. Yet, our single session of CRet was effective in achieving a decrease in the VAS pain immediately after the treatment (9.38 ± 10.16 mm). CRet may therefore be more effective than exercise to achieve an acute reduction in LBP. Consequently, CRet therapy appears to influence different tissues of the lumbar spine than therapeutic exercise, which supports the combined use of CRet and exercise to achieve pain relief and a normal FRP. We do note previous findings have a possible healing effect of CRet on passive spinal tissues by facilitating the proliferation of precursor cells and collagen remodulation[21]. Our study was a single intervention, so it's unclear what the long-term effects will be. Future research is required to evaluate these effects of CRet, as well as the benefits of combined

Table 1. Comparison of outcomes between the intervention and sham capacitive and resistive electric transfer (CRet) groups

		Intervention group		Sham group	
		Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
VAS (mm)		45.63 ± 23.52	9.38 ± 10.16*	47.22 ± 25.50	44.56 ± 29.42
Muscle stiffness	Superficial multifidus	8.84 ± 13.34	0.76 ± 0.54*	9.52 ± 8.96	10.02 ± 9.42
	Deep multifidus	13.74 ± 10.70	1.41 ± 1.21*	12.56 ± 14.90	12.56 ± 14.91
Muscle activity	CLT	1.16 ± 0.82	1.76 ± 2.45	1.25 ± 1.02	1.40 ± 1.42
	ICLL	2.19 ± 1.97	3.95 ± 7.15	2.54 ± 2.35	2.40 ± 2.81
	MF	2.99 ± 1.64	3.18 ± 2.11	3.51 ± 1.84	3.24 ± 2.14

Value are presented as the mean ± standard deviation. *$p<0.05$, compared to pre-intervention value.
CRet: capacitive and resistive electric transfer; VAS: visual analog scale; ICLT: thoracic component of the iliocostalis lumborum; ICLL: lumbar component of the iliocostalis lumborum; MF: lumbar multifidus.

CRet and therapeutic exercise for the treatment of CLBP.

In summary, our findings indicate an acute therapeutic benefit of the intervention on LBP and muscle stiffness. Research is needed to evaluate the effect of capacitive and resistive electric transfer therapy on passive spinal tissues and of combining this intervention with therapeutic exercise.

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Conflict of interest

There are no conflicts of interest to declare.

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