EFFECT OF CAPACITIVE AND RESISTIVE ELECTRIC TRANSFER ON TISSUE TEMPERATURE, MUSCLE FLEXIBILITY, AND BLOOD CIRCULATION

YOKOTA Y, TASHIRO Y, SUZUKI Y, TASAKA S, MATSUSHITA T, MATSUBARA T, KAWAGOE M, SONODA T, NAKAYAMA Y, HASEGAWA S, AOYAMA T.

J Nov Physiother 2017, 7:1 DOI: 10.4172/2165-7025.1000325

INTRODUCTION

Poor muscle flexibility increases the risk of musculoskeletal injuries such as muscle strain and low back pain, which are common in athletes [1-6]. Thus, maintenance and improvement of muscle flexibility is important; in this order, athletes and therapists use stretching and thermotherapy. Many studies show that thermotherapy combined with stretching is more effective to improve muscle flexibility than stretching alone [7-9]. However, it is unclear how thermotherapy alone influences muscle flexibility.

Thermotherapy increases extensibility in soft tissue [10]. This may lead to improve muscle flexibility. An increase in tissue temperature also produces vasodilation [10]. Insufficient blood circulation causes hypoxia, the production and release of algesic substances and tissue fibrosis, which lead to pain, muscle spasm, and joint contracture [11]. These conditions may reduce muscle flexibility. In addition, improvement of blood circulation can promote tissue repair and healing [12]. Thus, it is meaningful to evaluate the effect of thermotherapy on muscle flexibility and blood circulation to treat muscles.

Thermotherapy can be classified into superficial and deep thermotherapy. Heat conducted by superficial thermotherapy (ST) cannot reach muscle [10]. As a method of ST, hot packs (HP) are widely used in clinical practice. Capacitive-Resistive electric transfer (CRet) system is a form of deep thermotherapy [16] that can treat larger areas than other technologies. In addition, CRet does not require a surface-cooling system. Thus CRet is more convenient and safer than other devices.

The aim of the present study was to evaluate the effects of CRet and HP on tissue temperatures, muscle flexibility, and blood circulation.

MATERIALS AND METHODS

Participants

Thirteen healthy adults participated in this study (5 women and 8 men, mean ± standard deviation; age 22.0 ± 0.8 years, height 166.7 ± 0.1 cm, body weight 60.9 ± 9.9 kg).

Design

The participants randomly received three interventions: (1) Capacitive (CAP) and Resistive (RES) electric transfer (CRet trial), (2) hot pack (HP trial), and (3) CRet without power (sham trial). The intervention order was randomized, and each experiment was conducted more than 24 hours apart. The intervention and measurement were applied to the right hamstring muscle.

Instruments and measurements

Interventions: Indiba® device (Indiba S. A., Barcelona, Spain) was used for the CRet intervention. Treatment intensity was defined as 6 or 7 on a subjective analog scale (0: no thermal sensing, 10: worst possible thermal sensing) considered to be the most effective without feeling discomfort or pain [19]. Intervention was of 15 minutes (min) (5 min in CAP and 10 min in RES). The sham intervention was unpowered CRet but performed using the same method and conditions as those in the CRet intervention. In the HP trial, 15 min of moist heat with an HP was applied to the participants. The HP (S-PACK: SAKAI Medical Co.) was heated to 80 in a hydro-collator tank and wrapped in towels in eight layers considered to be most effective without feel discomfort or pain.

Measurement

Tissue temperature was measured using a Coretemp CTM-205 (electronic thermometer for noninvasive measurements). We measured 3 depths (skin superficial temperature [ST], and deep temperatures [DT] 10 mm and 20 mm below the superficial skin) simultaneously.

The passive straight leg raise (SLR) test was used to determine changes in the hamstring muscle's flexibility.

Blood circulation was measured with near-infrared spectroscopy (NIRS) using an OMEGAMONITOR BOM-L1 TR W. Thus, blood circulation around 15 mm below the skin surface was measured in this study. The measurement indexes of blood circulation were oxygenated (oxy-), deoxygenated (deoxy-), and total (total-) Hb concentrations. The total-Hb is the sum of oxy-Hb and deoxy-Hb.

RESULTS

Changes in tissue temperatures

ΔST, Δ10 mmDT and Δ20 mmDT were significantly higher in the CRet and HP trials than in the sham trial between T2 and T8. There were no significant differences between the CREt and HP trials in Δ10 mmDT; however, they tended to be higher in the CRet trial than in the HP trial between T2 and T8 (Figure 1).

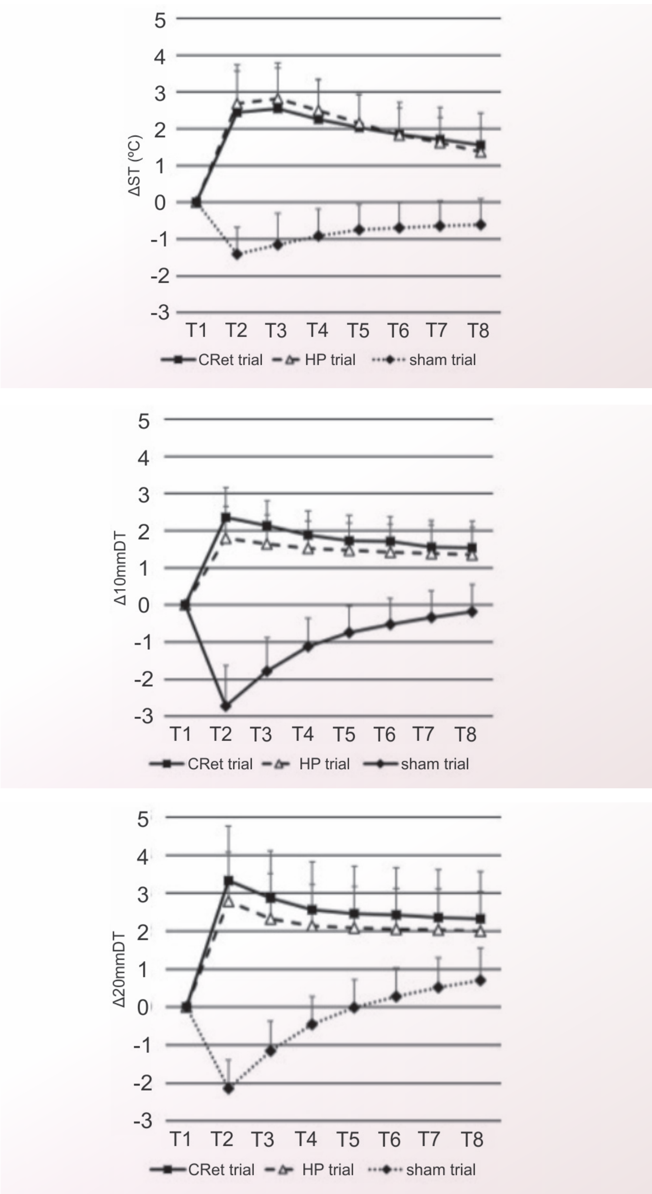

Figure 1. Changes in tissue temperatures in each intervention where: T1 (before intervention), T2 (immediately after intervention), T3-T8 (at 5 minutes intervals after intervention).

Changes in muscle flexibility

ΔSLR was significantly higher in the CRet trial than in the sham trial between T1 and T8 ($p<0.01$), moreover, it was significantly higher in the CRet trial than the HP trial between T5 and T8 ($p<0.01$), (Figure 2).

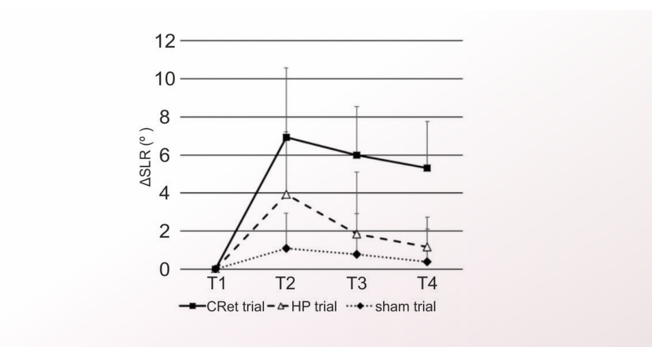

Figure 2. Changes in tissue flexibility in each intervention where: T1 (before intervention), T2 (immediately after intervention), T5 (15 minutes after intervention), T8 (30 minutes after intervention).

Changes in blood circulation

Δoxy-Hb and Δtotal-Hb were significantly higher in the CRet and HP trials than in the sham trial between I2 and I7. In each trial, Δdeoxy-Hb tended to decrease after the intervention.

DISCUSSION

The changes in the passive SLR test were significantly greater in the CRet trial than in the sham trial for 30 min after the intervention. This suggests that CRet could improve muscle flexibility. There are two possible factors for the change in muscle flexibility. The first factor is the increase in the extensibility of the soft tissue, including connective tissue composed primarily of collagen fibers [20-22] (Figure 3).

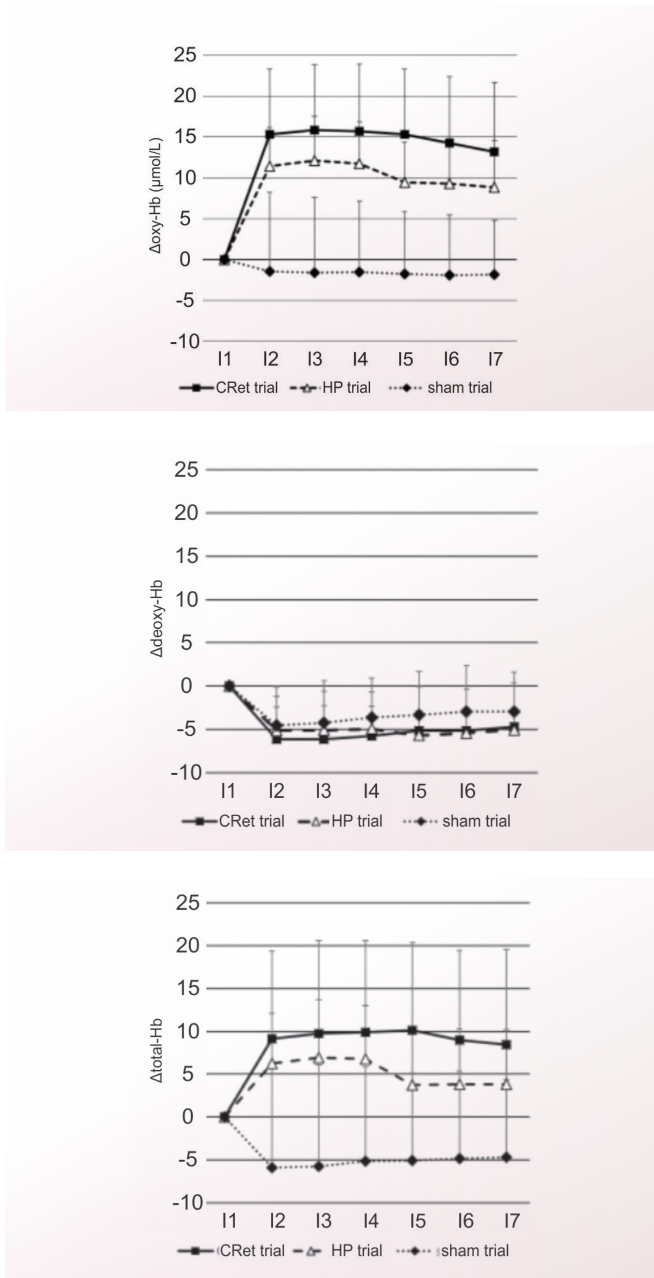

Figure 3: Changes in blood circulation in each intervention, where: I1 (before intervention), I2-I7 (at 5 minutes intervals after intervention)

As the temperature increases collagen extensibility increases, and the connective tissue viscosity and viscoelasticity of muscle fiber are reduced [23-25]. Subsequently, the extensibility of soft tissue increased, and muscle flexibility was improved. The second factor is the increase in participants' tolerance to pain from muscle stretching. Some previous studies reported that local thermotherapy increased the pain threshold [26-28].

The changes in the passive SLR test were significantly greater in CRet trial than in HP trial 15 and 30 min after the intervention, and no significant difference was observed between the HP and sham trials for the 30 min after the intervention. These results suggest that CRet is more effective to improve muscle flexibility than HP. We assume that this phenomenon was due to the increase in deep tissue temperature. There was no significant difference between CRet and HP trials in 10 mmDT and 20 mmDT; however, they tended to be higher in CRet trial than in HP trial for 30 mins after the intervention. These results suggest that CRet could warm deep tissue more effectively than HP. We assumed that CRet could reach the whole hamstring muscle and warm not only the biceps femoris and semitendinosus but also the semimembranosus enough to change the degree of the passive SLR test; on the other hand, HP could not warm the deep muscle sufficiently. Thus, the change in the passive SLR was significantly greater in the CRet trial than in the HP trial. In other words, CRet is more effective to improve muscle flexibility than HP.

Oxy-Hb, increased in CRet and HP trials, whereas deoxy-Hb decreased. This result shows that the change in total-Hb was due to the increase in oxy-Hb. An increase in oxy-Hb indicates an increase in the volume of fresh blood supplied by the arteries [34].

The results of this study indicated that CRet improved muscle flexibility. Various studies have investigated the effect of thermotherapy on muscle flexibility; however, many of them reported the effect of thermotherapy applied concomitantly with stretching [7-9]. In contrast, the present study indicated that CRet alone could improve muscle flexibility.

We could not objectively conclude whether the changes in muscle flexibility were due to the increase in soft tissue extensibility or the increase in the participants' tolerance to pain from muscle stretching.

CONCLUSIONS

The effect on muscle flexibility was higher in the CRet trial than in the HP trial. Additionally, CRet could improve the blood circulation as well as HP. The findings of this study suggest that CRet could be an effective means as thermotherapy.

REFERENCES

1. Feldman DE, Shrier I, Rossignol M, Abenhaim L (2001) Risk factors for the development of low back pain in adolescence. Am J Epidemiol 154:30-36.
2. Witvrouw E, Danneels L, Asselman P, D'Have T, Cambier D (2003) Muscle flexibility as a risk factor for developing muscle injuries in male professional soccer players. A prospective study. Am J Sports Med 31:41-46.
3. Worrell TW, Perrin DH (1992) Hamstring muscle injury: the influence of strength, flexibility, warm-up, and fatigue. J Orthop Sports Phys Ther 16:12-18.
4. Bradley PS, Portas MD (2007) The relationship between preseason range of motion and muscle strain injury in elite soccer players. J Strength Con Res 21: 1155-1159.
5. Kujala UM, Salminen JJ, Taimela S, Oksanen A, Jaakkola L (1992) Subject characteristics and low back pain in young athletes and nonathletes. Med Sci Sports Exerc 24: 627-632.
6. Mierau D, Cassidy JD, Yong-Hing K (1989) Low-back pain and straight leg raising in children and adolescents. Spine (Phila Pa 1976) 14: 526-528.
7. Draper DO, Anderson C, Schulthies SS, Ricard MD (1998) Immediate and residual changes in dorsiflexion range of motion using an ultrasound heat and stretch routine. J Athl Train 33: 141-144.
8. Draper DO, Castro JL, Feland B, Schulthies S, Eggett D (2004) Shortwave diathermy and prolonged stretching increase hamstring flexibility more than prolonged stretching alone. J Orthop Sports Phys Ther 34: 13-20.
9. Nakano J, Yamabayashi C, Scott A, Reid WD (2012) The effect of heat applied with stretch to increase range of motion: a systematic review. Phys Ther Sport 13: 180-188.
10. Cameron MH (2009) Physical Agents in Rehabilitation from Research to Practice, (4th edn) Philadelphia, PA: Saunders.
11. Morishita K, Karasuno H, Yokoi Y, Morozumi K, Ogihara H, et al. (2014) Effects of therapeutic ultrasound on intramuscular blood circulation and oxygen dynamics. J Jpn Phys Ther Assoc 17: 1-7.
12. Nadler SF, Weingand K, Kruse RJ (2004) The physiologic basis and clinical applications of cryotherapy and thermotherapy for the pain practitioner. Pain Physician 7: 395-399.
13. Kato S, Saitoh Y, Miwa N (2013) Repressive effects of a capacitive-resistive electric transfer (CRet) hyperthermic apparatus combined with provitamin C on intracellular lipid-droplets formation in adipocytes. Int J Hypothermia 29:30-37.
14. Kumaran B, Watson T (2015) Thermal build-up, decay and retention responses to local therapeutic application of 448 kHz capacitive resistive monopolar radiofrequency: A prospective randomised crossover study inhealthy adults. Int J Hyperthermia 31: 883-895.
15. Lehmann JF, Warren CG, Scham SM (1974) Therapeutic heat and cold. Clin Orthop Relat Res: 207-245.
16. Strickler T, Malone T, Garrett WE (1990) The effects of passive warming on muscle injury. Am J Sports Med 18: 141-145.
17. Lentell G, Hetherington T, Eagan J, Morgan M (1992) The use of thermal agents to influence the effectiveness of a low-load prolonged stretch. J Orthop Sports Phys Ther 16: 200-207.
18. Mutungi G, Ranatunga KW (1998) Temperature-dependent changes in the viscoelasticity of intact resting mammalian (rat) fast- and slow-twitch muscle fibres. J Physiol 508: 253-265.
19. Lehmann JF, Masock AJ, Warren CG, Koblanski JN (1970) Effect of therapeutic temperatures on tendon extensibility. Arch Phys Med Rehabil 51: 481-487.
20. Warren CG, Lehmann JF, Koblanski JN (1976) Heat and stretch procedures: an evaluation using rat tail tendon. Arch Phys Med Rehabil 57: 122-126.
21. Lehmann JF, Brunner GD, Stow RW (1958) Pain threshold measurements after therapeutic application of ultrasound, microwaves and infrared. Arch Phys Med Rehabil 39: 560-565.
22. Benson TB, Copp EP (1974) The effects of therapeutic forms of heat and ice on the pain threshold of the normal shoulder. Rheumatol Rehabil 13:101-104.
23. Minton J (1993) 1992 Student Writing Contest-1st Runner-up: A Comparison of Thermotherapy and Cryotherapy in Enhancing Supine, Extended-leg, Hip Flexion. J Athl Train 28: 172-176.
24. Karasuno H, Morozumi K, Fujiwara T (2005) Change in intramuscular blood volume induced by continuous shortwave diathermy. J Phys Ther Sci 17: 71-79.