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Change of Isometric Contractile Force and Muscle Activity Applying Heat according to the Time on Biceps Brachii Muscle

This study has investigated the effect of isometric contractile force and muscle activity applying sperficial heat according to the time from the biceps brachii muscle. In this study, 20 university students participants without musculoskeletal and neurological disorders. By applying a hot pack 5min, 10min, 20min and 30min respectively. After that measurement are skin temperature, contractile force and muscle activity. Skin temperature of the hot 5 min applied that rapidly changing. Increasing the time it takes to apply a variance has been reduced(p<.001). Isometric contractile force was not statistically significant but highest when applying the hot pack 5 minutes and lowest when applying the hot pack 30 minutes(p<.001). Muscle activity and median frequency was highest when applying the hot pack 5 minutes. To analyze the above results, it was found that isometric contractile force and muscle activity changed according to the applying time. These result lead us to the conclusion that this study will be more evidence for changes in muscle contraction to apply hot pack on clinic.

Key words: *Hot Pack, Isometric Contraction, Muscle Activity, Median Frequency*

Jae Keun Jeon[a], Sang Soo Kim[b], Da Haeng Kang[c], Bo Kyoung Kim[d], Ja Pung Koo[e], Ok Kon Moon[f], Joon Hee Lee[g]

[a]Hanlyo University, Gwangyang; [b]Daegu Health College, Daegu; [c]Sehan University Research Institute for Industry, Youngam; [d]International University of Korea, Jinju; [e]Pohang College, Pohang; [f]Kunjang College, Gunsan; [g]Sehan University, Youngam, Korea

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Address for correspondence
Joon Hee Lee, PT, Ph.D
Department of physical Therapy, Sehan University, 1113 Samho-eup, Youngam-gun, Jeonnam, Korea
Tel: 82-61-469-1478
E-mail: jhlee@sehan.ac.kr

INTRODUCTION

Thermotherapy is widely used in diverse forms in patient rehabilitation or sports medicine(1). Thermotherapy is divided into superficial heat(heat, infrared rays, paraffin bath, liquid, whirl pool bath) therapy and deep heat(ultrasonic wave, short wave, microwave) therapy based on heat penetration depths after heat application(2). In particular, superficial heat such as hot packs is one of the most widely used methods among chronic musculoskeletal system disease patients because it has advantages such as easy handling, low costs, non-invasive application(3).

Superficial heat is mainly applied to relieve pain and muscle spasm. Physiological reactions to heat raise tissue temperatures, increase blood flow rates through vasodilatation in local applied sites, increase the physical change and metabolic activity of collagenic tissues, relieve muscle spasm, change nerve reactions, and change musculoskeletal system activities(1, 4, 5). In particular, muscle strength and endurance decrease in the musculoskeletal system(6) so that the viscoelasticity of connective tissues increases(7). In addition, thermal stimulation changes nerve reactions to raise pain thresholds, change nerve conduction velocity, and affect muscle spindle firing rates. According to a previous study, when superficial heat was applied to chronic low back pain patients for two hours, the muscle activity of erector spinae muscle decreased and pain was relieved(8). Another previous study indicated that thermotherapy that combines superficial heat and deep heat caused different patterns of changes in the thoracic vertebral motor neurons through changes in the motor neurons(9) and still another previous study identified that thermotherapy combined with stretching exercises changed muscles' stretching force thereby causing significant changes in the active and passive ranges of motion of the joints(10).

Despite that thermotherapy has diverse physiological reactions and advantages, most previous studies except for some have focused on pain relief and muscle tone relief and studies of changes in skin temperatures, isometric contractile force, and muscle activity in relation to the time of application after the application of thermotherapy are insufficient. Therefore, the purpose of the present study was to apply heat to the biceps brachii muscle for different lengths of time and examine resultant changes in skin temperature and related changes in isometric contractile force and muscle activity.

METHODS

Subjects

The subjects of the study were a total of 20 healthy males without any peripheral vascular disease or musculoskeletal system disease. The study was conducted from May 11 to May 18, 2012. Before conducting the experiment, the purpose and method of the study were explained in detail to the subjects and voluntary agreement to participated in the present study was obtained from the subjects. All subjects underwent the experiment in the same measuring room and had an adapting time of at least 10 minutes before measurement. The indoor humidity in the measuring room was maintained in a range of 50~60%, and the indoor temperatures were maintained in a range of 24~27℃.

Measuring Instrument and Method

Application of heat

Electric hot packs of which the temperature is maintained at 65℃ when they are in contact with human bodies were evenly put into tight contact with the brachial region of each subject in a supine position by bending the hot packs round. The hot packs were applied for 10 minutes, 20 minutes, or 30 minutes.

Skin temperature measurement

Digital thermometers and wire sensors(Center-306, thermolog., Korea) were used to measure skin temperatures. The wire sensors and digital thermometers which are skin temperature measuring instruments were connected to a PC loaded with a themolog computer lingking program that can record and analyze temperatures at intervals of one second during measuring time when they were used. Skin temperatures were measured by placing the end of the wire sensors which are heat detecters on the center region of the biceps brachii muscle(11).

Isometric contractile force measurement

Maximum voluntary isometric contractile force was measured using an MP150(BIOPAC System Inc. CA, USA) system, a mechanomyography amplifier, and a dynamometer(TSD121C, BIOPAC System Inc. CA, USA) in which a wrist cuff is connected to a fixed rope. The analog signals coming from the instruments were converted into digital data by the MP150 system. The sampling rate of the dynamometer (TSD121C) was set to 125㎐ and the cut-off frequency of the, low pass filter was set to 5㎐. As a measuring posture, the subject was instructed to sit on the experimental chair maintaining the trunk upright. The maximum voluntary isometric contractile force of the right biceps brachii muscle which is the major hand side by instructing the subject to pull upward, the cuff connected to the dynamometer(TSD121C) while maintaining 90° flexion of the elbow joint and supination of the fore arm with the upper arm in tight contact with the trunk(12).

Measurement and Analysis of Electromyogram (EMG) Signals

To measure the muscle activity of the biceps brachii muscle, a surface EMG system(Bagnoli EMG system, Delsys Inc., USA) was used. The recording electrode was attached to the muscle belly of the biceps brachii muscle and the earth electrode was attached to a close region where the electrode would not disturb movements. To measure the muscle activity, when the subject felt maximum comfort, maximal voluntary isometric contraction(MVIC) of the biceps brachii muscle was induced based on the manual muscle strength test posture of the muscle and the data values were linearly filtered for five seconds. Then, the average value of the data values for three seconds was measured excluding those for the first one second and the last one second. The signal sampling rate was set to 1024㎐ and the measurement frequency band filter of the Bagnoli EMG system with a frequency bandwidth of 20~450㎐ and a 60㎐ notch filter were used. The collected EMG signals were stored and analyzed using the Acquisition and Analysis Software(Delsys, USA) program by analyzing the root mean square(RMS)(13).

To analyze the median frequency(MDF), the frequency spectrum of the stored EMG signals was obtained from 1,000 signals for one second and FFT(fast fourier transfomation) was repeatedly analyzed using a window length of one second and a window overlap of 0.5 seconds.

Data Analysis

In the present study, the SPSS 18.0 program was used for statistical analysis. For the experimental results, the means and standard deviations of all measured values were obtained. For each measurement variable, average values before the application of thermotherapy were set as base lines and paired t-tests were conducted for each measurement item for different lengths of the time of the application of thermotherapy to examine statistical significance. The statistical significance level was set to α=.05.

RESULTS

Comparison of General Characteristics of the Subjects

The total number of study subjects who participated in the present study was 20. Their mean age was 22.10±1.21 years, their mean height was 167.76±5.16cm, and their average weight was 65.12±7.3kg(Table 1).

Table 1. Type of lung disease

Division	Mean±SD
Age(years)	22.10±1.21
Height(cm)	167.76±5.16
Weight(kg)	65.12±7.23

Changes in Skin Temperature in Relation to the Length of Time of the Application of Heat

Compared to the base line 33.38±0.70℃, the skin temperatures increased to 36.90±0.46℃ when heat was applied for 5 minutes, to 38.24±0.49℃ when heat was applied for 10 minutes, to 38.63±0.30℃ when heat was applied for 20 minutes, and to 39.15±0.63℃ when heat was applied for 30 minutes. Compared to the base line, there were statistically significant differences at all lengths of time of application($p<.001$)(Table 2).

Table 2. Skin temperature changes in relation to the length of time of the application of heat

Division (n=20)	Skin temperature(℃)	Isometric contractile force(㎏)
Base line	33.38±0.70	45.27±9.44
Heat 5 min	36.90±0.46***	46.65±9.49
Heat 10 min	38.24±0.49***	44.78±11.03
Heat 20 min	38.63±0.30***	43.79±11.12
Heat 30 min	39.15±0.63***	40.50±9.38***

Values are mean±SD, ***$p<.001$

Changes the Isometric Contractile Force, Muscle Activity, and Median Frequency in Relation to the Length of Time of Application of Heat

Compared to the base line 45.27±9.44kg, the isometric contractile force increased to 46.65±9.49㎏ when heat was applied for 5 minutes but decreased to 44.78±11.03㎏ when heat was applied for 10 minutes, to 43.79±11.12㎏ when heat was applied for 20 minutes, and to 40.50±9.38㎏ when heat was applied for 30 minutes. Compared to the base line, statistically significant differences were shown when heat was applied for at least 30 minutes ($p<.001$)(Table 3).

Compared to the base line 0.54±0.10mV, the muscle activity increased to 0.57±0.10mV when heat was applied for 5 five minutes but decreased to 0.50±0.10mV when heat was applied for 10 minutes, to 0.49±0.09mV when heat was applied for 20 minutes, and to 0.47±0.09mV when heat was applied for 30 minutes. Statistically significant differences were

Table 3. Changes in the isometric contractile force, muscle activity, and median frequency in relation to the length of time of the application of heat

Division(n=20)	Isometric contractile force(kg)	Muscle activity(㎷)	Median frequency(㎐)
Base line	45.27±9.44	0.54±0.10	66.53±5.76
Heat 5 min	46.65±9.49	0.57±0.10*	72.89±8.64**
Heat 10 min	44.78±11.03	0.50±0.10*	64.58±4.54
Heat 20 min	43.79±11.12	0.49±0.09**	60.71±5.22**
Heat 30 min	40.50±9.38***	0.47±0.09***	60.85±3.97**

Values are mean±SD, *$p<.05$, **$p<.01$, ***$p<.001$

shown when heat was applied for 5 minutes, 10 minutes($p<.05$), 20 minutes($p<.01$), and 30 minutes ($p<.001$) respectively(Table 3).

Compared to the base line 66.53±5.76㎐, the median frequency increased to 72.89±8.64㎐ when heat was applied for 5 minutes but decreased to 64.58±4.54㎐ when heat was applied for 10 minutes, to 60.71±5.22㎐ when heat was applied for 20 minutes, and to 60.85±3.97㎐ when heat was applied for 30 minutes. Compared to the base line, statistically significant differences were shown when heat was applied for 5 minutes($p<.01$), 20minutes($p<.01$), and 30 minutes($p<.01$) respectively(Table 3).

DISCUSSION

In the present study, superficial heat was applied to the biceps brachii muscle for different lengths of time and changes in skin temperatures and resultant changes in muscle activity were examined. According to the results of the study, compared to the base line 33.38±0.70℃, the skin temperatures increased to 36.90±0.46℃ when heat was applied for 5 minutes, to 38.24±0.49℃ when heat was applied for 10 minutes, to 38.63±0.30℃ when heat was applied for 20 minutes, and to 39.15±0.63℃ when heat was applied for 30 minutes.

According to a study conducted by Fetrofsky et al. when a 49℃ hot pack wrapped by four layers of towels were applied to the skin for 30 minutes, the tissue temperature increased from 33℃ to 39℃(14). Myrer et al. measured actual deep muscle temperatures after applying hot cloth and reported that the temperatures of the 1㎝ and 3㎝ deep triceps brachii muscles increased from 34~36℃ to 37~38℃ when hot cloth was applied for 15 minutes similarly to the results of the present study(15).

In the present study, compared to the base line 45.27±9.44㎏, the isometric contractile force increased to 46.65±9.49㎏ when heat was applied for 5 minutes but decreased to 44.78±11.03㎏ when heat was applied for 10 minutes, to 43.79±11.12㎏ when heat was applied for 20 minutes, and to 40.50±9.38㎏ when heat was applied for 30 minutes. Compared to the base line, statistically significant differences were shown when heat was applied for 5 minutes, 10 minutes($p<.05$), 20minutes($p<.01$), and 30 minutes ($p<.01$). In a study conducted by Lewis et al. when hot packs maintained at 40℃ were applied to chronic low back pain patients' erector spinae muscle for two hours, whereas the muscle activity increased statistically significantly compared to the control group, the value of maximum voluntary isometric contractile force decreased although the difference was not statistically significant(16). According to a study conducted by Chia et al., when the brachial skin temperature was 16.7℃, the muscle activity was 0.22㎷ and isometric contractile force was 36.1Kg similarly to the results of the present study(17).

Compared to the base line 0.54±0.10㎷, the muscle activity increased to 0.57±0.10㎷ when heat was applied for 5 minutes but decreased to 0.50±0.10㎷ when heat was applied for 10 minutes, to 0.49±0.09㎷ when heat was applied for 20 minutes, and to 0.47±0.09㎷ when heat was applied for 30 minutes. Compared to the base line, statistically significant differences were shown when heat was applied for 5 minutes, 10 minutes($p<.05$), 20 minutes($p<.01$), and 30 minutes($p<.001$) respectively. According to a study conducted by Pereira, when microwaves were applied to the biceps brachii muscle for 16 minutes, compared to the control group, the isometric contractile force and muscle activity of the biceps brachii muscle decreased but the value of the median frequency increased(18). This result should be because, when muscle temperatures rise, vasodilatation occurs(19) and blood flows and nutrition supply to the muscle increase so that motor units' firing rates for muscle contraction increase making muscle contraction more efficient(20). In the present study, compared to the base line 66.53±5.76㎐, the median frequency of muscle contraction increased to 72.89±8.64㎐ when heat was applied for 5 minutes but decreased to 64.58±4.54㎐ when heat was applied for 10 minutes, to 60.71±5.22㎐ when heat was applied for 20 minutes, and to 60.85±3.97㎐ when heat was applied for 30 minutes. Compared to the base line, statistically significant differences were shown when heat was applied for 5 minutes($p<.01$), 20minutes($p<.01$), and 30 minutes($p<.01$) respectively.

Based on the present study, theories of previous studies could be identified to some extent. However, additional studies on the effects in relation to the lengths of time of application of heat should be conducted with diverse patients. This author hopes that diverse methods including superficial heat and contrast bath can be developed, studied, and applied in clinics.

CONCLUSION

The purpose of the present study was to apply heat to the biceps brachii muscle for different lengths of time and examine resultant changes in skin temperature and related changes in isometric contractile force and muscle activity. skin temperatures changed rapidly when heat was applied for 5 minutes but the amplitude of changes decreased over time($p<.001$). Isometric contractile force was the largest when heat was applied for 5 minutes and the smallest when heat was applied for 30 minutes($p<.001$). The muscle activity was the highest when heat was applied for 5 minutes($p<.05$) and the lowest when heat was applied for 30 minutes($p<.001$). The median frequency was the highest when heat was applied for 5 minutes ($p<.01$) and the lowest when heat was applied for 20 minutes($p<.01$).

Based on the results of the present study, it could be seen that thermotherapy for muscle strength improvement should be the most effective when it is applied for 5 minutes. However, since the present study was conducted with healthy adults, later studies should be conducted with diverse patients.

REFERENCES

1. Prentice WE. Therapeutic Modalities in Sports Medicine. 1999(fourthed); WCB/McGraw-Hill. Boston. USA.
2. Perret C, Poiraudeau S, Fermanian J. Validity, reliability and responsiveness of the finger tip-to-floor test. Arch Phys Med Rehabil 2001; 82:1566-1570.
3. Grana WA. Physical agents in musculoskeletal problem: heat and cold therapy modalities. Instr Course Lect 1993; 42:439-442.
4. Brukner P, Khan K. Clinical Review of Sports Medicine, 2001(second ed.); McGraw-Hill, Roseville, NSW.
5. Zuluaga M, Briggs C, Carlisle J, et al. Sports Physiotherapy: Applied Science and Practice. 1995(Eds.); Churchill Livingstone, Melbourne.
6. Edwards RHT, Harris RC, Hultman E, et al. Effect of temperature on muscle energy metabolism and endurance during successive isometric contraction, sustained to fatigue of the quadriceps muscle in man. J Physio. 1972; 220:335-352.
7. Pernot E. S., Tanter M. The link between tissue elasticity and thermal dose in vivo. Brosses Phys Med Biol 2011; 56(24):7755-7765.
8. Lewis SE, Holmes PS, Woby SR, et al. Short-term effect of superficial heat treatment on paraspinal muscle activity, stature recovery, and psychological factors in patients with chronic low back pain. Arch Phys Med Rehabil 2012; 93(2): 367-372.
9. Yoon SW, Lim YE, Lee JW. Influence of Superficial Heat and Deep Heat for Lumbo-sacral Segment on H-Reflex. Journal of the Korean Academy of Clinical Electrophysiology 2007; 5(2): 1-9.
10. CA Knight, CR Rutledge, ME Cox, M Acosta. Effect of Superficial Heat, Deep Heat, and Active Exercise Warm-up on the Extensibility of the Plantar Flexors. Phys. Ther. 2001; 81: 1206-1214.
11. Kim TY, Jung DI, Kim YI, Yang JH. Shin SC. Anesthetic effects of lidocaine hydrochloride gel using low frequency ultrasound of 0.5 MHz. J Pharm Pharm Sci. 2007; 10(1): 1-8.
12. Shin HK, Cho SH, Lee YH, Kwon OY. Quantitative EMG changes during 12-week DeLorme's axiom strength training. Yonsei MED J. 2006; 47(1): 93-104.
13. Jeong WS, Jeong JY, Kim CK, et al. Effect of Lower Limb Muscle Activity on Balancing through Sprinter Patterns of PNF. JKCA 2011; 11(3): 281-292.
14. Petrofsky J, Batt J, Bollinger JN, et al. Comparison of different heat modalities for treating delayed-onset muscle soreness in people with diabetes. Diabetes Technol Ther 2011; 13(6): 645-655.
15. Myrer JW, Measom G, Durrant E, Fellingham GW. Cold and hot pack contrast therapy: subcutaneous and intramuscular temperature change. J Athl Train 1977; 33: 238-241.
16. Sandra Lewis E, Paul Holmes, Steve Woby R, et al. Short-term effect of superficial heat treatment on paraspinal muscle activity, stature recovery, and psychological factors in patients with chronic low back pain. Arch Phys Med Rehabil 2012; 93: 367-72.
17. Chia-Fen Chi, Yuh-Chuan Shih, Wen-Lin Chen. Effect of cold immersion on grip force, EMG and thermal discomfor. INT J IND Ergonomic 2012; 42(1): 113-121.
18. Wagner Menna Pereira, Luiz Alfredo Braun Ferreira, Luciano Pavan Rossi, et al. Influence of heat on fatigue and electromyographic activity of the biceps brachii muscle. J Bodyw Mov Ther 2011; 15: 478-484.
19. Okada K, Yamaguchi T, Minowa K, Inoue N. The influence of hot pack therapy on the blood flow in masseter muscle. J Oral Rehabil 2005; 32: 480-486.
20. Thompson LV. Effects of age and training on skeletalmuscle physiology and performance. Phys Ther 1985; 74: 71-81.