The relationship between EMG activity and human sensibility during cold air exposure of different temperatures

Chul-Ju Kim, Wonhak Cho, Seong-Ryoul Ryoo and Hyeonki Choi#

School of Mechanical Engineering, Sungkyunkwan University, 300 Cheoncheon-dong, Jangan-gu, Suwon, Republic of Korea , 440-746
Corresponding Author / E-mail: hkchoi@skku.edu, TEL: +82-31-290-7455, FAX: +82-31-290-7455

KEYWORDS : Cold exposure, Electromyograph, Muscle activities, Skin temperature, Human sensibility

The environment of room needs to be thermally more comfortable and healthy. The immediate physiological effects of cold exposure are well documented, and include vasoconstriction activated by thermal receptors in the skin, increased blood pressure, and increased secretion of stress hormones. What we do not know is how long it takes cold exposure before people are at risk of suffering the effects of cold exposure. As front region of the body is commonly the body part most exposed to the cold when people are standing at air conditioner, this study is aimed to examine the relationship between EMG activity and human sensibility during cold air exposure of different temperature. EMG was recorded from four muscles of the front region of the body. The subjects exercised during 15 minute under 8.4 met condition and were exposed for 15 minutes in cold air. We measured the muscle activity and human sensibility assessment. We watched the sensibility apparatus per 1 minute for human sensibility assessment during experiment. In levator labii superioris m., we found that the time periods to reach the maximum EMG activities were 140s at 16℃, 380s at 17℃ and 580s at 18℃. The time periods of human sensibility assessment were 20s, 80s and 100s, respectively. In the rectus femoris m., time periods of EMG maximum activity were 180s, 500s and 820s, respectively and time periods of human sensibility assessment is 80s, 110s and 140s, respectively. In comparison to 16℃, the exposures to ambient temperatures of 17℃ and 18℃ significantly increased time periods of the maximum EMG activity and human sensibility assessment. The time decreased significantly after the exposure to 16℃. In comparison to time measured at 16℃, the time periods of EMG maximum activity at 17℃ and 18℃ were shorter. The subjective human sensibility assessment and skin temperature was afforded to the proof of this result. Consequently, we provided the proper time periods of air conditioning which makes comfortable thermal environment for human in cold air.

Manuscript received: January XX, 2011 / Accepted: January XX, 2011

1. Introduction

People are often exposed to cold which causes uncomfortable cold thermal sensations. In occupational conditions, frequent exposure to cold has been suggested to be a risk factor for musculoskeletal disorders by increasing the physical strain of workers and increasing the risk of accidents [1]. The same could be true also for leisure time and sports activities in cold environments. The amount of cold exposure that is sufficient to cause deterioration of muscle performance is not known [2].

According to Knight, the rate of temperature decrease during cold exposure depends on the temperature between the body and the cold modality, regeneration of body heat and modality during cooling, the heat storage capacity of the cold modality, the size of the cold modality, area of the body in contact with the cold modality, the duration of application and the individual response variability. In addition, the rate and magnitude of the temperature reduction depends on the cold modality used (e.g., ice pack, cold pack, ice massage, immersion in ice water, cold air) and the tissues that are trying to be cooled [3]. It has been established during cold exposure skin temperature decreases faster and to a greater amount than deeper tissues [4]. There is a rapid decline in the temperature of the skin during the first couple of minutes, and then the rate of cooling slows until the skin temperature is a few degrees above the temperature of the modality [5]. Barnes and Larson [6] demonstrated cooling the forearm in 10°C water for 30 minutes decreased skin temperature over the flexor digitorum superficialis muscle to 16.29°C, while 62.7% of the total temperature decrease occurred during the first two minutes of cold exposure. Immersing the hand in 15°C water for 10 minutes reduced skin temperature over the first dorsal interosseous

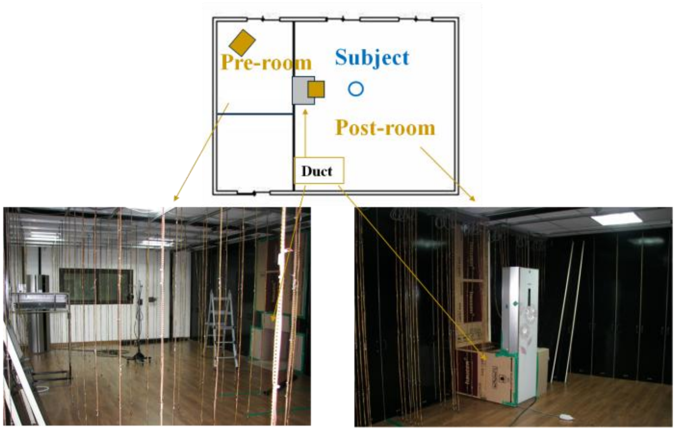

Fig. 1 Experimental schematics

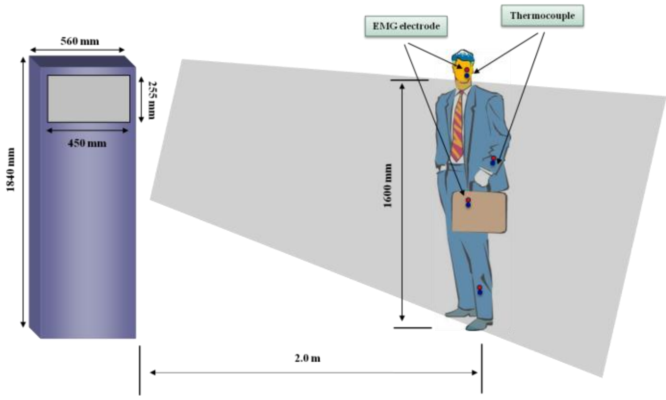

Fig. 2 Locations of EMG and skin temperature sensors

muscle to 21.5 ± 0.16°C [7]. However, Oksa et al.[8] showed an average skin temperature of 25.8 ± 0.6°C following 60 minutes exposure to 10°C ambient air, thus indicating a lesser degree of skin temperature decline with ambient air-cooling. This is due to the fact that water is a 20 times greater conductor of heat than air [9]. Haymes and Rider [10] showed thirty-five minutes of cooling the anterior thigh with ice decreased skin temperature to approximately 15°C, while subcutaneous temperature decreased to approximately 19°C.

There is not much information in the scientific literature on EMG activity and functional changes in the muscle after cold exposure. The studies that have been done have examined the effects of cooling on EMG-activity during isometric and submaximal exercise compared to dynamic and maximal exercise. The number of active motor units in the muscle and the frequency of motor unit discharge have been found to determine the amplitude of the EMG signal [11]. In addition, the duration of motor unit action potentials, the number of active motor units and frequency of motor unit discharge influence the frequency components of the EMG signal [12]. Conflicting results during exercise following muscle cooling have been found in the EMG signal; muscle cooling has been shown to decrease the EMG frequency [13], increase the amplitude [14], and decrease the amplitude [13]. The different results may be due to different cooling and exercise protocols. It has been shown that exposure to ambient air temperature of 10°C for at least 60 minutes increased the EMG amplitude compared to exposures at 23 and 40°C during isometric contractions of the quadriceps muscle ranging from 10 to 100% of maximum voluntary contraction [14]. Oksa et al. [15] found that repetitive dynamic work in the cold causes enhanced muscle EMG activity and increased level of coactivation of the agonist-antagonist muscle pairs. Participants performed wrist flexion-extension exercise at 10% maximal voluntary contraction for 20 seconds and repeated it six times at 25°C (muscle temperature 35.3 ± 0.80°C) and at 5°C while exposed to both systemic (muscle temperature 32.8 ± 0.6°C) and local cooling (muscle temp 32.6 ± 0.8°C) of the forearm. During concentric contractions the EMG activity of the forearm flexors and extensors was significantly higher in both cold conditions compared to the 25°C condition. During the eccentric contraction, the EMG activity of the forearm flexors was significantly higher and the activity of the extensors was higher at the beginning of the first work bout in relation to the 25°C activity. In agreement with these findings Bawa et al. [16] found EMG activity indicated that during light arm extensions the biceps brachii and triceps brachii muscles cocontracted together in cooled subjects. In contrast, Bergh and Ekblom [17] did not find any changes in timing of onset and termination of EMG activity in the vastus lateralis, semitendinosus, and biceps femoris muscles of one subject during tests of isokinetic maximal strength, isometric strength, vertical jumping, and cycle ergometer sprinting after cooling the legs in a water bath (muscle temperature 30-35°C). The study is aimed to examine the relationship between EMG activity and human sensibility during cold air exposure of different temperatures.

2. Method

2.1 Experimental design

A total of five students from Sungkyunkwan University were voluntarily participated in this study. Their mean age was 26 (SD ±4) years, mean body height 170 (SD ±5) cm, mean body mass 68 (SD ± 6) kg. The subjects were informed of the nature, purpose and possible risks/inconvenience caused by the experiment. A medical examination was conducted to confirm that they were healthy. A written consent to participate in the study was obtained before starting the experiments.

They performed the experiments each day first under control conditions in a climatic room (20m^2) in which temperature was adjusted to 30.0±0.3℃. In climatic chambers the relative humidity was 50±3% and air velocity less than 0.2 m/s. During the experiments the subjects were lightly clad in shorts, socks and athletic shoes. EMG and skin temperature was recorded from four muscles of the front region of the body by using a computerized data recording and analysis system. The subjects exercised during 15 minutes under 8.4 met condition and were exposed to cold air at 16, 17, and 18 ℃ for 15 minutes. In cold air, we measured the muscle activity and skin temperature and human sensibility assessment. We watched the sensibility apparatus per 1 minute for human sensibility assessment during experiment. We set the period of time of human sensibility assessment as the time subject feel the sensation of coldness for the first time.

2.2 EMG measurements

EMG signals from four muscles were acquired and recorded for 10 min. The EMG data were acquired simultaneously from both heads of four muscles, using an eight-channel portable system of EMG amplifiers connected in parallel (MyoSystem 1400, Noraxon USA, Inc.). After having and scrubbing the skin with alcohol, disposable Ag/AgCl surface electrodediscs with a diameter of 9 mm

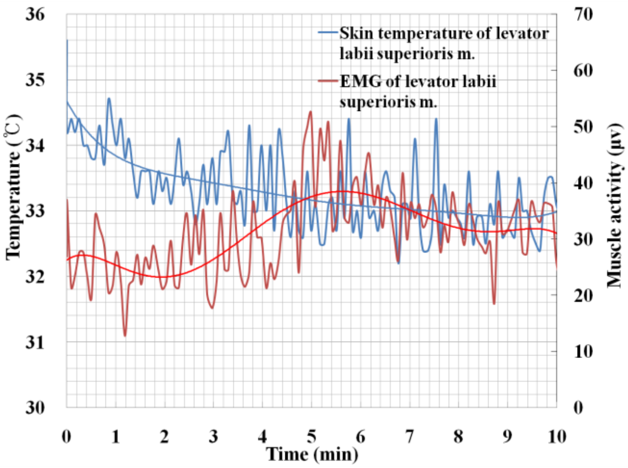

Fig. 3 An example of EMG activity and skin temperature of levator labii superioris m.

(Noraxon Dual Electrodes) were attached to the subject's skin at locations recommended by Perotto and Delagi [18].

For each muscle, two electrodes were placed at a distance of approximately 30 mm in the direction of the muscle fibers. A reference electrode, shared by the six measurement channels, was placed on the bony part of the lateral aspect of the knee joint. Cables and interfaces were shielded to eliminate interferences. EMG was recorded from four muscles of the whole body using a computerized data recording and analysis system (MyoSystem 1400, Noraxon USA, Inc.). EMG signals were pre-amplified by factors in the range of 1000–4000 (depending on the subject) and captured by a 12-bit A/D board (PLC 818, Scientific Solution Lab, USA) at a sampling rate of 1 kHz. Signal envelopes were calculated using a digital band, 10-200Hz band pass filter and six-order Butterworth 7–11 Hz [19] filter to evaluate the activity time frames of the EMG bursts and to locate the mid-time values of their duration. The selected four muscles were as follows: levator labii superioris m., extensor carpi ulnaris m., rectus femoris m., tibial anterior m.. In the study, EMG of extensor carpi ulnaris m., and tibial anterior m. was not significant. The focus of this article is therefore the oscillations in the levator labii superioris m. and rectus femoris m..

3. RESULTS

An example of EMG activity and skin temperature of levator labii superioris m. is shown in Fig. 3. In levator labii superioris m., we found that the time periods to reach the maximum EMG activities were 140s at 16℃, 380s at 17℃ and 580s at 18℃. The time periods of human sensibility assessment were 20s, 80s and 100s, respectively (Fig. 4). In the rectus femoris m., time periods of EMG maximum activity were 180s, 500s and 820s, respectively and time periods of human sensibility assessment is 80s, 110s and 140s, respectively (Fig. 5).. In comparison to 16℃, the exposures to ambient temperatures of 17℃ and 18℃ significantly increased time periods of the maximum EMG activity and human sensibility assessment. The time decreased significantly after the exposure to 16℃. In comparison to time measured at 16℃ time values of EMG maximum activity at 17℃ and 18℃ were shorter. The subjective human sensibility assessment and skin temperature was afforded to the proof of this result (Fig. 6).

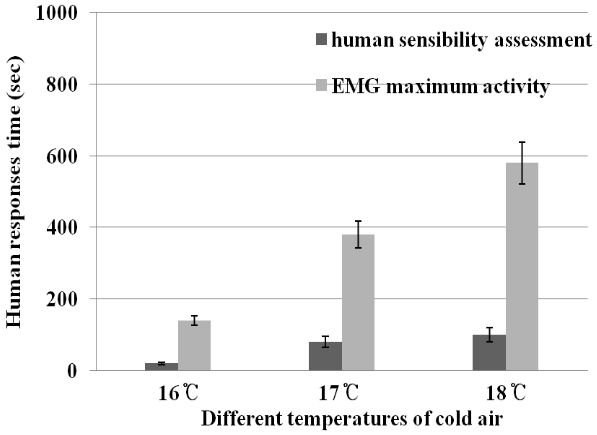

Fig. 4 Difference of human response times due to cold air (The location sensor: levator labii superioris m.)

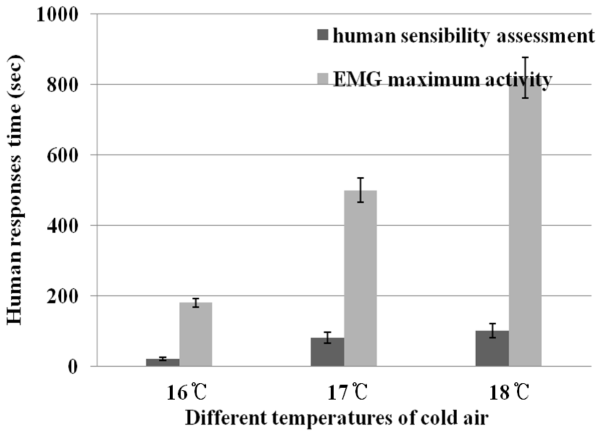

Fig. 5 Difference of human response times due to cold air (The location sensor: of rectus femoris m.)

4. Conclusions

This study examined the relationship between EMG activity and human sensibility during cold air exposure of different temperature. The results of this study show a relationship between the degree of cooling and the decrease in muscle performance as well as in the changes of EMG activity of the muscles. Three level of cooling was found to be sufficient to cause a significant change in EMG activity, skin temperature and human sensibility assessment. Also, this study was that Human bio-signals are significantly correlated with human sensibility during exposed to cold air.

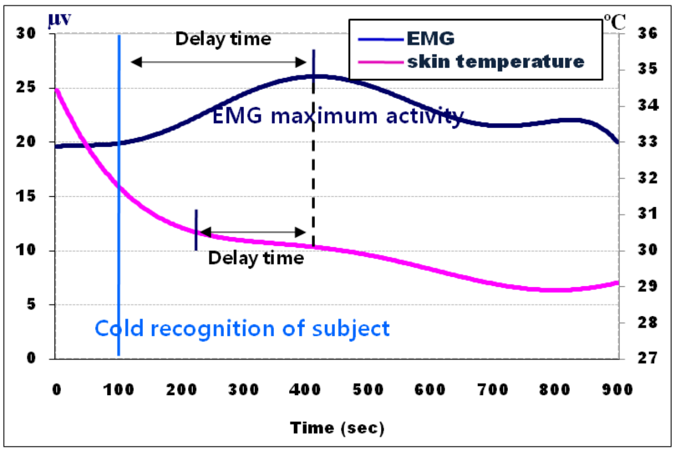

Fig. 6 Human response times due to cold air exposure

ACKNOWLEDGEMENT

This paper was supported by Samsung Electronics.

REFERENCES

1. Rantanen J. and Lehtinen S., “Working environment and health in Finland,” Katsavksia Vol. 119, Finnish Institute of Occupational Health, Helsinki, 1992.
2. Oksa j., Rintama k. H. and Rissanen S., “Muscle performance and electromyogram activity of the lower leg muscles with different levels of cold exposure,” Eur J Appl Physiol, Vol. 75, pp. 484-490, 1997.
3. Knight K. L., “Cryotherapy in sport Onjury Management. Champaign,” IL: Human Kinetics, 1995.
4. Knight K. L., Aquino J., Johannes S. M. and Urban C. D., “A re-examination of Lewis’ cold-induced wasodilation in the finger and ankle,” Athletic training, Vol. 15, pp. 238-250, 1980.
5. Varpalotai M. and Knight K. L., “Pressures exerted by elastic wraps applied by beginning and advanced student athletic trainers to the ankle and the thigh with and without an ice pack,” J Athlet Training, Vol. 26, pp. 246-250, 1991.
6. Barnes W. S. and Larson M. R., “Effects of localized hyper-and hypothermia on maximal isometric grip strength,” American Journal of Physical Medicine, Vol. 64, pp. 305-314, 1985.
7. Wade A. J., Broadhead M. W. , Cady EG, Llewelyn M. E., Tong H. N. and Newham D. J., “Influence of muscle temperature during fatiguing work with the first dorsal Interosseus muscle in man: a 31P-NMR spectroscopy study,” Eur J Appl Physiol, Vol. 81, pp. 203-209, 2000.
8. Oksa J., Rintamäki H. and Rissanen S., “Muscle performance and electromyogram activity of the lower leg muscles with different levels of cold exposure,” European journal of applied physiology and occupational physiology, Vol. 75, pp. 484-490, 1997.
9. Haymes E. M. and Wells C. L., “Environment and human performance,” Champaign, IL: human Kinetics, 1986.
10. Haymes E. M. and Rider R. A., “Effects of leg cooling on peak isokinetic torque and endurance,” American corrective therapy journal, Vol. 37, pp. 109-115, 1983.
11. Milner-Brown H. S. and stein R. B., “The relation between the surface electromyogram and muscular force,” journal of physiology, Vol. 246, pp. 549-569, 1975.
12. Lindstrom L., Magnusson R. and Petersen I., “Muscular fatigue and action potential conduction velocity changes studied with frequency analysis of EMG signals,” electromyography and clinical Neurophysiology, Vol. 10, pp. 341-356, 1970.
13. Petrofsky J. S. and Lind A. R., “The influence of temperature on the amplitude and frequency components of the EMG during brief and sustained isometric contractions,” European journal of Applied physiology and Occupational physiology, Vol. 44, pp. 189-200, 1980.
14. Bell D. G., “The influence of air temperature on the EMG/force relationship of the quadriceps,” Eur J Appl Physiol, Vol. 67, pp. 256–260, 1993.
15. Oksa J., Ducharme M. B. and Rintamaki H., “Combined effect of repetitive work and cold on muscle function and fatigue,” J Appl Physiol., Vol. 92, pp. 354–361, 2002.
16. Bawa P., Mathhews P. B. C. and Mekjavic I. B. C., “Electromyographic activity during shivering of muscles acting at the human elbow,” Journal of Thermal Biology, Vol. 12, pp. 1-4, 1987.
17. Bergh U. and Ekblom B., “Influence of muscle temperature on muscle strength and power output in human skeletal muscles,” Acta Physiol Scand, Vol. 107, pp. 33-37, 1979.
18. Perotto A. and Delagi E. F., “Anatomic Guide for the Electromyographer-The Limbs and Trunk,” Tomas, Springfield, IL., USA, 1996.
19. Winter D. A., “Human balance and posture control during standing and walking,” Elsevier Science B. V., 1995.