The Variation of Surface Electromyography due to different metabolism and skin temperature during exposure to cold air

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In the last few years attention has been focused on the effect of cold environments. 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. This study aimed to examine the two cases of relationship. One case was the relationship between the EMG and skin temperature responses to whole body. The other case was the relationship between EMG and human metabolism. The experiments were done at two different physical exercises when subsequently exposed to cold air. EMG signals were recorded from four muscles of the front region of the body by using a computerized data recording and analysis system. The subjects exercised for 15 minutes under 5.3 and 8.4 MET condition and were exposed to cold air at 19℃. In 5.3 MET, muscle activities increased when they were exposed in cold air and decrease as time goes by. Especially, muscle activities rushed the increase after 6 minute and decreased after 9 minute in cold air. After that they increased gradually again. In 8.4MET, also muscle activities increased when subjects were exposed to the cold air and decreased as time goes by. But, the response times were significantly different; they increased after 9 minute and decreased after 12 minute in cold air. And muscle activities increased as the increment of muscle contraction. In the concrete, although there was a time gap 5.3 MET and 8.4 MET, muscle activities had a tendency to increase. After that, these appearances were gradual decrement. Particularly, in 8.4 MET, we could see that muscle activities were rapidly getting to increment after 9 minutes. Also result of skin temperature displayed a similar trend. In our opinion, this result was due to the rapid increment of muscle contraction as evaporation of sweat. Comparing with each case, we could find the increment degree of muscle activities were due to the perspiration of human skin. And these results suggest that prior physical exercise may predispose a person to greater heat loss and to experience a larger decline in EMG and skin temperature when subsequently exposed to cold exposure.

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1. Introduction

The environments of rooms are needed to be more thermally comfortable and healthy as being indoor time in the modern building has been gradually increased. And further, these conditions of environment are in demand which will be developed better as quality of life has dominated our society. Recently, the personal air-conditioning systems have been developed rapidly to satisfy the individual sensation and save the energy, competing with the central ones [1].

Cold exposure stresses the human body by making it more difficult to maintain core temperature. The physiologic stress endured during cold exposure is evident when measuring changes in heart rate, blood pressure, and oxygen consumption. As the body loses heat to the environment primarily through convection and radiation, a shivering response is initiated. Under such conditions, the innate mechanism of muscle shivering is triggered to produce heat which is marked by an increase in oxygen consumption, or VO2. Simultaneously, peripheral vasoconstriction occurs to decrease the amount of blood (and heat) reaching the skin's surface in an effort to preserve the core temperature. A natural consequence of this shunting is an increase in blood pressure [2].

Upon entering a cooler environment, the body will adjust to restore heat balance. Heat balance can be restored by reducing heat loss or, on the other hand, increasing heat production. Behavioral aspects can intervene at both points: clothing can reduce heat loss and

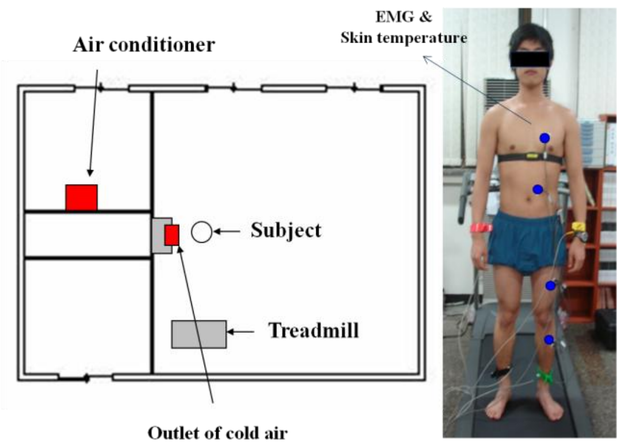

Fig.1 Experiment schematic and location of EMG and skin temperature mark

activity, and food intake can increase heat production. Even when behavioral aspects are taken into account, physiological reactions during resting conditions occur [3]. The reduction of heat loss is established by vasoconstriction, which decreases heat transfer from core to the skin. This reduces the temperature of the skin and distal parts of the body [4].

On the other side of the balance, heat can be produced by several mechanisms, summarised as adaptive thermogenesis. Adaptive thermogenesis during resting conditions is subdivided into non-shivering thermogenesis (NST) and shivering thermogenesis (ST). Under severe cold circumstances, shivering starts soon but depends on the interplay between core temperature and skin temperature [5]. and the change in skin temperature [6]. Shivering is a very efficient way to produce heat, and the peak shivering intensity can increase heat production up to five times the BMR. The intensity of shivering is determined by the severity of cold exposure, the amount of fat-free mass (FFM), the subject's fitness [7] and the rate of shivering is determined by the severity of cold exposure, the amount change of the skin temperature [6]. If cold exposure is not so severe, shivering does not start immediately [8]. Although NST in humans preceding the onset of shivering, or in addition to shivering, has been observed before [9], opinions on the existence and mechanisms involved are still divided [7].

Although shivering has been intensively studied, the period preceding shivering has hardly been described [8]. Nevertheless, the state of being exposed to mild cold without shivering is a condition occurring frequently in daily life. In an earlier investigation, we showed an increase in heat production in response to mild cold without shivering [10] and that the relative magnitude of NST was related to the temperature response. This can have implications for energy balance and the risk of gaining weight [11, 12]. Insight into factors such as body composition, body shape, resting metabolic rate and gender related to the cold-induced heat production can be of importance in the treatment and prevention of obesity [13].

The diminished power output due to cooling may be compensated for by recruiting more muscle fibers as has been shown by increased EMG amplitude during dynamic exercise [14]. It has been found that the decrease in muscle performance seems to be velocity dependent: fast exercises (pedaling 145 rpm) are affected more than are slower ones (54rpm), suggesting that fast-twitch fibers are more susceptible to cooling [15, 16]. Bigland-Ritchie et al. [17] have found that due to cooling the frequency component of the EMG was shifted towards lower frequencies, which also implies that the fast-twitch fibers are not used as efficiently in the cold as in thermo neutral conditions.

This study aimed to examine the two case of relationship. One case was the relationship between the EMG and skin temperature

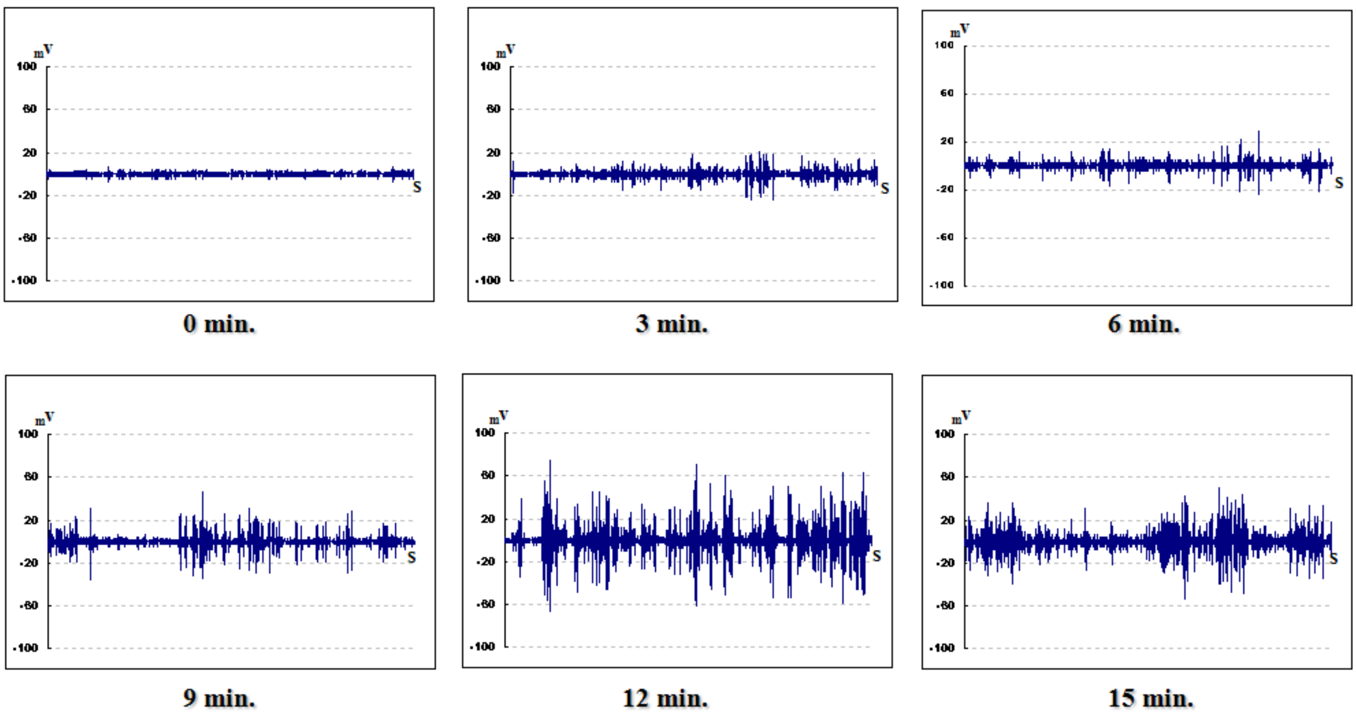

Fig.2 EMG activities of the selected muscles

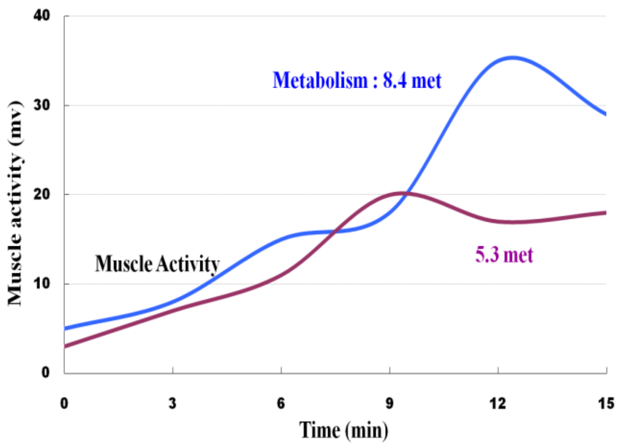

Fig. 3 The behavior of muscle activities in different metabolism

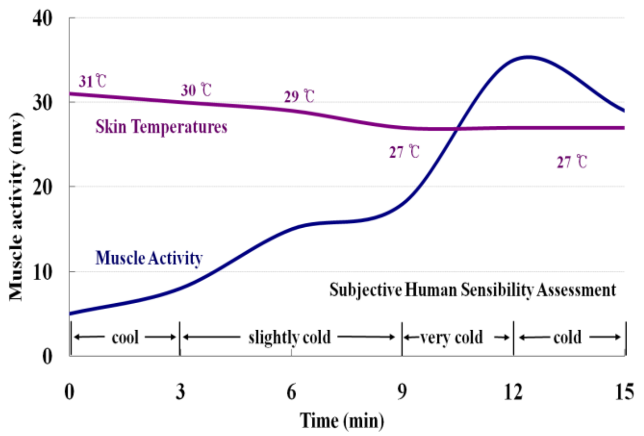

Fig. 4 Human responses to cold air in the front region of the body

responses to whole body. The other case was the relationship between EMG and human metabolism to whole body, and these experiments were done at the special front region of the body, exposure to cold from the air-conditioner.

2. Method

2.1 Experimental design

Four subjects (males) participated in this study. The average values of anthropometrical data were as follows: age (mean ± SD) was 27±1 yrs; height 170±6 cm; weight 65.5±10.0 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 25.0±0.5℃. In climatic chambers the relative humidity was 55±4%. 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 (Fig. 1). The subjects exercised during 15 minutes under 5.3 met and 8.4 met condition and were exposed to cold air at 19 ℃ for 15 minutes. In cold air, we measured the muscle activity and skin temperature and made them done the subject human sensibility assessment. We watched the sensibility apparatus per 1 minutes for human sensibility assessment during experiment.

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

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 front region of the 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 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: pectoralis major m., rectus abdominis m., rectus femoris m., tibial anterior m..

2.3 Skin temperature measurements

Skin temperatures were measured by surface thermistors (YSI probes, series 409B, Yellow Springs Instruments Co. Ltd.) placed on the dorsal side skin of the pectoralis major m., rectus abdominis m., rectus femoris m., tibial anterior m.. Temperatures were registered and saved over 0.1 sec intervals (Tiretherm, IDEE, Maastricht, The Netherlands).

3. RESULTS

Figure 2 and 3 show the muscle activities, as metabolism change when the subjects were exposed to the cold air. In 5.3met, muscle activities increased when they were exposed in cold air and decreased as time went by. Especially, they rushed the increase after 6 minutes and decreased after 9 minutes in cold air. After that they increased gradually again.

Figure 4 shows the muscle activity, skin temperature and the subject human sensibility assessment when the subject was exposed to cold air. Muscle activity increased when it opened with cold air and decreased as time went by. Especially, it rushed the increase after 9 minutes and decrease after 12 minutes in cold air. And skin temperature increased when the subjects were exposed in cold air and decreased as time went by. Also, according to the subjective human sensibility assessment, the subjects’ values were changed from cool to cold as time went by (Fig 5).

In cold air, the skin temperature decreased and the muscle under skin began to contract. And muscle activities increased as the

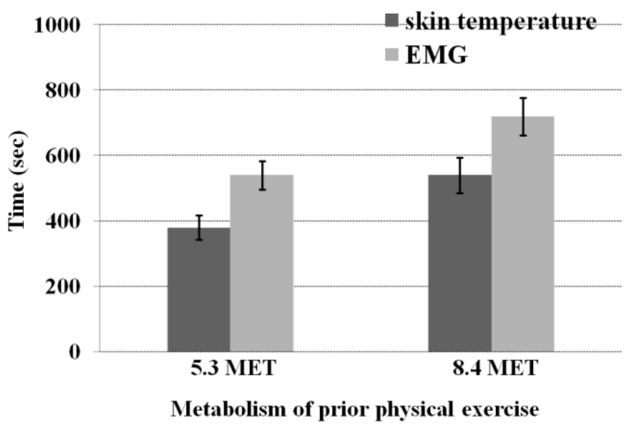

Fig. 5 Human responses times of two different metabolisms

increment of muscle contraction. Although there was a time gap between 5.3 met and 8.4 met, muscle activities had a tendency to increase, and these appearances were on the decrease gradually. Particularly, in 8.4 met, we could see that muscle activities were rapidly getting to increment after 9 minutes.

4. Conclusions

In this study, we examined the two case of relationship. One case was the relationship between the EMG and skin temperature responses to whole body. The other case was the relationship between EMG and human metabolism to whole body, and these experiments were done at different physical exercise when subsequently exposed to cold air. Muscle activities increased when they were exposed in cold air and decrease as time goes by. Also result of skin temperature displayed a similar trend. In our opinion, this result was due to the rapid increment of muscle contraction as evaporation of sweat. Comparing with each case, we could find the increment degree of muscle activities were due to the perspiration of human skin. These results suggest that prior physical exercise may predispose a person to greater heat loss and to experience a larger decline in EMG and skin temperature when subsequently exposed to cold exposure. But, if we were to accurately measure the human skin condition, we would get the more quantitative human activity data. In the future study, we will consider to measure a precise data of human skin humidity, including the sweat excreted from skin. And we also need to develop the epoch analyzing methods of the experimental data about various human bio-signals.

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REFERENCES

1. Donaldson G. C., et al,. "Effect of humidity and small air movement on thermal comfort under a radiant cooling ceiling by subjective experiments," Int. J. Biomaterial, Vol. 45, pp. 45-51, 2001.
2. Kaitlin M. W., "Excess Body Fat Lessens the Metabolic Response to Cold Exposure," Vol. 45, pp. 45-51. 2001.
3. Warwick P. M. and Busby R., "Influence of mild cold on 24 h energy expenditure in 'normally' clothed adults," Br J Nutr Vol. 63, pp. 481–488, 1990.
4. Frank S. M., Raja S. N., Bulcao C. F. and Goldstein D. S., "Relative contribution of core and cutaneous temperatures to thermal comfort and autonomic responses in humans," J Appl Physiol, Vol. 86, pp. 1588–1593, 1999
5. Benzinger T. H., "Heat regulation: homeostasis of central temperature in man," Physiol Rev, Vol. 49, pp. 671–759, 1969.
6. Fiala D., Lomas K. J. and Stohrer M., "Computer prediction of human thermoregulatory and temperature responses to a wide range of environmental conditions," Int J Biometeorol, Vol. 45, pp. 143–159, 2001.
7. Eyolfson D. A., Tikuisis P., Weseen G. and Giesbrecht G. G., "Measurement and prediction of peak shivering intensity in humans," Eur J Appl Physiol, Vol. 84, pp. 100–106, 2001.
8. Vybiral S., Lesna I., Jansky L. and Zeman V., "Thermoregulation in winter swimmers and physiological significance of human catecholamine thermogenesis," Exp Physiol, Vol. 85, pp. 321–326, 2001.
9. Nedergaard J., Golozoubova V., Matthias A., Asadi A., Jacobsson A. and Cannon B., (2001) "UCP1: the only protein able to mediate adaptive non-shivering thermogenesis and metabolic inefficiency," Biochim Biophys Acta, Vol.1504, pp.82–106, 2001.
10. Ooijen A. M., van Marken Lichtenbelt W. D., van Steenhoven A. A. and Westerterp K. R., "Seasonal changes in metabolic and temperature responses to cold air in humans," Physiol Behav, Vol.82, pp.545–553, 2004
11. Dauncey M. J., "Influence of mild cold on 24h energy expenditure, resting metabolism and diet-induced thermogenesis," Br J Nutr, Vol.45, pp. 257–267, 1981
12. Ravussin E., Lillioja S., Knowler W. C., Christin L., Freymond D., Abbott W. G., Howard B. W. and Bogardus C., "Reduced rate of energy expenditure as a risk factor for body-weight gain," N Engl J Med, Vol.318, pp.467–472, 1988
13. Van Marken Lichtenbelt W. D. and Daanen H. A., "Cold-induced metabolism," Curr Opin Clin Nutr Metab Care, Vol. 6, pp. 469–475, 2003.
14. Rome L. C., "Influence of temperature on muscle recruitment and muscle function in vivo," Am J Physiol, Vol. 259: pp. 210-222, 1990.
15. Sargeant A. J. "Effect of muscle temperature on leg extension force and short-term power output in humans," Eur J Appl Physiol, Vol. 56, pp. 693-698, 1997.
16. Faulkner J. A., Zerba E., and Brooks S. V., "Muscle temperature of mammals: cooling impairs most functional properties," Am J Physiol, Vol.28, pp. 259-265, 1990.
17. Bigland-Ritchie B., Donovan E. F. and Roussos C. S., "Conduction velocity and EMG power spectrum changes in fatigue of sustained maximal efforts," J Appl Physiol, Vol. 51 pp. 1300-1305, 1981.