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# Effects of Wearing Gloves and Sex on Endurance Time and the Corresponding Finger Skin Temperature During a Cold Immersion

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## 1. Introduction

Many workers, such as commercial fishermen, power-line workers in temperate climates, and frozen-food processing industry workers, need to perform manual work in cold environments. Exposure to cold environments and contact with cold materials have been reported impair tactile sensitivity in the hands (Enander, 1984), hand dexterity (Schiefer et al., 1984; Riley & Cochran, 1984; Enander & Hygge, 1990; Heus et al., 1995), and tracking performance (Goonetilleke & Hoffmann, 2009). Manual dexterity is frequently used to evaluate hand function and is important during hand manipulation. Hand/finger skin temperature is considered a vital factor in dexterity (Schiefer et al., 1984; Enander, 1984; Enander & Hygge, 1990; Brajkovic & Ducharme, 2003, Chen et al., 2010) and hand performance (Riley & Cochran, 1984; Havenith et al., 1995, Chen et al., 2010). More importantly, such impairment may lead to an increased number of accidents (Müller, 1982; cited by Havenith et al., 1995).

Several epidemiologic studies have shown that, in addition to heavy physical work, awkward and static postures, repetition of movements, and vibration, cold may be a risk factor for occurrence or aggravation of musculoskeletal disorders (MSDs), such as in the fish-processing industry (Chiang et al., 1993; Nordander et al., 1999) and meat-processing factories (Kurppa et al., 1991; Piedrahíta et al., 2004). A report by the European Agency for Safety and Health at Work (2010) also noted that the risk of MSDs increases with work in cold environments.

In order to protect the hands from cold, gloves are recommended as a first line of defense. Unfortunately, although wearing gloves does not affect muscular fatigue (Chang & Shih, 2007), doing so could cause a negative effect on exertion (Shih, 2007; Chang & Shih, 2007) and dexterity (Bishu & Klute, 1995; Ou, 2003). On the other hand, gloves can insulate the hands against cold. For example, in a dialogue test of 12°C-water and 5-minute immersion to assess the hand-arm vibration syndrome (ISO/CD 14835-1, 2001), researchers have

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revealed that wearing gloves can not only reduce pain but also delay a decrease in finger skin temperature (FST) (Suizu et al., 2004; Suizu & Harada, 2005). In addition, Nag and Nag (2007), who evaluated the hazards and health complaints associated with fish processing activities in India, indicated that, during a 2-hour period of work, wearing latex gloves could improve the FST and HST, raise morale in female workers, and alleviate cold-induced symptoms. Therefore, due to both the delay on FST decrease and reduction in perceived pain, one of the objectives of this study is to examine if wearing gloves can prolong the endurance time (ET) in a cold immersion, and if thicker gloves will lead to longer ET.

Geng et al. (2001) indicated that type of material and surface temperature affected the contact cooling of the finger significantly. They found that materials with high thermal conductivity and/or lower surface temperature decreased FST more rapidly. The trend of a FST decrement during cold immersion should slow gradually as the heat balance approaches. At first, rapid heat dissipation occurs between two objects in contact due to a great difference in temperatures, accompanied by a rapid decrease in FST, a noticeable sensation of cold, and associated induced pain. Wearing gloves could delay the reduction in FST and reduce the perception of pain (Suizu et al., 2004; Suizu & Harada, 2005), and it is supposed that wearing gloves could also extend ET. Consequently, it is worthwhile and interesting to identify the FST at the point of pain tolerance during cold immersion, for FST has been reported as a crucial factor affecting hand dexterity (Schiefer et al., 1984; Enander, 1984; Enander & Hygge, 1990; Brajkovic & Ducharme, 2003; Chen et al., 2010). Wolff (1984) defined pain tolerance as 'that point at which a subject will terminate or withdraw from noxious stimulation' and argued that tolerance measures in the laboratory are analogous to clinical pain.

Meanwhile, experimental pain, such as that induced by cold water, is usually rated by psychophysics, which investigates the correspondence between the magnitude of stimulus properties as assessed by both the instruments of physics and the perceptual systems of people (Baird & Noma, 1978). Over the years, many types and shapes of scales have been developed for use in psychophysical studies. One of the most commonly used scales for evaluating subjective qualities during dynamic physical work is the 15-point rated perceived exertion (RPE) scale developed by Borg (1970). Later on, Borg (1982) developed a new rating scale constructed as a category scale with ratio properties called the Category Ratio scale (CR-10 scale). It combines the positive attributes of category and ratio scales and hence allows relative comparisons as well as level estimations. Borg recommends the use of the CR-10 scale to determine subjective symptoms, such as aches and pain. Åkesson et al. (1999) and Dederling et al. (2006), for example, used this scale to rate pain. Since the CR-10 scale functions as a ratio scale, most kinds of mathematical operations are permitted.

During cold-water immersion, different levels of perceived pain are generated, gradually rising from the bottom to the top of the pain tolerance scale defined by Wolff (1984). Pain tolerance as a dependent variable is the central behavioral measure of an individual's ability to endure any given level and type of pain stimulation (Keefe & Williams, 1992). The second objective of the present study is, therefore, to examine the FST of different gloved conditions under a given level of perceived pain as classified by Borg's CR-10 scale. In addition, a linear model between Borg's CR-10 scale and ET and FST is explored.

Furthermore, the variability of experimental pain perception results from a variety of sources, such as psychosocial factors, biological factors, and experimental variables. A sex difference in response to experimental induced pain is reported to be significant, and female workforces are increasing in size and importance in some light manual operations. Even though women have generally been reported to have a lower pain threshold, a greater ability to discriminate painful sensations, higher pain ratings, and a lower tolerance for pain (Berkley, 1997), studies employing different populations and types of pain have not consistently found differences in gender and pain intensity. If the capacity of cold tolerance of the hands depends on gender, such a difference is an interesting issue and should not be ignored. The functional capacity chosen here is the endurance of the hand during immersion in cold water and its correspondence to different levels of perceived pain. The issue of interest is whether two factors, wearing gloves and gender, affect this functional capacity. Pain tolerance as a dependent variable is, therefore, the central behavioral measure of an individual's ability to endure any given level and type of pain stimulation (Keefe & Williams, 1992). Consequently, the present paper also examines the sex effect on the capacity for tolerance of cold-water-induced pain on hands and the corresponding change in FST.

In summary, the main objective of the present study is to explore the effects of gloves and sex on FST and ET under different levels of cold-induced pain cataloged according to the CR-10 scale in a cold immersion. Additionally, the linear relationship between the CR-10 scale, ET, and FST will be studied.

## 2. Methods

Most studies on hand cooling have been carried out with immersion into cold water (cold pressor test) (Petrofsky & Lind, 1980; Suizu & Harada, 2005; Geurts et al., 2006; Coulangue et al., 2006), contact with cold materials (Havenith et al., 1992; Chen et al., 1994), or exposure in cold air (Candas & Dufour, 2007). The cold pressor test, a procedure in which subjects are instructed to immerse a limb into a cold-water bath, has been considered one of the most valid methods for inducing pain to meet the criteria of controllability, reliability, discriminability, convenience, and validity (Hirsch & Liebert, 1998). Thus, the cold pressor test was employed in the present study to cool the skin temperatures.

### 2.1 Participants

Fifteen men and fifteen women participated in the experiment, and all but two males were right-handed. They were free from any neuromuscular and musculoskeletal disorders, and their demographics and anthropometrics are shown Table 1.

### 2.2 Apparatus and materials

The apparatus and materials employed were as follows.

1. A water bath made by Firstek Co. (Model: B102) was used. It can maintain the temperature constantly at a desired level with an electronic thermo-sensor and a heater. The minimum temperature is the ambient temperature plus 5°C, and the maximum is 80°C. Its exterior (W×D×H) is 54×33×27 cm<sup>3</sup>, and the interior is 49×29×15 cm<sup>3</sup>.

- 2. A submersible cooler made by Firstek Co. (Model: HC-101) was used to cool the water from the ambient to -20°C. At 20°C, the cooling efficiency is 750 Kcal/hr. During immersion, it was submersed in the water bath to cool the water, and the water temperature was set and regulated by the electronic thermo-sensor of the previous water bath.
- 3. A digital thermometer and hygrometer (TECPEL Co.; Model: DTM301) was used to monitor the ambient temperature and humidity at the same time. The temperature range measured was from -10°C to +50°C. Relative humidity measured ranged from 20% to 99%.
- 4. A digital 4-channel thermometer made by TECPEL Co. (Model: DTM319) with a size of 184x64x30 (WxDxH) mm<sup>3</sup> was used to record skin temperatures. The memory capacity is 16,000 records of data. The sampling rate was 6 data/minute, and it was connected to a personal computer with an RS-232 link.
- 5. Latex gloves with six available sizes made by Modern Healthcare Co. (Model: 1010) were used. Here, the latex gloves are evaluated due to their widespread use in processing and packing in the frozen foodstuff industry in Taiwan.

| Item (unit)       | Sex    | Mean  | SD   | Range     |
|-------------------|--------|-------|------|-----------|
| Age (yr.)         | Male   | 24.1  | 4.9  | 20~35     |
|                   | Female | 28.8  | 4.8  | 22~38     |
| Height (cm)       | Male   | 172.8 | 4.3  | 165~180   |
|                   | Female | 160.2 | 4.5  | 150~168   |
| Weight (kgw)      | Male   | 70.5  | 10.4 | 55~103    |
|                   | Female | 54.5  | 5.6  | 45~65     |
| Hand length (cm)  | Male   | 18.9  | 0.6  | 17.8~19.7 |
|                   | Female | 17.3  | 0.8  | 16.2~19   |
| Palm length (cm)  | Male   | 9.8   | 0.5  | 8.8~10.8  |
|                   | Female | 9.0   | 0.6  | 8.0~9.8   |
| Palm breadth (cm) | Male   | 8.2   | 0.3  | 7.6~8.7   |
|                   | Female | 7.0   | 0.3  | 6.6~7.5   |

Table 1. The anthropometric data of subjects (SD: standard deviation)

2.3 Experimental procedures and data acquisition

All participants were well informed of the goals and procedures first. The mean ambient temperature (standard deviation, SD) was 19.2°C (1.1°C), and mean relative humidity (SD) was 62% (8%). Before immersion, two channels of the 4-channel digital thermometer were applied to monitor the FST on the ventral side of the distal phalanges of both the thumb ( $FST_T$ ) and the little finger ( $FST_L$ ) of the left hand. The thermo-sensor was first fixed by surgical tape to the fingertips, then a thick waterproof bandage was wrapped, and the fingers were covered by additional rubber coverings. Finally, adhesive tape was used to close the opening of the rubber coverings without severe tape tension that might occlude

blood flow. Initial FSTs (denoted by  $FST_{T0}$  and  $FST_{L0}$ ) were both controlled in a range of 30–35°C by immersing the left hand in a 30°C-water bath for a short duration to minimize the possible inference of initial FST on endurance time (ET) needed to reach a corresponding level of pain perceived. To standardize limb submersion across subjects, subjects were instructed that, when signaled, they should place their left hands into the water up to about 1/3 of the forearm above the wrist.

From the beginning of immersion to withdrawal of their left hands from the water tank, participants were instructed to self-report five perceived levels of cold-water-induced pain according to the Borg 10-point CR scale: just noticeable (0.5), weak (2), strong (5), very strong (7), and extremely strong (10) discomfort (almost unbearable). At the same time, the associated ET ( $ET_i$ ,  $i = 1, 2, 3, 4, 5$ ) and corresponding FSTs ( $FST_{Ti}$  and  $FST_{Li}$ ,  $i = 1, 2, 3, 4, 5$ ) were recorded.

## 2.4 Experimental design and data analysis

A nested-factorial design was employed, in which the factors were sex, subject (nested within sex), gloved condition, and level of perceived pain. Three gloved conditions involved bare hand (0G), wearing a single layer (1G), or wearing a double layer (2G) of latex gloves. The water temperature was set at 10°C, and each treatment was repeated twice. The level of significance ( $\alpha$ ) was set at 0.05, and the responses analyzed are as follows.

1. The endurance time (ET) was the time needed to reach the five separate perceived pain levels, denoted by  $ET_i$  ( $i = 1, 2, 3, 4, 5$ ). Each  $ET_i$  was the mean value of two replications. Here the  $ET_5$  is the time to reach the pain tolerance defined by Wolff (1984).
2. The  $FST_i$  corresponded to  $ET_i$ .  $FST_i$  is a mean value measured on the little finger ( $FST_{Li}$ ) and thumb ( $FST_{Ti}$ ) of two replications ( $i = 1, 2, 3, 4, 5$ ). They are 1-min average values calculated from 30 sec before and after the time  $ET_i$  of each replication.
3. The exchange rate of FST at different pain levels from the beginning. They are defined as  $Rate_{i0} = (FST_i - FST_0) / ET_i$ , where  $i = 1, 2, 3, 4, 5$ .

## 3. Results

### 3.1 Endurance Time (ET)

As shown in Table 2, which shows the ANOVA results for all responses, all main effects were significant, as well as the gloved $\times$ level. In general, males had a longer ET than females (113.9 vs. 101.9 sec). Figure 1, demonstrating the gloved effect at different levels of perceived pain, indicates that wearing gloves is able to prolong ET, and more layers is associated with longer ET. Definitely, the longer ET contributed to greater cold-water-induced pain.

Figure 1 further shows that, based on the bare hand (0G) condition, subjects were willing to immerse their hands in a 10°C water bath for about 2 and 3 times longer in the 1G and 2G conditions, respectively. In detail, Table 3 indicates that the ET of the 1G condition was from



2.5 times at  $ET_1$  to 1.9 times at  $ET_5$  ; for the 2G condition, it was from about 4.3 times to 3.1 times from  $ET_1$  to  $ET_5$  . The ET of 2G was around 1.6-1.7 times that of 1G for all pain-perceived levels.

| Sources of variation | ET   |        |         |         | Rate  |         |         | FST  |       |         |         |
|----------------------|------|--------|---------|---------|-------|---------|---------|------|-------|---------|---------|
|                      | d.f. | MS     | F-value | p-value | MS    | F-value | p-value | d.f. | MS    | F-value | p-value |
| Subject (Sex)        | 28   | 58468  | 24.408  | 0.0000  | 4.742 | 19.591  | 0.0000  | 28   | 49.7  | 24.9    | 0.0000  |
| Sex                  | 1    | 16200  | 6.763   | 0.0097  | 1.427 | 5.894   | 0.0156  | 1    | 22.5  | 11.3    | 0.0009  |
| Gloved               | 2    | 531877 | 222.037 | 0.0000  | 1.122 | 4.634   | 0.0103  | 2    | 298.8 | 149.5   | 0.0000  |
| Level                | 4    | 230914 | 96.397  | 0.0000  | 4.596 | 18.988  | 0.0000  | 5    | 304.1 | 152.2   | 0.0000  |
| Sex*Gloved           | 2    | 4515   | 1.885   | 0.1532  | 0.117 | 0.482   | 0.6181  | 2    | 1.2   | 0.6     | 0.5627  |
| Sex* Level           | 4    | 36     | 0.015   | 0.9995  | 0.144 | 0.594   | 0.6671  | 5    | 0.8   | 0.4     | 0.8339  |
| Gloved*Time          | 8    | 19600  | 8.182   | 0.0000  | 0.541 | 2.234   | 0.0244  | 10   | 18.1  | 9.0     | 0.0000  |
| Sex*Gloved* Level    | 8    | 83     | 0.035   | 1.0000  | 0.025 | 0.103   | 0.9991  | 10   | 0.1   | 0.1     | 1.0000  |
| Error                | 392  | 2395   |         |         | 0.242 |         |         | 476  | 2.0   |         |         |
| Total                | 449  |        |         |         |       |         |         | 539  |       |         |         |

Table 2. The ANOVA results

|        | Level of perceived pain |     |     |     |     |
|--------|-------------------------|-----|-----|-----|-----|
|        | L1                      | L2  | L3  | L4  | L5  |
| Gloved |                         |     |     |     |     |
| 1G/0G  | 2.5                     | 2.3 | 2.1 | 2.0 | 1.9 |
| 2G/0G  | 4.3                     | 3.6 | 3.4 | 3.3 | 3.1 |
| 2G/1G  | 1.7                     | 1.6 | 1.6 | 1.6 | 1.7 |

Table 3. The times of ET based on 0G or 1G at different levels of perceived pain

3.2 Finger Skin Temperature (FST)

First, to examine the  $FST_0$ , which was controlled in a range of 30-35°C prior to immersion, the overall mean (SD) was 32.1 (0.56). ANOVA showed that there was no significant difference in  $FST_0$  between genders or among gloved conditions. That is, the initial FST,  $FST_0$ , was well controlled. Table 2 indicates that all main effects and gloved×level interaction were significant on FST. Figure 2 demonstrates the gloved effect on FST at different pain-perceived levels and indicates that, given a pain level, more layers corresponded to lower FST. At  $ET_5$ , the FST was 29.1, 27.3, and 24.7°C for 0G, 1G and 2G,

respectively, and it was 3.1, 4.8, and 7.5°C lower than  $FST_0$  for 0G, 1G and 2G. In general, greater perceived pain corresponded to lower FST. The significant sex effect reveals that the FST of females was 0.4°C higher than that of males, but this minor difference seems negligible in the workplace.

3.3 The exchange rate on FST

Moreover, the ANOVA results for the exchange rate on FST in Table 2 revealed that all main effects and gloved×level interaction were significant. The gloved×level interaction plotted in Figure 3 reveals that with fewer layers the gloves, the rate was steeper. The variation in heat exchange for the bare hand condition (0G) from the beginning to the end was the steepest (-1.22~ -2.00°C/min), second for 1G (-1.14~ -1.72°C/min), and the flattest for 2G (-1.44~ -1.67°C/min). In the whole immersion process, the mean exchange rates on FST ( $Rate_{50}$ ) were -2.00, -1.71, and -1.65°C/min for 0G, 1G, and 2G, respectively. Males had a greater reduction rate in FST than females (-1.7 vs. -1.54°C/min).

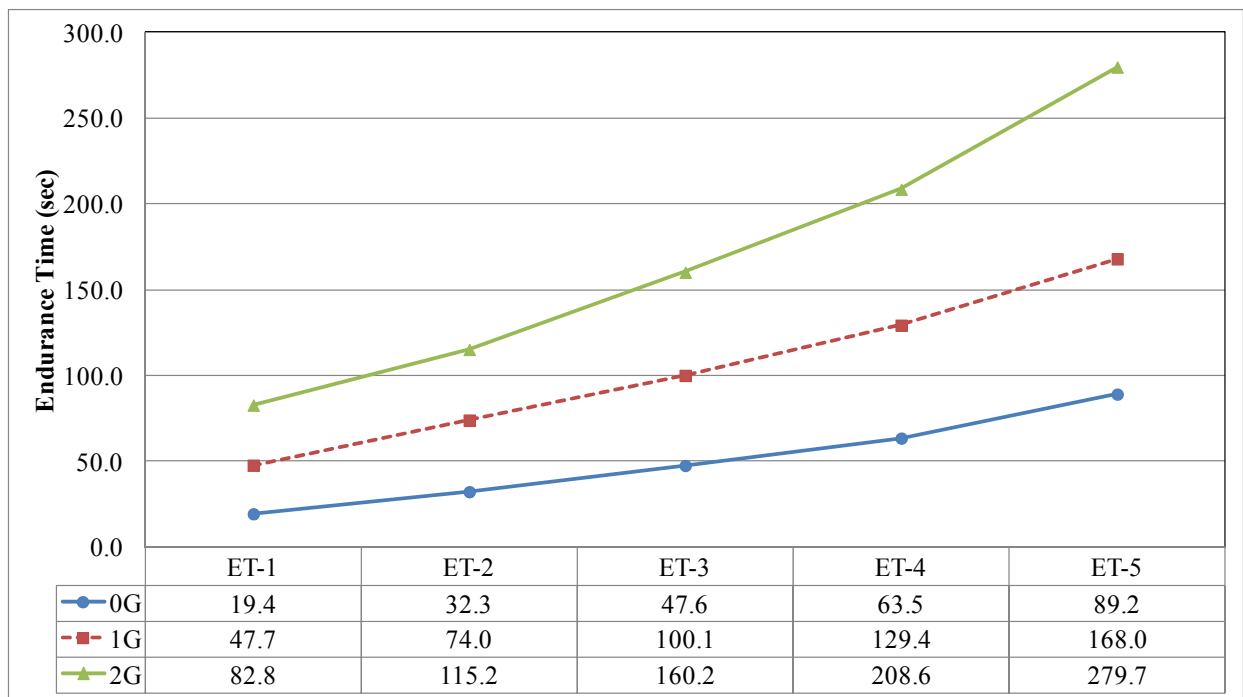


Fig. 1. Gloved effect on ET at different levels of perceived pain



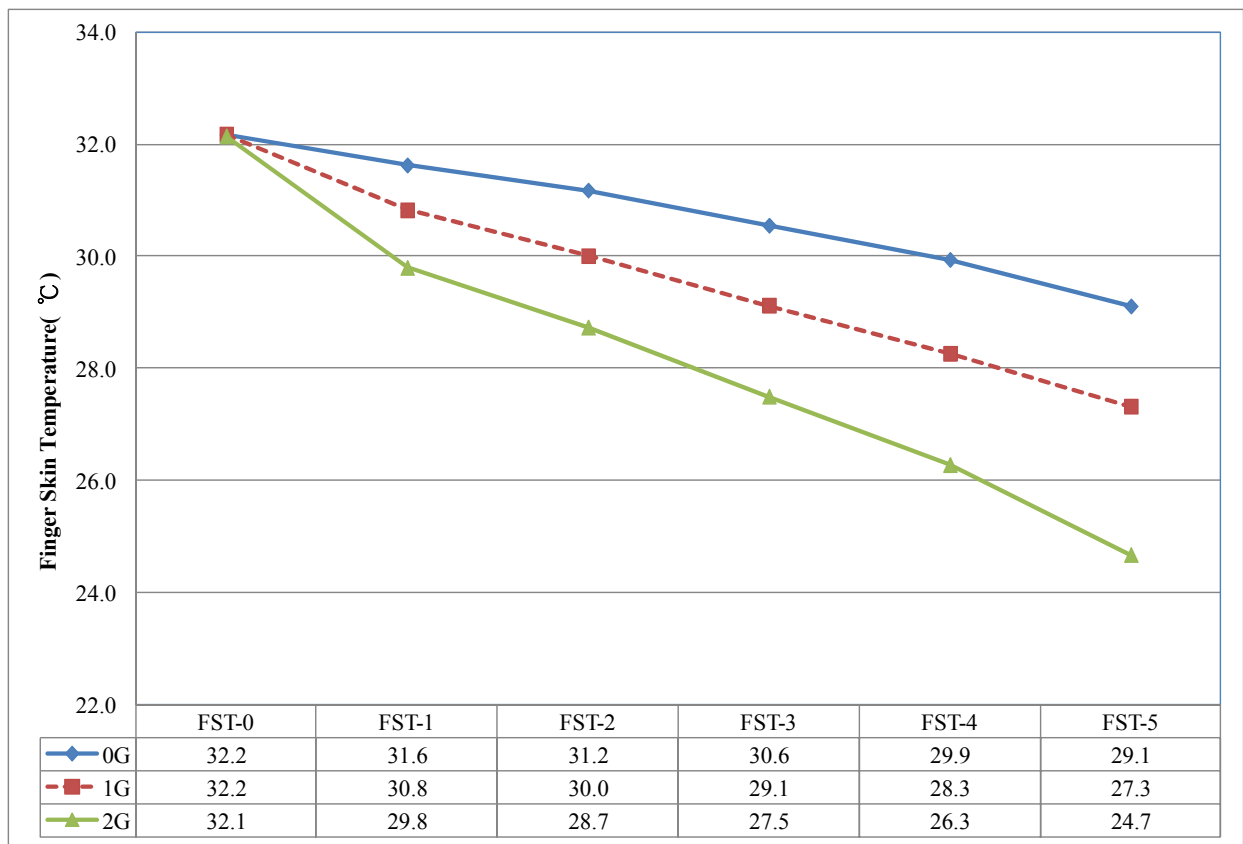


Fig. 2. Gloved effect on FST at different levels of perceived pain

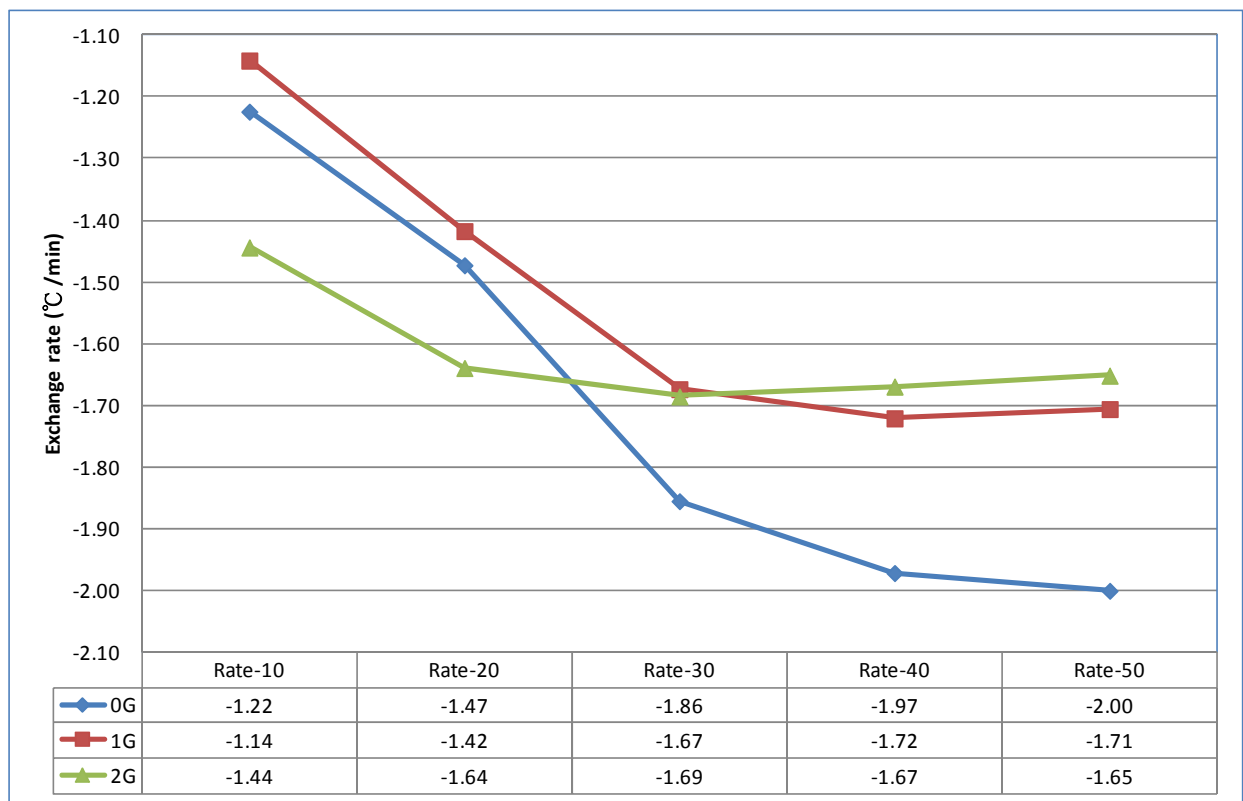


Fig. 3. Gloved effect on exchange rate on FST at different levels of perceived pain

3.4 The linear relationships between Borg’s CR scale, ET, and FST

Five self-reported levels of perceived pain, based on Borg’s CR scale, were first assigned the number 0.5 (just noticeable), 2 (weak), 5 (strong), 7 (very strong), and 10 (extremely strong), respectively. The linear relationship between Borg’s CR scale (predictor) and  $ET_i$  was examined for the bare-hand condition of each subject. For both sexes, all the intercepts ( $\beta_0$ ) and all the slopes ( $\beta_1$ ) differed from zero significantly. Intercepts ( $\beta_0$ ) were in the range of -3.6 ~ 42.2 for males and 0.6 ~ 39.8 for females. The slopes ( $\beta_1$ ) were in the range of 2.3 ~ 26.6 for males and 1.4 ~18.6 for females. The corresponding  $R^2$  ranged from 0.70 to 0.99 for males and 0.55 to 0.97 for females. These results imply that Borg’s CR scale is a good predictor for how long subjects are willing to immerse their bare hands in 10°C water.

Moreover, to compare the gloved effect on ET and  $\Delta FST$  ( $FST_i - FST_0$ ), the ET and  $\Delta FST$  values among subjects were averaged. A simple regression model using Borg’s CR scale as the predictor was built. Table 4 shows the intercept ( $\beta_0$ ), slope ( $\beta_1$ ), and  $R^2$ . It indicates the  $R^2$  s were very high, all above 0.95.

For ET, except for  $\beta_0$  under the 2G condition, the  $\beta_0$  s and all  $\beta_1$  s between males and females seemed not to differ pronouncedly. That could be why the ET of males was 12 sec longer than that of females (113.9 vs. 101.9 sec). In addition,  $\beta_0$  s among the three gloved conditions seemed to differ dramatically, as did the  $\beta_1$ . The reason could be that more layers of gloves led to a longer ET. As to FST, with more layers of gloves, FST decreased more greatly when increasing by one Borg rating, and males seemed to be able to bear more reduction in FST than females. The aforementioned findings are consistent with the ANOVA results.

| Gloved | Parameters | ET   |        | $\Delta FST$ |        |
|--------|------------|------|--------|--------------|--------|
|        |            | Male | Female | Male         | Female |
| Bare   | $\beta_0$  | 16.4 | 14.8   | -0.59        | -0.23  |
|        | $\beta_1$  | 7.5  | 6.7    | -0.26        | -0.26  |
|        | $R^2$      | 0.98 | 0.99   | 0.99         | 0.99   |
| 1G     | $\beta_0$  | 46.8 | 40.7   | -1.55        | -1.04  |
|        | $\beta_1$  | 12.3 | 12.3   | -0.33        | -0.39  |
|        | $R^2$      | 0.99 | 0.99   | 0.99         | 0.99   |
| 2G     | $\beta_0$  | 82.2 | 57.3   | -2.52        | -1.80  |
|        | $\beta_1$  | 20.3 | 20.3   | -0.50        | -0.56  |
|        | $R^2$      | 0.99 | 0.98   | 0.99         | 0.99   |

Table 4. The regression parameters for using Borg’s scale as predictor at different gloved conditions (  $ET$  or  $\Delta FST = \beta_0 + \beta_1 \times Borg$  )

In order to eliminate individual differences, normalized  $ET_i$ , say  $ET_i(\%)$  ( $i = 1, 2, 3, 4, 5$ ), was tested. It was found that neither the gloved effect nor the sex effect was significant under any given pain-level. Mean  $ET_i(\%)$  was 26.5, 41.6, 58.7, 76.1, and 100 for just noticeable, weak, strong, very strong, and extremely strong, respectively. The linear model was built as  $ET(\%) = 23.6 + 7.53 \times Borg$ ,  $R^2 = 0.99$ . It indicated that to increase one point in the Borg scale, subjects could immerse their hands in the 10°C water for 7.53% more of the ET.

As expected, a longer ET (predictor) led to more reduction in FST ( $\Delta FST$ ), and a good linear relationship was found between the two ( $\Delta FST = \beta_1 \times ET$ ). The slopes ( $\beta_1$ ) of the regression model for the bare-hand, 1G, and 2G conditions were -2.04, -1.77, and -1.66 (°C/min), respectively. The  $R^2$ s were all above 0.99, indicating that the bare-hand condition allowed greater heat dissipation on the hand than the gloved condition did.

#### 4. Discussion

Cold may act in two ways to increase the risk of musculoskeletal disorders: directly, by its effect on body tissue, and indirectly, from the possible problems caused by the personal protective equipment used to alleviate its effect (Hagberg et al., 1995). Wearing gloves can retard the heat exchange, and, as expected, this prolongs the time of exposure of the hand in 10°C water. Unexpectedly, this longer exposure even leads to lower FST. At first, it was expected that the shorter ET of the bare-hand condition would be associated with a lower FST, but this expectation was not observed. In contrast, the shorter barehanded ET could be contributed by the impact of touching the cold water directly, which resulted in a faster rate of heat exchange. One of the goals of wearing gloves is to protect the hands from contact with cold/hot objects. According to the above results, under a given level of perceived pain, more layers of gloves extended the ET, leading to a lower corresponding FST. This trend may have been caused by the retarded heat exchange due to the wearing of gloves. Wearing gloves could prolong the ET to reach a given FST (Clark & Cohen, 1960) or delay the reduction in FST at a given endurance time (Suizu et al., 2004; Suizu & Harada, 2005). A lower FST associated with wearing gloves first numbs the hands, and gradually impairs the hand function and performance (such as dexterity, sensitivity, and strength generation), eventually leading to frostbite and damage to the hands. On the positive side, wearing gloves is at least able to prolong the exposure time in a cold environment, and this actually delays the harmful impact from the cold directly. The slower exchange rate could be one reason to encourage subjects to keep their hands in the cold water longer (with longer ET). As a result, wearing gloves seems to be a good recommendation, but adequate time to rewarm the hands is important to avoid a continuous reduction of FST.

Clark and Cohen (1960) investigated the effect of cooling rate (fast: 0°F and slow: 20°F) on manual operating time (knot tying) during cold exposure and during subsequent rewarming (75°F). During cooling, they indicated that the time needed to reduce FST to a given working temperature was longer, and more operating time was observed when the cooling rate was slow; additionally, a slow cooling rate was also associated with a longer rewarming time and longer operating time during the subsequent rewarming stage. Furthermore, Sawada et al. (2000) evaluated how repeated 10-min cooling of fingers with a 5-min rest pause schedule at work affected cold-induced vasodilatation, pain, and cold sensation in the fingers in three ambient temperature conditions (30, 25, and 20°C). They

found that, at the ambient temperature of 20°C, the cold-induced vasodilatation response weakened continuously upon repetition of immersion and almost disappeared during the final immersion, and the recovery of FST during each post-immersion rest was delayed gradually upon repetition of immersion. At all three ambient temperatures, the pain and cold sensation induced by each cold-water immersion significantly decreased upon repetition of immersion. Later on, Geurts et al. (2005) additionally examined the effects of cold adaptation on the thermal response and neuromuscular function of the hand. They indicated that there was no significant change in maximal voluntary contraction strength or evoked contractile characteristics of the first dorsal interosseus after cold adaptation. Nevertheless, the mean and minimal FST decreased significantly after adaptation; the onset time was delayed and the amplitude of cold-induced vasodilatation decreased. The above findings seem to suggest that local cold adaptation of the hand does not enhance hand temperature or function, but it may put the hands at a greater risk of cold injury. Daanen et al. (1993) found impaired finger dexterity as FST fell below 14°C. Schieffer et al. (1984) found a slight reduction and a strong decrease in manual dexterity at 20-22°C and 15-16°C on FST, respectively. As a result, less heat exchange could acclimatize hands to the cold water gradually. The problem raised is that hands with lower FST and working in a cold environment for a long time could suffer reduced performance, and the lower FST could also potentially increase the possibility of musculoskeletal disorders. Unfortunately, wearing gloves for the sake of safety could enhance the local cold adaptation of the hand but lower the FST. Such a conclusion implies that when a bare hand directly contacts the cold water, FST falls more rapidly than when gloves are worn. Rapid reduction of FST causes a rapid sensation of pain, and it shortens the time for which subjects are willing to endure the pain.

The longer ET and lower FST of males seem to demonstrate that males have greater tolerance for cold-water immersion. These findings support past studies reporting a significant sex difference in response to experimental induced pain, and reports that women generally have a lower pain threshold, a greater ability to discriminate painful sensations, higher pain ratings, and a lower tolerance for pain (Berkley, 1997).

Finally, there is a good linear relationship between Borg's CR scale, ET, and reduction in FST. It is clear that the slope,  $\beta_1$ , is the change in response magnitude when the predictor changes by one unit. As to the intercept,  $\beta_0$ , it contains some unclear information, such as the difference in individuals, sex, age, and race. More studies are needed to identify and explain the meaning of the intercept.

## 5. Conclusions

Wearing gloves can insulate the hand in cold water and decrease the speed of heat dissipation; therefore, wearing gloves possibly allows hands to accommodate gradually to the cold environment and possibly prolongs the endurance time. With gloves, FST decreases gradually to reach a level lower than that in the bare-hand condition, and this could possibly not only impair hand performance but also encourage operators to prolong the duration of working. Such a practice could increase the probability of injury to the hands in a cold environment. In addition, males have greater tolerance for cold-water immersion. Finally, good mutual linear relationships exist among ET,  $\Delta$ FST, and Borg's CR-10 scale.

## 6. References

- Åkesson, I., Johnsson, B., Rylander, L., Moritz, U. & Skerfving, S. (1999). Musculoskeletal disorders among female dental personnel- clinical examination and a 5-year follow-up study of symptoms. *International Archives of Occupational and Environmental Health*, 72(6): 395-403.
- Baird, J.C. & Noma, E. (1978). *Fundamentals of scaling and psychophysics*. Wiley, New York.
- Berkley, K.J. (1997). Sex differences in pain. *Behavioral Brain Science*, 20: 371-380, 435-513
- Bishu, R.R. & Klute, G., 1995. The effects of extra vehicular activity (EVA) gloves on human performance. *International Journal of Industrial Ergonomics*, 16: 165-174.
- Borg, G.A.V. (1970). Perceived exertion as an indicator of somatic stress. *Scandinavian Journal of Rehabilitation Medicine*, 2(3): 137-148.
- Borg, G.A.V. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exertion*, 4(5): 377-381.
- Brajkovic, D., & Ducharme, M. B. (2003). Finger dexterity, skin temperature, and blood flow during auxiliary heating in the cold. *Journal Applied Physiology*, 95: 758-770.
- Candas, V., & Dufour, A. (2007). Hand skin temperature associated with local hand discomfort under whole-body cold exposure. *Journal of the Human-Environment System*, 10(1): 31-37.
- Chang, C.H. & Shih, Y.C. (2007). The Effects of Glove Thickness and Work Load on Female Hand Performance and Fatigue during an Infrequent High-Intensity Gripping Task. *Applied Ergonomics*, 38(3): 317-324
- Chen, W. L., Shih, Y.C., & Chi, C.F. (2010). Hand and finger dexterity as a function of skin temperature, EMG, and ambient condition. *Human Factors*, 52(3): 426-440
- Chen, F., Nilsson, H., & Holmer, I. (1994). Finger cooling by contact with cold aluminum surfaces- effects of pressure, mass, and whole body thermal balance. *European Journal of Applied Physiology*, 69: 55-60.
- Chiang, H.C., Ko, Y.C., Chen, S.S., Yu, H.S., Wu, T.N., & Chang, P.Y. (1993). Prevalence of shoulder and upper-limb disorders among workers in the fish-processing industry. *Scandinavian Work Environment Health*, 19(2): 126-131
- Clark, R.E., & Cohen, A. (1960). Manual performance as a function of rate of change in hand temperature. *Journal of Applied Physiology*, 15: 496-498.
- Coulanges, M., Hug, F., Kipson, N., Robinet, C., Desruelle, A. V., Melin, B., Jimenez, C., Galland, F., & Jammes, Y. (2006). Consequences of prolong total body immersion in cold water on muscle performance and EMG activity. *Pflügers Archiv European Journal of Physiology*, 452: 91-101.
- Daanen H.A.M., Wammes L.J.A., & Vrijkotte T.G.M. (1993). *Windchill and dexterity*. Report IZF A-7, TNO Institute for Perception, Soesterberg, NL.
- Dedering, Å., Harms-Ringdahl, K., & Nèmeth, G. (2006). Back extensor muscle fatigue in patients with lumbar disc herniation. *European Spine Journal*, 15(5): 559-569
- Enander, A. (1984). Performance and sensory aspects of work in cold environments: a review. *Ergonomics*, 27: 365-378.
- Enander, A. E., & Hygge, S. (1990). Thermal stress and human performance. *Scandinavian Journal of work Environment & Health*, 16(Suppl. 1): 44-50.
- European Agency for Safety and Health at Work (2010). *OSH in figures: Work-related musculoskeletal disorders in the EU – Facts and figures*. Office for Official Publications of the European Communities.



- Geng, Q., Holmér, I., & Coldsurf research group (2001). Change in contact temperature of finger touching on cold surface. *International Journal of Industrial Ergonomics*, 27:387-391.
- Geurts, C. L. M., Sleivert, G. G., & Cheung, S. S. (2006). Local cold acclimation during exercise and its effect on neuromuscular function of the hand. *Applied Physiology Nutrition and Metabolism*, 31: 717-725.
- Geurts, C. L. M., Sleivert, G. G., & Cheung, S. S. (2005). Effect of cold-induced vasodilatation in the index finger on temperature and contractile characteristics of the first dorsal interosseus muscle during coldwater immersion. *European Journal of Applied Physiology*, 93: 524 - 529.
- Goonetilleke, R. S. & Hoffmann, E. R. (2009). Hand-skin temperature and tracking performance. *International Journal of Industrial Ergonomics*, 39(4): 590-595.
- Hagberg, M., Silverstein, B., Wells, R., Smith, M. J., Hendrick, H. W., Caravon P., & Perusse, M. (1995). Identification, measurement and evaluation of risk. In: Kuorinka, Forcier (Eds.), *Work Related Musculoskeletal Disorders (WMSD's), a reference book for prevention*. Taylor & Francis, London, pp. 139-145 and 162-163.
- Havenith, G., Van de Linde, E. J. G., & Heus, R. (1992). Pain, thermal sensation and cooling rates of hands while touching cold materials. *European Journal of Applied Physiology*, 65: 43-51.
- Havenith, G., Heus, R., & Daanen, H.A.M. (1995). The hand in the cold, performance and risk. *Arctic Medical Research*, 54(Suppl. 2): 37-47.
- Heus, R., Daanen, H. A. M., & Havenith, G. (1995). Physiological criteria for functioning of hands in the cold: a review. *Applied Ergonomics*, 26(1): 5-13.
- Hirsch, M.S. & Liebert, R.M. (1998). The physical and psychological experience of pain: the effects of labeling and cold pressor temperature on three pain measures in college women. *Pain*, 77: 41-48
- ISO/CD 14835-1 (2001). *Mechanical vibration and shock-Cold provocation tests for the assessment of peripheral vascular function-Part 1: Measurement and evaluation of finger skin temperature*. ISO/TC 108/SC 4/WG 11.
- Keefe, F.J. & Williams, D.A. (1992). Assessment of pain behaviors. In D.C. Turk and R. Melzack (Eds.), *Handbook of pain assessment*, Guilford Press, New York: 277-292.
- Kurppa, K., Viikari-Juntura, E., Kuosma, E., Huuskonen, M., & Kivi, P. (1991). Incidence of tenosynovitis or peritendinitis and epicondylitis in a meat-processing factory. *Scandinavian Journal of Work and Environmental Health*, 17(1): 32-37
- Nag, P.K. & Nag, A. (2007). Hazards and health complaints associated with fish processing activities in India- Evaluation of a low-cost intervention. *International Journal of Industrial Ergonomics*, 37: 125-132.
- Nordander, C., Ohlsson, K., Balogh, I., Rylander, L., Palsson, B., & Skerfving, S. (1999). Fish processing work: the impact of two sex dependent exposure profile on musculoskeletal health. *Occupational and Environmental Medicine*, 56: 256-264.
- Ou, Y.C. (2003). *The Influence of Operator-Equipment/tools Interface Factors on the Performances*. National Defense Management College, unpublished master thesis.
- Petrofsky, J. S., & Lind, A. R. (1980). The influence of temperature on the amplitude and frequency components of the EMG during brief and sustained isometric contraction. *European Journal of Applied Physiology*, 44: 189-200.



- Piedrahíta, H., Punnett, L., & Shahnavaz, H. (2004). Musculoskeletal symptoms in cold exposed and non-cold exposed workers. *International Journal of Industrial Ergonomics*, 34(4): 271-278
- Riley, M. W., & Cochran, D. J. (1984). Dexterity performance and reduced ambient temperature. *Human Factors*, 26: 207-214.
- Schieffer, R.E., Kok, R., Lewis, M.I., & Meese, G.B. (1984). Finger skin temperature and manual dexterity; some inter-group difference. *Applied Ergonomics*, 15(2): 135-141.
- Shih, Y.C. (2007). Glove and Gender Effects on Muscular Fatigue Evaluated by Endurance and Maximal Voluntary Contraction Measures. *Human Factors*, 49(1): 110-119.
- Suizu, K., Inoue, M., Fujimura, T., Morita, H., Inagaki, J., Kan, H., & Harada, N. (2004). Influence of waterproof covering on finger skin temperature and hand pain during immersion test for diagnosing hand-arm vibration syndrome. *Industrial Health*, 42: 79-82.
- Suizu, K. & Harada, N. (2005). Effects of waterproof covering on hand immersion tests using water at 10°C, 12°C and 15°C for diagnosis of hand-arm vibration syndrome. *International Archives Occupation Environment Health*, 78: 311-318.
- Sawada, S., Araki, S., & Yokoyama, K. (2000). Changes in cold-induced vasodilatation, pain and cold sensation in fingers caused by repeated finger cooling in a cool environment. *Industrial Health*, 38:79-86
- Wolff, B.B. (1984). *Methods of testing pain mechanisms in normal man*. In P.D. Wall and R. Melzack (Eds.), *Textbook of Pain*, Churchill Livingstone, New York, 186-194.

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