Investigating the Effects of Size on Glove Thermal Insulation Using a Thermal Hand

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Introduction In the past few decades, a large number of studies regarding thermal insulation of clothing have been carried out using thermal manikins. Furthermore, the effects of wind speed, body movement, garment size, and clothing design on the thermal insulation of clothing have been investigated (Li, et.al., 2011; Psikuta, et.al., 2012). It was found that thermal insulation increases with increasing clothing size. Thermal insulation for gloves has also been measured to assess comfort using thermal hands (Dotti, et.al., 2017; Zimmermann, et.al., 2008). However, the previous studies mainly focused on the thermal insulation among different types of gloves, rather than across different-sized gloves of the same type. Actually, the air gap thickness and volume between the skin of the hand and the gloves varies with the size of the gloves and on different locations on the hand, thereby affecting the heat and mass transfer between the skin and its thermal environment. Consequently, different-sized gloves will affect the thermal responses of hand and fingers as well as the thermal comfort. To design the next generation of high-performance gloves, it is critical to investigate the effects of size/fit on thermal insulation of gloves to enable both thermal protection and thermal comfort. In this study, the thermal insulation of two types of gloves with different sizes was measured and the effect of size/fit on thermal insulation was established.

Methods A thermal hand was used to test the dry thermal insulation of gloves and mittens in a climate chamber. It consists of eight independently heated thermal zones (palm, dorsal, thumb, index finger, middle finger, ring finger, little finger, and wrist). During the experiments, the ambient temperature and humidity of the chamber were set at 20±0.5°C and 65±5% according to ASTM F2732. The air velocity in the chamber was less than 0.1 m/s during the testing. The skin temperature of the thermal hand was set to 35 °C.

Three gauntlet Gore-Tex gloves (Style 1) and three gauntlet Gore-Tex mittens (Style 2) were selected with size M, size L and size XL from tight to loose. Average airgap thickness of fingers, palm and dorsal of gloves and mittens was obtained by averaged measurements of needle penetration depth through the glove/mitten to the thermal hand. A one-way ANOVA was applied to analyze the difference of the thermal insulation among the gloves and mittens respectively. A p-value of no more than 0.05 was considered statistically significant. Linear regression was applied to establish the relationship between the thermal insulation and air gap thickness.

Results and discussion The thermal insulation of the gloves and mittens increased with the sizes, shown in Figure 1 left. Generally, mittens have a larger air gap and higher insulation. The ANOVA analysis showed significant difference in the thermal insulation of different-sized mittens (p <0.05). To further investigate the relationship between sizes and thermal insulations of mittens, linear regression equation between thermal insulation and air gap thickness was established as Equation 1,

$$y=0.01x + 0.3555 \quad (1)$$

where y is the thermal insulation of mittens (°C·m²/W) , and x is the average air gap thickness of mittens (cm). The experimental and regression results showed that thermal insulation of mittens increased with the air gap thickness.

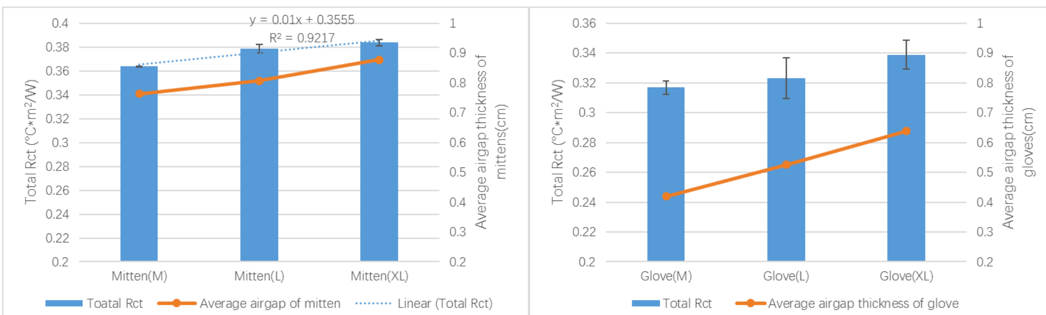

Figure 1. Total Rct of the gloves and mittens

However, there is no significant difference in the thermal insulation of different-sized gloves (p >0.05). One possible reason is the air gap thicknesses among glove sizes are minimal and not differentiable, especially at the fingers where size difference is mainly manifested by length but not circumference. On the other hand, mittens have more air trapped in, and less surface area for heat loss due to the design with four fingers together, compared to the gloves, thus allowing the still air to provide insulation that is more salient.

Conclusion The thermal insulation increased with the size for both the gloves and mittens due to a larger air gap thickness for the looser gloves. However, the effects of size on thermal insulation depend on the design. Significant difference in the thermal insulation was found among the mittens of different sizes, but not among the gloves of different sizes.

Reference

Xiaohui Li, Yunyi Wang, Yahoo Lu (2011). Effects of body postures on clothing air gap in protective clothing. Journal of Fiber Bioengineering & Informatics, 4(3), 277-283

Agnes, P., Joanna, F., Iwona, F., & Rene R. (2012). Quantitative evaluation of air gap thickness and contact area between body and garment. Textile Research Journal, 82(14), 1405-1413

Carsten Z., Wolfgang H., Bernhard K., & Karl J. (2008). Thermal comfort range of a military cold protection glove: database by thermophysiological simulation. Eur J Appl Physiol,

104,229-236
F Dotti, M Colonna, & A Ferri (2017). Thermal comfort of dual-chamber ski gloves. 17th World Textile Conference AUTEX 2017.