Radiant Heat Transfer Capabilities of Activewear Fabrics Analyzed by Infrared Thermography

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Keywords: infrared thermography, thermal comfort, heat transfer, active wear

Introduction/Significance. Clothing provides a layer of insulation for the human body and inflicts a barrier to heat transfer between the skin surface and the external environment, which can complicate the body's thermoregulatory function (Stapleton, Hardcastle, & Kenny, 2011). Therefore, many garments have been designed in the apparel industry with the purpose of providing enhanced heat dissipation, moisture management, and overall thermal comfort when worn during circumstances promoting heat stress, such as engagement in physical activity while in heated environments (Fohr, Couton, & Treguier, 2002). Heat transfer through clothing fabric occurs primarily through conduction and radiation (Havenith, 1999). Radiant heat transfer is one of the available pathways of heat loss from the body, and the amount of heat lost can vary depending on the fiber types of the clothing fabric worn. This study analyzes the differences in the heat transfer capabilities of four different fabric blends when heated at a temperature that simulates human body skin temperature. The information gained in this study can be added to the body of knowledge in selecting the most effective garments for heat transfer in thermally extreme conditions.

Literature review/Theoretical framework. Different research techniques have been employed to measure the radiant heat transfer characteristics of textiles. These include the use of thermal manikins, human subjects, and mathematical equations. With analyzing human subjects, fabrics can be examined in real-life circumstances, but the disadvantages with this technique are that it is time consuming, and the amount of heat given off by the subjects' bodies cannot be controlled for (Havenith, 1999). While many studies have been performed using human and non-human subjects, no studies have been published testing the heat transfer properties of fabrics when using a controlled temperature source and infrared thermography.

Methods. Four fabric samples, which were mostly widely used among extent activewears in the market, comprised of different blends were tested in the study. The compositions of the different fabric samples were as follows: 100% cotton (COT); a blend of 85% nylon and 15% elastane (NYL); a blend of 82% polyester and 18% elastane (POLY); and a blend of 48% Outlast® viscose, 48% Supima cotton, and 4% spandex (PCM). The latter fabric sample, produced by Outlast® Technologies, LLC, contained microencapsulated phase change materials (PCM) coated within the fibers. Fabric samples were heated for a period of 15 minutes by an SR 80 Extended Area Infrared Radiation Source. The SR 80 uses a blackbody emitter, which is an infrared radiation source that is used as a test standard for infrared testing in the 2 to 15 micron region of the radiation spectrum. Each fabric sample was firmly draped over the front of the source's emitter head, covering the total area of the emitter plate. To simulate the temperature of human skin, the temperature of the blackbody emitter was set at 35°C for all trials, which falls within the normal range of 32-35°C (Freitas, 1999). At the conclusion of each 5-minute interval, thermal images of each sample's surface (while still draped) were taken with an infrared imaging device (Computerized Thermal Imaging™ Thermal Imaging Processor). As a representation of the amount of heat transferred through the fabric, mean temperatures and temperature ranges of each sample's surface were obtained using the infrared imaging device. Subsequent "wet" trials were also administered, in which each sample was evenly sprayed with one ounce (1 fl. oz.) of water prior to being draped over the front of the emitter head.

Results/Conclusion. For the "dry" trials, the difference in mean temperature measurements between fabrics was significant ($p = 0.00$), with PCM (25.86 ± 0.24°C) being significantly lower than COT (26.62 ± 0.21°C), NYL (27.09 ± 0.10°C), and POLY (26.59 ± 0.14°C), and POLY being significantly lower than NYL. Thus, indicating the possibility that a dry garment comprised of a nylon/spandex blend may perform better than the other fabrics tested in transferring radiant heat from the human skin. Temperature ranges were also significantly different between fabric samples ($p = 0.00$), with PCM (2.16 ± 0.16°C) having a significantly higher range than COT (1.34 ± 0.15°C), NYL (1.51 ± 0.07°C), and POLY (1.28 ± 0.06°C). There were no significant differences in temperature means ($p = 0.52$) and temperature ranges ($p = 0.10$) between fabric samples for the "wet" trials. However, the lack of significance in the ranges may have come as a result of the high standard deviations found in COT (3.80 ± 3.90°C), PCM (6.96 ± 2.22°C), and POLY (7.60 ± 3.69°C). The NYL and POLY samples each displayed an increase of > 5°C in temperature means from 5 min. to 15 min. of heating, which may very well be due to their hydrophobic characteristics. This study shows that there are significant differences between various fabric compositions in the amount of heat they transfer, when heated by an extended area radiation source. This info can be used to help individuals (especially those in physically active populations) make informed decisions concerning their choice of garments for activities in environments promoting heat stress.

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