Thermo-Physiological Comfort Assessment of Performance Cooling Fabrics in Medical Personal Protective Equipment (PPE)

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Introduction. Healthcare workers wear medical PPE during contagious disease outbreaks to prevent the second contamination of the diseases (WHO, 2014). Medical PPE is typically made of impermeable outer fabrics that create a protective barrier and restrict the penetration of contaminated blood and bodily fluids into the PPE system. By the impervious nature, the fabric traps air from escaping the garment, which results in an extremely unfavorable inner-clothing environment for healthcare workers (Grelot et al., 2015). This is especially concerning in areas that already have hot and humid climates, such as Africa (Grelot et al., 2015). Given the vital need, the purpose of the study was to evaluate cooling performance of the selected fabrics – currently available in the sportswear and outdoor industries – in reducing thermo-physiological discomfort of healthcare workers while wearing the required PPE.

Previous methods of cooling for PPE include liquid cooling garments, air cooling garments, and ice cooling garments (Chan et al., 2015). While the previous approaches present effective cooling performance to some extent, they all require the integration of an extra cooling device into a garment, thus imposing additional weight and bulkiness to the wearer. Our approach in this study was to offer a more tolerable microclimate PPE environment by incorporating performance cooling fabrics into a base-layer garment that can be worn under the medical PPE.

Procedures. We prototyped 4 test garments consisting of a round-neck t-shirt and athletic shorts, out of the 4 selected fabrics (3 cooling fabrics and a control fabric with no cooling properties). The cooling fabrics were donated by sportswear companies in the U.S. The research procedures were approved by the Institutional Review Board (IRB) of the researchers' university. For thermo-physiological comfort testing, we recruited 8 participants aged 18-29 and had no history of musculoskeletal or diabetic problems. They were recruited by convenient sampling via the emailing system of the researchers' university. Interested participants were directed to contact the research lab to schedule their visits and they were offered an opportunity to review the consent form and data collection procedures prior to participation. During the first visit, they were asked to 1) fill out a survey asking about their demographic background, 2) have their physical body dimensions measured (height, weight, BMI, fat %, etc.), and 3) participate in a 30-min exercise program. The physical exercise program (step 3) was repeated 4 times wearing a test-garment made of each of the 4 different fabrics. The participants wore the following layers of medical PPE: a) their own underpants, b) an inner-layer test garment (selected in random order), and a full-ensemble of medical PPE consisting of an isolation gown, head covering, face mask, goggles, and surgical gloves. Critical biofeedback (HR, BR, skin temperature) were monitored using a physiological sensor vest, and subjective thermal comfort was measured using a standardized ISO evaluation tool, immediately after each 30-min exercise program.

Fabric Samples. To briefly describe, Fabric 1 was a jersey knit fabric designed to increase evaporative cooling by increasing airflow between the skin and fabric and wicking moisture away from the wearer. Fabric 2 was also a jersey knit fabric designed to cool the wearer using xylitol treated yarns, and Fabric 3 was another jersey knit fabric designed to cool the wearer using crushed volcanic rock in the fiber structure to increase absorption of moisture and promote quick drying. Fabric 4 was our control fabric (cotton/polyester jersey knit) with no cooling properties.

Results. The average age of the subjects was 22 years old (SD = 3.46). The average height and weight were 71.00 inches (SD = 3.00) and 150.5 lbs. (SD = 9.99) respectively. The average BMI was 21.27 (SD = 2.55), and the average fat % was 10.37 (SD = 1.42). The room temperature and humidity remained consistent ranging at 70 – 72°F (Mean = 71.00, SD = 1.41) and 23 – 27% (Mean = 25.33, SD = 2.08). Using IBM SPSS 24.0, we performed repeated-measures t-tests (within-subjects and between-subjects) at the 95% confidence level. Overall, the biofeedback markers, especially the average skin temperature and maximum heart rate, indicated that Fabric 3 exhibited the most effective cooling performance during and post exercising. The trend was consistent within- and between-subjects at $p < .05$. Furthermore, Fabric 1 signified effective cooling performance post-exercise only (i.e., during the 10-min resting) by demonstrating a dramatic decrease in skin temperature (from 37.4°F to 36.5°F, $p = 0.015$), while the rest of the fabrics showed plateaued or slightly increasing trends in skin temperature post-exercise. This indicates that Fabric 1 possessed an effective cooling property to facilitate fast cool-down of the human's skin temperature, post physical activities. On the other hand, Fabric 2 and 4 showed no noticeable cooling performance during the experiments. These results indicate that although Fabric 2 was advertised to have embedded cooling properties that makes it suitable for sportswear, it did not show much improved cooling functions, which was comparable to the result of the control fabric (Fabric 4). Additionally, subjects shared insights on their subjective perceptions of PPE wearing experiences, and pointed out the most uncomfortable heat stress areas such as the facial area and arms where the cooling fabrics were not worn on their skin.

Conclusions. The findings of this study determined the cooling effectiveness of the performance fabrics available on the current market, and identified effective cooling fabrics that could be used in medical PPE applications. This study was conducted in a lab setting, and it will be desirable to verify the study findings with human subjects representing diverse physical and demographic backgrounds in real medical fields.

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