Effects of Ventilation System for Windbreaker on Temperature and Sweat Control

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Introduction: It is important that individuals can regulate their body temperature during and after physical activities to prevent body injuries. Many active individuals may opt to wear windbreakers for temperature control during physical activity due to lightweight and easy donning and doffing features. However, use of water-repellent and wind resistant materials restricts sweat evaporation, a way of controlling body temperature (Grujic & Gersak, 2017). To solve this problem, some commercially available windbreakers incorporate thermoregulatory factors such as mesh linings and vents. However, there is room for improvement to existing windbreakers to provide adequate temperature and sweat control effects. This study explored and developed windbreaker designs that can effectively control body temperature and evaporate sweat using strategically placed ventilation systems on the garment.

Methods: 1) *Prototype Development.* Two prototypes, prototype with overarm ventilation from the wrist to the neck opening referred to as VOA, and prototype with underarm ventilation from the wrist to the torso hem along the side seams referred to as VUA, were developed for the wear test. A commercially available windbreaker made of 100% polyester without lining was used for both prototypes as well as a control prototype without any ventilation system. For optimal airflow effects, a few ventilation opening widths were reviewed. A less than one-inch width ventilation may hamper the goal of having a big enough aperture for convective air exchange through these apertures (Ueda, Inoue, & Havenith, 2005) while a more than one inch opening can result in a garment size increase (Joseph-Armstrong, Hagen, & Maruzzi, 2010). Therefore, a one-inch width vent was chosen for both prototypes. For an effective cooling system, a 5mm hex mesh polyester fabric was selected for an even outflow of air. Hex's shape mimicking round holes is favorable for the highest cooling capacity (Chludzińska, 2019; Chludzinska & Bogdan, 2017). An invisible zipper was used for closure of both ventilation systems.

2) *Wear Test.* To evaluate the effects of windbreaker ventilation systems on temperature and sweat control, a wear test was conducted with three male participants ages 20-24 years old who participate in indoor and outdoor activities two to four times a week. Prior to testing, the participants signed a consent form to participate in the wear test and completed a background questionnaire. After confirming participants' consent, the wear test began on a university campus. Participants were asked to complete a six-lap (15-minute) exercise alternating between walking and jogging for each lap around the indoor track for a total distance of one mile. A five-minute jog up and down a flight of stairs followed the mile. After the exercise, there was a cool down period where they stood with their hands resting on their waists for a total of 15 minutes. A wearer acceptability survey was completed after all exercises. The procedure was repeated in each wearing condition: VOA, VUA, Control without ventilation. All prototypes were washed after each wear test. To collect temperature data, a 2.5" length adhesive thermometer strip was placed on the participant's forehead, forearms, upper back, and chest in accordance with Narczyk, Siwiec, and Pleskacz (2016). To assess temperature control effects, participants' temperatures were collected five times, once before exercise and four times after exercising. To collect sweat data, brown paper napkins were used to absorb the participants' armpit sweat twice after the exercises and sweat volume was

analyzed using photographic images of the wet brown napkins. Participants assessed wearer acceptability on their perceived temperature and sweat control effects, comfort, and willingness to purchase. All collected data were analyzed by comparing the mean scores among the prototypes.

Results: 1) *Body Temperature Control Effects.* The wear test results showed that prototype VOA was the most effective in keeping the body temperature close to the base temperature. VOA at every location showed a gradual decrease from 5 to 10 minutes. This is because body heat releases upward, making the overarm ventilation an optimal placement to release heat. The test results showed that VUA had the highest mean temperature differences indicating the least effectiveness in cooling down body temperatures. No ventilation from the control prototype was more effective than VUA and less effective than VOA. It is consistent with the results of the sweat evaporation effects below.

2) *Sweat Evaporation Effects.* Analysis of sweat evaporation was conducted using AATCC standard spray test ratings with lower numbers for more absorption (range 1 to 5). The average mean score was 2.8 for VOA, 4.5 for VUA, and 3 for control prototype. Table 1 shows an example of sweat volume for the right side armpit of one of the participants. The sweat evaporation results reflect that underarm ventilation was the most effective in evaporating armpit sweat due to the opening being closer to the sweat glands by providing strong air flow for a faster dry.

Table 1. Example of sweat volume (AATCC standard spray test ratings with numbers).

	VOA (Overarm Ventilation)	Control (No Ventilation)	VUA (Underarm Ventilation)
Sweat volume	Average 2.8/5	Average 3/5	Average 4.5/5

Based on the temperature and sweat evaporation testing results, it is concluded that overarm ventilation is the most effective in temperature control yet is the least effective in sweat control whereas underarm ventilation is the least effective in temperature control yet is the most effective in sweat control. Placing one ventilation maximizes results and the other ventilation is minimized. It results in performance of no ventilation being between VOA and VUA as shown in Figure 1.

Figure 1. Temperature and sweat control tendency of ventilation systems.

3) *Wearer Acceptability.* For body temperature control effects, participants responded that VUA regulates body temperature better than control and VOA prototypes. However, temperature data from the wear test showed that VOA regulates body temperature the most effectively. This may be because participants felt cool and having less sweat as VUA evaporated sweat quickly. Regardless of ventilation placement, two out of three participants were willing to purchase a windbreaker with a ventilation system.

Conclusion: The most significant finding of this study showed that overarm ventilation enables body temperature to cool down, both during and after physical exercise, while underarm ventilation helps evaporate sweat quickly. For more accurate results, a comprehensive test with a larger number of participants and various windbreaker types needs to be conducted in the future. This study results may help designers to consider effective ventilation systems for optimal temperature and sweat control effects.

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