Water-Vapor Resistance Difference between a Male and Female Thermal Manikin Wearing Ballistic Vests

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With other personal protective equipment including the helmet, the ballistic vest has been widely utilized for individual protection against fragmentation as well as handgun and rifle projectiles. In Iraq and Afghanistan, American military personnel have used ballistic vests to protect themselves from injuries from everything from high-velocity bullets to bomb fragments (Michael, 2006).

The ballistic vest is categorized into two classes, soft and hard ballistic vests (Chen & Chaudhry, 2005), based on the materials contained within the vest. The soft ballistic vest is generally composed of 20 to 35 fabric layers of synthetic ballistic-resistant fibers. In contrast, the hard ballistic vest consists of rigid ceramic plates or other fiber-composite plates designed to be inserted into the internal pockets of the vests. The type of vest used depends on the wearer's need and the situation. For instance, military personnel tend to wear both soft and hard armor ballistic vests as they require high levels of protection in combat environments whereas law enforcement personnel usually wear only soft ballistic vests (Westrick, 2001).

Despite the increase in ballistic vest use for numerous dangerous applications, ballistic vests for military personnel are primarily designed for males because of the heretofore infrequent presence of female military personnel in combat areas (Tung, 2008). Yet over time, female soldiers have become increasingly involved in dangerous and physically demanding military areas (Todd, Paquette, & Bensel, 1997). The percentage of female soldiers in the U.S. Armed Forces has increased steadily over the past three decades (Ricciardi, 2007). However, female military personnel still wear the unisex-designed ballistic vest, called the InterceptorTM vest (Tung, 2008), for training and some military operations. Female soldiers have complained that the InterceptorTM vest fits poorly in the chest, neckline, and armhole areas—all important places that could potentially influence wearer's performance and safety.

Furthermore, the ballistic vest, which is layered with multiple ballistic textile materials to provide protection against threats, can be significantly correlated with thermal insulation (Huck & McCullough, 1985). The heat and water-vapor resistances of the multi-layered ballistic vest are expected to be high. In addition, the vest is susceptible to forming air gaps between the layers; trapped air in a garment increases the thermal insulation (Huck & McCullough, 1985) and decreases the ability to transfer heat and sweat from the microenvironment (body—garment) to the external environment.

Therefore, this study examined the water-vapor resistance of the ballistic vest, one of the major concerns in the use of protective clothing, on a female thermal manikin and a male manikin wearing one of the most popular unisex-designed ballistic vest. The water-vapor resistance values on females and males were compared.

The Sweating Thermal Manikin, manufactured by Measurement Technology Northwest, was located inside a controllable environmental chamber; customized thermal breasts were used to convert the male thermal manikin to the female body shape. Three different testing garments were used: 1) T-shirt + Army Combat Uniform (ACU), 2) T-shirt + Army Combat Uniform (ACU) + the InterceptorTM vest, and 3) T-shirt + Army Combat Uniform (ACU) + the InterceptorTM vest + front and back hard plates. The water-vapor resistant values of the ballistic vest were collected on both the male and female manikins. To increase the reliability of the study, three tests were collected for each of testing garments. The experiment employed a randomized complete block factorial design, incorporating three levels of factor garment conditions with the different genders (i.e., female and male). The dependent variable was R_{et}, representing the water-vapor resistance value of the ballistic vest.

The results highlighted significant differences among the garment conditions in R_{et} ($F(2, 17) = 24.839$, $p < .000$). However, no significant difference occurred between the genders in R_{et} ($F(1, 17) = .000$, $p > .992$). A post hoc LSD test showed that the second garment condition (T-shirt + ACU + ballistic vest; mean = 21.8559, SD = 1.0404) was grouped with the third garment condition (T-shirt + ACU + ballistic vest + hard plates; mean = 22.6450, SD = 1.6975) while the first garment condition (mean = 17.6833, SD = 1.0893) remained its own group. These results indicate that no significant difference in R_{et} occurred regardless of whether hard plates were added or not. However, it showed significant differences in R_{et} between wearing no ballistic vest and wearing a ballistic vest.

Based on the results, it can be concluded that females and males do not have any R_{et} differences while wearing the ballistic vest. However, a significant difference in the R_{et} value was found between wearing the ballistic vest and not wearing it. When wearing the ballistic vest, the R_{et} value increased, indicating that sweat from the body could not go through the ballistic vest; rather, it remains in the microclimate environment, between the body and the ballistic vest. Therefore, a better-designed vest or a vest specifically designed to improve the water-vapor resistance value should be developed.

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