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Investigation of Female Firefighter Fit and Ergonomics in Structural Turnout Suits

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The number of female firefighters continues to grow from 1% in the 1980s, to 7% as of 2014 (Haynes & Stein, 2016). Despite the growing number of women in firefighting, structural turnout suits are predominately designed and manufactured to fit the male human form (Boorady et al., 2013; Park et al., 2014). According to, “*A National Report Card on Women in Firefighting*,” 80% of female firefighters experience issues with ill-fitting PPE, which is four times greater than men’s self-reported poor fit (20.9%) (Hulett, Bendick, Thomas, & Moccio, 2008). Physical gender differences in human form have been published demonstrating significant variances between males and females. Sizing data demonstrates vast differences in waist to hip variation among men and women (Boorady et al., 2013; SizeUSA, 2003). Improper fitting structural turnout suits for female firefighters may lead to restricted range-of-motion (ROM) and mobility when performing critical tasks, especially in the chest and hip areas, where body dimensions vary greatly between men and women (SizeUSA, 2003). Previous research (Langseth-Schmidt, 2014; Park et al., 2014) has been limited, however, as it has not considered female firefighter user needs for the full structural turnout ensemble, including turnout coat, pants, thermal hood, helmet, and self-contained breathing apparatus (SCBA). Therefore, the purpose of this research project was to assess current issues of improper fit and garment design for female firefighters when wearing a structural turnout ensemble.

This study evaluated structural turnout gear worn by local firefighter subjects using a questionnaire and three-dimensional body scanning technology to identify areas of improper fit. The impact of improper fit on ROM was assessed by recruiting both male and female firefighter subjects to participate in an ergonomic mobility wear trial. To achieve the purpose of this study, the following objectives were established:

1. To assess and compare current male and female firefighter user needs including garment design, fit, and restriction of movement through a questionnaire survey.
2. To measure male and female firefighter body dimensions and quantify structural turnout suit fit using three-dimensional body scanning technology.
3. To conduct an ergonomic ROM wear trial to identify and analyze gender differences in firefighter mobility when wearing structural firefighter turnout suits.

The recruitment of 12 local firefighters, six female and six male participants, between 20-50 years of age, was conducted. Subjects were invited to campus for a single test session to complete the user needs survey and to be body scanned in three garment configurations: base layers (BL), turnout suit (TS), and turnout ensemble (TE). Each subject then conducted a ROM protocol while wearing all three garment configurations. Subjects were asked to bring and wear their own individual set of turnout gear (turnout coat, pants, thermal hood, helmet, and SCBA) (Park et al., 2014). Garment sizing information was recorded for each individual participant’s ensemble elements.

Firefighters were asked to rate the importance of fit for their turnout suits as it related to comfort, mobility, and protection. For various activities including walking, bending, kneeling, and reaching, each firefighter described their level of satisfaction with the fit of their turnout suit in the following garment areas: coat length, sleeve fit, chest, shoulder, back, neckline, pant leg, waist, hip, and crotch. Firefighters were also asked to describe areas of their turnout suit where they experience the most issues with improper fit and what modifications they make to address such problems. Three-dimensional body scanning was conducted using an Image Twin body scanner by TC² to assess the bulkiness and fit of each participant when wearing the three garment configurations (BL, TS, & TE). Measurements included arm and pant length, crotch height, chest and waist circumference, sleeve length, surface area, and the volume of specific parts of the body which were then analyzed and compared between garment configurations and by gender. Participants then conducted a ROM protocol in each suit configuration which assessed mobility in multiple joint locations (elbow, shoulder, neck, hip, and knee) using goniometers (instruments which measures angles) to measure active flexion/extension/abduction.

User needs data was analyzed by gender to determine fit differences between male and female firefighters. Body scans when wearing the TS and TE were compared to BL measurements to determine significant differences in PPE fit, throughout the body, between garment configurations and gender. Similarly, significant differences in ROM between gender and garment configurations were analyzed using t-tests as it is a commonly used method for this type of data set. Results from the user needs survey demonstrated the additional fit issues that female firefighters face compared to their male counterparts. Body scanning indicated larger air gaps in female firefighter turnout suits illustrating bulkier garment fit which can lead to increased risk for trips, sprains, and strains. Data from the ROM protocol reflected the broader ergonomic issues of the design of structural turnout suits for all firefighters, regardless of gender.

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