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Evaluation female firefighter anthropometrics for improved mobility and design in personal protective clothing for the United States fire service

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Keywords

female firefighter, anthropometrics, personal protective equipment, functional design, mobility

Background and Aims

There is a lack of available and properly designed personal protective clothing (PPC) for females in the fire services which can lead to an increased risk of onsite injury, reduction in mobility, and poor wear comfort due to improper fit (1). Gaps in the optimal functional design and mobility for PPC could stem from the lack of anthropometric data on the female firefighter. This study's aim was 1) to implement innovative technology to body scan US female firefighters to develop the first ever female firefighter specific anthropometric database and 2) analyze the anthropometric data and compare it to current sizing requirements in National Fire Protection Association (NFPA) standards.

Introduction

In the United States, 9% of the fire service is comprised of female firefighters with this percentage continuing to rise (2). As more females join the fire services, the importance of donning personal protective equipment (PPE) that appropriately fits the female firefighter's body form is significant; especially given the design differences between structural and wildland turnout suits. Previous research has shown that 80% of the female firefighter population experiences issues with their ill-fitting PPE, a rate four times greater than self-reported male firefighters – this in turn leads to a 33% greater risk of injury for female firefighters (3-7). Often female turnout coats and pants are simplified, and shorter versions templated from male patterns. This approach creates wide, voluminous openings in the sleeve cuff and oversized collars in the jacket, which has increased risk of exposure of hazardous materials (8). Currently, there is no US female firefighter anthropometric database that PPC manufacturers and designers can use to support product development for female specific clothing and gear. It is this study's aim to provide a database that is accessible and will aid in improvements related to the fit, function, and protection of female personal protection clothing.

Methodology

Utilizing a novel approach to collecting body measurements, this research used three-dimensional (3D) mobile scanning capabilities and a developed standardized protocol, from which 189 female firefighters were scanned, and anthropometric data was collected to develop the first ever US female firefighter database. Select body measurements from the database were then analyzed and compared to the current NFPA standards' sizing requirements for both structural (NFPA 1971 *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting*) and wildland firefighting (NFPA 1977 *Standard on Protective Clothing and Equipment for Wildland Fire Fighting and Urban Interface Fire Fighting*). Descriptive statistical analysis was performed to assist in the comparative analysis.

Results

When examining and comparing the collected anthropometric data to the NFPA 1971 and 1977 standards' sizing requirements, it was found that the minimum size requirements for wildland protective clothing are much larger than those for structural turnouts, except in the waist. In addition, a large percentage of the collected anthropometric data was found to be outside the required size ranges outlined in both standards. For instance, 31% of the females scanned in this study had chest circumferences smaller than the minimum NFPA 1977 size extra small (XS) requirement. For structural firefighting turnout gear, the analysis showed 23.5% of female firefighters measured larger in the waist than the largest female specific sizing requirement for the turnout pant. This is just one of many statistical examples highlighting the discrepancies identified by this comparison between the NFPA standard sizing requirements and the actual body measurements of US female firefighters.

Discussion

It is important to note that it is a common occurrence for a female firefighter to be issued both a structural turnout coat and pants and wildland shirt and pants depending on their geographical location and fire agency. In fact, findings related to this scope of research found that 39% of US female firefighters perform duties for both structural and wildland firefighting. It was also found that the NFPA 1977 standard did not have male and female specific sizing for wildland shirts, meaning that the size ranges applied to both genders; therefore, indicating that a large portion of female firefighters are wearing shirts that are much too large for their body.



Figure 1. Example of 3D mobile technology used.

Table 1. NFPA 1977 Wildland Shirt Sizing Requirement Analysis.

Measurement	NFPA 1977 Range	Participant Average	Participant Median	Participant Mode	Participant Min	Participant Max
Collar Length/ Circumference	37.5-50cm	36.7cm+	36.3cm+	37.2cm+	31.8cm+	43cm
Front Length	63-75.5cm	74cm	74cm	74.2cm	65.8cm	82.8cm+
Sleeve Cuff/ Wrist Circ.	30.5-37cm	16.8cm+	16.7cm+	17.1cm+	15cm+	19.5cm+
Bottom/Hip Circumference	96.5-147cm	114cm	112cm	114.5cm	97cm	114.6cm

+ outside of NFPA 1977 size range

Conclusions

The analysis demonstrated usability of mobile 3D body scanning as a method for body measurement collection of female firefighters. There is also an opportunity for improvement in sizing for wildland shirt and pants as the current standard sizing requirements do not accurately capture the range of female firefighters. There is a similar opportunity for improvements in sizing guidance for structural turnout gear specified for women, as a significant portion of the study's participants had fallen outside the size range requirements.

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