A Comparative Anthropometric Analysis of Female Firefighters versus the General U.S. Female Population

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Background: Female firefighters are four times as likely to experience issues with ill-fitting personal protective clothing (PPC) as their male counterparts (FEMA,1993; Hulett, et al., 2008; Hollerbach, et al., 2017; USFA, 2019; McQuerry, et al., 2023) which places them at a 33% greater risk of injury (Liao, et al., 2001; McQuerry, 2020). Several studies directly attribute some of this risk to wearing ill-fitting PPC (Andersen, et al., 2016; Sokolowski et al., 2022; McQuerry et al., 2023). Andersen (2016) found women in the military who wore men's PPC had a higher rate of musculoskeletal injury. In the fire service, women's PPC is available, but worn by less than 9% of female firefighters as they are often either unaware, not given the option to select women's gear, or find that the existing women's PPC does not fit or function well (McQuerry, et al., 2023). The latter is in large part due to a lack of available female firefighter anthropometric data. *Prior to this study, no anthropometric database of U.S. female firefighters existed,* therefore PPC manufacturers have been forced to assume that women in the fire service are the same anthropometrically as the general U.S. female population.

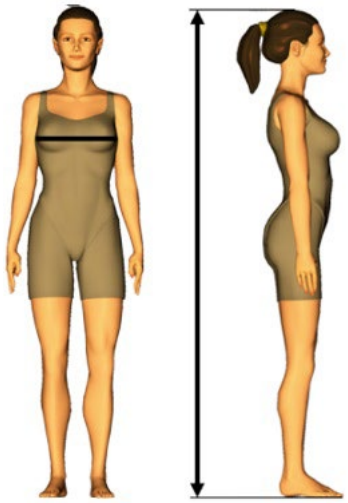

Figure 1. Avatar of a) bust circumference and b) height.

Studies have shown that career choice and level of activity can influence one's body and shape (Rhea et al., 2004; Morris & Chander, 2018). Previous research on female military personnel, a more fit, tactical athlete population similar to firefighters, demonstrated that women in the military are significantly different anthropometrically from the U.S. general female population both in stature and other key measurements critical for apparel design and fit (Gordon, et al., 1988; Gordon, et al., 2014). Designing PPC based on a population's anthropometrics is crucial as it impacts pattern development which in turn, affects sizing and fit. Some PPC manufacturers' current approaches are to "custom-fit" female firefighters in turnout suits that are originally patterned to fit the male human form, using after-market customizations (e.g. shortening the hem length) (Gu et al., 2019). From an apparel design standpoint, this approach is not optimal and instead, to produce better fitting women's firefighting PPC, manufacturers need to develop female specific patterns. To do so, a better understanding of the complexity of U.S. female firefighter anthropometrics is required.

To mitigate and eliminate female firefighters' increased risk of injury, appropriate sizing and fit of women's PPC in the fire service must be addressed. The purpose of this research was to determine if female firefighters in the U.S. are anthropometrically different

from the general female population to best inform the design of women's PPC for the fire service. To the researchers' knowledge, no study has directly compared the anthropometrics of female firefighters to those of the general female population in the U.S. Results will indicate if (1) differences exist between the body dimensions of female firefighters and those of the general female population, and (2), determine if women's firefighting PPC can be produced based on the anthropometrics of the general population. This comparative analysis will inform standards bodies, manufacturers, and end users regarding how female firefighters' body measurements impact sizing, fit, and overall health and safety.

Methods: A comparative analysis contrasting two distinct samples of anthropometric datasets were compared. The U.S. female firefighter database, produced in the researchers' previous study, was collected via remote three-dimensional body scanning (MeThreeSixty, Size Stream, Cary, NC) of structural and wildland female firefighters (n=187). The second data set was acquired via the USA Size North America survey collected by Humanetics (Morrisville, NC) and included U.S. women ages 18-55 (n=4632), representative of fire service age. From the 100+ body measurements taken from each participant, two primary measures (Figure 1: bust and height) were selected and served as key indicators for overall body scale and vertical length. Secondary measurements for circumference (waist, hip/seat, thigh, knee, ankle, wrist, and collar) and length (arm/sleeve length, inseam, front crotch length, and center back waist length) typically considered for apparel production were compared. Utilizing iSize software (Humanetics), descriptive statistics were calculated for each data set and differential comparisons were performed. In addition, correlational analysis via 2D scatter plots was used to illustrate comparative differences in key measurements between the two datasets.

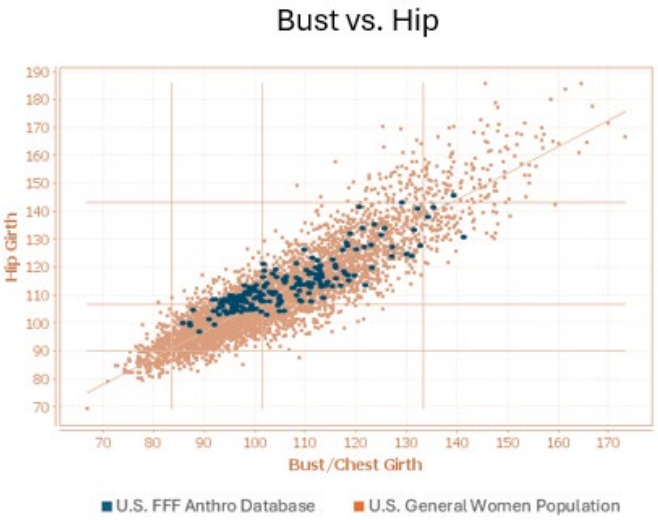

Figure 2. Correlation analysis of bust versus hip.

Results: For the primary measures, female firefighters were found to be taller (170±6.6cm) by 6.7 cm, on average, than the general population (163±6.7cm.). For bust circumference, female firefighters generally fell within the average body size of the U.S. female population in terms of dimensional scale. For secondary circumferential measures, female firefighters were found to have a wider waist (102 ± 11.2 cm) by 10 cm, on average, and slightly wider hips (114 ± 8.9 cm) by 3-5 cm. These measures suggest the female firefighter sample in this study may have a more uniform, or straighter, upper body shape. For all lower body/leg circumferential measures, female firefighters, on average, had a 2 cm larger thigh, knee, and ankle circumference than the general female population sample. Similar results were also found in the neck/collar (1.3 cm >) and wrist (1 cm >) circumference. Comparatively, while the upper body measurement for sleeve length was found to be nearly the same as the general U.S. female population, leg

inseam length, front crotch length, and center back waist length, were also 2 cm longer for female firefighters, on average, corresponding with the findings for height.

The correlation between bust and hip (Figure 2) measures illustrates that female firefighters with relatively smaller busts (90-100 cm) have larger hips compared to the general female population. This finding along with others, based on the sample datasets considered in this study, indicate that women in the fire service are taller, have a more uniform torso shape, and are slightly larger in lower body stature compared to the general female population. These findings may be attributed to a more active occupation due to the intense level of movement required on the job (Rhea et al., 2004).

Conclusions: Female firefighters report 80% dissatisfaction with the fit of their turnout gear which significantly increases their risk of injury (McQuerry, et al., 2023; FEMA, 1993; USFA, 2019). For safety reasons, improving the sizing and fit of women's firefighting PPC is critical. The anthropometric differences identified in this study suggest that female firefighter body measurements should be considered when designing and developing patterns for women's firefighting PPC. Adopting U.S. general female population anthropometrics for pattern and sizing system development is discouraged. It should be noted a limitation of this study is the small sample size for female firefighters. Further research is needed to collect a larger sample size for enhanced statistical analysis comparisons.

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