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# Examination of current U.S. female firefighting personal protective equipment (PPE) sizing and fitting process challenges: an opportunity to improve safety

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## Abstract

Between 2010 and 2014, the National Fire Protection Association (NFPA) estimated that female firefighters experienced 1260 injuries on the fireground each year. Previous research attributed some of these injuries to ill-fitting fire personal protective equipment (PPE). Therefore, in this mixed-method paper, the authors explored the relationship between fire PPE and injuries, and how they related to sizing and fit. To achieve this aim, data were collected from manufacturer-provided web communications regarding sizing and fit, user surveys ( $n = 74$ ), and 1:1 interviews ( $n = 31$ ) with U.S. female firefighters. The data considered how the size and fit standards established by the NFPA and how leading fire PPE manufacturers' interpretation of standards impacted fit for female firefighters. Interview and survey data pinpointed experiences with the PPE sizing processes that led to poor fit. The data also identified previously undocumented knowledge gaps between NFPA size standards, commercialized products, and processes used by manufacturers and firehouses to fit female practitioners. The study discovered several opportunities to improve the size and fitting process women experienced when acquiring new turnout gear. With effective fire industry partnerships and future research, women can experience fewer injuries, improved comfort, and work performance with their PPE while establishing equality with their male counterparts.

**Keywords:** Female firefighters, PPE, Sizing, Fit, NFPA standards

## Introduction

In 2018, the NFPA estimated there were 1,115,000 career and volunteer firefighters in the United States (U.S.) (Evarts & Stein, 2020). Of those firefighters, 8% (93,700) identified as women. Despite sex disparity in the fire service, the population of female firefighters is growing, and research must be directed towards understanding their unique challenges (Hollerbach et al., 2017).

Haynes and Stein (2017) reported that a new injury occurs every eight minutes for U.S. firefighters. Between 2010 and 2014, the NFPA estimated that female firefighters experienced an average of 1260 injuries on the fireground each year (Campbell, 2017). Previous studies found that women experienced higher rates of injury than their male firefighter counterparts (Liao et al., 2001; Sinden et al., 2013). These injuries were attributed to (in no order of importance) (1) the impact of working in a male-dominated field, (2) harassment, (3) similar rates/types of injury between sexes, (4) inadequate training, (5) ill-fitting gear, and (6) functional techniques/endurance (Hollerbach et al., 2017). Hulett et al. (2008) reported that women have nearly four times (79.7%) the number of issues with ill-fitting firefighting PPE compared to their male counterparts (20.9%).

Several researchers have conducted qualitative studies to understand the size and fit challenges experienced by female firefighters for coats, pants, boots, and gloves (Boorady et al., 2013; Hulett et al., 2008; McKinney et al., 2021; Park et al., 2014; Park & Langseth-Schmidt, 2016). Regarding turnout coats, Boorady et al. (2013) found that turnout coats were not available in sizes small enough for women from manufacturers or not always available in female-specific sizes at their respective firehouses. Hulett et al. (2008) reported that 38.9% of women surveyed had challenges with their turnout coats. Boorady et al. (2013) explained the specifics of turnout coat fit issues including, they were too large, too long, or too bulky on the female body, and poor fit placement of pockets that impaired function and comfort during fireground activities. Furthermore, research by Park et al. (2014) aligned with these fit challenges, where women reported coat body and sleeve lengths were too long; sleeves, shoulders, and necklines were too wide or oversized, and the neck collar was too high, limiting the range of motion and field of vision. They also reported that women had challenges with their coats fitting too tight at the chest and hips (Park et al., 2014). More recently, McKinney et al. (2021) comparably found the same issues reported by previous authors, with an additional discovery of looseness at the waist.

Similarly, female firefighter pant sizes were not small enough or not always available in female-specific sizes (Boorady et al., 2013). Respondents in Boorady et al. (2013) explained that fire protective pants fit too large (waist), too long (crotch, leg), or too bulky on the female body, along with poor placement of pockets and suspenders. Park et al. (2014) further explained how poor pant fit restricted lower body motion due to low crotches (being too long), poor fit at the hips, and poor fit at the boot interface (too tight). Park and Langseth-Schmidt (2016) found turnout pants were ill-fitting, specifically at the hips (tight), rise (tight), and legs (loose). McKinney et al. (2021) concurred with these previously reported results, except they found mixed assessments for fit at the hips and thigh.

In the realm of firefighter boots and gloves, there is less documented research regarding size and fit challenges for women. Park et al. (2014) identified that female firefighters felt their gloves and boots were oversized, affecting mobility, dexterity (gloves), and comfort (boots). Concerning fit, Hulett et al. (2008) reported women experienced problems with boots (46.8%) and gloves (57.8%) fit. Boorady et al. (2013) reported that the overall boot fit was too long/large to the point that participants in their study lost boots during fire activities (e.g., climbing). Regarding gloves, female

firefighters reported that they continuously had to readjust gloves while handling critical equipment (Boorady et al., 2013).

Current fire PPE sizing and fit standards are important to understand, to address the size and fit challenges experienced by female firefighters. In the U.S. the NFPA sets these standards. NFPA 1971: Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting includes requirements for PPE manufacturers, including required size ranges and measurement techniques to fit firefighters into products (NFPA, 2018a). NFPA 1500: Standard on Fire Department Occupational Safety, Health, and Wellness Program provides further guidelines for manufacturers about product fit overlap requirements to prevent bodily exposure to fire-related hazards (NFPA, 2018b).

According to the NFPA (2018a), turnout coats and pants must be available in standard size ranges, including measurement increments between sizes, per Additional file 1: Appendix A. Female firefighters' coats and pants should be sized with 'women's-specific patterns' (NFPA, 2018a). They also require manufacturers to provide instructions about product sizing (NFPA, 2018b). Regarding fit overlap, the NFPA deems there should be at least two inches (50.8 mm) between the turnout coat bottom hem and pant waistband. The overlap is measured while the user is wearing both products in the following two positions: (1) standing with hands reaching overhead, and (2) standing with hands reaching overhead with the body bent dynamically at 90 degrees forward, to either left or right side and back (NFPA, 2018b).

For firefighter turnout boots, the NFPA requires manufacturers to produce sizes 5–16 for men and 5–10 for women, including half sizes and a minimum of three widths (NFPA, 2018a). Notably, the NFPA size range for women is less than what U.S. shoe companies typically offer—which is 5–12 (Zappos, 2022). Like the NFPA's requirements for coats and pants, separate women's lasts (forms used to construct/size boots) must be used for women's boot models, and dual sizing for the same pair of boots cannot cover men's and women's sizes. Manufacturers should also provide a size conversion chart based on Brannock device measures of heel-to-toe length, arch length, and foot width (NFPA, 2018a). The boot height should be a minimum of 9.84 inches (250 mm) to cover the firefighter's calf. It is measured perpendicularly from the center of the insole at the heel up to the lowest point of the boot's top line (excluding the tongue and gusset) (NFPA, 2018a).

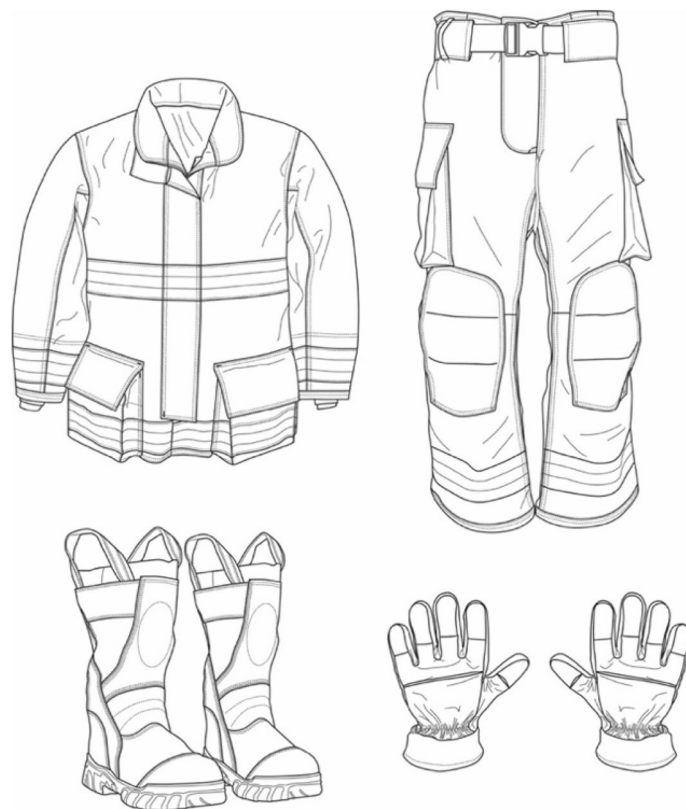
The NFPA provides guidelines for measuring fire glove size (Additional file 2: Appendix B) and the sizes associated with the measures (Additional file 3: Appendix C). First, the index finger (D2) measurement is taken with a straight ruler from the tip of the finger to the base of the finger at the crease (palm side) (NFPA, 2018a). Hand breadth is measured with anthropometric calipers from the outside of the index finger (D2) to the outside of the fifth finger (D5) (NFPA, 2018a). Both measurements are taken to the nearest 1/16 inch (1.57 mm) (NFPA, 2018a). Standard sizes required by glove manufacturers include 64N, 70N, 70W, 76N, 76W, 82N, and 82W, where N defines 'Normal' and W 'Wide' (NFPA, 2018a). The NFPA does not require glove sizes to be gender specific. When custom-sized or specially fitted gloves are created, the size on the label should be notated as the closest hand measurement provided in Additional file 2: Appendix B, followed by the word "Custom." This labeling requirement does not appear to exist for

custom coats, pants, or boots. Gloves must fit two inches (50.8 mm) beyond the wrist crease for a safety overlap with the coat sleeve (NFPA, 2018a).

Despite the guidelines set forth by the NFPA, female firefighters continue to be plagued by ill-fitting gear that impacts work performance, impedes comfort, and causes injury. Fit challenges have been repeatedly documented in the literature for over a decade with insufficient improvement. To improve fit effectively, researchers must pinpoint the systematic areas of improvement across the entire sizing and fit process. Therefore, the purpose of this paper was to understand the relationship between ill-fitting fire personal protective equipment (PPE) (coats, pants, gloves, and boots) and injuries for female firefighters, specifically as they relate to fit and sizing processes. To address this aim, the authors systematically examined how leading fire PPE manufacturers interpreted the size and fit standards set forth by the NFPA, along with the processes used to obtain PPE by female firefighters. For clarity, the authors defined sizing as the measurements and classifications recommended by the NFPA or used by PPE manufacturers to assign products to firefighter bodies. Fit was defined as—how sized PPE interfaces with the body and other garments, including other PPE.

## Methods

This research focused on coats, pants, boots, and gloves or firefighter PPE that were cut and sewn from rolled materials (Fig. 1). In the fire PPE industry, three distinct entities are believed to affect how well female firefighters are sized and fitted into PPE. They include the (1) NFPA, (2) PPE manufacturers, and (3) the representatives that size and



**Fig. 1** Typical cut and sewn Personal Protective Equipment worn by firefighters

fit firefighters at their firehouse. Therefore, three types of data were collected through a content analysis (Hsieh & Shannon, 2005) to understand how manufacturers and firehouses fitted and sized women into commercialized products based on current NFPA standards. They included (1) qualitative published web communications from leading U.S. PPE manufacturers on product sizing and fit, (2) quantitative survey responses from U.S. female firefighters on their experiences of being sized and fitted for PPE, and (3) 1:1 qualitative interview data from U.S. female firefighters to understand the impact of NFPA standards, manufacturers' communication of size/fit information (e.g., size charts, measuring instructions), available product sizes, and product size selection practices on the fit issues that they experience.

#### **Leading U.S. PPE manufacturer sizing and fit communications**

Manufacturer size charts and fitting instructions that communicated product sizes available to firewomen were retrieved from top brands' websites to understand sizing and fit information. Website content was analyzed to answer the following questions—based on the requirements published in the NFPA standards:

- What methods do manufacturers communicate online to help female firefighters select coat, pant, boot, and glove sizes?
- Are turnout coats, pants, boots, and gloves provided by manufacturers in the standard size measurement ranges required by the NFPA?
- What measurements are required by each manufacturer to size coats, pants, boots, and gloves?
- Do manufacturers provide distinct male and female-sized coats, pants, boots, and gloves?

The researchers identified key fire PPE manufacturers through interviews with industry experts (T. Regan, personal communication, October 2020; S. McQuade, personal communication, September 2020) and market research (The Fire Store, 2021a, 2021b, 2021c). From this inquiry, Globe, Lion, and Honeywell were the top three turnout coats, pants, and boot manufacturers (S. McQuade, personal communication, September 2020; The Fire Store, 2021a; The Fire Store, 2021b). Pro-Tech 8, Shelby, and Honeywell were the leading brands for gloves (T. Regan, personal communication, October 2020; The Fire Store, 2021c).

#### **Female firefighter survey**

The researchers developed an online survey distributed through Qualtrics to collect information from U.S. female firefighters regarding their experiences being sized and fitted into turnout gear. The survey was distributed via weblink to firefighters who participated in the 2018 Women in Fire conference (previously known as iWomen) in Washington D.C. This conference is the largest international gathering of women who work in the fire services. Seventy-four U.S. female firefighters participated in the survey.

The researchers' Institutional Review Boards (IRBs) approved the survey before it was distributed to the participant pool. The survey consisted of a consent page, basic

demographic questions (sex, birth year, firefighter experience, type, ethnicity, race), and specific questions regarding sizing and fit procedures. Questions included:

- What sex was your turnout coat/pant/boot made for? Choices included (a) Men, (b) Women, (c) Unisex, and (d) I don't know.
- Was this turnout coat/pant/boot/glove purchased specifically for you? Choices included "Yes" and "No", with an open "Please explain" box for the "No" choice.
- Did you select the turnout coat/pant/boot/glove size yourself? Choices were "Yes" and "No, the size was selected by" with a fill-in-the-blank box.
- How was the size of the turnout coat/pant/boot/glove selected for your body? Choices included (a) It was chosen based on a similar size I wore before, (b) It was chosen based on my body measurements compared to a chart, (c) I tried on various sizes from a sample set of sizes brought to the station by the manufacturer, (d) I tried on various styles and sizes that were available in the station, and (e) Other (please explain).
- Were there any difficulties in selecting your turnout coat/pant/boot/glove size? Choices included "Yes" and "No", with an open "Please explain" box for the "Yes" choice.
- Describe any modifications you have made to the fit of your turnout coat/pant/boot/glove. An open-ended response box was provided for this question.

Participants could take as much time as needed to answer the survey questions, but on average, the survey took about seven minutes to complete. Responses were analyzed by exporting data from Qualtrics to Excel to conduct descriptive analyses and calculate percentages, consistent with content analysis procedures outlined by Hsieh and Shannon (2005). Responses to open-ended or fill-in-the-blank questions were organized by gear type. Within each gear type, responses were organized into themes, and percentages were calculated.

#### **Female firefighter 1:1 interviews**

The researchers conducted 31 structured interviews with U.S. female firefighters regarding their experiences being sized and fitted into coats, pants, boots, and gloves. The interviewees were also participants in the May 2018 Women in Fire conference in Washington D.C. Like the survey, the researchers' IRB approved the interview method and protocol. Conference organizers also approved the method and location of the interviews. Three of the researchers conducted the interviews upon the interviewee's permission. Questions included:

- How was your turnout coat/pant/boot/glove acquired?
- How was your turnout coat/pant/boot/glove size determined?
- Were there any difficulties in selecting your turnout coat/pant/boot/glove size?
- Have you modified the fit of your turnout coat/pant/boot/glove?

Interviews spanned between 6 to 40 min and were captured with an iPhone audio recorder. The total duration of each interview was retrieved from the information

automatically saved with the recorded audio file. Files were saved with non-identifying alphanumeric codes to protect participant privacy and transcribed using Rev (Rev, n.d.). One of the researchers reviewed the transcripts to verify their accuracy. When an audio transcription did not make sense, the reviewing researcher communicated with the interviewing researcher of that transcript to clarify the data.

Before analyzing the interviews, the researchers worked together to develop a codebook based upon physical fit variables identified in functional apparel literature. Codes were: (a) Length, (b) Circumference, (c) Modifications to Fit (Park & Langseth-Schmidt, 2016), (d) Bulk (Boorady et al., 2013), and (e) Mobility (Boorady, 2013; Park et al., 2014). Additional codes related to product sizing, obtaining gear, and garment/body locations were also developed. They included two sub-categories: Acquisition and Size Selection Process. Sub-codes of Acquisition included (a) New/Pulled from stock at the station, (b) New/Purchased for me, (c) Used/Handed down, and (d) Purchased by self. Sub-codes of the Size Selection Process were (a) Selected by self, (b) Others selected, (c) Based on a similar size worn before, (d) Based on body measurements, (e) Sample set of sizes provided by the manufacturer, and (f) Tried on various styles/sizes available at the station. Definitions were written for each code to ensure consistency among researchers. The researchers conducted two rounds of code verifications on a subset of the data to confirm inter-rater reliability (98%) (Saldaña, 2021).

The finalized codebook and audio transcripts were entered into Dedoose, a Qualitative Data Analysis Software (QDAS) tool. This tool allows for thematic coding by reviewing the audio transcripts and matching content to the predetermined codes and grouping coded segments according to code co-occurrences to identify major themes (Saldaña, 2021). The researchers read each sentence in each interview and applied all relevant codes to each sentence. In Dedoose, the researchers coded the entire dataset to understand co-occurrence frequencies. Coded excerpts were exported to Excel and filtered by product type (coat, pant, boot, glove). Coded excerpts were then further filtered into codes for acquisition, sizing, fit challenges, and product modifications. Each group of coded excerpts was analyzed to identify common sizing and fit practices experienced by U.S. female firefighters when acquiring PPE. Key interview themes emerging from the data included purchase specificity, size selection, and difficulty finding a size.

## Results

### Leading U.S. firefighter manufacturer sizing and fit communications

The researchers reviewed the websites of three key U.S. turnout coats, pants, and boots manufacturers (Globe, Lion, and Honeywell) and three glove manufacturers (Pro-Tech 8, Shelby, and Honeywell). The results are an aggregate of information across manufacturers organized into three main themes and further ordered into product types. The themes include *measuring methods for size selection*, *size measurement ranges*, and *distinct sizes for female firefighters*.

### *Measuring methods for size selection*

*Turnout coats and pants* The three-turnout coat and pant manufacturers included in this analysis used different methods for sizing firefighters. Globe required a custom fitting

with a local distributor, where firefighters tried on sized sample sets to achieve their best fit (Globe, 2022a). Lion provided a video guide for sizing and fitting coats and pants, including instructions on how to size women (Lion, 2010). They further clarified that each measurement should be taken over station wear (apparel worn at the firehouse) and rounded up to the closest even size presented in Lion's sizing chart (Fire-End & Crocker Corp, 2015).

Honeywell's turnout coats and pants are custom-tailored for each firefighter (Honeywell, 2018a). Firefighters may be sized with a measuring tape (Method 1) or through the use of sized samples (Method 2) (Honeywell, 2018a). In Method 1, measurements are taken over station wear and recorded in a sizing document, noting 'non-proportional' measurements—unusually large neck, stomach, upper arm, or forearm dimensions (Honeywell, 2018a). With Method 2, personal fit preferences within safety guidelines, such as a 'loose fit' can be determined for individual firefighters since they can physically try on the products (Honeywell, 2018a).

*Boots* Regarding footwear, all the manufacturers required a distribution representative to size fire boots in person.

*Gloves* All manufacturers (Pro-Tech 8, Shelby, and Honeywell) recommended that the firefighter self-select their glove size. Pro-Tech 8 provided the NFPA measurement guidelines presented in Additional file 2: Appendix B and Additional file 3: Appendix C for sizing (Pro-Tech 8, 2018). Shelby provided no sizing directions (Shelby, 2022), and Honeywell communicated that firefighters should select a glove size that is comfortable and allows their hands to function correctly (Honeywell, 2022).

### ***Size measurement ranges***

*Turnout coats and pant* Based on the analysis of manufacturer's online communications to size and fit female firefighters into coats and pants, all the top three U.S. brands followed NFPA's minimum requirement to size and fit firefighters with chest, sleeve, waist, and inseam measures. Illustrated in Table 1, Globe included only the minimum measurements required by the NFPA, Lion included inseam and hip measurements, and Honeywell determined coat and pant fit with double the number of measures required by Globe and Lion. It is important to note that Lion sizes their turnout gear using four measurements for men and five measurements for women (Lion, 2010). The male measurements were chest, waist, sleeve length, and inseam. The female measurements included the four preceding measurements plus a hip measurement.

Size measurement ranges for coats and pants, for each of the three manufacturers are presented in Table 2. Globe and Lion both included male and female-specific measures, however, their sizing nomenclature was inconsistent (Fire-End & Crocker Corp, 2015; Globe, 2019). For example, Globe used measures to notate size (e.g., 32", 34", 36"), whereas Lion used a combination of measures and alpha sizes (e.g., XS–XXL for coat sleeves, XXS–XXL for pant inseams). In Lion's size chart, they also advised that women's sizes are 3" (76.2 mm) shorter than the men's sizes. Honeywell did not provide an online size chart for coats and pants. Instead, they provided a guide for obtaining measurements that can be used to create a custom-tailored fit by the manufacturer (Honeywell, 2018a).



**Table 1** Measures communicated by the top Personal Protective Equipment manufacturers for coat/pant sizing

Measure	Globe	Lion	Honeywell
Chest	X	X	X
Sleeve	X	X	X
Waist	X	X	X
Lengths*	X	–	–
Inseam	–	X	X
Overarm	–	–	X
Back Length	–	–	X
Shoulder	–	–	X
Bicep	–	–	X
Hips**	–	X	X
Crotch Rise	–	–	X
Suspender Length	–	–	X

\*The manufacturer did not clearly define the ‘Lengths’ measure on their website

\*\* A female-only measurement—this measurement was not included for male products

**Table 2** Combined sizing measures for Globe, Lion, and Honeywell turnout coats and pants

Manufacturer	Measure	Male	Female	Increment (inches/mm)
Globe (Globe, 2019)	Chest	34–60" (863.6–1524 mm)	28–50" (711.2–1270 mm)	In 2" (50.8 mm) increments or to order
	Sleeve	32–38" (812.8–965.2 mm)	28–34" (711.2–863.6 mm)	In 1" (25.4 mm) increments or to order
	Waist	30–60" (762–1524 mm)	28–50" (711.2–1270 mm)	In 2" (50.8 mm) increments or to order
	Lengths	26–36" (660.4–914.4 mm)	24–34" (609.6–863.6 mm)	In 2" (50.8 mm) increments or to order
	Inseam	–	–	–
	Hips	–	–	–
Lion (Fire-End & Crocker Corp, 2015)	Chest	34–56" (863.6–1422.4 mm)	34–56" (863.6–1422.4 mm)	–
	Sleeve	28–42" (711.2–1066.8 mm) XS–XXL	28–41" (711.2–1041.4 mm) XS–XXL	–
	Waist	26–56" (660.4–1422.4 mm)	20–46" (508–1168.4 mm)	In 2" (50.8 mm) increments
	Lengths	–	–	women’s sizes are 3" (76.2 mm) shorter than the men’s sizes
	Inseam	23–35" (635–889 mm) (XXS–XXL)	21–33" (533.4–838.2 mm) (XXS–XXL)	In 2" (50.8 mm) increments
Honeywell* (Honeywell, 2018a)	Hips	–	–	–
	Chest	–	–	–
	Sleeve	–	–	–
	Waist	–	–	–
	Lengths	–	–	–
	Inseam	–	–	–

\*Honeywell does not provide an online size measurement chart for coats and pants, as their products are custom tailored

**Table 3** Globe, Lion, and Honeywell boot sizing

Manufacturer	Size type	Male U.S. size	Female U.S. size	Widths
Globe	Full sizes	5–18	5–12	Narrow, Medium, Wide, X-Wide
	Half sizes	5½–15½	5½–11½	Narrow, Medium, Wide, X-Wide
Lion	Full sizes	5–16	5–10	Narrow (W's), Medium, Wide, X-Wide (M's only)
	Half sizes	5 ½–15 ½	5 ½–9 ½	Narrow (W's), Medium, Wide, X-Wide (M's only)
Honeywell	Full sizes	5–16	–	Narrow, Medium (D), Wide (E), (EEE)
	Half sizes	5 ½–15 ½	–	Narrow, Medium (D), Wide (E), (EEE)

From Globe (2022b), Lion (2021), Honeywell (2019)

**Table 4** National Fire Protection Association, Pro Tech 8, and Shelby glove sizing

NFPA size	Pro Tech 8 size	Shelby size
64N	XS	XXS
70N	S	XS
70W	M	S
76N	M/L	M
76W	L/XL	L
82N	XL	XL
82W	XXL	J

From NFPA (2018a), Pro-Tech 8 (2018), Shelby, (2022)

**Boots** None of the manufacturers (Globe, Lion, and Honeywell) provided size charts with foot measurements or Brannock device conversions—likely because they required a distribution representative to size fire boots in person. All manufacturers provided boots in whole and half sizes, starting at a size 5 (Table 3). Only Globe and Lion provided boot models in the NFPA required male and female sizes. Globe fire boots came in four widths—Narrow, Medium, Wide, and X-Wide (Globe, 2022b). Lion fire boots came in three men's widths—Medium, Wide, and Extra-Wide and three women's—Narrow, Medium, and Wide (Lion, 2021). Honeywell boots were not sized according to gender and came in multiple widths, including Narrow, Medium/D, Wide/E, and EEE (Honeywell, 2018b). However, for some of the widths (e.g., Narrow, X-Wide), not all styles were offered (Honeywell, 2019).

**Gloves** Both Pro-Tech 8 and Shelby provided size charts that corresponded with the NFPA sizing scheme illustrated in Additional file 3: Appendix C. Pro Tech 8 gloves were sized XS-XXL and Shelby gloves from XXS to Jumbo, as shown in Table 4 (Pro-Tech 8, 2018; Shelby, 2022). Honeywell did not provide a chart to show how their glove sizes corresponded to the NFPA sizes. Honeywell gloves came in eight sizes from 2XS to 3XL and one of four fit types depending on the glove style (Honeywell, 2022).

#### **Distinct sizes for female firefighters**

**Turnout coats and pants** Both Globe and Lion provided distinct female sizes. Compared to Globe, Lion offered additional inseam and hip measures to help address the documented female challenges with hip and inseam fit. Honeywell did not provide an online male and female size chart for coats and pants, as their products are made-to-measure,

suggesting that female firefighters would receive products that distinctly fit their sizing needs.

*Boots* It is unknown if the boot manufacturers used separate women’s lasts to create their female boot models because this information was not available online. Globe and Lion communicated distinct female boot sizes, but it was unclear how their female sizes differed in measurement from the men’s. Honeywell boots were only communicated as unisex sizes.

*Gloves* None of the manufacturers (Pro-Tech 8, Shelby, and Honeywell) provided female-specific sizes. Separate sizing for female firefighters is not a current requirement by the NFPA.

**Female firefighter survey results**

Seventy-four U.S. female firefighters (mean age=41 years, with mean experience=10.7 years) participated in the survey. Basic participant demographics are presented in Table 5.

When assessing turnout coat sizing and fit, women specifically reported difficulties with pocket location, the body being overall too large/long and the sleeves too long even with the smallest available size, along with limited size availability. Ten percent of the respondents reported having alterations made at a factory or a local tailor to help improve fit. Some of the women within this 10% reported they had coats custom-made by the manufacturer based on their body measurements because their body shape did not fit within the commercial size offerings.

Survey results also noted that women made modifications to their pants to improve fit. Four percent reported shortening their pants with suspenders, and 1.8% modified the length of their pants by folding up the hem (without sewing). Seven percent reported having full custom pants made by a manufacturer based on their body measurements.

**Table 5** Participant demographics

Attribute	Participant response	Percentage
Type of fire fighter	Career	61 %
	Volunteer	22 %
	Both career and volunteer	8 %
	Trainee	7 %
	Fire inspector	3 %
Ethnicity	Not Hispanic, Latino, or Spanish	88 %
	Hispanic, Latino, or Spanish	11 %
	Preferred not to answer	1 %
Race	White	84 %
	Other	7 %
	Black/African American	4 %
	Native American/Alaskan Native	3 %
	Native Hawaiian	1 %
	Preferred not to answer	1 %

Total participants = 74. 100% of the participants responded to all of the survey demographic questions

Regarding turnout boots, women experienced sizing and fit difficulties caused by the boot opening not being large enough for their calf and the footbed width being too wide or narrow. To help correct fit issues, 11.8% of participants reported adding insoles, and 2.0% used oil to reshape the boot around their foot. When assessing gloves, over half of the women surveyed found difficulty finding a glove size. Table 6 summarizes the survey results.

#### Female firefighter 1:1 interview results

Thirty-one U.S. female firefighters (mean age=41.9 years, with mean experience=16.3 years) participated in the 1:1 interviews. Basic participant demographics are presented in Table 7.

Eight-hundred and three co-occurrences between firefighter coat, pant, boot, glove and acquisition, sizing, fit challenges, and product modifications were identified in Dedoose from the transcribed interviews. Of those co-occurrences, 29.1% were related to coats, 23.4% pants, 22.3% boots and 25.2% gloves. Three key interview themes emerged from the data and included, *purchase specificity*, *size selection*, and *difficulty finding a size*.

For the co-occurrences related to turnout coat acquisition, more than half of them (64.0%) were associated with women receiving new coats that were specifically purchased for them, while the remaining were akin to getting used or handed-down coats from other firefighters. When determining coat size, the most common method discussed was using a sizing system (41.9%), followed by body measurements (28.4%), referencing sizes worn previously (23.0%), and trying on new stock available at the fire station (6.7%). The following excerpt describes how this process was experienced by a female firefighter.

*Yeah, so the local rep sponsor normally comes. However, it's always normally an older male. So, when females have issues about gear not fitting correctly or they don't really make something the appropriate size they say, sorry about it, that's all we have. They don't have a lot of female oriented gear. I'm a fairly average size person in general, but I have a very long torso but wider hips, so I need a shorter coat to make sure I don't literally catch when I'm bending down. To get a longer coat, you always have to get a wider chest, which I don't necessarily need, or the sleeves will end up being too long. They're not tailored to female bodies at all.*

Of all the co-occurrence themes related to turnout coats, the participants most discussed physical fit at 47.1%, with the female body shape identified as the challenge to achieving a good fit. The following comment demonstrates the challenges of having a female body. *"I just feel like I'm being consumed by it [coat], that I can't move well. I mean, for me, the issue is getting one that's large enough to fit my chest, but then isn't enormous."* A small co-occurrence (7.7%) of coat modifications was reported from the female firefighters interviewed.

All the co-occurrences between turnout pants and acquisition were related to women having them purchased new for them. Similarly, to turnout coat sizing, the most common method used for pants was through the use of a sizing system (42.9%),

**Table 6** Summary of survey results

Attribute	Participant response	N	Percentage
Coat size and fit			
Coat size worn	Wore men's coat size	36	50.8 %
	I did not know coat size by sex classification	18	23.9 %
	Wore unisex* coat size	16	20.9 %
	Wore women's coat size	4	4.5 %
Purchase specificity	The coat was bought specifically for me	46	62.7 %
	The coat was not originally bought for me but assigned or handed down	28	37.3 %
Coat size selection	Someone else selected my coat size	62	83.0 %
	I selected my coat size	12	16.4 %
How the coat size was selected	The size selected was based upon body measurements compared to a chart	43	57.6 %
	I tried on various sizes at the firehouse	18	24.2 %
	I tried on various sizes provided by the manufacturer	13	18.2 %
Difficulty finding coat size	No, I did not have difficulty finding my coat size	50	67.2 %
	Yes, I had difficulty finding my coat size	24	32.8 %
Pant size and fit			
Pant size worn	Wore men's pant size	38	51.8 %
	Wore unisex* pant size	31	41.0 %
	Wore women's pant size	5	7.1 %
Purchase specificity	Pant was bought specifically for me	50	68.0 %
	Pant was not originally bought for me but assigned or handed down	24	32.1 %
Pant size selection	Someone else selected my pant size	61	82.1 %
	I selected my pant size	13	17.9 %
How pant size was selected	The size selected was based upon body measurements compared to a chart	47	63.0 %
	I tried on various sizes provided by the manufacturer	13	17.9 %
	I tried on various sizes at the firehouse	11	16.1 %
	I selected the size I wore before	3	3.6 %
Difficulty finding pant size	No, I did not have difficulty finding my pant size	59	80.4 %
	Yes, I had difficulty finding my pant size	15	19.6 %
Boot size and fit			
Purchase specificity	Boots were bought specifically for me	50	68.0 %
	Boots were not originally bought for me but assigned or handed down	24	32.1 %
Boot size selection	I selected my boot size	54	73.0 %
	Someone else selected my boot size	20	27.5 %
How the boot size was selected	I tried on various sizes at the firehouse	35	47.1 %
	I tried on various sizes provided by the manufacturer	22	29.4 %
	I selected the size I wore before	16	21.6 %
	The size selected was based upon body measurements compared to a chart	1	2.0 %
Difficulty finding boot size	Yes, I had difficulty finding my boot size	38	51.0 %
	No, I did not have difficulty finding my boot size	36	49.0 %
Glove size and fit			
Glove size worn	Wore men's glove size	33	45.1 %
	Wore unisex glove size	31	41.2 %
	I did not know glove size by sex classification	9	11.8 %
	Wore women's glove size	1	2.0 %

**Table 6** (continued)

Attribute	Participant response	N	Percentage
Glove size selection	I selected my glove size	60	80.4 %
	Someone else selected my glove size	14	19.6 %
How glove size was selected	I tried on various sizes at the firehouse	30	40.0 %
	I tried on various sizes provided by the manufacturer	22	30.0 %
	I selected the size I wore before	14	20.0 %
	I tried on various sizes/styles at a retail store or supplier	6	7.5 %
	I requested a smaller custom glove from the manufacturer	2	2.5 %
Difficulty finding glove size	No, I did not have difficulty finding my glove size	42	57.0 %
	Yes, I had difficulty finding my glove size	32	43.1 %

According to the NFPA, unisex coats or pants should not be available by manufacturers. Total participants = 74. 100% of the participants responded to all of the survey questions regarding turnout coats, pants, boot, and glove sizing/fit

**Table 7** 1:1 Interview participant demographics

Attribute	Participant response	N	Percentage
Type of fire fighter	Career	26	86.3 %
	Volunteer	2	4.5 %
	Both career and volunteer	3	9.1 %
Ethnicity	Not Hispanic, Latino, or Spanish	24	77 %
	Hispanic, Latino, or Spanish	4	13 %
	Preferred not to answer	3	10 %
Race	White	21	68 %
	Other	3	10 %
	Black/African American	6	19 %
	Preferred not to answer	1	3 %

Total participants = 31. 100% of the participants responded to all of the demographic questions

followed by referencing previously worn sizes (27.1%), body measurements (22.9%), and trying on new stock available at the station (7.1%). The following synopsis explains an interviewee’s experience of being sized into turnout pants.

*I wish I could get a 28 because they’re just huge, but they don’t make those, or our department doesn’t offer those. I feel like the guy who sized our gear was not a very good sizer cause a lot of people got some f’d up sizes.*

Of all the co-occurrence themes related to turnout pants, physical fit issues (female-related) were most discussed at 42.0%, with pant modifications reported at 12.2% from the firefighters interviewed. Regarding pant fit, another female firefighter interviewed explained -

*...they make you look like a beached whale. The waist comes up ... I tried on a pair of women’s pants, and it was an inch away from my bra line, that’s how high they came up, and I was like, you’ve got to be kidding me. This is terrible.*

Like the acquisition of turnout coats, many of the co-occurrences (73.7%) related to turnout boot acquisition were associated with women receiving new boots purchased

for them. Twenty-one percent of the co-occurrences were connected to women purchasing their boots, and 5.3% received used boots worn by another firefighter. The most common method discussed to size turnout boots was with a sizing system (46.7%), followed by referencing sizes previously worn (35%), trying on new stock available at the fire station (10%), and through foot measures (8.3%). For example, the following interviewee explains her frustration with the boot sizing process.

*It's very frustrating. As a matter of fact, when I went to get my last fire boots, I requested women's boots, and they said, yes, we have those; it's just a size and a half smaller. That's not women's boots; those are men's boots. Our feet are different, and this is a fight that I have had with them, so I had to get the men's, I got Warrington's a size and a half smaller on the men's side just to fit me, and they still do not fit properly though.*

Female fit-related issues with turnout boots were most discussed at 47.5%, with modifications reported at 7.8% from the firefighters interviewed. One firefighter discussed, "I feel clumsy. I feel like clown shoes 'cause they just don't fit me right. And it makes me nervous, especially on a ladder, then I really feel like ... I don't know. Just clumsy." Another interviewee explained modifications she made to improve boot fit - "I put custom insoles in them, so I spent my own money on insoles 'cause they wouldn't provide them, and they're just clunky."

Of all the turnout gear discussed in this paper, the glove sizing and fit processes explained through the 1:1 interviews were the most unique. Most of the glove co-occurrences were associated with women purchasing their own (81.8%), followed by 18.2% purchased by the station house for the firefighter. None of the women interviewed for this study discussed wearing used gloves. Glove sizing was determined by the previous size worn (53.2%), followed by the use of a sizing system (24.7%), hand size (14.3%), and trying on products in stock at the fire station (7.8%). One interviewee discussed her experience with the glove sizing process.

*It's like going to a store and saying, a size 12 at this store is not a size 12 at that store. So, it really just depends on the manufacturer. And then if that's the only thing that we're going to get, then you're like, Okay, well, maybe I'm a tweener. So, I'd rather go [with a size] a little tighter because the glove grows when you're working. If it gets wet, it blows up, and it's super loose.*

Another interviewee discussed issues of not having small enough sizes available –

*Because even the extra smalls [are] still big. So, I feel like there's too much movement in it. So, if my hands are sweaty, and because I don't put them on, and they're hanging. I've had glass go in them. And I put them on to fight a fire. Because I'm already having loose issues, but when gloves get wet, they become very loose.*

Fit-related issues with turnout gloves were discussed at 47.0%, with modifications reported at 4.5% of the women interviewed. Frustration with turnout glove fit is explained by the following exert: "Okay, we need the protection. So, you need them to fit. At the same time, they're so thick that your dexterity ... I mean, dexterity is already bad in all your gear anyways. Serious. It's horrible."

**Discussion**

This paper examined the issue of ill-fitting PPE for female firefighters by analyzing how U.S. manufacturers interpreted NFPA standards to develop sizes for fire gear and the size and fitting selection process to select PPE. The objectives were to uncover knowledge gaps so that sizing and fitting processes could be improved and have a better exchange of information and collaboration between the NFPA, manufacturers, and the representatives that size and fit female firefighters (Fig. 2).

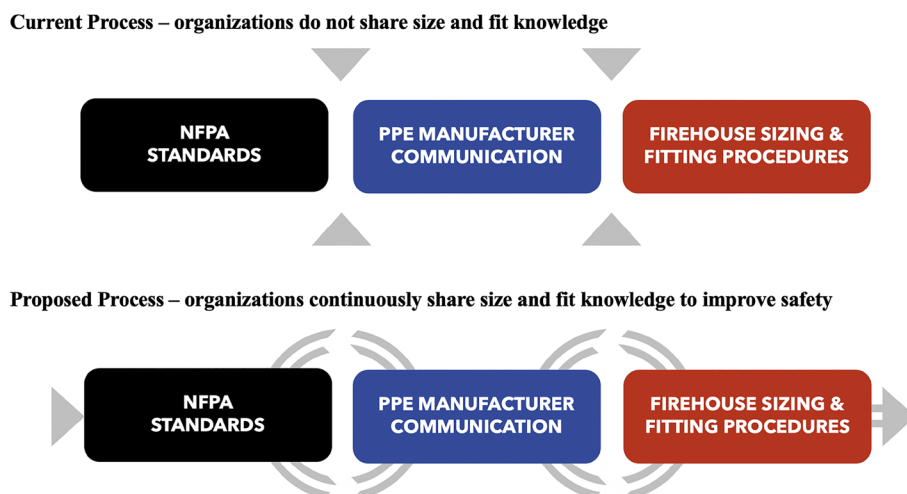
The three types of data collected (leading U.S. firefighter manufacturer sizing and fit communications and survey and interview data from current female firefighters) helped to provide a holistic picture of how women make fit decisions and concessions when acquiring gear. The research uncovered opportunities for the NFPA to evolve standards to improve female firefighter safety. Actionable directives for fire industry practitioners were also created based on literature and the results of this study to improve female firefighter safety.

**Manufacturer communication findings and recommendations**

Results of the manufacturers’ website sizing and fit communication analysis uncovered several opportunities to improve the challenges faced by female firefighters, as reported in the literature (Table 8). Specifically, the authors considered whether available information and products helped firewomen to obtain gear that fits them well.

This research uncovered many approaches manufacturers used to communicate and direct firefighters to size their PPE. Methods ranged from online instructions (Lion, Pro-Tech 8), custom fitting with a local distributor (Globe), physical measurements with a measuring tape (Honeywell), and trying on physical samples (Globe, Honeywell, Lion, Pro-Tech 8, Shelby). Even though there is a trend for turnout coats, pants, boots, and gloves, to be sized in person, this effort did not result in better fitting gear for women.

Measuring methods used by manufacturers for size selection of turnout coats, pants, boots, and gloves exposed a disconnect between the measurements used for sizing and



**Fig. 2** Reducing knowledge gaps between entities can facilitate exchange of information to improve sizing/fit. *NFPA* National Fire Protection Association, *PPE* Personal Protective Equipment



**Table 8** Female firefighter Personal Protective Equipment sizing and fit challenges

	Sizing	Fit: Length	Fit: Circumference	Fit: Other
Coats	Not sized small enough Lack of size access	Too long (body, sleeve, collar)	Too wide/bulky/ oversized (waist, sleeve, shoulders, neckline) Too tight (chest, hip)	Pocket placement
Pants	Not sized small enough Lack of size access	Too long (leg, crotch)	Too wide/bulky/oversized (waist, legs*) Too tight (hips*, calf/ boot)	Pocket placement Suspender placement
Boots	Not sized small enough Lack of size access	Too long	Too wide	N.A
Gloves	Not sized small enough Lack of size access	Too long	Too wide	N.A

Information is from Boorady et al. (2013), Hulett et al. (2008), McKinney et al. (2021), Park et al. (2014), Park and Langseth-Schmidt (2016)

\* McKinney et al. reported mixed findings (2021)

the measurements needed for product development. Overall, manufacturers have taken care to integrate NFPA standards, but there is a gap in how the required measurements are incorporated into products and sizing systems. There is a need to improve existing measurement definitions, add new measures for better product creation, and develop in-depth anthropometric databases—that incorporate more relevant product-related measurements. Actionable directives that fire PPE manufacturers could integrate to improve sizing and fit for women are presented below and summarized in Table 9.

Manufacturers rely on their sizing representatives and firefighters to take accurate measurements when fitting gear. However, the measurement definitions provided by manufacturers are not distinctly defined. Better directions could be devised and added to manufacturer websites so anyone could size PPE more accurately. For example, measurers may be unsure whether to measure the waist circumference at the navel, small of the back, or at a different location. A clear definition of this measure would improve waist fit—an area with known fit challenges for women—with little effort from the manufacturer.

Although manufacturers make coats and pants specifically for female firefighters, and they are sized smaller than the men's products, there are opportunities to improve sizing and fit. Coats and pants should be shorter proportionally to fit the female neck, torso, arm, legs, and crotch better to improve the adoption. There are also opportunities to improve the circumferential body fit for the female chest, waist, sleeve, shoulders, neckline, hip, legs, and rise. To address these issues, an anthropometric study of female firefighters (static and dynamic) could assist with measures to inform better length and circumferential fit and provide a more comprehensive sizing chart.

There are existing anthropometric studies of female firefighters—however, none of the currently available databases provide measurements that provide an in-depth understanding of proportions. In addition, none of these databases (Hsiao et al., 2014; Stirling, 2002) offer measurements to accurately draft coat and pant patterns. To connect anthropometric data with the development of better-fitting coats and pants, manufacturers need additional size chart length measures. These measures could include neck, the high point of shoulder to waist, the high point of shoulder to hip (better to understand the

**Table 9** Actionable directives that manufacturers could integrate, per manufacturer communications

	<b>PPE manufacturer actionable directives</b>	<b>Justification</b>
1	Add more relevant body measures to size women into coats/pants	Not enough body measures to appropriately size/fit women into coats/pants
2	Add clear body measurement definitions	Currently, it is not always clear where body measurements should be taken to size women into products
3	Create boot sizing charts with foot measurement or Brannock device conversions	None of the manufacturers researched in this study provided online boot size charts with foot measurements or Brannock device conversions for firefighters to size themselves
4	Provide real and separate women's boot sizes per NFPA requirements	One manufacturer (Honeywell) in this study did not post women's-only boot sizes online
5	Provide boot and glove size consistency across manufacturers and models	It is difficult and confusing to select boots and sizes within and across manufacturers as they are inconsistent
6	Provide women's specific glove sizing	In firefighting, the hands are important for operating equipment. Keeping them safe with appropriately fitting gloves ensures the female firefighter can work to their maximum potential
7	Create online glove sizing charts with the required NFPA hand measurements (Additional file 2: Appendix B and Additional file 3: Appendix C)	None of the manufacturers researched in this study provided online glove size charts
8	Conduct anthropometric studies to understand the female firefighter-specific body, foot/calf, and hand measures (static and dynamic)	Current measures used to make female firefighters turnout gear are not based upon female firefighters' bodies
9	Conduct wear tests (static and dynamic) with existing coat/pant, boot, and glove products to understand current size/fit challenges	Adoption of female-specific turnout coats and pants is less than 50%. Almost 50% of the women who participated in this study reported physical fit issues with their fire boots. About 45% of the female participants reported physical fit issues with their fire gloves. Wear tests using existing products can be an efficient way to understand issues before new product development
10	Develop better training modules and tools for manufacturer representatives to understand the unique nuances of sizing/fitting the female body into PPE	Satisfaction of turnout product sizing and fit for women is poor. Researchers have cited issues with the size/fit of female firefighters' PPE (Table 1)

*PPE* Personal Protective Equipment, *NFPA* National Fire Protection Association

location of product features like pockets and suspenders), acromion to the wrist, acromion to neck front, waist, inseam, and crotch. Additional measures could include the bicep, cape, front and back shoulder width, neck, hip, thigh, and calf. With these measures more accurate pattern blocks could be drafted to help fit the female body shape.

For boots, relevant anthropometric measurement data (static and dynamic) could be collected from female firefighters' feet to inform boot last shapes or communicate better foot measures for fitting. Since female firefighters described the boot calf fit as an issue, adding a calf circumference measure could be helpful to sizing. Wear tests of existing products could also be informative to uncover size/fit issues.

An examination of glove size and fit communication revealed an opportunity to develop gloves that size and fit better for women, especially with the reported issues of finger length (too long) and palm width (too wide). Wear tests of existing products could also be conducted, along with new anthropometric measurement data (static and dynamic) from female firefighter hands (beyond the index finger and palm breadth measures). This data could inform better pattern shapes and more accurate sizing charts.

### **Female firefighter survey & 1:1 interview findings and recommendations**

Survey and 1:1 interview data yielded findings to solidify future goals of outfitting women better in the fire service. Manufacturers must improve their fitting process, conduct wear tests, and invest in anthropometric studies to improve turnout coats, pants, boots, and gloves. The sections below discuss female firefighter experiences and provide recommendations on how manufacturers can improve their product offerings.

#### ***Coats and pants***

Survey results and 1:1 interviews regarding size and fit experiences of acquiring turnout coats and pants uncovered several opportunities to serve female firefighters. The first was that more women wore men-sized coats and pants than women-sized products. Many respondents reported they wore 'unisex' products, even though NFPA requires separate male and female sizes. Likely, 'unisex' are male-sized products. It should be made clear to female firefighters that women's sizes are available for procurement at their stations. In instances where the women's products are not fitting their bodies appropriately, manufacturer representatives that fit firefighters need to document the fit challenges accurately so that the knowledge can influence future product development. In 2008, Hulett et al. reported similarly and commented that even though manufacturers have offered women's fire PPE since the 1990s, suitably sized women's gear is still unavailable (Hulett et al., 2008).

Most survey respondents and 1:1 interview participants had their coats and pants purchased for them, yet over 30% received used or previously acquired products that may have been a part of a firehouse inventory system. This practice could affect fit, performance, and safety. For women who receive used or previously acquired products, a fail-safe process should be implemented to ensure the assigned products are as safe as ones that could be purchased new for them.

Most female firefighters reported that someone else (e.g., manufacturer rep or station manager) sized them during the sizing process, and their size was determined by comparing their body measurements to a sizing chart. In fewer instances, women tried on styles available at their firehouse or brought in by the manufacturer to size into a product. Under 10% of the respondents received custom products based on their body measures. From the survey data, we know that women lacked access to women's sizes or lacked access to products in small enough sizes. This demonstrates that manufacturers or company representatives could take better care in measuring women for gear. A larger measurement set to capture body shape would assist manufacturers to understand where the size/fit challenges lie, so future products could be developed more appropriately.

Similar to previous studies (Table 8), female firefighters expressed frustration finding female-orientated gear, smaller sizes, and challenges with lengths and circumferences. Some expressed that they thought manufacturer representatives did a poor job sizing because many firefighters at their station received poorly fitting products. These findings demonstrate the necessity of improving the sizing process and the importance of developing more appropriately sized products for female firefighters based on anthropometry. Manufacturer representatives might also need to be trained to measure female firefighters differently to understand the nuances of fitting the female form. A protocol should

be developed to document sizing issues experienced with the current product to share with internal product development teams and the NFPA. The interface between manufacturer representatives and female firefighters when sizing new gear could be a powerful relationship to collect data and improve future products.

### ***Boots and gloves***

The survey and 1:1 interviews found that most women acquired and sized their turnout boots by trying on sizes available at their firehouse or through ones provided by a manufacturer. Although women had the autonomy to size and fit boots themselves, more than half of the respondents reported difficulties finding a size that fits well. These findings parallel previous studies (Table 8) where women said boots were unavailable in small enough sizes or the boots were too long/wide. Like the survey findings for coats and pants, this suggests an opportunity to develop new products that better fit the female foot and calf by collecting anthropometric data and wear testing products during development. There may also be an after-market opportunity or new product space for manufacturers to provide fire-specific insoles to assist with fit, comfort, and foot stability.

Women in the study reported wearing men's or unisex sized gloves versus female sizes (2%). Interestingly, all current fire gloves from the leading U.S. manufacturers are unisex, suggesting that women think female options are available. Likely, this confusion is coming from the different fit options offered by manufacturers where the slim fitting styles have been adopted as "women's fit". 1:1 interviews revealed that most women sized their gloves by trying on ones available at their station or provided by a manufacturer. They often made repeat purchases of the same glove for consistency but noted that fit could be different between brands.

Most women acquired and sized their gloves by trying on sizes available at their firehouse or through ones provided by a manufacturer. Almost half of the respondents reported difficulties finding a glove size that fit well, and this paralleled previous studies where women reported gloves were unavailable in small enough sizes or too long/wide (Table 8). When female firefighters acquired gloves they liked, repeat purchases of the same sized/branded glove were made. These findings suggest that researchers and manufacturers could potentially develop female-specific gloves by collecting anthropometric data to determine sex differences. Wear testing protocols of current fire glove products could also be conducted to capture systematic data of where size and fit challenges exist.

Manufacturers need to understand that the female body has more shape variability to remedy sizing and fit turnout challenges. Special care should be taken to systematically document issues they can reference when developing new products during the sizing process. More measures should be built into sizing tables to achieve a better fit. Anthropometric studies and wear tests could be organized to provide input, to improve future products. From the 1:1 interviews and survey data, actionable directives that manufacturers could integrate to improve female firefighter turnout sizing and fit are summarized in Table 10.

### **NFPA standard findings**

This research identified opportunities for the NFPA to evolve standards to improve female firefighter safety through better sizing and fit procedures. Standards should be

**Table 10** Actionable directives that manufacturers could integrate, per survey results and 1:1 interviews

	PPE manufacturer actionable directives	Justification
1	Provide more transparent communications to firehouse gear managers and female firefighters that women's size-specific coats/pants are available, per NFPA requirements	Female firefighters adopting fire coats/pants in women's sizes is low (< 50%). Women may not know that gendered products are available to them
2	Add more relevant measures to size women into coats/pants	Not enough measures to appropriately size/fit women into coats/pants
3	Develop a method for firehouses when sizing/fitting female firefighters in used or gear purchased for other firefighters/inventory	In this study, 30% of the women surveyed wore gear not purchased for them. Interviewees reported receiving used fire coats
4	Develop better training modules and tools for manufacturer representatives to understand the unique nuances of sizing/fitting the female body into PPE	About 25% of the women surveyed in this study experienced physical fit issues with their fire coats/pants. Through interviews, women reported that manufacturer representatives did a poor job sizing because many female firefighters at their station received poorly fitting products
5	Consider developing after-market insoles for assistance with the fit, arch support, and comfort	From the survey, women reported that their boots were too long/wide, and they purchased after-market insoles to help resolve those fit issues
6	Develop women's-specific sized fire gloves	Almost 50% of the female survey respondents reported difficulties finding a glove that fits well
7	Provide size/fit consistency across manufacturers and models	The interview data discovered that fit within and between brands was inconsistent
8	Conduct anthropometric studies to understand the female firefighter-specific body, foot/calf, and hand measures (static and dynamic)	Current measures used to make fire coats/pants, boots, and gloves are not based upon female firefighter bodies, feet/calves, and hands
9	Systematically document the existing product's female size/fit challenges through wear tests (static and dynamic)	Wear tests using existing products can be an efficient way to understand issues before new product development

PPE Personal Protective Equipment. NFPA National Fire Protection Association

clearer for manufacturers regarding product development and communication to firefighters regarding sizing and fitting procedures. For coats and pants, several opportunities were identified where the NFPA could develop better sizing and fit procedures for women. One simple idea is to communicate to all-female firefighters and station managers that PPE coats and pants are available in women's sizes and should be offered to all women—no matter the budget of the firehouse or rank of the individual.

A second opportunity is for the NFPA to define measures more clearly for sizing. To demonstrate why defining measures are needed, the current NFPA definition for the waist location can be an example. In the standards, it is currently called "waist" with no direction as to where on the body the waist is. In the apparel industry, there are five methods of defining/measuring the waist in the apparel industry. Four of them are methods defined by anthropometry literature, including (1) the small of the back where the spine has the largest indent when the body is viewed from the side, (2) at the smallest circumference between the hips and bust, (3) at the centerline between the bust and hip levels and (4) at the center of the waist region with a proportional length (e.g., small of the back minus 4 cm) (Xia et al., 2020). The fifth waist placement is at the navel level. With current NFPA standards, it is unknown which waist measurement definition to follow and for women—measurements taken at any one of these five locations could vary greatly and impact fit. Without a consistent definition and directive from NFPA, it would be impossible to consistently size and fit women correctly into turnout coats or pants.

None of the current NFPA measures explain how the measurements relate to each other along the length of the body. The chest measurement is an example where it is not defined by how far in length it is from the waist. This non-standardized method of measuring may explain why women have issues with their coats fitting too long on their bodies and why they cover their pant pockets. Women are not smaller versions of men; they are proportionally different. Therefore, the products made for female bodies need to be developed with circumferential and length measures derived from their actual bodies.

The existing NFPA standard also lacks the appropriate measurements to size/fit pants for women. Women tend to have larger hips than waist measures, yet there is no hip measurement requirement. Frustrations reported with hip/crotch tightness and comfort could be better addressed with the addition of a hip measure and a length measure of the hip from the waist. Other measures like thigh and calf circumference, crotch rise, and dynamic hip circumference (in a squat position) could help assign sizes or build better functioning custom pants for women. The NFPA might consider partnering with researchers or manufacturers to sponsor an anthropometric study to collect 3D body scan data and measurements from female firefighters relevant to product development.

While PPE sizing standards are often different from ready-to-wear, it is important to note that the increment between sizes set forth by the NFPA for coats and pants is overall larger and more static than what is found in traditional women's ready-to-wear apparel (ASTM 5585-11, 2011). For misses sizes 00–20, the ASTM 5585-11 standard sets proportional graded increments at 0.5" to 2" (6-50 mm) for chest, 0.125" (3 mm) for sleeve length, and 0.75" to 2.25" (19-50 mm) for waist (ASTM 5585–11, 2011). Additionally, ready-to-wear sizes accommodate waist girths as small as 23.875" (606 mm) (ASTM 5585-11, 2011). If the NFPA continues to regulate increments between sizes, then a smaller increment should be explored. Additionally, more dynamic grading increments based on anthropometric data could drastically improve sizing systems in fire gear. The NFPA should work with researchers, manufacturers, and firehouses to develop better PPE sizing regulations and procedures. The NFPA could be involved to certify each manufacturer is sizing PPE products the same way. They could also sponsor a wear test of current products to formally document female fit issues using a national database and share information directly with manufacturers for future product development.

Recommendations for better turnout boot sizing and fit could include having manufacturers size the boot interior to the Brannock device and ensure that manufacturers have those conversion charts and Brannock devices readily available when sizing. None of the women in this study mentioned having their feet measured with a Brannock device as part of their boot sizing process. Like coats and pants, the NFPA might consider partnering with researchers or manufacturers to sponsor an anthropometric study to collect 3D lower leg/foot data and define measurements from female firefighters relevant to boot last development. Given that some firefighters are using after-market insoles, the NFPA might choose to build requirements for the materials those products are made from as a preventative safety measure. Many of these devices are produced from plastics and foams that could melt under high temperatures.

In firefighting, the hands are essential, yet nearly half of the women surveyed/interviewed had fit issues with their gloves. There was no evidence of women using the index finger and hand breadth measurements required by the NFPA for sizing gloves. Women

in the study reported they found their glove size by physically trying on gloves, suggesting that this method was more accurate. Perhaps it is time to require female-specific glove sizes or develop a standardized naming convention between manufacturers for glove sizing to decrease confusion between size names, as manufacturers have different methods. As mentioned, the NFPA might also consider partnering with researchers or manufacturers to sponsor an anthropometric study to collect 3D female hand data and define measurements relevant to glove development. In all, the NFPA has a prominent role in influencing change to improve female firefighter safety and performance, and this research has defined several ways to evolve current regulations. The NFPA could integrate the following actionable directives to improve female firefighter turnout sizing and fit (Table 11).

### Conclusions

This research addressed the issue of ill-fitting PPE for female firefighters by examining the process to acquire PPE, to inform future practices and procedures to better size and fit products, to reduce the risk of injury. The study was unique because it addressed the major contributing factors to ill-fitting PPE gear for women—the undocumented knowledge gaps between size standards, commercialized products, and processes used

**Table 11** Actionable directives that the NFPA could integrate to turnout sizing and fit

	NFPA actionable directives	Justification
1	Provide more transparent communications to firehouse gear managers and female firefighters that women's size-specific coats/pants are available, per NFPA requirements	Female firefighter's adoption of fire coats/pants in women's sizes is poor (< 50%)
2	Develop clear measurement definitions that are understood by anyone involved with sizing/fitting turnout coats/pants	Currently, the NFPA standard provides no measurement definitions
3	Include more measurements to help size women into coats/pants better	The current NFPA measurement requirements do not capture women's challenges with sizing/fitting fire coats/pants (e.g., hip circumference and lengths)
4	Develop training modules and tools for manufacturers to use for sizing/fitting the female body into fire coats/pants, boots, and gloves	In this study, women reported that manufacturer representatives did poorly at sizing them
5	Mandate sizing/fit communication methods and compliance across manufacturers	Manufacturers inconsistently communicate their sizing and fit methods
6	Require accurate boot volume size conversions to Brannock device or related measurement tool	Boots inconsistently fit across manufacturers
7	Mandate that all firehouses and manufacturers provide Brannock devices or related measurement tools to size/fit firefighters into boots	None of the participants in this study used a Brannock device to size/fit into boots
8	Build new requirements for after-market insoles	After-market insoles can be made of low-melt point materials, so there may be a need to specify materials next to the foot for safety
9	Require female-specific glove sizing	Currently, the NFPA does not require women's glove sizes. More than 50% of the subjects in this study experienced physical glove fit issues
10	Mandate all firehouses and manufacturers provide glove sizing tools to size/fit firefighters	None of the participants in this study used the NFPA index finger and handbreadth measurement guide
11	Sponsor an anthropometric study to understand the female firefighter-specific body, foot/calf, and hand measures (static and dynamic)	Current measures used to make fire turnout gear are not based upon female firefighter bodies. Additionally, better grading increments based on anthropometry data are needed

by manufacturers/firehouses to fit female practitioners. It also provided actionable directives that could be adopted immediately by manufacturers, firehouses, and the NFPA to improve safety for women.

The limitations of this study included smaller sample sizes and leading questions that focused on sex-related issues. However, questions were developed to understand the sizing and fit experiences of female firefighters. The firefighters who participated in the study also volunteered their time, so only women with size and fit issues may have chosen to participate. Despite limitations, the findings paralleled other related studies; and the two sets of qualitative data (survey and 1:1 interviews) netted similar results. The 1:1 interviews helped to provide a deeper understanding of survey data alone. Besides, as the manufacturer's sizing and fit content were collected from the internet, better information could be available through physical catalogs, tech cards, or trained representatives. However, given the importance of digital communication, the authors felt web content should be where the most accurate and current information is housed. In conclusion, this study uncovered several opportunities to improve the size and fitting process women experience with acquiring new turnout gear. With effective partnerships and future research, there is the potential for women to experience fewer injuries and improved performance with their PPE, establishing equality with their male counterparts.

### Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s40691-022-00314-8>.

**Additional file 1: Appendix A.** Required Standard Size Ranges and Increments for Firefighter Coats and Pants. Note. Information is from the NFPA (2018a).

**Additional file 2: Appendix B.** Measurement Locations for Index Finger Length (Left) and Hand Breadth (Right). Note. Redrawn from NFPA 1971 (NFPA, 2018a).

**Additional file 3: Appendix C.** Hand measurements and corresponding fire glove sizes. Note. Redrawn from NFPA 1971 (NFPA, 2018a)

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### Author contributions

SS and LG collaborated with Women in Fire to devise the study and develop the method of data collection. SS, LG, YW, EM and KM collected data at the 2018 Women in Fire conference and coded 1:1 interview data. SS developed the initial draft of the manuscript with assistance from CB. Figures were created by CB and SS. LG, YW, EM and KM provided feedback and edited the manuscript. All authors read and approved the final manuscript.

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#### Availability of data and materials

The datasets analyzed for the study are available from the corresponding author on reasonable request.

#### Declarations

##### Ethics Approval and Consent to Participate

This research was conducted under the approval and supervision of University of Minnesota IRB Approval Number 1701S03841: Sizing and Fit Research for Trade Workers using PPE, Kansas State University IRB Approval Number 9415: Anthropometric Study of Firefighters: Male and Female Full body, Hands and Feet, Iowa State University IRB Approval Number 18-038-00: Anthropometric Study of Firefighters: Male Hands and Feet and Female Full Body, Hands and Feet, and University of Missouri IRB Approval Number: 2010430C: Anthropometric Study of Firefighters: Male Hands and Feet and Female Full Body, Hands and Feet.

##### Competing interests

The authors declare that they have no competing interests.

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