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An Investigation on Female Firefighters' Challenges with Current Firefighting Turnout Coat and Pants

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Abstract

As more females integrate into fire service, it is essential to provide them with appropriate personal protective equipment (PPE), particularly firefighting turnout coat and pants. Previous research has highlighted the challenges firewomen face regarding the fit and comfort of their gear; however, no efforts have been made to comprehensively examine the designs, materials, and sizing systems of female-specific firefighting turnout coat and pants. Thus, this research aims to understand the concerns of female firefighters regarding existing turnout coats and pants, including but not limited to size and fit. This study is distinctive because it provides a comprehensive exploration of female firefighters' concerns about the design and fit of their turnout ensembles. To achieve this goal, the researchers conducted a systematic literature review and analysis. The study reviews the challenges firewomen face when working in their turnout gear, identifies the gaps in the fire service's PPE market, and propose potential solutions to address the concerns of female firefighters.

Keywords: Firewomen; Female firefighters; Turnout gear; Personal Protective Equipment; Fit

Abbreviations: PPE: Personal Protective Equipment; NFPA: National Fire Protection Association; SCBA: Self-Contained Breathing Apparatus

Introduction

In recent decades, there has been a steady increase in the number of female firefighters in the United States (U.S.). In 2020, the National Fire Protection Association (NFPA) estimated that there were 89,600 female career and volunteer firefighters in the U.S. [1]. This figure represents nine percent of the total 1,041,200 firefighters in the country and indicates a growing trend [1]. For comparison, the 2000 U.S. Census reported only 11,000 female firefighters [2]. As more women integrate into the fire service, it is essential to assess and understand the needs of female firefighters and provide them with appropriate equipment.

Firefighting personal protective equipment (PPE) is designed to protect firefighters from heat and hazardous environments during fire ground emergencies [3]. A complete set of fire service PPE includes a "turnout coat, turnout pants, boots, gloves, helmet, face mask, hood, and a self-contained breathing apparatus" (SCBA) [4]. By wearing this complete array of equipment, firefighters are effectively shielded from high heat, corrosive chemicals, and harsh surfaces [5]. The NFPA has established comprehensive standards and testing requirements for designing and producing firefighting PPE [5]. This study focuses on turnout coats and pants, which are regulated by NFPA 1971. Turnout coats are defined as the element of PPE, which protects the firefighter's "upper torso and arms, excluding head and hands"; while turnout pants protect the "lower torso and legs, excluding ankles and feet" [6].

Firewomen's challenges with current firefighting PPE

Despite the importance of PPE for both sexes, female firefighters find themselves primarily underserved by the existing turnout coats and pants available in the market [7]. The

issue of manufacturers failing to accommodate female firefighters adequately is well-documented [2,8]. The predominant reason for this is that the design of such gear has historically been based on male body dimensions, with the female equivalent simply being a downsized version [7,9]. However, women are not merely smaller versions of men in terms of height and weight; rather, they have distinct body shapes with diverse proportions [4,7,8]. Differences between men and women become apparent when considering the bust area, waist circumference, hip breadth, and even extend to smaller anatomical areas like neck circumference and finger length [2,8,10]. Thus, female firefighters face challenges finding and selecting properly fitting turnout gear from available options [7].

To address this issue, many female firefighters often choose a larger size based on their widest measurements, typically their bust and hips [7]. However, this selection process can result in various problems, such as poorly fitting sleeves, waist, coat length, and pant legs [7,8]. These challenges are not trivial, as improperly fitting turnout gear can directly affect female firefighters' comfort, mobility, and safety [7]. Thus, many female firefighters often must adopt a make-it-work approach [7]. It is typical for firewomen to utilize suspenders and belts to secure oversized equipment; however, when accessories fail to address the issue, ill-fitting gear can be a source of distraction for firewomen, leading to constant adjustments and readjustments while performing their duties [7].

On the other hand, some firewomen have access to customized gear in certain instances [7,8]. However, a global survey by Watkins et al. [11] showed that merely a fraction of firewomen with access to customized gear were satisfied with the available selection. This dissatisfaction may arise because manufacturers typically focus on customizing male-specific or unisex gear for women rather than designing gear specifically for female firefighters [7].

Both practices noted above would risk firewomen performing essential occupational tasks on fire grounds. Studies reveal that improperly fitted turnout gear can lead to injuries on the fire ground, including harmful exposure, falls, and extreme fatigue [4,7]. Moreover, ill-fitted equipment is not practical and functional. In this context, the term "functional" refers to how well the equipment can be utilized in its intended role. Thus, to reduce physical strain and enhance the effectiveness of firewomen's occupational tasks, providing them with better-fitted and functional turnout gear is critical.

Female-specific firefighting turnout gear

Female-specific turnout gear refers to gear that is specifically tailored for the female physique. It needs to be designed and constructed with an understanding of the female body's distinct dimensions [7]. A better-fitted, female-specific turnout gear can enhance firewomen's mobility and safety while increasing wearer comfort and the overall usefulness or function of the gear [7]. For example, current turnout gear includes features such as pockets and kneepads that are often rendered useless for firewomen due to their improper placement and lack of accessibility when worn on a female body [7,8,12]. Developing turnout gear tailored explicitly for females could address this issue. Besides, female-specific firefighting gear could simplify the process of choosing the correct size of turnout coat and pants for female firefighters, thereby reducing the necessity for special modifications [2,4,7].

Studies have advocated for developing turnout gear tailored explicitly for females [4,8,12,13]. Sokolowski and colleagues [7] examined the current challenges of female-specific PPE in sizing and fitting progress. In their study, major brand's sizing systems were studied. However, this study did not examine brands' online information beyond size and fit. Besides, as a regulatory body, NFPA 1971 has a recent addition in 2018 specifying that "men's and women's sizing shall be accomplished by men's and women's individual patterns" [6]. Nevertheless, the compliance status regarding pattern design for turnout coats and pants on the market remains unclear. Furthermore, little research has been found where a female-specific turnout coat and pants have been conceptualized, developed, and evaluated for physical comfort or fit.

Research Objectives and Questions

The objective of this research is to understand the concerns of female firefighters regarding existing turnout coats and pants, including but not limited to size and fit. This study is distinctive because it provides a comprehensive exploration of female firefighters' concerns about the design and fit of their turnout ensembles. Specifically, the research questions (RQ) guided this research is: What are female firefighters' concerns with existing turnout coats and pants?

Methods

To address the proposed RQ, the researchers investigated the concerns and needs of female firefighters for turnout ensembles, focusing specifically on fit and size issues related to the female physique. This investigation was based on a systematic literature review of articles, technical reports, and NFPA standards.

Search strategy

The review process began with a comprehensive search in the electronic databases of EBSCO and ProQuest. Four key terms were used in varying forms: 'firewomen', 'firefighters', 'turnout gear', and 'personal protective equipment'. Boolean operators 'AND' and 'OR' were applied to ensure maximal retrieval of relevant results. The search focused on peer-reviewed articles, technical reports, and NFPA standards published between January 1, 2000, and April 30, 2023. The initial screening involved scanning titles for relevance, and any articles that did not directly investigate the relationship between firefighters and their turnout gear were omitted. Following the initial screening, the researchers scrutinized the abstracts of the remaining articles more rigorously. The selection criteria required the studies to 1) explore issues regarding sizing and fit, 2) incorporate firewomen as study participants, and 3) distinctly delineate firewomen in their findings. In the final screening phase, any articles with a sample size of fewer than 10 female participants were excluded to ensure robust statistical analyses and reliable findings. After screening, four articles were selected for the final

systematic review (Table 1). For each study, the researchers collected data about female firefighters' challenges regarding the sizing and fit of their turnout coats and pants, sample size, and study methods.

Table 1: Four articles selected for systematic review.

Title	Year	Authors	Journal/Publisher	Keywords/or Key Findings
Exploration of Firefighter Bunker Gear Part 2: Assessing the Needs of the Female Firefighter	2013	Boorady et al. [8]	Journal of Textile and Apparel, Technology, and Management	firefighter, protective clothing, sizing
Perception of Firefighters' Turnout Ensemble and Level of Satisfaction by Body Movement	2014	Park & Hahn [12]	International Textile and Apparel Association	firefighter, satisfaction, body movement, fit
Understanding firewomen's fit problems with their coats and pants and its impact on mobility and safety	2021	McKinney et al. [7]	WORK: A Journal of Prevention, Assessment, and Rehabilitation.	turnout gear, firefighter, protective equipment
Female firefighters' increased risk of occupational exposure due to ill-fitting personal protective clothing	2023	McQuerry et al. [13]	Frontiers in Materials	female firefighter, personal protective clothing, turnout gear, wildland, protection, fit, sizing

Result

The researchers found limited studies focusing on fit issues among firefighters, particularly female firefighters. Only four articles had all participants as firefighters and had discussions on the fit and design of turnout gear in which female firefighters were the primary focus or, at minimum, were distinguished from the male firefighters as part of the results. Table 2 lists the key findings of these four articles related to design and fit challenges. In this table, "M" means male, and "F" means female.

Table 2: Systematic review findings.

Study	Method (Participants)	Female Firefighter Turnout Gear Design and Fit Challenges	
		Turnout Coat	Turnout Pants
Boorady et al. [8]	Focus Groups (N = 23)	Design-Placement: pockets, suspenders	Design-Placement: pockets
		Fit-Length: oversized coat, sleeve	Fit-Length: oversized pant, crotch
Park & Hahn [12]	Survey (N = 314 F, 202 M)	Fit-Circumference: oversized neckline, shoulder, and sleeve; tight chest, hip	Design-Placement: pockets, kneepads
		Fit-Length: oversized coat, sleeve	Fit-Circumference: tight lower pant leg
			Fit-Length: oversized crotch
McKinney et al. [7]	Interview (N = 35 F)	Fit-Circumference: oversized waist, shoulder, and sleeve; tight neck, chest, and hip	Design-Placement: kneepads
		Fit-Length: oversized coat, sleeve, and collar	Fit-Circumference: oversized waist; tight thigh and pant hem
			Fit-Length: oversized crotch, inseam
McQuerry et al. [13]	Survey (N = 954 F)	Design-Placement: pockets	Design-Placement: pockets
	Focus Groups (N = 37 F)	Fit-Circumference: oversized collar; tight chest, hip	Fit-Length: oversized crotch
	Body Scans (N = 189 F)	Fit-Length: oversized collar and sleeve	

Exploration of firefighter bunker gear part 2: Assessing the needs of the female firefighter

Boorady et al. [8] divided their assessment of female firefighters' concerns into five categories: garment design, sizing, fit, mobility, and fabrication. Regarding garment design, female firefighters expressed dissatisfaction with the style of suspenders, the placement of the radio pocket on their turnout coats, and the bellows style pockets on their turnout pants, finding them uncomfortable for their female figures [8]. Sizing was another issue raised by firewomen, as they faced challenges with oversized coats, pants, suspenders, boots, and gloves due to the lack of firefighting gear specifically designed for females [8]. Firewomen also voiced fit-related concerns. Their coats, sleeves, and pant legs were excessively long [8]. Some female firefighters resorted to raising their suspenders to address the problem of long pants temporarily, but this solution was not sustainable as the suspenders would stretch out over time [8]. Additionally, the issue of oversized crotch fit was highlighted as a significant obstacle to carrying out critical firefighting duties [8]. Regarding mobility and fabrication, firewomen identified the bulkiness and weight of their turnout gear as significant limitations on their movement [8]. As a result, the researchers recommended further studies to explore the development of size systems tailored explicitly to female firefighters to produce turnout gear that caters to their needs [8].

Perception of firefighters' turnout ensemble and level of satisfaction by body movement

Park and Hahn [12] examined the satisfaction levels of 516 firefighters, 314 of whom were female. The researchers assessed participants' satisfaction with various aspects of the turnout ensemble, including coat length, chest, sleeve length, armhole, sleeve fit, shoulder, neckline, coat pockets, pants length, leg fit, crotch, hip, waist, and cargo pockets [12]. The study found that female firefighters expressed lower satisfaction than their male counterparts across all areas of the turnout ensemble. Both male and female firefighters encountered common fit issues, such as oversized necklines, poorly placed pockets and kneepads, oversized crotches, and tight lower pant legs. Regarding female firefighters, the researchers specifically observed difficulties in managing excessive length along the neckline, shoulders, and sleeves. In addition, oversized coat length, tight chest fit, and tight hips were identified as particular issues for female firefighters. To address these challenges, firefighters in the study recommended incorporating more customizations and developing turnout gear tailored to the specific needs of female firefighters [12].

Understanding firewomen's fit problems with their coats and pants and its impact on mobility and safety

McKinney et al. [7] conducted interviews with 35 female firefighters to investigate the issues related to the fit of their turnout coats and pants and the subsequent impact on mobility and safety. The researchers found that the female firefighters experienced tightness in the areas of the neck, chest, and hips of their turnout coats [7]. Simultaneously, there was excessive looseness around the waist, shoulder, and sleeves [7]. Moreover, the coat's length, including the sleeves and collar, needed to be shorter [7]. Such ill-fitting coats interfered with their ability to climb ladders and reach items on the ground [7]. Similarly, the turnout pants posed considerable fitting issues, with female firefighters finding it challenging to find pants that fit their waist and hips simultaneously [7]. Additional comments included loose thigh fittings, tight pant hems, improperly positioned kneepads, and excessive crotch and inseam lengths [7]. Ill-fitted turnout pants restricted movement due to low crotch levels and caused shoulder pain from suspender usage [7]. A recurring problem highlighted by the female firefighters was the lack of access to turnout gear that catered to the female body shape [7]. Participants emphasized how poorly fitting gear negatively impacted their ability to perform essential movements such as crawling, bending over, walking, raising their arms, and squatting, ultimately compromising their safety [7]. The researchers concluded that firefighting PPE brands should create female-specific turnout gear rather than customizing gear already designed for the male physique [7].

Female firefighters' increased risk of occupational exposure due to ill-fitting personal protective clothing

Through focus groups with 37 women, McQuerry et al. [13] collected data on the fit challenges faced by female firefighters. Their research differentiated between the challenges faced by structural firefighters and wildland firefighters. However, this review will only discuss findings relevant to the design of structural turnout gear. The study found female firefighters struggled with turnout coats, often finding the collars too wide and lengthy [13]. They also experienced discomfort due to tightness around the chest and hip areas [13]. Additionally, the sleeves of the jackets were reported to be overly long [13]. For turnout pants, the main issue highlighted by female firefighters was the excessive length in the crotch area [13]. The participants underlined that these fit problems with their PPE impeded mobility, thus compromising safety and comfort [13]. The female firefighters suggested modifications such as flared turnout coats to accommodate their hips better and more strategically placed pockets [13].

Insights for the design and development of female-specific turnout gear

Turnout gear that caters to female firefighters must ensure an optimal balance between fit, safety, and functionality. Ensuring the gear is designed to fit female body shapes, including narrower shoulders, wider hips, and variations in torso and leg lengths, is crucial [4,7,8]. Gear should be neither too loose, which could result in snags, nor too tight, which could restrict mobility.

Another critical element is the adjustability of the gear. Given firewomen's diversity in body shapes and sizes, turnout gear must offer features adjustable to different needs. These could include adjustable waistbands and expandable pleats. Such adjustable features ensure a more personalized fit, enhancing comfort and safety while on duty.

Furthermore, the design should consider the ergonomics of female firefighters in terms of practical utility. The placement of pockets, utility loops, or attachment points for gear should be assessed with female body types in mind. Locations of pockets, for instance, should be adjusted for easy access. Finally, the gear should be designed for easy donning and doffing, even under stress. Fastening methods such as zippers or clasps should be efficient and straightforward.

Discussion

In this study, a systematic review was conducted to address the RQ. Then based on the findings, the researchers suggested critical improvements for revolution the design and develop female-specific turnout coats and pants. In this section, the researchers discussed the key findings from the systematic review and then provided suggestions for improving turnout coats and pants for firewomen.

Firewomen's concerns on existing turnout coats and pants

The systematic review examined the various design and physical fit challenges female firefighters experience when wearing their turnout coats and pants. Common recurring issues with turnout coats included an oversized neckline/collar, sleeves, and coat length, as well as tight chest and hip measurements [7,8,12,13]. Likewise, recurring issues with turnout pants included an oversized crotch, inseam, and tight lower pant hem [7,8,12,13].

Design-related problems that were frequently mentioned included inappropriately placed pockets and kneepads, resulting in a loss of functionality [7,8,12,13]. Outlier issues related to turnout coats included oversized waist, shoulders, and tight neck [7]. Outlier challenges of pants included suspender design, oversized waist, and tightness at the thigh [7,8].

All the studies reviewed noted that ill-fitting gear adversely affects the mobility and safety of female firefighters when performing critical firefighting tasks. Boorady et al. [8] revealed that since turnout gear is not designed for the female body shape, female firefighters opt for gear sizes that best accommodate their widest features (e.g., bust, hips) relative to the male physique. This results in oversized and ill-fitting turnout gear, disproportionately affecting female firefighters and creating bulkiness and excess weight [8]. In the past, the proposed solution for female firefighters has often centered around increased customization of their turnout gear [2,4,12]. However, the findings from this review suggest that female-specific turnout gear would be a more practical approach to resolving the current issues [7,8,12].

Design suggestions for turnout coats and pants for firewomen

Based on the systematic review findings, the researchers identified key areas that are needing improvement to help turnout coat and pants design fit the female body shape.

First, this research revealed a notable absence of female-specific designs among the current market. This conclusion was drawn based on a visual analysis of each design. Notably, the NFPA advocates for separate patterns to achieve gear sizing for females and males, yet none of the current brands explicitly indicated the presence of male and female designs [6]. Particular attention was paid to design features around the bust and hips, which were problematic for many female firefighters [7,8]. The researchers noted that none of the turnout coat designs available in the current market indicated their capability to contour to the female bust.

Similarly, the design of turnout pants predominantly featured a low rise. While this design may be suitable for male firefighters, it may not be optimal for female body shapes. A higher waist design in turnout pants better accommodates women's lower waist-to-hip ratio, providing a comfortable, secure fit that prevents slipping during intense operations. Distributing gear weight more evenly reduces hip and lower back strain, which is particularly beneficial for female firefighters with wider hips and smaller waists. This design may also negate or lessen the need for suspenders, which can cause discomfort, particularly on the shoulders and across the bust [8].

These findings imply that female firefighters encounter more physical fit issues with their turnout coats and pants than their male counterparts. These findings align with previous studies conducted by Hullet et al. [2], Park & Hahn [12], Park & Langseth-Schmidt [4], and Watkins et al. [11]. To address this issue, numerous studies have recommended the development of female-specific turnout gear [7,8].

Thus, this study holds practical importance, as it suggests novel, functional, and female-specific designs for firefighting turnout coats and pants. The researchers suggest new designs fit female body shapes, including narrower shoulders, wider hips, shorter sleeves, and variations in torso and leg lengths, and provide adjustability at the bust and waist. The placement of pockets, utility loops, or attachment points for gear was assessed with the female physique in mind. It also includes articulated elbows and a bi-swing back to ensure a full range of movement, a free-hanging throat tab to enhance neck protection, a drag rescue device, and detachable lining to meet NFPA requirements. The researchers suggest future exploration of designs through digital technologies, optimize it through iterations, prototypes, and evaluations, and develop new communication avenues.

Implications for the firefighting industry and female firefighters

The implications of this research extend to multiple stakeholders in the firefighting industry, including the NFPA, turnout gear manufacturers, fire departments, and female firefighters. The development of a female-specific design for turnout coats and pants, along with wear trials involving female firefighters, addresses the longstanding issue of ill-fitting gear for women. This research allows the NFPA to update their standards, manufacturers to cater to the unique needs of female firefighters, fire departments to advocate for properly fitted gear, and female firefighters to benefit from improved comfort, mobility, and safety. These outcomes contribute to a more effective and supportive environment within the firefighting industry.

Limitations of the study and future research directions

Additional research is needed in the following three areas. First, there is a need to accurately identify and quantify the average body type or build of female firefighters, particularly those in the United States. Ideally, body measurements of firewomen would be collected using 3D body scan technologies, and a sizing system specifically for the U.S. firewomen should be developed based on large-scale anthropometric data with recommendations for fit customization. Second, multi-layer prototypes could be made of industrial-level materials and novel functional/smart textiles and produced with new digital technologies, such as incorporating 3D printed knee pads for customization and attaching smart devices for health and safety monitoring. Third, evaluation of the prototypes though wearing trials should be performed with the participation of firewomen following a systematically designed testing protocol. It would be even better if the thermal comfort or pressure of the turnout coat and pants prototypes were tested with a sweating fabric mannequin in a setting mimicking an onsite fire emergency.

Besides, building upon this research, future investigations can examine the customization of other vital components of firefighting gear, including gloves, boots, suspenders, and helmets, using a similar study design. Extending the research to these areas, an in-depth understanding of the ergonomic considerations and anatomical variations specific to female firefighters can be achieved.

This research method could also be migrated to developing other types of functional clothing, such as protective gear for underserved populations such as the elderly and females in different emergency service areas.

Conclusion

This research first studied the female firefighter's concerns with their turnout coats and pants by conducting a systematic review and analysis. Then it proposed improvements for enhancing the design and performance of female-specific turnout coats and pants.

This study was critical because there is a rise in the number of firewomen who are in urgent need of effective PPEs. It is helpful to not only academics, policy and standard makers, but also manufacturers who are considering the production of female-specific designs. It also helps fire departments, who should know the challenges female-firefighters experience when working in ill-fitting gear, to discern between female-sized and female-specific designs of turnout gear. The research also benefits organizations that advocate for the safety of female firefighters. This research can also help female firefighters know what to consider or ask for when choosing, customizing, or altering their turnout coats and pants.

Acknowledgment

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Conflicts of interest

None.

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