

**Exploration of Firefighter Turnout Gear
Part 1: Identifying Male Firefighter User Needs**

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ABSTRACT

Firefighters serve as first responders and encounter a wide variety of hazards while performing their job tasks. They also perform an array of movements when responding to emergencies. It is thus critical that their personal protective equipment allow firefighters to perform their duties with minimal limitations and maximum safety. This research explored the issues firefighters experience when wearing their gear to identify areas needing improvement. Researchers conducted focus groups of male firefighters throughout the country to identify areas of concern for firefighters regarding their gear. Data were analyzed using an interpretive thematic analysis method that revealed three main problem areas: gear function, wearer comfort, and protection provided. Specific issues related to these problem areas are discussed, and suggestions are made for ways to improve firefighter gear to enhance the experience of the end user. Findings from this study serve as a guide for future researchers and manufacturers creating new gear, as well as developing enhanced education and training of firefighters regarding their gear.

Keywords: firefighter; protective clothing; user needs

INTRODUCTION

The role of the firefighter has changed dramatically over the past two decades. Firefighters have become the first line of defense for America – they are the first ones called to a variety of situations: fire, chemical spills, car accidents, and

medical emergencies. While structural firefighters' primary responsibility is to put out fires that threaten people and property, as first responders, they are also called on to respond to incidents involving hazardous materials, extrication from vehicles after a

crash, and provide emergency medical services in some communities.

The nature of fighting fires has changed also. Improvements in building codes and changes made to construction and the type of materials used in construction as well as programs about fire safety and the use of home fire alarms have resulted in fewer home fires. However, the fires that do occur are hotter and more dangerous than ever before because of these changing dynamics. Thus, firefighting is hazardous and arduous, even “one of the most physically demanding occupations” (Coca et al., 2008, p 351).

Another effect of the changing dynamics of firefighting is that the protective equipment necessary to fight fires has changed as well. Changes to bunker gear have included improvements in thermal imaging, chemistry, and technology. Firefighters perform their duties while wearing protective clothing specifically designed for thermal protection in firefighting, commonly referred to as turnout gear or bunker gear.

Firefighter bunker gear includes the coat, pants, boots, hood, helmet, and gloves which meet the NFPA 1971 and 1975 standards. NFPA Standard No. 1971 specifies that the coat and pants ensemble consist of three layers: a thermal barrier, a moisture barrier and a thermal shell which work together to protect the wearer from burns, cuts and moisture buildup. The bunker set comes in three different styles: (1) hip length coat with a straight hem worn with high waist “bib” style pants, (2) a shorter length coat worn with bib style pants and (3) a longer coat worn with pants worn at the natural waist. A knit Nomex® hood covers the head, neck and is worn under the coat. The coat sleeves interface with the gloves through an attached knit gauntlet which loops over the thumb holding the sleeve securely in place. The gloves overlap the sleeve to create a secure barrier. Firefighter boots are made of either rubber or leather (and sometimes a combination of the two materials) and are typically anywhere between 11” to 14” high. The

pants are worn over the boots. The gloves are leather or a leather/Kevlar® mix with elastic at the wrist and sometimes have a knit cuff. Different cuff lengths are offered depending on the glove style and manufacturer. Some gloves also have a breathable polymer liner to guard against hazardous liquids and offer resistance to blood borne pathogens. The helmets are made in a traditional shape with six wedges creating the crown attached to a wide brim. Helmets can be made of leather or fiberglass for the outside shell and have rigid foam inside for impact protection. There is a suspension system of straps to fit the helmet to the individual head. Helmets have Nomex® back neck and ear protection flap and can also be equipped with a face shield. In addition to bunker gear, firefighters also wear a self-contained breathing apparatus (SCBA) with complete face mask. They must also carry an arsenal of tools to help them perform their job; hammers, flashlights, a communications radio, and more.

Firefighters wear the type of bunker gear chosen by their station or department, or may have the freedom, and expense, to purchase the gear themselves. Whichever way the firefighters come about obtaining their gear, the gear itself is rarely considered perfect. Any shortcomings of the gear can be further exacerbated by poor management and/or maintenance of the protective clothing and inappropriate departmental policies regarding purchasing gear. The problems the firefighters face in the field are complex as is choosing the right combination of gear to wear. While most of the gear must meet minimal safety standards as set forth by the National Fire Protection Association (NFPA), these standards are only a baseline. Properly fitting protective ensembles are essential to all firefighters in order to provide optimal performance and safety.

This research considers the complete ensemble worn by firefighters and looked to the firefighters themselves to determine areas which may need improvement in the clothing and gear, as well as departmental policies, and

maintenance or management of the ensemble by firefighters.

BACKGROUND

There are over 80,000 injuries every year to firefighters with an estimated economic cost of \$2.8 to \$7.8 billion per year (Tri-Data Corporation, 2005). Approximately 47% of these injuries happen on the fireground or at the scene of a fire. Despite reductions in the number of fire calls per year, the rate of injuries has remained the same for the last 15 years (Tri-Data, 2005). This report notes that these injuries may take place when PPE may have been worn improperly or not used in accordance to the standards and accepted practices. The proper use of personal protective equipment (PPE) is required in order to obtain the highest level of protection it provides.

Protective clothing that is designed without the wearer in mind may end up not being used and therefore not being protective (Huck & McCullough, 1988). The Occupational Safety and Health Administration (OSHA) states that “fit and comfort should be taken into consideration” when selecting PPE (p 8). OSHA (2003, 8) also states that “PPE that fits well and is comfortable to wear will encourage employee use of PPE.”

Other research also indicates a need to involve the user in PPE evaluation. Akbar-Khanzadeh, Bisesi and Rivas (1995) researched the comfort level of PPE in the workplace and found that most of the workers in an automobile plant were uncomfortable wearing their PPE. Akbar et. al (1995) state that “the optimum level of comfort while wearing PPE can only be achieved through ergonomic design and field research” (p 197), and “the comfort and fit of PPE can be considerably improved when employees actively participate in the selection and testing of PPE” (197).

Much of the existing research on firefighter PPE focuses on the thermal protective properties alone. Only one study (Huck, 1988) was found that utilized

firefighters in assessing PPE. Thermal manikins are utilized extensively in firefighter PPE testing and research. Yet the Performance Clothing Research Group of Leeds University found that the use of a thermal manikin did not accurately determine the fit of a garment, a contributing factor to clothing comfort (Holmes, 2006). The manikin underestimated the level of comfort for any activity other than standing still. This gives further reason to question firefighters concerning the comfort of their PPE.

Rossi (2003) determined that fire fighters have two thermal hazards to be aware of – the fire and heat stress. The weight of firefighting equipment and working load that firefighters must work against added to the high temperatures they work under increased their heat stress quickly and drastically reduced the performance of the firefighters. Firefighters carry 75 to 100 pounds of additional weight when wearing their PPE. Newer styles of bunker gear are more insulative than previous styles, increasing thermal protection but also increasing weight and bulk. Francescani (2001) found that burn injuries decreased 70% since the introduction of the new styles of gear. However, previous research has found that the bulk and weight of the bunker gear inhibits the mobility of the firefighter (Adams & Keyserling, 1991; Coca, et. al, 2008; Huck & McCullough, 1988; Huck, 1991). This impact on wearer mobility may also contribute to certain types of injuries (Huck & McCullough, 1988; Huck, 1991).

PPE is the first defense between the wearer and the outside conditions; thermophysiological comfort is important to protect the wearer from outside elements. Ruckman, Murray and Choi (1998) indicated that thermophysiological comfort could be improved by allowing body heat to be transferred outside the garment and therefore preventing heat buildup. Regulating firefighters’ body temperature in this manner is difficult as the bunker gear must not allow the overheated air to enter the space between the garment and the body.

Rosenblad-Wallin (1985) suggested a user-oriented product development approach to designing protective clothing. Huck and McCullough (1988) noted that prior to their study, little research had been done that included firefighters' subjective evaluation of the bunker gear. We found no research since this study that examined bunker gear through the user's experience. Adams and Keyserling (1996) advocate testing subject populations to ascertain levels of discomfort and through this, to identify the exact locations to improve wearability. Therefore, this study was designed to subjectively assess bunker gear for male firefighters and identify areas of improvement for future product development.

METHOD

A semi-structured focus group interview methodology was selected for this study. This data collection method was chosen for the in-depth information that can be obtained from participants as they describe their individual perceptions and experiences. Focus group participants are

also stimulated by comments made by others in the group, thus the ensuing comments and discussions are often more descriptive and dynamic than individual interviews (Esterberg, 2002). Using a semi-structured interview procedure allowed for flexibility in data collection while ensuring consistency among groups.

Questionnaire

Focus group questions were developed to elicit information regarding the participants' current and past gear designs and how their gear allows them to accomplish their work tasks. An initial set of nine questions (Table 1) was asked in the same order at each focus group site. Additional questions were asked in focus groups to obtain clarification or encourage more detail to supplement participants' initial responses to the interview questions. By following a preliminary interview protocol, interviewer bias was minimized (Kvale, 1996) while still allowing flexibility for researchers in guiding group discussions to gain further insights as needed.

Table 1. Focus Group Questions

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1. What do you like best about your gear?
 2. What do you dislike most about your gear?
 3. Can you tell me a real situation in which your gear kept you from moving in a way you needed to move? What were you doing at the time?
 4. What would you change about your gear if you could?
 5. What kind of adjustments do you make to your gear to improve your wearing experience?
 6. What activities or movements are you doing when you make the adjustments?
 7. Are there any features of your previous gear that you miss?
 8. What elements of the ensemble as a whole are in need of the most improvement?
 9. What would you like to see in your next set of bunker gear?
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Procedure

After obtaining approval from the University Institutional Review Board, fire departments in four states were contacted to identify male firefighters willing to serve as focus group participants. Fire stations were selected for this study from different regions of the country, and included both career and

volunteer departments serving urban and rural populations, ensuring a broad representation of the firefighter population. Firefighters participated voluntarily, and included full- and part-time firefighters. Eight fire stations were visited (Table 2). Focus groups ranging in size from two to 21 participants were held at each fire station.

The average focus group consisted of 8 firefighters and lasted between 60 and 90 minutes. Participants' consented to having their responses audio recorded to ensure all

comments were captured. Each focus group session recording was transcribed for accuracy in data analysis.

Table 2. Focus group information

Site	Urban/Rural	Career/ Volunteer	City Populations	Area of Country	Total # of Firefighters	# of Participants
1	Urban	Career	58,000	Midwest	55	9
2	Urban	Career	30,000	East	65	7
3	Urban	Career	40,000	Midwest	75	6
4	Rural	Volunteer	9,500	Midwest	40	10
5	Urban	Career	650,000	South	900	2
6	Urban	Career	900,000	Pacific	1200	21
7	Urban	Career	350,000	Midwest	850	6
8	Urban	Career	27,500	Midwest	82	6

Data Analysis and Interpretation

Responses from the focus groups were analyzed using an interpretive thematic analysis method. Two researchers read each transcript individually to identify ideas from the focus group participants' comments. The researchers then met together, and using a back and forth iterative process (Spiggle, 1994), grouped the comments and ideas into overarching themes. These major themes related to how the gear functioned for the firefighters, wearer comfort, and protection provided by the gear. The researchers then reevaluated the individual transcripts and the comments grouped within each of the 3 themes to further classify the comments into related issues: gear design, fabrication, fit, mobility, and issues with donning and doffing the gear. By following an interpretive thematic analysis method, researchers were able to identify the issues of greater concern to participants based on their comments.

RESULTS

Gear Function

Over half of the firefighters' comments were related to how the gear functioned for them. Gear function included successful and unsuccessful aspects of design and fabrication, as well as the mobility and donning/doffing issues of the gear.

Garment Design

Participants had strong opinions about the pockets on their gear. They want more pockets that are placed in convenient locations for easy access to their gear. One firefighter simply stated, *The more the merrier. You can't put enough pockets and stuff on coats* (Site #1), while his colleague agreed, *I don't use the [pants] pockets in the back because they're hard to get to. They're kind of forgotten about* (Site #1). Another firefighter expressed his desire for more pockets, even on the inside of the coat. *A couple of inner pockets on the inside [of the*

coat], like one big pouch with a little Velcro put on the inside of your jacket for something you don't want to touch the elements for whatever reason (Site #7).

Participants also discussed how the typical patch or bellows pocket design found on turnout gear is not ideal. One firefighter said:

It's just kind of stuck on pockets and bulky. But I'm sure there could be a way that they're more part of the gear rather than just sticking out. These pockets are just a little on the small side. The pockets on the pants basically are stuck on. They're on the outside. So, if you're crawling through a tight space and you have much in that pocket, it's very easy to get them caught on things...If there was a way to design that was more streamlined...so that's not likely to catch on things because if we have to crawl through a tight space, anything extra is going to catch. (Site #1)

Other firefighters discussed their desire for a different system for supporting the weight of the pants. The suspenders place most of the weight of the pants on their shoulders, where the air pack weight also rests. This leads to fatigue when they are in their gear for long periods of time. They also have trouble adjusting the suspenders easily. One participant explained:

The suspenders tend to be a big problem with the pants in that if you don't get the right fit of suspenders for your frame, you may tend to not wear suspenders in the proper cinched up way...which again affects the pants not being properly up, because if you pull the suspenders up so that the pants are up where they're supposed to be, sometimes either the design of the suspenders becomes uncomfortable, so you adjust them down to move it out of the area where your air pack is going to rest on top of it. (Site #2)

Gear Fabrication

Participants discussed two problems they experience due to the fabrics used in their gear: reduced sensation for touch and tears in the gear. Several firefighters indicated that they lose their sense of touch, particularly in their hands, because of the thickness of gear and gloves. One firefighter stated, *The gloves are horrible. The gloves are two inches thick or above (Site #7). Others agreed, saying "The dexterity of the glove is terrible. If they could be thinner, but have the same protection. It's like an oven mitt glove (Site #1), and I don't like the gloves, the gloves are terrible. You can't really grab or use your fingers (Site #6).*

Alarmingly, one participant admitted to taking his gloves off to use his hands when actively fighting fires: *Well, when I'm going into a fire, I don't do it with gloves on. You've got to take all this off (Site #2).* Another firefighter discussed the issues of working with his gloves on in more detail: *The gloves make pressing buttons impossible. It's lucky the key button for the radio is so big. Trying to switch a channel, we think we are on channel 5 and are on channel 3. We've got to take our gloves off. It's time consuming. It's dangerous (Site #5).*

Firefighters also noted that their gear developed tears very easily, particularly in spots where the gear is likely to catch, such as pockets. One participant said, *I've seen a lot of pockets get torn and caught going through walls and stuff (Site #3).* Another expanded on this sentiment, and expressed his desire for reinforced materials in places that commonly tear.

I have concerns...things like they used to have more leather and reinforced areas around the elbows. And now...a lot of places have gotten away from leather because of the chemicals they deal with...even when they reinforce with more material, it'll still wear out in the joints, in the knees, the elbows and like the pockets....bunker pants and you've got a pocket....put tools in

there and there's constantly holes poked in them so your tools are falling out of the pockets because they are not reinforced as well as they used to be....If they could find a better way to reinforce those things. (Site #3)

Mobility of Wearer

Firefighters in this study related that their mobility was hindered when wearing the gear. This reduction in range of motion was a challenge for firefighters when trying to accomplish tasks quickly. One firefighter said, *It's not good for moving quick. It's hard to crawl on the ground (Site #6)*. Another noted that not only does the bulk of the gear create mobility issues, but so do all of the extra gear items they have to wear and carry, such as the tools in their pockets and the SCBA straps. He said:

It's the other things that are hanging off of it. Mainly the hoses and the straps on the belts for the SCBAs more than anything. And there's not much you're going to change on that unless you somehow fully encapsulate that so it's all smooth and there's no rough edges. I suppose they have those things. Flat SCBA cylinder would be interesting. (Site #1)

Another firefighter described his frustration with the reduced mobility, and the impact it has on firefighters' stress as they try to move through fire scenes.

But it's what drives anxiety levels for firefighters, just fighting with your own gear to get through a crappy situation. If you've ever been in an actual structure fire, an actual home that's lived in, you don't have these nice big hallways and lanes. You're fighting the elements around you, and people live in small places. You'd be amazed at how people get to their apartments. Tiny little stairways that lead up to attics, the fifth floor of a wooden structure. You run out of air just getting up there. (Site #2)

Still other firefighters felt the mobility issues were predominantly related to the low crotch and baggy pants. One participant commented, *I think a lot of that is the crotch on the pants hangs so low that, I mean, it just limits your mobility. I mean if they had snugger fit where you could get more extension out of your legs (Site #3)*. Another participant also felt the pants were an issue and brought on greater fatigue for firefighters.

You're inside with the gear on and you're limited to get the full range of motion, it's tugging against you, and so it wears you out faster so you're not able to do as much work. Pants problem, restrictions, are generally the pants...the crotch hanging too low, or baggy pants...throwing your foot and leg through a ladder to lock yourself into a ladder, that can be a problem. (Site #2)

Donning and Doffing

The firefighters indicated that they had issues donning and doffing their gear, especially once it is wet. Wet gear creates more resistance when donning and doffing than dry gear, since the gear is worn over station uniforms or other clothing items. This issue is only exacerbated by how long it takes for the gear to dry. One participant said, *When the interior, the inside lining gets wet, you cannot put your coat back on (Site #1)*. Another agreed, *The problem with them in getting wet, we'd almost have to have a back-up set right there because once they're wet, trying to put them back on after a fire is terrible (Site #1)*.

This phenomenon was not limited to the coat and pants. Firefighters struggled just as much to put their gloves back on once they get wet. One firefighter said,

If you hang it out, it takes forever. We have our own dryer downstairs, but you know, as wet as we get, soaking wet, if you just let it air dry it can take several days. Especially gloves (Site #3).

A second firefighter explained,

Especially when you're on a structure cause then your hands going to be soaking wet on the inside of that glove. And the inside of the glove is so hard after you take it off the first time to try to put your fingers back in (Site #4).

Besides donning and doffing issues related to the wet gear, firefighters experienced issues related to the closure systems on their gear. The closure system on the coat is particularly cumbersome for firefighters. They described that the zipper is difficult to find under the coat flap. In regards to this issue, one participant said, *I can't imagine trying to get them off fast enough if you were being steam burned inside and you've gone outside (Site #1).* They also find the Velcro closure difficult to line up correctly on the coat and pants when trying to dress quickly.

In addition to donning issues with the coat, pants, and gloves, firefighters found it difficult to put on their boots. One participant described the donning issues of boots.

When you put your feet in there, both the inside lining and the boot kind of collapse down and you got a kind of fight your foot through to get your foot down in there...if they had more vertical support in that upper part of the boot it would help....we have a lot of guys that you put your foot in there so many times that liner separates and it really affects guys and their boots. (Site #3)

Wearer Comfort

Approximately one third of all comments related to the comfort firefighters experienced when wearing their gear. Participants discussed three aspects of their gear that they believed had the biggest impact on their comfort: fabrication, design, and how the gear fits. The majority of these comments were related to the fabric performance and properties.

Gear Fabrication

Firefighters in our study discussed their frustration with the high absorbency and poor breathability of the gear. They felt the gear fabric allows too much water to penetrate into the gear when fighting fires, and that this water is absorbed into the gear fabric. They also felt that the gear did not breathe well and locked heat and perspiration inside the garment. One participant said, *I don't know how breathable the moisture barrier is. If it could keep moisture out, but wick it out and let you perspire and let that get out (Site #1).*

Other participants expressed their concern that the gear's breathability and absorbency issues caused extra stress for firefighters. One firefighter said, *On a day to day basis, every time you put that gear on, you add a considerable amount of stress to the body (Site #2).* Another agreed,

Fifteen percent of fire fighter deaths are heart attacks and there's more studies that a lot of that could be dehydration. So if there's some way to get more heat out or more of your sweat and body heat out, that would be a good thing to do (Site #1).

Firefighters also commented that the gear was heavy, because of the thickness of the thermal protective layers. A firefighter expressed his desire for lighter gear: *That would be great if we could find some kind of way to make the jacket, the turn out gear lighter. They could use like a honeycomb material or something (Site #7).* Another stated his concern for the weight of the gear and the impact it has on the body.

If you go into a working structure, of course, you've got your SCBA on, but that adds another 40 or 50 pounds, then you've got the gear on, and by the time you get in there, you're packing quite a bit of weight and you're exerting a lot of physical energy that could really show. I mean, you tire out pretty quick unless you're in really good shape.

(Site #4)

Garment Design

The major issue firefighters related about gear design and comfort was the glove and cuff design. Firefighters indicated that they found the gauntlet style gloves uncomfortable, as well as the cuff of the coat. They reported that the gauntlet style gloves did not fit them as well as the other glove styles and that the cuff on the coat was tight and hard to get their thumbs into the thumb holes. They also explained that the interface between the coat and glove was not working well for them. One firefighter summed this up well, saying:

Gloves are very cumbersome to work in. The interface between...we have the longer wristlets....and then you put your gloves on, and by the time you get the glove on the wristlet and the glove binds up and you can't get them over top of each other and you have to constantly fight to get your hand. (Site #3)

Fit

Firefighters in our study expressed that their gear did not fit them well in a variety of ways, causing discomfort. Participants acknowledged that some fit issues began with too much variation in how measurements were taken and what gear was ordered from one firefighter to the next:

There's such a huge discrepancy as far as following extra fit for some people and not for others and just all across the board. So that's where most of the sizing and fit issues come from. I think people desire a little closer fit because they're in their turnout gear so much (Site #1).

The two most common fit issues mentioned included: (1) pants being too big in the waist, which caused the crotch to sit too low and the pants to drag on the ground, and (2) boots being too tall. One firefighter said, *My pants are too big and so they're constantly falling...That's a fit issue, if your pants are hanging off your shoulder, so is your air packet (Site #1).* Another agreed,

Pants didn't fit. So, they'd have to drag on the ground and we'd rip the very back of the pant...They have a higher cut on the back, because typically firefighters you'll see them all frayed in the back (Site #1).

The low crotch was problematic to a number of our participants. One stated, *It's hard to step up or hop over fences, squeeze through places, because of the low crotch (Site #2).* Another said,

I think the crotch is too low and maybe I just need some longer pants, so it always feels like that's hindering me, too, cause you know, you can't, you know, bring your legs so far up and it feels kind of binding (Site #7).

In addition, several participants reported that their boot length was not appropriate. One firefighter summed up the height issue with the boots, saying, *The boots are bulky, and don't really fit too well. Boots are high, and it's hard to bend legs because the top of the boots hit so high (Site #6).* Several participants stated that they felt there should be more variations in pant length and boot heights to avoid these more common fit issues.

Three focus groups also discussed the need to be able to adjust the gear for variations in body measurements that occur from weight gain and loss. The cost of the gear is prohibitive to owning multiple sets of gear to accommodate weight fluctuations, so several of our participants acknowledged that while their gear fit them well when it was first ordered, it no longer provided adequate fit due to changes in their weight and body dimensions. Participants expressed a desire to have gear that incorporated minor size adjustment systems, particularly for girth measurements.

Protective Properties of the Gear

Roughly 15% of participants' comments focused on the protective properties of their gear. These comments related to how the materials and fabrics of the turnout gear impacted the protection and

ways they perceived the turnout gear design affected their protection. While they expressed sentiments related to ways their protection could be improved, they also acknowledged that they were generally pleased with the amount of protection the gear provided.

Gear Fabrication

Participants in all of the focus groups shared that the thermal protection offered by the gear was more than adequate for the areas of their body that are less exposed, such as their torsos, arms, and legs. Some firefighters noted that they have experienced negative effects of the thermal protection offered by the gear, though. For example, one firefighter stated,

Sometimes your turnout gear fools you to the fact that it insulates you too well, and you can get too close, especially if you're hitting it with water and you create a tremendous amount of steam. You can get scalded or you can get burned (Site #2).

Another firefighter shared this same sentiment:

Firemen get in to trouble before they know they're getting too hot. I mean as far as you can go into higher temperature fires and not know that you're in too far until it's too late. There should be a way to...tell or sense how hot the fire is around you so you don't get into a situation where you're in a place that's too hot to be (Site #3).

While many participants were concerned with their ability to sense potentially dangerous temperatures, others expressed that they could often have a sensation of getting sunburned on more exposed portions of their body, such as the hands, feet, knees, and ears. One firefighter stated,

When you're crawling, your hands feel the heat first....you're pulling that material tighter to your skin...it's kind of too much protection affecting your

mobility....the first place that you really feel the heat is your hands, your feet, your knees and your ears....the hood does okay, but it doesn't do as good (Site #3).

Firefighters in four focus groups expressed that their hoods allow too much heat to reach their ears and face edges. Similarly, they discussed feeling too much heat through the knee pads of their pants when crawling, and expressed a desire to have more thermal protection and padding built into the knee pads to minimize this sensation.

Garment Design

Firefighters discussed concern that the garment design impacted the protection allowed by the gear by affecting the body surface covered. Participants commented that they appreciated longer coat styles which afforded greater coverage and protection when bending at the waist and reaching overhead. One focus group participant said, *You're reaching up sometimes it pulls away from your bunker pants and you don't have that protection there. You kind of expose yourself to heat if you're close enough to (Site #3).* In particular, firefighters in our study liked coats with a tail in the back. This style of coat allowed for more coverage and protection while minimizing the total overlap of the coat and pants, especially in the front of the gear where too much overlap was problematic for donning and doffing purposes.

DISCUSSION

This study explored the needs of male firefighters related to their turnout gear and how their current and past gear allows them to accomplish their work tasks. Common issues reported by participants in this study included how the gear functioned for the firefighters, as well as the comfort and protection provided by the gear. Aspects affecting how the gear functioned for firefighters included the garment design and

fabrication, the mobility allowed by the gear, and the ability to don and doff the gear quickly. Participants reported that gear fabrication, design, and fit had the most impact on their comfort, and discussed concerns they had about the protection allowed by the current gear materials and design. The majority of comments related to how the gear design and materials of the gear impacted male firefighters.

Firefighters in our study described two major areas of concern related to garment design: pocket placement and design, and the suspender system. Participants expressed their desire to have more pockets on the coat, where they are easily accessible and less likely to catch on things as they move around. They suggested that the gear manufacturers explore other options for pocket designs, rather than the typical patch or bellows pockets that are sewn onto the gear with exposed seams and edges that can catch easily. Based on participants' responses, it is recommended that gear manufacturers move toward new pocket designs, such as inseam pockets, that would be less likely to catch as firefighters navigate through small spaces. Responses also indicate that male firefighters would prefer the majority of their pockets to be located on the coat for easy access.

They also discussed the need to redesign the gear so that the weight of the pants and the air pack are not both hanging from their shoulders. The firefighters expressed interest in redesigning the gear so suspenders are not needed to hold up the pants. They related that it is often difficult to adjust the suspenders to obtain a good fit, and that the suspenders place the weight of the pants directly where the weight of the air pack rests on their shoulders. The air pack is quite heavy, weighing from 25-35 pounds, so any additional weight on their shoulders is tiring. In addition, several firefighters commented that the suspender design allowed the pants to sit too low, which led to reduced range of motion for their legs and difficulty accomplishing regular tasks, such as climbing through windows or up ladders, crawling, and squatting.

Firefighters in our study identified a number of ways that the turnout gear materials affected their comfort, protection, and ability to perform their specific job functions. These issues included absorbency and breathability of the gear, the bulk and weight of the fabrics, and changes in their sensation of touch and heat. Participants noted that the gear absorbed too much water and perspiration to allow for comfort and ease of donning and doffing. Furthermore, the gear didn't allow heat to escape, resulting in possible steam burns if the firefighters got too hot in the fire. Based on responses in this study, it is recommended that further development and testing of turnout gear materials be conducted to explore ways of reducing the absorbency of the thermal protective liners, while increasing the overall breathability of the gear. It would also be beneficial to evaluate the total weight of gear that firefighters are required to wear and identify methods for reducing the weight and bulk of fabrics in the gear.

In addition to the weight of the gear, the bulk of the fabrics also contributed to a reduced sensation of touch, particularly in the hands. The firefighters in our study expressed a desire to have thinner gloves that provided thermal protection while maintaining their sensation of touch and dexterity. Several firefighters related that they have to remove their gloves to accomplish simple and regular tasks, such as pressing their radio buttons or reaching into a pocket. Analysis of the glove fabrics and design could greatly reduce this phenomenon, therefore providing enhanced protection for firefighters.

Another major issue of concern for male firefighters in our study included their ability to sense the heat of the fire. Participants noted that on their extremities, such as face, ears, neck, hands, and feet, they felt heat almost too easily, but they didn't feel the heat of the fire hardly at all on the areas of their body covered by their coats and pants. Firefighters expressed concern that their gear made it too easy to get into dangerous temperatures before they became

aware of how hot the fire was. They want to be able to feel the heat more readily throughout the gear to avoid getting too deep into the fire, where they could get burns on their extremities before they could get out of the fire's heat. It is advisable that the amount of thermal protection available for the extremities of the body be increased to avoid potentially dangerous situations where firefighters may be burned.

CONCLUSION

Areas of improvement needed in turnout gear for male firefighters were identified in this study. Materials used in turnout gear and small issues with gear design caused the majority of issues for participants in our study. Respondents discussed their desire to have gear that is lighter, thinner, less absorbent, and more breathable. The firefighters noted that the materials used in their gear place additional physical stress on their bodies as they try to perform an already stressful and difficult job. They are primarily satisfied with the protection provided when wearing their gear, but stated that more uniform thermal protection over their body would be more desirable. Further development of the materials used in turnout gear is recommended to address these issues.

Participants have some fit issues with their gear, particularly with the pants, that affect their mobility. It is difficult to determine conclusively from participants' comments in this study if the fit issues derive from the pant shape or the suspenders not functioning well. This issue warrants further design investigation to provide a solution that will allow firefighters greater mobility and enhanced work performance.

It is recommended that materials be developed and tested to improve issues surrounding absorbency, bulk, weight, and breathability. These materials should be incorporated into prototype gear designs that include design changes to address issues noted above and tested to determine successful changes.

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