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Survey of Firefighters' usage of Ballistic Vests in North America

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ABSRACT

Reports of bullet injuries to firefighters and emergency medical technicians (EMTs) are often found in media reports and firefighter periodicals. There are also several incidents where firefighters were shot and killed in emergency situations (e.g. domestic violence, civil unrest, active shooter scenarios, etc.) that don't include fire. First responders must, therefore, be appropriately equipped with ballistic vests to execute multidisciplinary missions that go against the single-discipline paradigms. This paper presents the results of a survey conducted on the current use of ballistic vests by firefighters and Emergency Medical Services (EMS) personnel in North America. The survey results provide information on the types of ballistic vests typically worn, deployment practices, levels of ballistic protection and training practices for firefighters. This paper describes how ballistic vests are worn with turnout gear and identifies the need to consider the effects of wearing ballistic vests on heat strain, interoperability of firefighter gear, as well as potential flammability issues and exposures to thermal threats from flammable materials.

Keywords: ballistic vests, firefighters, protective gear

1: Introduction

The growing number of tragic deaths from firearms injuries leaves little doubt that firefighters and EMS personnel need ballistic protection in many emergency response scenarios (Zam, 2021). Federal agencies have recognized the need for ballistic protection for firefighters and EMS responders (Dos Santos & Son, 2024). As part of a research report conducted by the Federal Emergency Management Agency (FEMA) on Mitigation of Occupational Violence to Firefighters and EMS Responders, National Institute for Occupational Safety and Health (NIOSH) recommended that firefighters should be provided ballistic vests or bullet-resistant personal protective equipment to train on, and consistently enforce its use when responding to potentially violent situations (Taylor et al., 2017). Department of Homeland Security (DHS) endorses such acquisitions and provides funds through the Assistance to Firefighters Grants Program (AFG) program to fire services to buy ballistic protective equipment. Fire departments nationwide are responding to this need by issuing ballistic protective Personal Protective Equipment (PPE). Many fire departments require that ballistic-resistant vests be worn on emergency calls. These departments need more guidance and information to help their selection and use of ballistic PPE in emergency response. Ballistic vests can add more than forty

pounds of weight to the firefighter, besides adding bulk, stiffness, and ergonomic encumbrance. The discrepancy between the heat resistance requirements of turnout suits certified to the National Fire Protection Association (NFPA) 1971 standard and the lack of flammability and heat-resistant requirements for ballistic vests is also apparent (Nayak et al., 2014). This is an important safety consideration if firefighters wear ballistic vests with turnout suits while performing limited fire suppression activities in hostile environments, including suppressing fires generated by burning cars and dumpster fires. Some materials used in ballistic vest construction, particularly materials made from polyester and nylon fibers in ballistic plate carriers, burn and melt in heat and flames. This paper discusses the findings of an extensive survey of firefighters and EMS personnel who wear ballistic vests in emergency response. It identifies a need for a better understanding of performance trade-offs associated with firefighter selection and use of ballistic vests.

2: Methodology

We surveyed 300 firefighters to obtain information about their use of ballistic vests in phases of firefighting response and active shooting scenarios. Also, we had a discussion meeting with a manufacturer of firefighter ballistic vests. Our goal was to obtain a better understanding of the factors contributing to the selection of ballistic vests in firefighter operational response scenarios, including the use of turnout gear. We formulated questions in SurveyMonkey. The research survey was reviewed and approved by the North Carolina State University Institutional Review Board (IRB) on May 10, 2023, as exempt from the policy as outlined in the Code of Federal Regulations (Exempt d.2). The NC State University IRB complies with requirements found in Title 45 part 46 of The Code of Federal Regulations. The survey link was sent to different fire departments across the USA and 300 firefighters responded to it. We also emailed a few manufacturers of ballistic vests for firefighters and one manufacturer responded to it.

We surveyed firefighters in North America, primarily located in the United States. Responses may be different for firefighters located in parts of the world that conduct firefighting operations in different climates ranges, use different firefighting tactics or wear gear certified to performance standards other than the NFPA 1971 Standard for Structural Firefighter PPE. The findings of this study do not represent specific response scenarios or conditions. Every fire scene is unique and presents different risks to firefighter safety. Therefore, this study does not attempt to recommend any particular operational tactics, gear selection, job assignment or rehabilitation routine. These are decisions best made by professional firefighters on the scene.

3: Results

3.1: Geographic Locations

Using the Survey Monkey™ platform, we surveyed firefighters from different geographical regions of the country representing different climate zones (Figure 1a). Most of the firefighters surveyed were from the South Atlantic (40%), Mountains (20%), and Middle Atlantic (10%) regions of the United States. Responses came from urban, suburban, and rural areas (Figure 1b).

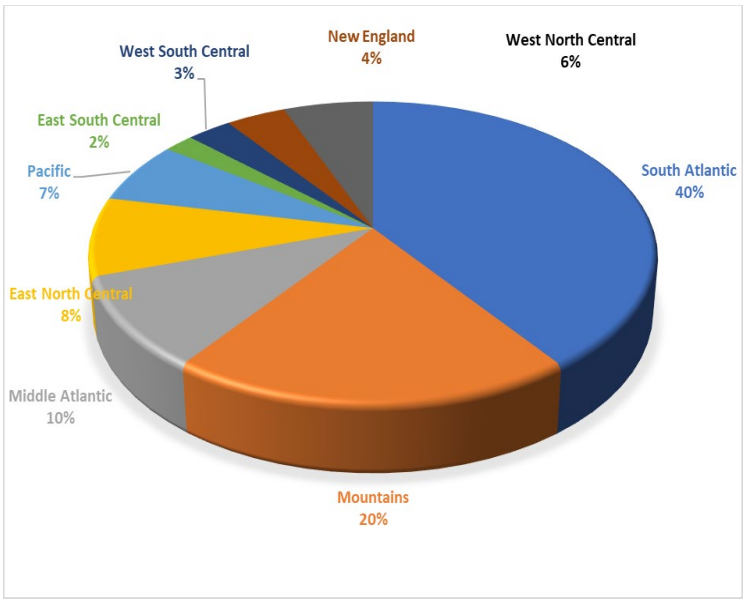


Figure 1a. Geographic location of the firefighters surveyed

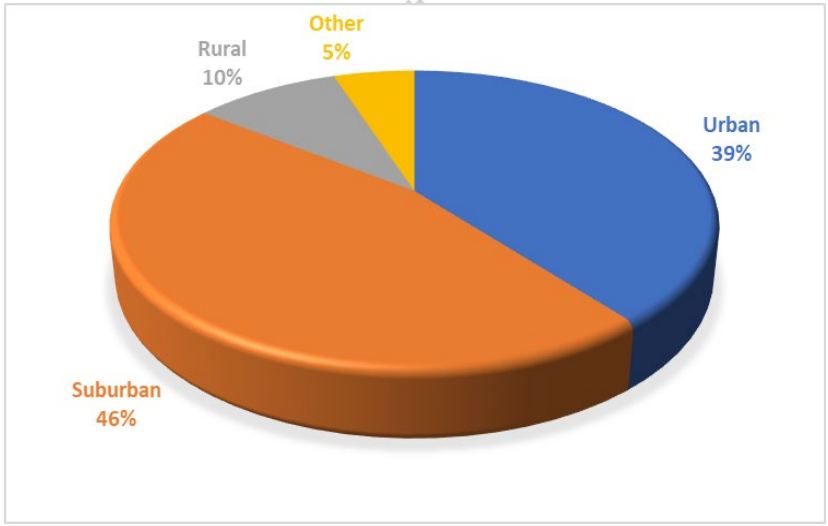


Figure 1b. Regional distribution of surveyed responders

3.2: Distribution by rank and firefighter

Firefighters who responded to the survey held different ranks and had different years of service. Most were career firefighters; however, many were volunteer firefighters, or they worked in departments made up of both career and volunteer firefighters (Figure 2a). They held various ranks and performed different jobs in the fire department (Figure 2b). Most had significant experience as firefighters. Their average service time exceeded 5 years, with many having more than 20 years of experience as firefighters and emergency responders (Figure 2c).

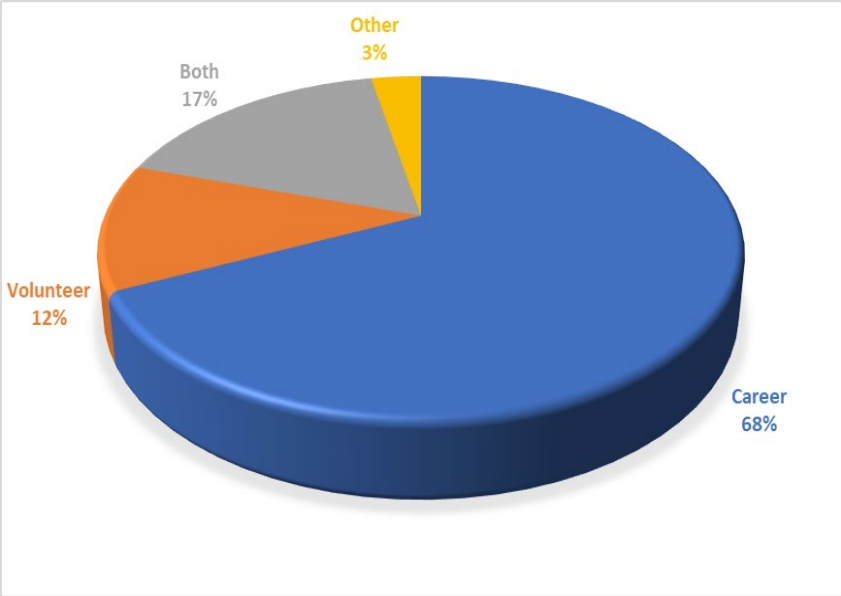


Figure 2a. Distribution of career and volunteer firefighters participating in the survey

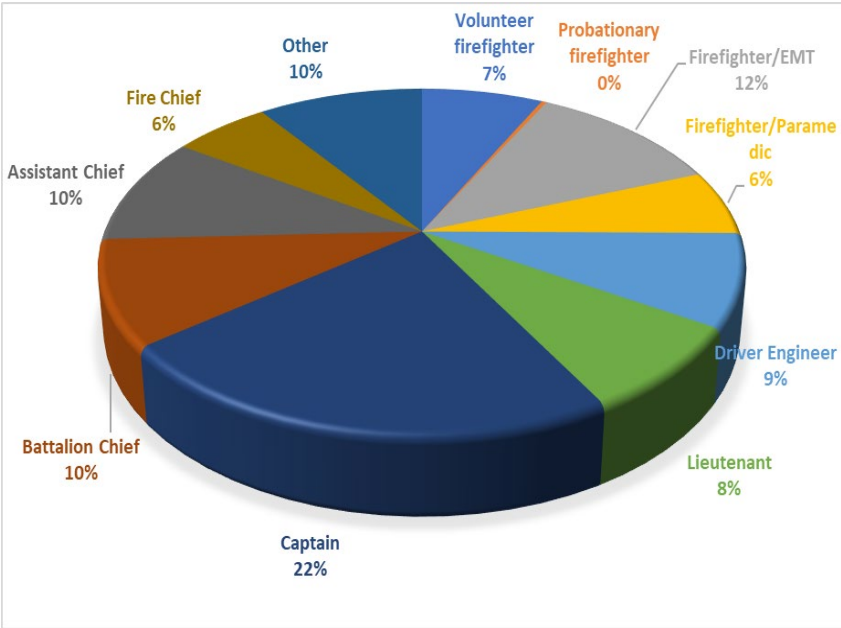


Figure 2b. Rank of firefighters participating in survey

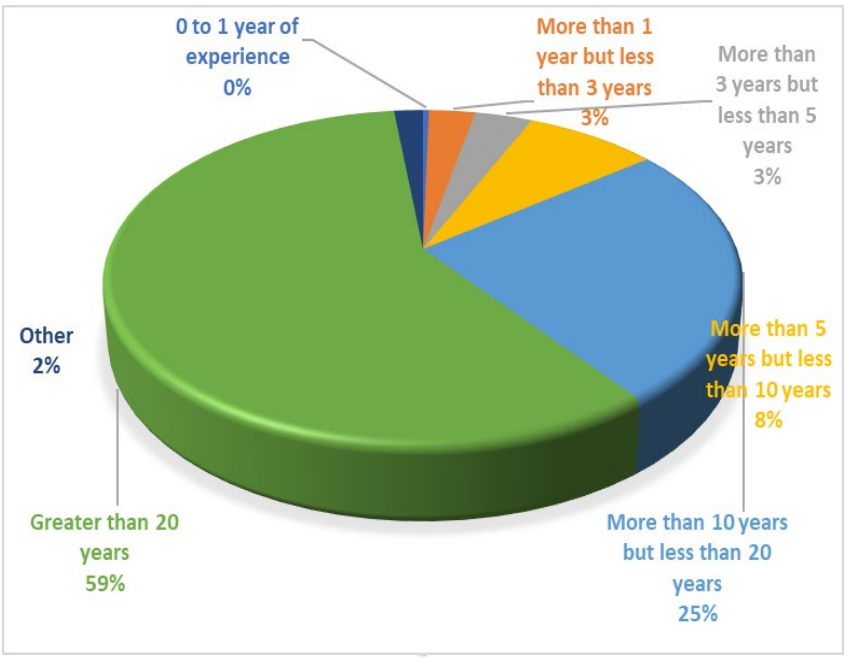


Figure 2c. Years of experience of firefighters participating in the survey

3.3: Firefighter use of ballistic gear

Our survey found that most (78%) responding firefighters have access to ballistic protective equipment. Figure 3 showed the most commonly deployed items of ballistic gear including ballistic protective helmets, soft ballistic vests, and side and back armor planes.

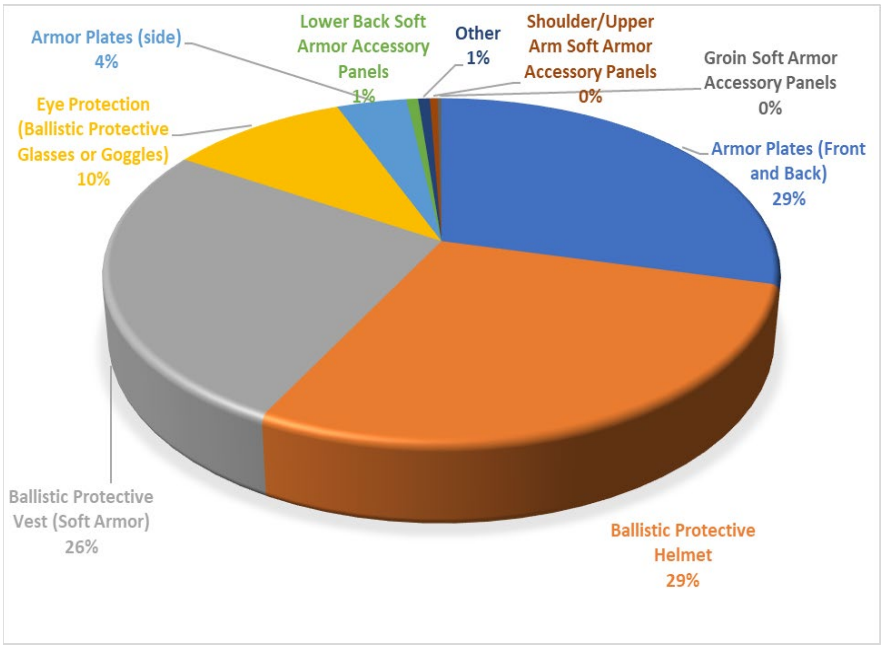


Figure 3: Ballistic protection worn by firefighters

Firefighters typically wear ballistic vests over a station uniform without turnout gear (51%). They wear ballistic vests with ballistic helmets, ballistic eyewear (12%), and ballistic vests worn under turnout jackets (2%). It is important to understand the reasons for this choice to reduce the barriers to the use of ballistic gear.

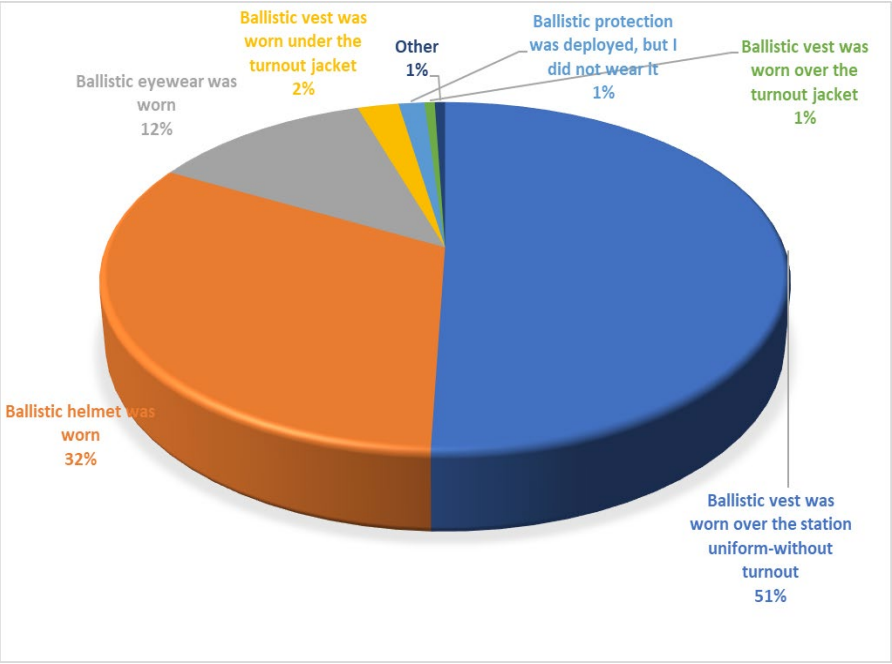


Figure 4. Configurations firefighters wear with the ballistic protective vest

3.4: Ballistic vest issuance and training:

According to survey results, 69% of ballistic protective equipment is a shared resource whereas 12 % of ballistic equipment is issued individually (Figure 5).

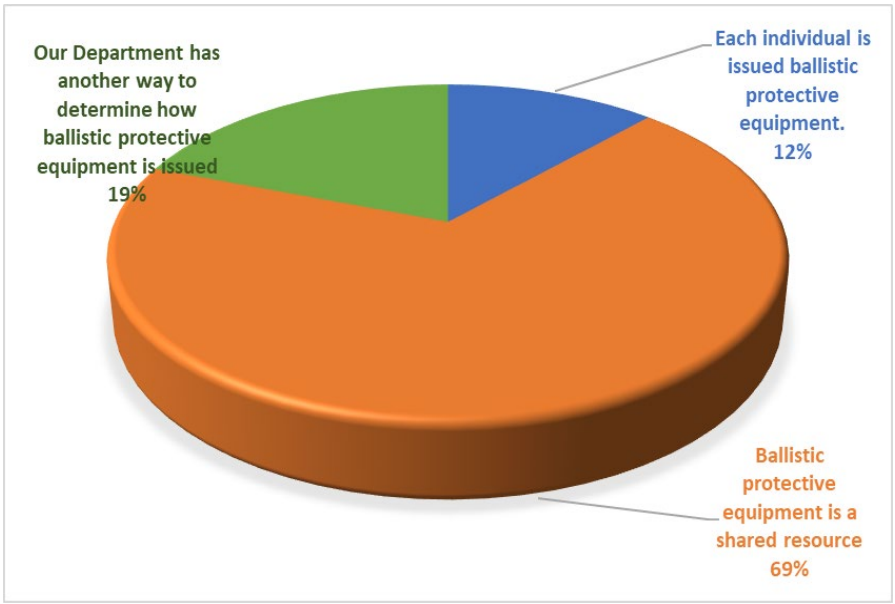


Figure 5. Issuance of ballistic equipment individual or shared

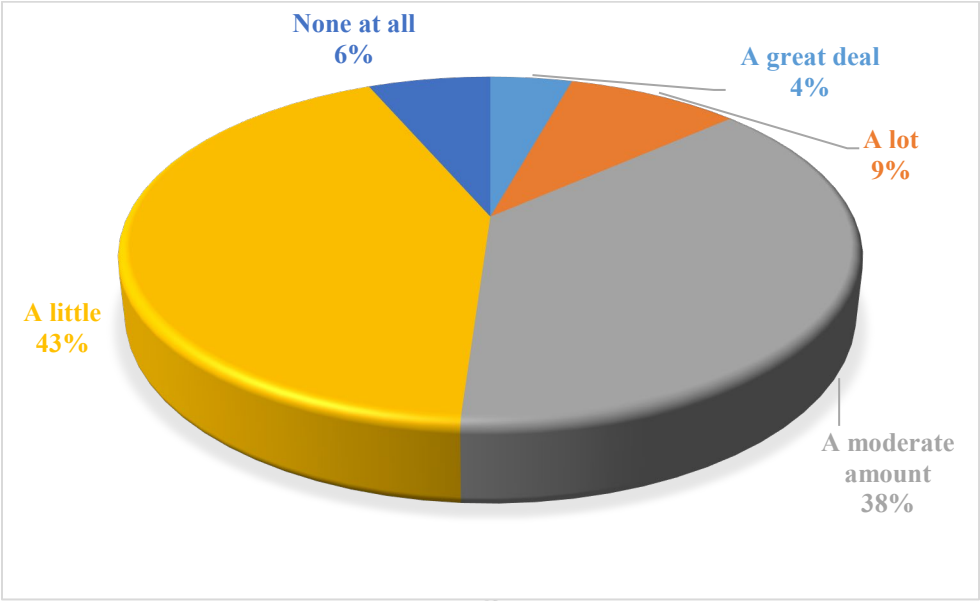


Figure 6. Training on equipment

Survey results showed that only 4% of firefighters received a great deal of training, while 43% received little, and 6% received no training.

The survey also showed the scenarios where the firefighters received ballistic protective equipment training, such as active shooter (54%), civil unrest (25%), and EMS (17%) (Figure 7). This indicates that firefighters are being prepared for high-risk and potentially dangerous situations where they need ballistic protection.

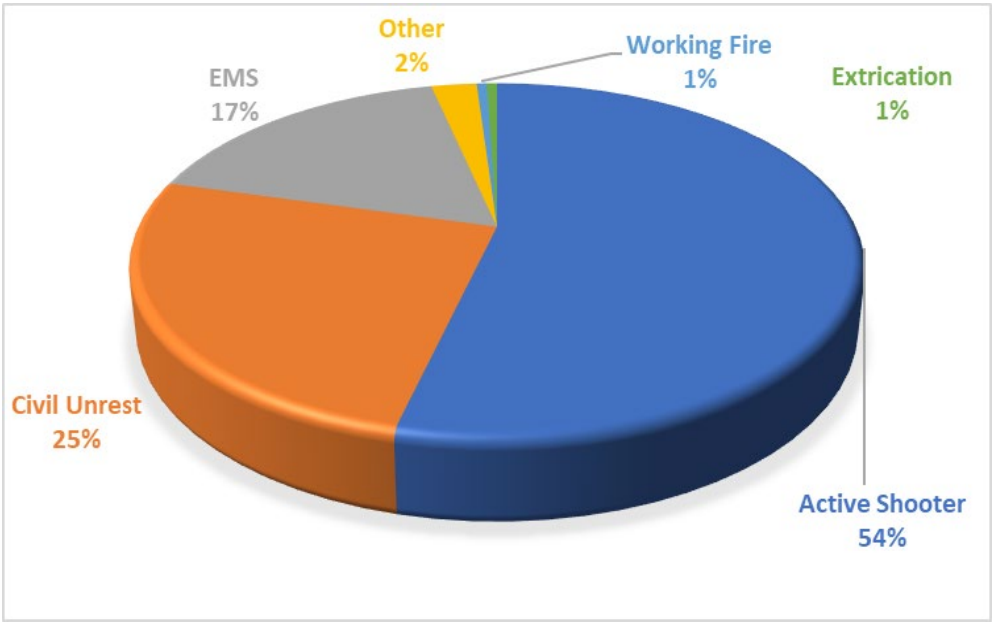
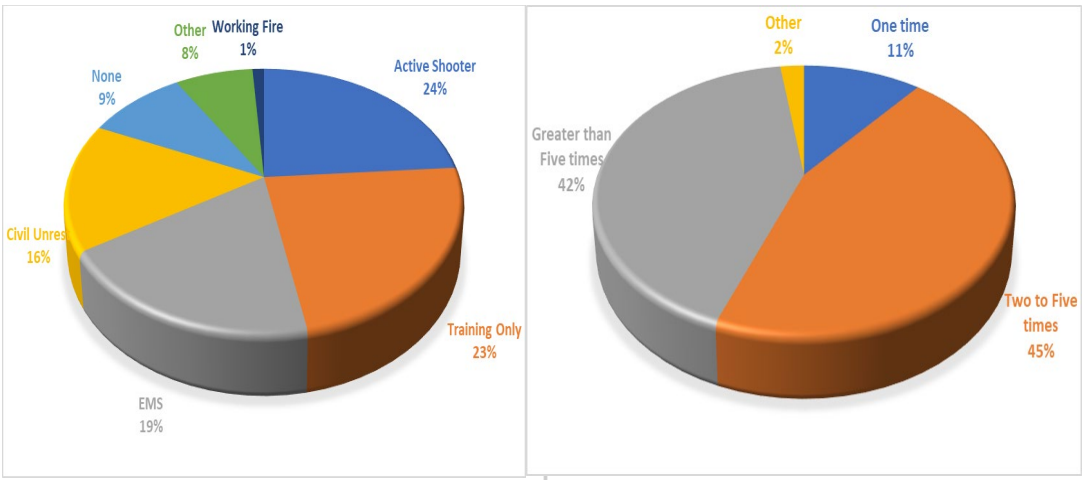


Figure 7. Emergency response where scenarios firefighters received ballistic protective equipment training

3.5: Scenarios encountered by firefighters where ballistic protection is deployed

The deployment scenarios where firefighters use ballistic protective equipment include active shooter (24%), EMS (19%), and training (23%) (Figure 8). Nine percent of firefighters had never worn ballistic protective equipment.



(a) (b)

Figure 8. Scenario where firefighters have personally worn ballistic protective equipment (a) & Frequency of firefighters' use of ballistic protective equipment (b)

Our survey shows that 45% of firefighters have worn ballistic protective equipment two to five times over the course of their service (Figure 8b). Some have worn ballistic gear more frequently, while others may wear it only once in their career as a firefighter.

3.6: Discussion of firefighters' ballistic vests with a manufacturer

Researchers reached out to several manufacturers via email and had a discussion with a manufacturer of ballistic vests for firefighters. Although the researcher was able to meet with only one manufacturer, the discussion was very informative. Therefore, the discussion was included in the results section.

Table 1 showed a summary of the information gathered from the manufacturer that markets ballistic PPE to firefighters. It provides a better understanding of the factors that influence their selection of ballistic vests by fire departments.

Table 1. Content analysis: Factors that influence firefighters' selection of ballistic vests

Theme	Subtheme
Top priority considerations	Wearability with turnout gear
	Interoperability with SCBA and helmet
	Low budget
	Maximum protection
Ballistic vest features for firefighters	One size fit all/ adjustable
	Not flame resistant
	NIJ certified
Law enforcement (LE) vs firefighter (FF) ballistic vests	LE have very specific and different movements than FF which leads to different cuts of ballistic vests

	Rectangle neckline and armhole for FF whereas round for LE
	Not best fit but easy to make panels for FF because of straight cut
Issues	Costly
	Bulky
	Less Mobility
	One size fits all causes fir problem
Common vest configurations	Soft armor
	NIJ Level IIIA (*handgun-9mm ammunition)*
	Extra front and back plates/panels for rifle protection
	Side panels are stab resistant
Current gaps in FF ballistic vests that should improve	should be an everyday wear vest
	should be lighter in weight
	Should provide custom fit or at least two sizes (from size Small-Medium and Large- Extra Large) vests

Firefighters' top priorities when selecting ballistic vests include cost, maximum protection, compatibility with SCBAs and helmets, and wearability with turnout gear. The ballistic vests are not usually flame resistant but are usually adjustable, one-size-fits-all, and NIJ-certified. Firefighter ballistic vests, in contrast to law enforcement vests, feature rectangular necklines and armholes for improved mobility; nonetheless, the straight-cut design facilitates panel manufacture but does not offer the best fit. High cost, bulkiness, decreased mobility, and fit problems imposed upon by the "one size fits all" are some of the main obstacles. Ballistic vests for firefighters should be made lighter, more wearable, and offered in at least two sizes (S-M and L-XL) for a better fit.

4: Discussion

Figure 5 indicated that most fire departments share ballistic protective equipment, typically one size fits all ballistic vests approach is often driven by budget considerations. Other considerations are related to limitations in size variations of ballistic vests that could create fit problems for firefighters with different body shapes and sizes. Poorly fitting gear can hinder mobility and limit the range of motion compromising the safety of the firefighters by reducing their active movement and agility (Harbison et al., 2023).

It is significant that only 4% of firefighters responding to the survey received training on the wear and use of ballistic protective equipment by the fire department (Figure 6). The apparent lack of training could contribute to the inefficient use of ballistic vests by firefighters and could potentially compromise their safety. It could also contribute to physical discomfort in its use as well as equipment damage resulting in increased costs for replacement or repair. It might also result in improper use in the event of an emergency where firefighters might be unaware of extra weight, and movement restrictions added by ballistic vests which could hinder the firefighters' response or make them more susceptible to injuries.

Fire departments typically recommend wearing ballistic vests for deployment scenarios that involve ballistic threats. Their purchasing decisions are nominally designed to provide ballistic gear that provides the maximum protection for firefighters, balanced with consideration of the cost of the PPE purchased. Given the potential urgency of emergency incidents, the need for training for active shooter situations is apparent. However, the lower percentages for other

response scenarios, notably for EMS and response to working fires, indicate the need for more comprehensive training on firefighter use of ballistic gear. Therefore, it is critical to determine whether training sufficiently addresses the individual challenges and requirements of different deployment scenarios. For example, training for using ballistic vests when working with flames, or in conjunction with turnout gear, needs to be considered.

Our survey showed that ballistic gear is most often used in active shooter scenarios, a finding that is consistent with the focus on this response scenario in training. At the same time, our data showed that a high percentage of firefighters' reports wearing ballistic equipment only in training. This indicates that a significant portion of responders have not encountered deployment situations requiring the use of ballistic protection gear. This may be due to the relatively low frequency of response scenarios that call for the deployment of ballistic gear. However, the survey also showed that a substantial number of firefighters use ballistic protective equipment in EMS and civil unrest scenarios. This finding confirms the importance of training for the deployment of ballistic gear when it may be required in these responses. It also raises concerns regarding the efficacy of the training effectiveness in terms of translating into real-world usage. It would be useful to better understand why some firefighters do not wear ballistic gear in response situations where they have been trained to wear it.

4.1: Ballistic vests for firefighters

Firefighters encounter a bewildering range of options when specifying and procuring ballistic vests. Different categories of ballistic vests provide different levels of protection against firearms; stab resistance against edged or pointed weapons; or combined protection against ballistic and stab threats. Manufacturers produce ballistic vests specifically for firefighters and EMS personnel, and they offer PPE options for both for law enforcement applications. Most commercially available ballistic vests for firefighter use are certified by the National Institute of Justice (NIJ). Content analysis showed that most of the ballistic vests for firefighters are soft armor.

A typical soft ballistic vest has front and back panels and an additional panel insert for added protection. There are also adjustable straps over the shoulders and around the waist to adjust to the length and girth of the torso. The materials used, the number of layers on the front and rear panels, and the thickness of the supplementary panels are chosen based on the threat levels. The front and back panels are usually constructed with multiple layers of aramid yarn-based bullet-resistant fabrics for soft ballistic vests.

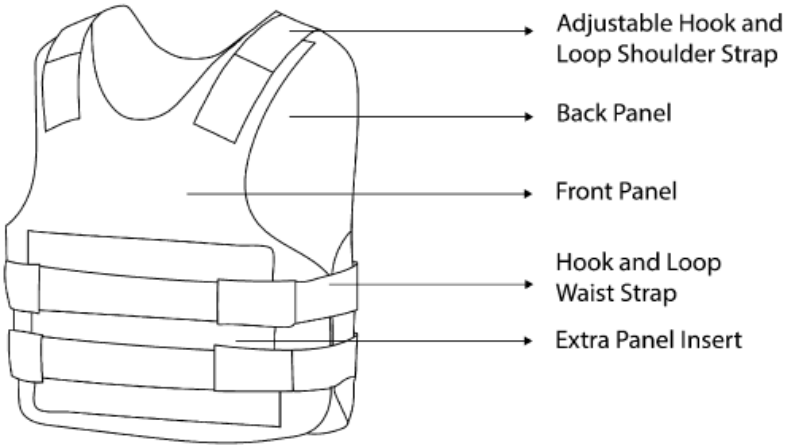


Figure 9. Structure of a basic ballistic vest (Mica & Suh, 2023)

According to the manufacturers, ballistic vests for firefighters are similar in design apart from the fact that they are cut differently around the neck and armhole. For law enforcement officers, the neckline and armhole are cut in a round shape to optimize mobility and protection. For firefighters, the neckline and armholes are cut in a square shape for the convenience of manufacturing as square shaped neckline and armholes are easier to cut and sew than round shape. Since firefighters do not have to move or hold guns in a specific posture, the square neckline and armhole do not hinder their range of motion and mobility whereas round shaped neckline and armhole provide more coverage and range of motions for the law enforcement officers.

4.2: NIJ Levels for Ballistic Vests:

The National Institute of Justice (NIJ) establishes ballistic resistance criteria for personal ballistic vest (*NIJ Standard 0123.00*, 2023). Market research showed that ballistic vests for firefighters are also NIJ-certified and maintain NIJ threat levels. NIJ threat levels indicate the levels of protection provided by different types of ballistic vests against certain ballistic threats. The NIJ ballistic threat categories are IIA, II, IIIA, III, and IV, with each level providing increased protection against heavier caliber gunfire. These threat levels provide guidelines for the selection of proper ballistic vests based on the specific hazards the firefighters might encounter. While these levels provide uniform classification for protection, the performance of ballistic vest is also dependent on factors such as materials, fit, and the design details of the overall ballistic system.

Table 2. NIJ threat levels for ballistic vests (Specification for NIJ Ballistic Protection Levels and Associated Test Threats, NIJ Standard 0123.00, 2023)

		NIJ Level IIA	NIJ Level II	NIJ Level IIIA	NIJ Level III	NIJ Level IV
Ammunition Size	Bullet Velocity	1165 ft/s	1245 ft/s	1470ft/s	2780 ft/s	2880 ft/s
.9mm		x	x	x	x	x
.44 Magnum				x	x	x
5.56mm					x	x
7.62mm NATO					x	x
.30 Armor Piercing (M2AP)						x

Vargas (2016) assessed the effect of wearing ballistic vests underneath firefighter turnout gear based on the threat level. The lower the threat level, the lower the weight of the ballistic vest. Therefore, as would be expected, lower weight ballistic vests offered the least amount of protection (Levels II and III), although it provided more flexibility and had less impact on performance. Conversely, heavier-weight ballistic vests provided the maximum amount of ballistic protection (Level IV) at the expense of mobility and heat strain.

4.3: Performance guidelines for the selection and use of ballistic vests by firefighters

Our survey data showed that 81% of firefighters surveyed shared or were issued ballistic vests by the fire department (Figure 5) and Table 1 showed that firefighters use ballistic vests that are NIJ certified with threat level IIIA. Nevertheless, policies on the procurement and deployment of ballistic vests by fire departments vary in fire departments across the country (Vargas, 2016). Little documented information is

available on how firefighters wear ballistic vests with turnout gear or station uniforms. Because these factors affect firefighter heat stress, mobility, and thermal protection in emergency response, this is a critical gap in available information.

The ASTM E3348 recommends ballistic gear that provides at least level IIIA protection based on the ability to stop bullets, as certified to the NIJ Standard-0101.06 standard for non-law enforcement applications (ASTM E3348, 2022; Mukasey et al., 2008). ASTM E3348 also recommends studies to understand whether additional ballistic protection causes more harm than good in terms of heat stress, since there are no existing scientific studies regarding this. ASTM E3348 suggests wearing ballistic vests under turnout suits to protect ballistic vests against the hazards of flammable or thermoplastic components. It cites no study on the efficacy of this approach, nor does it identify testing protocols to assess the effect of ballistic gear on thermal protective performance in fire environments. It also suggests the use of fire-resistant clothing with ballistic vests without identifying clothing ensemble options or describing how ballistic vests may be included in an effective multi-threat ensemble for firefighters.

In many ways, the ASTM E3348 guidelines reflect the contradictory set of circumstances now faced by fire departments across the country. They are increasingly required to issue and train firefighters and EMS personnel on the selection and use of ballistic gear in emergency response while lacking the basic information on the trade-offs of using it with firefighting gear, particularly from heat stress or burn injuries. They lack the scientific data about performance trade-offs needed to develop best practices for using ballistic gear when this PPE is needed in firefighting or EMS response.

NFPA 3000 standard identifies threats for firefighters in active shooting scenarios as hot, warm, and cold zones (NFPA 3000, 2021). The hot zone is an area where there is a known, direct, and immediate life threat. PPE is included but is not limited to ballistic protection equipment (BPE). The warm zone has the potential for a hazard or an indirect threat to life. PPE is included but is not limited to BPE. The cold zone has little or no threat due to its geographic distance from the threat. An identifying garment or visible identification is recommended for this zone. NFPA 3000 recommends BPE for fire and EMS personnel to be NIJ certified and at least at NIJ level IIIA as tested according to NIJ 0101.06 standard. NFPA 3000 also recommends that integrated response teams use ballistic helmets, and carry a flashlight, medical exam gloves, and an individual first aid kit. PPE and BPE worn externally should be identified with the agency or responder role. BPE care, maintenance, and replacement practices should follow NIJ 0101.06.

4.4: Effects of ballistic vests on interoperability of firefighter gear

Our content analysis (Table 1) showed that interoperability plays an important role in terms of choosing ballistic vests for firefighters. Many fire departments use a situation-based policy that requires firefighters to wear ballistic vests whenever violent activities may occur at a scene, including response to incidents of domestic violence, active shooting, and warm zone operations (Loone, 2020; Miller, 2018; Parrot, 2019). Since shooting incidents are unpredictable, some departments mandate wearing ballistic vests for all EMS personnel on emergency calls (Miller, 2018). Other departments require ballistic vests for firefighters on all emergency calls (*Firehouse*, 2013). When responding to non-fire emergencies, emergency medical responders usually wear ballistic vests over their station uniforms. If a firefighter is required to wear a ballistic vest with their turnout gear, they typically wear it under the turnout jacket (Vince, 2020). However, some fire departments recommend only wearing ballistic vests over turnout suit (Loone, 2020).

Many studies have shown that ballistic vests significantly affect the performance of operational tasks when worn in military and

law enforcement applications (Dempsey et al., 2013; Loverro et al., 2015; Park et al., 2011; Taylor et al., 2016). However, these findings do not translate to ballistic vest effects on firefighters and EMT job performance as they perform distinctly different tasks wearing different PPE than soldiers and law enforcement personnel. It is significant that no systematically conducted ergonomic studies currently provide an assessment of the interoperability of ballistic vests with essential elements of firefighter gear as well.

5. Effect of ballistic vests on responders

5.1: Effects of ballistic vests on responder heat strain

While it is logical to assume that deploying ballistic vests can have deleterious effects on firefighter mobility, no studies yet exist on the possible effects of heat strain on firefighters. There is a gap in our understanding of how to wear ballistic vests in combination with a turnout suit. This knowledge gap is compounded by the general lack of studies that focus on female disparity in terms of available and correctly fitting PPE.

Most departments advise wearing ballistic gear underneath a turnout to protect the gear from the heat that can melt or degrade the materials and components used in its construction (*Assistance to Firefighters Grants Program*, 2023). However, some fire departments wear ballistic vests over turnout suits. These examples of conflicting approaches to wearing ballistic vests with turnouts underscore the need for a scientifically considered study on the effect of gear configuration on factors of fit, ergonomic functionality, and physiological heat strain.

Numerous studies have been conducted on the effects of turnout design, materials breathability, and environmental conditions on firefighter heat stress, ranging from using advanced thermal manikins to measure heat transfer through firefighter garments to the application of physiological models to predict human heat stress response (Jun Li et al., 2007; McQuerry, Barker, et al., 2018; McQuerry, DenHartog, et al., 2018; McQuerry et al., 2017). These studies showed that adding moisture vapor impermeable components to turnout suits significantly reduced heat loss by sweat evaporation from the human body (McQuerry, DenHartog, et al., 2018). This is a significant finding because a ballistic vest covers a sizeable fraction of skin area; about 50% of the skin surface in the torso area of the body (Biermann, 2003). Since heat loss from sweat evaporation is a major mechanism of cooling the body, it is reasonable to expect that wearing a ballistic vest that covers a significant portion of the skin surface will have a significant effect on the firefighter's heat strain.

Wearing allistic vests adds to firefighter heat strain, not only by adding thermal insulation and evaporative resistance to PPE but also by adding weight to the clothing ensemble. Military laboratories have extensively studied these effects; wearing a military ballistic vest over a duty uniform reduced work tolerance time by one-half, with major deleterious effects caused both by the increased thermal insulation and evaporative resistance and by the weight of the vests (Xu et al., 2016). Because of the obvious differences in military and firefighter gear, and the differences in use conditions, findings from military studies cannot predict the heat strain of ballistic vest for firefighter applications.

Therefore, there is a need for research to determine how much heat strain is caused by wearing ballistic gear for firefighters in different environmental conditions. This would provide the technical foundation for operational decisions that can result in reducing the heat stress hazard to firefighters and EMS in situations where they wear ballistic vests. It would show how different combinations of wearing ballistic vests with firefighting gear can affect firefighter heat stress. This information is needed for the optimum deployment of ballistic vests specifically for firefighter operations. It would help firefighters select ballistic vests

and manage work protocols to reduce heat strain.

5.2: Effects of ballistic vests on potential burn injury

According to the ASTM Guide to Body Armor for Non-Law Enforcement Applications, if they choose to wear body armor/ballistic vests with turnout suits, firefighters should wear the gear under their turnout to protect flammable or thermoplastic components in the ballistic vest construction (ASTM E3348, 2022). However, the guide does not provide evidence of the efficacy of this approach or identify testing protocols to assess the effect of ballistic gear on flammability in fire environments. It also suggests using other fire-resistant clothing with ballistic vests without identifying clothing options. It does not account for instances where firefighters may wear their ballistic vests over their turnouts thereby directly exposing the ballistic gear to intense heat and flames. It does not consider the burn injury hazard presented to responders by flaming liquids (e.g., Molotov Cocktails) hurled at them. There have been several recent reports of firefighters and first responders being attacked with Molotov Cocktails or fires started by Molotov Cocktails (Cummings, 2016).

The discrepancy between the heat resistance requirements of turnout suits certified to the NFPA 1971 standard and the lack of any thermal performance requirements for ballistic vests are apparent. The NFPA 1971 Standard requires that all components used in the construction of turnout suits meet minimum flame and heat resistance requirements as demonstrated in flammability tests and by five-minute exposure to 500F in an oven test (NFPA 1971, 2018). In contrast, there are no current requirements that ballistic vest, worn by firefighters in fire environments, be tested to demonstrate that it meets minimum flammability and heat resistance levels. This is an important safety consideration, particularly because the low level of heat and flame resistance of materials used in some ballistic vest raises questions about their use in fire environments. Some soft ballistic vests, known for their lightweight ballistic performance, contain high molecular weight polyethylene that melts at about 150°C, far below the temperatures possible in a fire environment (Tam & Bhatnagar, 2016). Thermoplastic fibers, such as nylon and polyester fibers are in ballistic plate/vest carriers or hook and loop straps. These thermoplastic materials could melt and lose strength if exposed to the temperatures routinely encountered in firefighting operations.

Therefore, the flammability of ballistic vests should be an issue of significant ongoing concern to firefighter safety. The questions that need to be addressed include: Does wearing ballistic vests made from non-FR or non-heat-resistant materials in fire environments constitute a burn injury risk to firefighters in fire suppression activities? Does wearing ballistic gear under a turnout suit mitigate the burn injury risk, even if some of the components used in the construction of ballistic vests are thermoplastic materials, such as polyester, which melts at relatively low temperature.

5.3: Disparity of Female Firefighters in Research Studies

In 2018, there were an estimated 93,700 (~8%) female firefighters in the United States (Fahy et al., 2022). Additionally, approximately 21% of EMS paramedics are female, and they had a 23% growth from 2012-2022 (*Women in Public Service*, 2014). Despite differences in gender, female firefighters and emergency responders are expected to perform the same duties as their male counterparts, however, they often deal with gear and equipment that was designed for the male form.

Despite the growth and equal expectations of performance, there are few studies of firefighter and EMS PPE that include considerations for the differences between the male and female forms. Especially apparent with PPE, functionality, and performance can be compromised due to the need for a female to use a male-designed system. For maximum protection, ballistic

vests should fit snuggly against the wearer to maintain the levels of protection afforded by the vest (ASTM E3348, 2022). The ASTM guide for ballistic vests in non-LE applications does have a note that indicates that ballistic vest sizing may be different between men and women and includes a reference to ASTM E3003 which provides guidance for measuring a ballistic vest wearer for both male and female personnel. It also states that body shape should be considered. Similar to firefighter turnout suits, ballistic vests may impact females differently, and considering potential differences will be a fundamental part of this research effort.

Most firefighter turnouts today are designed for the male size and shape, leaving female firefighters to choose between the best-fitting sizes available. This can often lead to poor fitting PPE for women firefighters. Loose, bulky, tight, and uncomfortable PPE can have a significant impact on firefighter performance and can ultimately increase the probability of compromising the health and safety of the firefighter. Firefighter research studies typically only consider male anthropometry in the development, testing, and experimental conclusions. Unfortunately, this causes the conclusions and outcomes to be less valid for a growing portion of the fire service population.

6: Conclusion

Firefighters wear ballistic vests in high-risk operations where there is a strong likelihood of encountering gunfire and ballistic threats. Apart from that, firefighters need to wear ballistic vests to simulate real-world situations and train themselves to become accustomed to the use and limitations of the equipment. Our survey found that about 80% of fire departments had ballistic protective equipment, including ballistic helmets, armor plates, and vests. Because of differences in body shapes and forms, most of the shared ballistic gear among firefighters may cause fit problems. Also, training on the use of this equipment was lacking, with a large number of respondents receiving minimal to no training. In addition to insufficient training, the actual use of ballistic protection varied among the firefighters. While many of the firefighters had worn ballistic gear several times, a significant number had worn it only once. Overall, the survey highlighted the need for more extensive training and better knowledge of the factors influencing firefighters' use of ballistic vests in various operating settings.

There is an ongoing need for a better understanding of performance tradeoffs associated with firefighter selection and use of ballistic vests. More information is needed about current use practices and conditions commonly associated with different response scenarios. There is an additional need for studies of the effects of ballistic vests on firefighter heat strain and mobility, and how wearing ballistic gear, with or without a turnout suit affects these factors, for both male and female firefighters. This survey study not only provides useful information to firefighters and responders but also casts a light on the importance of ballistic vests for firefighters and how broadly they are being used by firefighters across the United States.

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Appendix A

Survey Questions

1. In which region of the United States do you work?
2. Please choose the answer that best describes the community your department serves.
3. What position below best describes your current job position?
4. Are you currently a Career or Volunteer Firefighter?
5. How many years of experience do you have working within the fire service?
6. What configuration did you wear your ballistic protective vest during these situation(s)? (select all that apply)
7. During the scenario(s) you identified here, what Ballistic protection did you wear?
8. Please select all of the Ballistic Protective Equipment currently owned or in-use by your department.
9. Is the ballistic equipment individually issued or is it a shared resource?
10. For which scenarios listed below have you received Ballistic Protective Equipment training?
11. For which scenario(s) listed below have you personally worn Ballistic Protective Equipment?
12. How many times have you worn your ballistic equipment in these situations?

Appendix B

Q & A

The discussion included some questions and answers relevant to ballistic vests for firefighters are as follows:

1. Researcher: What are the considerations that should be prioritized to purchase a ballistic vest for firefighters?

Manufacturer: *I think the wearability of the ballistic vest with firefighter turnout gear should be the top priority. As we know, firefighters wear helmets and self-contained breathing apparatus (SCBA). Ballistic vests should be interoperable with them*.

2. Researcher: How different are the ballistic vests sold to firefighters from law-enforcement (LE) officers?

Manufacturer: *In the late 80's, first responders wore covert ballistic vests unless there was a SWAT team. Now overt or blends into uniform ballistic vest is preferred. Ballistic vests are new to the Fire Dept. The main difference between law enforcement and non-law enforcement officers is in movement patterns. The profile of the ballistic vests should be cut differently.*
For the LE officers, there are always custom-made ballistic vests, but this is not the scenario for the first responders. There is one vest per truck/ one size fits "most" for the first responders. The sizing is done based on middle 80% body type that fits well because of low budget.
Correct solution: In this situation, if custom made ballistic vests are not economically feasible, it is encouraged to have at least two sizes of ballistic vests: one-S/M & another-L/XL to obtain better fit.

3. Researcher: Are there any details in the ballistic vests for firefighters that are different than usual?

Manufacturer: *There are different movement patterns for LE and first responders. LE officers have very specific or less movements than the first responders. Neckline and armhole are rectangle in shape for fire or EMS (not best fit but easy to make panels because of the straight cut) and round for LE officers to provide max coverage.*

4. Researcher: What are the threat levels and configurations of existing ballistic vests for the first responders?

Manufacturer: *Soft ballistic vest- IIIA NIJ (handgun-9mm ammunition) for firefighters/EMS people as a foundation of*

personal protective equipment. They may carry rifle plates in front and back for extra protection with Level IIIA in case of emergencies. There might be side panels too that are stab resistant. Most of the vests are adjustable. The vests are not flame-resistant though and they are not NFPA certified.

5. Researcher: What are the current gaps you think should improve in terms of ballistic vests for first responders and EMS personnel?

Manufacturer: Ballistic vests should be an everyday wear vest. Current vests are bulky, hinder mobility, and are costly. It should be lighter in weight and provide a more custom fit.