

Fit Problems and Design Modifications of the Ballistic Vest for Female Police Officers

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Federal Bureau of Investigation's Law Enforcement Officers Killed and Assaulted Program statistics showed that more than 70,000 officers have been assaulted by firearms and more than 1,700 have been feloniously killed by firearms from 1987 through 2015 (National Institute of Justice, 2018). During the past three decades, the ballistic vest has saved more than 3,000 police officers' lives (National Institute of Justice, 2018). Despite the development of modern ballistic vest which offers effective ballistic protection, it does not provide adequate fit and comfort to the female wearer which makes it less likely to be worn (Barker & Moore, 2007), thereby, put the officers in the risk of severe injury and fatal hazard.

Ballistic vests are designed to protect the crucial organs in the torso from gunshot and projectiles (National Institute of Justice, 2004), therefore, it triples the likelihood of survival of a wearer shooting to the torso (Barker, et al., 2010). The ballistic vests for police officers are usually multi-layered woven or laminated fabric which is nonflexible and heavy (National Institute of Justice, 2014), therefore, creates poor fit to the female body. If the ballistic vest does not fit correctly, it is unable to provide adequate coverage and protection. According to Cuppola (2014), the number of female law enforcement officers in the U.S. is between about 12 to 20 percent and body armor issues conveyed by some female officers include improper fit, riding up or shifting out of place, skin abrasions, bust cups too large and bust cups too small. Hence, there is a crucial need for the development of the ballistic vest that fits well to the female body with required protection and coverage for the improved security and performance of female police officers (Leipold, 2011).

Soft ballistic vests for female police officers should be designated in a way which is different from male and gender-neutral vests so that it can incorporate curved or shaped protective panels to accommodate the female bust (Abtew, et al., 2011). Ballistic vest for male and gender-neutral might be suitable for flat-chested females but might not be suitable for larger busts because the busts push the front ballistic panel forward which causes the enlargement of the underarm gap. It results in the reduction of coverage between the front and rear panels (Coppola, 2014). Darting is a process of overlapping fabric at an angle and is considered the most common way to shape ballistic material around the bust (Mahbub, 2015). However, if the darts don't hit at the right point, the ballistic vest will follow the wrong contours and won't fit the body. Therefore, it will create not only unsightly but also poor fit which is might affect ballistic protection (Bacish, 2007). The creation of contour of the front panel of the female ballistic vest also includes cutting and stitching of the materials in the first layer of the ballistic vest to form bust cups. However, cutting or stitching is considered the area of potential weakness for ballistic vests. The discontinuity of the yarns in that area sharply reduces the capability of ballistic resistance (Yang & Chen, 2016).

Market research showed the use of bust darts, adjustable shoulder strap and overlapping side seams for female ballistic vests by most of the manufacturers (Ekdahl & Raza, 2014) to accommodate female body shape. In spite of having these design features, female police still experience

insufficient fit and comfort with their daily activities wearing ballistic vests. To identify specific fit problems and design solutions, 9 female police officers and detectives were interviewed who are required to wear ballistic vests in the line of duty. They were asked open-ended questions. It helped them to explain the reasons behind their answers and if they have any additional information about fit that they want to introduce as well. The responses helped to understand and determine the wearer's expected design features of the ballistic vest. The qualitative data analysis included the content analysis from the open-ended questions and major themes in the data were identified. This analysis allowed to determine and define valid meanings of data and to identify sub-themes and themes through the coding process.

The data analysis showed that under the theme "Fit problem", 78% participants mentioned that the ballistic vest was "not cut to shape", 56% of them indicated that ballistic vests are "made for guys", and 33% mentioned, "needs to be tailored". Under the theme "Effect of Poor Fit", there are three subthemes. These were "Chafing" (mentioned by 44% participants), Choking (mentioned by 11% participants), and "Shifting" (mentioned by 33% participants). Under the theme "Areas of discomfort", 89% of participants mentioned chest curve or full bust area, 45% mentioned waist curve or stomach, 22% mentioned armhole and 11% indicated neck. Under the theme "Uncomfortable movements", they mentioned running (78%), bending over (78%), crawling (45%), sitting (11%), and jumping (11%). Under the theme "Factors affecting movements", 11% of participants mentioned "Weight and flexibility", 11% mentioned "fit", 11% mentioned "does not move like regular clothing" and 11% mentioned "too tight in the back". Under the theme "Expected features for fit and comfort" 89% of participants mentioned "Extra curves", 55% mentioned "Customization", and 33% mentioned "Increased flexibility".

The result showed that the fit problem occurs because the existing ballistic vest does not conform to the female body shape. As a result, the participants suffer from various discomfort while performing certain activities that might affect their operational performance and protection. Most of the wearers expect tailoring and customization of the ballistic vest with extra curves and increased flexibility. To solve these fit problems several design modifications could be proposed for the existing ballistic vests that are commercially available. Firstly, the waist dart could be incorporated to accommodate the waist curve or stomach. Secondly, adding a back pleat might facilitate mobility during certain body movements. Thirdly, the inner fabric layers could be elasticized to provide a wider range of motion which will facilitate mobility further. Additionally, the wearers expect an extra curve in the ballistic vest which can be incorporated with princess lines. However, it includes cutting and stitching that might affect protection at the front torso. Finally, the development and implementation of flexible material that is capable of sufficient ballistic protection are significantly necessary.

Future research could be done by incorporating more participants and making a prototype with their expected design features to test if the design modification could improve the fit of the ballistic vests for female police officers in different body positions.

Designing clothing for a certain function needs more than just creativity. To design functional clothing, a designer must be aware of the content and process. Moreover, designers should seek out and fulfill the wearer's needs and expectations to ensure fit, comfort, mobility, and safety. Therefore, this study found out what kind of fit problems of ballistic vests are experienced by the female police officers, how it affects their regular movement and activities, and what kind of features they expect to feel

comfortable with wearing a ballistic vest. Since police officers need to wear a ballistic vest for a considerable amount of time during their duty, it is significantly important to make them comfortable with a proper fit, and ensure protection. Thereby, this study suggests the aforementioned design features to contribute to ensure protection for those who protect us.

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