ECG Monitoring via Apparel for Female Firefighter's Safety (III)

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1 Contextual review and concept

Fire fighters respond to calls involving emergencies such as structural and automobile fires, airplane and train crashes as well as medical issues. This is a very physical job requiring the fire fighter to climb ladders, break down doors, and perform search and rescue activities often while being present in intense heat. Currently, there are 1,066,500 active career and volunteer fire fighters in the United States (US Home Security, 2019). About half of them are female firefighters. More than 100 fire fighters die in the line-of-duty in the U.S. each year which is three times higher than the fatality rate for the general working population (US Home Security, 2019). The leading cause of death among fire fighters is sudden cardiac death (SDC). While some of the causes of SDC can be correlated to lifestyle choices, the addition of a physically intensive, extremely hot work environment may also increase SDC. It has been determined that fire fighters have two thermal hazards to be aware in in their job – the fire itself and heat stress (Rossi, 2003). Heat stress is being exposed to extreme heat and the body is unable to cool itself properly which can result in a life-threatening condition such as a heat stroke or heart attack. Electrocardiogram (ECG) monitoring becomes essential as an early warning sign to detect related to heart conditions. Fire fighters are a high-risk group working in a high stress environment and need a specially designed smart clothing solution to monitor their health. For this project, smart clothing was created aimed at developing future solutions to support the management of heart disease as well as provide support for daily health monitoring for fire fighters. Traditionally, in order to obtain an ECG, a commercial hydrogel with a high adhesive factor is applied to electrodes which are subsequently applied directly to the body in order to monitor the wearer's health. Constant application and reapplication of the electrodes causes skin allergies and pruritus from wearing the hydrogel for an extended time. An alternative method of applying the electrodes was researched. This project developed a prototype garment which could be worn by fire fighters as a base layer or as part of the station uniform which could monitor the health of the fire fighter through a constant ECG reading as they work.

Intelligent biomedical clothing usually refers to clothing with sensors that are close to or in contact with the skin (Lymberis & Olsson, 2003). Traditional commercial hydrogel patches and one of three tested conductive textile patches (a 50% Nylon, 40% copper and 10% nickel fiber tricot knit coated with silver) were used to design two types of t-shirts with embedded ECG devices. The conductive textile was adopted to replace traditional commercial hydrogel.

2 Aesthetic properties and visual impact

There are several types of station uniforms. This project is focused on designing an ECG firefighter station uniform for female firefighter. Female firefighter's body shape needs a special care in proper fit so that the conductive fabric remains in contact with the body and can detect data. The following graphic explains the design details to meet these requirements.

				
Closed up color code thread embroidery	Four different color code thread embroidery to avoid mistake	Zipper at side to accommodate female body couture	Inner pocket for portable ECG machine (about 13.05 ± 0.01grams) 4-lead ECG monitoring device	Using Velcro to secure lining and t-shirt and easy to remove

3 Process, technique, and execution

A basic T-shirt style was selected to develop a female firefighter's undergarment as a prototype. A draft pattern was used to create pattern. In initial trials, it was found that for the participants with C-cup or larger breasts the t-shirt would gap directly under the breast tissue and the lower sensors would not be in full skin contact. Custom alterations to the patterns based on cup size were performed as well as the addition of a side zipper in order to ensure good fit and skin contact with the sensors. In this project, we used a textile-based pressure sensor which is both highly sensitive and has excellent durability, fast response, and a relaxation time based on highly conductive fibers coated with dielectric rubber materials. The conductive fibers were fabricated by coating polyester (styrene-block-butadien-styrene or SBS) polymer on the surface of polyester (p-phenylene terephthalamide or Kevlar) fiber, followed by converting silver (Ag) ions into Ag nanoparticles directly in the SBS polymer.

4 Cohesion, design contribution and innovation

While previous versions of this prototype dealt strictly with male participants, in this project females were the focus. The initial project showed success in collecting data (ECG) on male participants using conductive textile patches to continually monitor the fire fighter. However, we found that due to the curves of the female figure, it posed issues with having the sensors remain in contact with the body. This issue was resolved through the creation of bra cup size specific alterations to the t-shirt and the addition of a zipper in order to ensure the fabric always contacts the skin. Sensors are enclosed in the layers of fabric, or it is the fabric itself that is used as the sensors.

References

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