

Impact of Self-Contained Breathing Apparatus on Air Gaps in Structural Firefighter PPE



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Introduction

Air acts as an insulator and in excess, can lead to heat stress in some applications, such as in structural firefighter turnout suits. Air gaps (volume occupied by air within the firefighter turnout suits) are essential to providing thermal protection for firefighters as it slows the heat transfer to the skin while firefighters are on active duty. However, excess air gaps can lead to heat stress. Therefore, an optimized balance in air gaps must be struck when donning the full turnout ensemble, including personal protective equipment (PPE) elements such as the self-contained breathing apparatus (SCBA). PPE elements often tend to decrease the ability of firefighters to perform their tasks and pose a risk to their safety. Apart from on-site hazards, heat stress accumulation over an extended period could result in increased cardiovascular problems (Cheung et al., 2010). The number one cause of acute firefighter fatalities is due to overexertion and heat strain (Campbell & Perillo, 2023). Bulky and oversized gear can easily lead to reduced mobility and excess buildup of metabolic heat (Cheung et al., 2010). Hence, the purpose of this research was to study the air gaps formed within turnout suits, with and without a self-contained breathing apparatus (SCBA).

Methodology

- 11 active male and female firefighters were recruited.
- Participants were informed of the IRB approved study protocol and signed an informed consent form.
- Then, participants were body scanned in each of the three garment configurations: compression layer (CO), base layers (BL) and turnout suit (TS) using a Sizestream-SS20 Body Scanner
- A fourth scan was performed with the participants using a Self-Contained Breathing Apparatus (SCBA).
- A Sizestream-SS20 Body Scanner was used.
- Body Measurement data from the scanner were used to study air gaps formation in the turnout suits.
- Horizontal contour measurements were taken across several regions in the front torso of the body with and without the SCBA.
- (Ease gap differences (inches) = Turnout suit measurement – Turnout suit w/SCBA measurements) was calculated using the horizontal contour measurements.



Figure 1. 3D Body Scan of Firefighter in turnout suit without SCBA (side view)



Figure 2. 3D Body Scan of Firefighter in turnout suit with SCBA (side view)



Figure 3 : SS20 Scanner used for the 3D body scans of the firefighters.

Results

Average Measurements for all 11 Participants			
Body Measurement Type	Turnout Suit measurement (inches)	Turnout Suit w/SCBA measurement (inches)	Ease gap Differences (inches)
Across Chest Tape Measure	22.345	21.055	1.291
Front Waist Tape Measure	28.978	27.344	1.633
Bust Prominence Left	11.164	10.655	0.509
Bust Prominence Right	11.200	10.673	0.527
Across Axilla Chest Front Length	28.500	31.282	-2.782
Front shoulder width	20.810	21.260	-0.450
Stomach FP Circumference Tape Measure Front Left	14.409	12.982	1.427
Stomach FP Circumference Tape Measure Front Right	14.464	14.364	0.100
Waist Circumference Tape Measure Front Left	13.818	13.318	0.500
Waist Circumference Tape Measure Front Right	13.400	13.345	0.055

Table 1: Differences of the horizontal contour measurements across several regions of the front torso compared between firefighters in turnout suits with and without SCBA.

Discussion

Overall, it is seen that the SCBA while donned on, reduces mobility within the front torso by a significant amount. Limitations of the study included difficulty in determining the exact decrease in torso volume and circumference as the scanner accounts for the SCBA as a part of the body. Similarly, An increase is seen in the across axilla chest measurement and the front shoulder width. We hypothesize that this might be due to the presence of the SCBA straps at the axilla chest and shoulders. Further research on this unique result is necessary.

Conclusion

It is seen that majority of front body measurements decreased when donning the SCBA suggesting significant restrictions for fit. The largest reductions in front body measurements were in the Front waist, across chest and the front left circumference of the stomach with an average reduction greater than an inch. Largest individual reductions of up to 5 inches (p=5) were seen in some participants in the front waist and across chest measurements.

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