Effect of Protective Clothing and Fatigue on Functional Balance of Firefighters

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Abstract

We investigated the effects of wearing personal protective equipment (PPE), design of PPE (Standard vs. Enhanced), and fatigue during a simulated firefighting activity on the functional balance of firefighters. We defined functional balance as the ability to prevent a loss of balance and maintain body posture while performing functional tasks. A novel Functional Balance Test (FBT) was used to assess functional balance of firefighters while stepping up, stepping down, turning, walking along a beam, and passing under an obstacle. Data are presented from fifty-seven male firefighters, who were randomly divided into two groups: Standard PPE (n=28) and Enhanced PPE (n=29). The specially designed Enhanced PPE was lighter, more breathable, and capable of air circulation, compared to traditional Standard PPE. Each participant performed the FBT at three time periods (baseline with station uniform, pre-activity with PPE, and post-activity with PPE after a live-fire simulated firefighting activity). The firefighting activity involved alternating 2-minute rest-work cycles of four stations: stair climb, forcible entry, room search, and hose advancement. The FBT had four trials each with and without an overhead obstacle. Performance errors (major and minor), performance time, and a composite performance index were recorded. Wearing PPE significantly impaired functional balance, as noted by increases in all performance metrics. Following the firefighting activity, performance time increased by 3% but the number of minor and major errors decreased by 13% and 32%, respectively, suggesting that firefighters may trade-off between speed and accuracy depending on perceived threat to balance safety. There was no significant difference in functional balance between the Enhanced PPE and Standard PPE groups, suggesting that Enhanced PPE with a passive cooling system and an external circulating hose is not effective in improving functional balance of firefighters. A better designed PPE, with an improved cooling system and minimal (or no) protruding attachments may be of benefit in terms of firefighter functional balance.

Keywords: Firefighting; Personal protective equipment; Functional balance; Overhead obstacle

Introduction

Every year, more than 38,000 firefighters are injured on the fireground [1]. Among causes of moderate or severe injuries of firefighters, slips, trips, and falls are the most significant cause (28%) of firefighting injuries, followed by overexertion (23%), struck by objects (17%), exposure to detrimental environment (15%), and others (17%) [1]. A 2003 study reported that the average medical cost per claim due to slips, trips, and falls was $8,662 – a value that was 60% higher than the average costs for all claims [2]. Firefighters regularly work in hot, smoky, and slippery fireground conditions with many obstacles. To provide protection under these circumstances, firefighters wear fully encapsulating “bunker gear style” personal protective equipment (PPE), which includes bunker coat, bunker pants, boots, helmet, face mask, gloves, and self-contained breathing apparatus (SCBA) [3]. The primary design requirements for firefighter PPE are to provide protection from the by-products of combustion (heat, smoke, gases), but current designs and typical materials have significant negative impacts on balance, mobility, thermoregulation, etc. Furthermore, during emergency operations, firefighters may become fatigued by the strenuous firefighting activity and heat stress, which can further impair balance control.

In spite of the obvious benefits of PPE in protecting firefighters from heat, smoke and fire, the use of PPE may negatively affect firefighters’ functional balance. Functional balance was defined as the ability to prevent a loss of balance and maintain body posture while performing functional tasks. Wearing PPE may impair the functional balance of firefighters due to its heavy weight, bulkiness of the material, and a SCBA face mask, which limits vision [4,5]. Wearing PPE also changes the firefighter’s center of gravity [6], increases fatigue [7], and imposes physiological burdens, e.g., increased oxygen consumption and heart rate [7–10]. The heavy, insulative aspect of PPE also contributes to increased metabolic work done by the firefighter, resulting in increased heat stress [11,12] that might negatively impact functional balance. During firefighting activity, heat stress and the resulting elevation in body temperature hastens muscular fatigue, promotes dehydration, increases cardiovascular strain, and interferes with cognitive function [13,14]. While relatively few studies have investigated the effects of firefighting PPE on functional balance [4,15], no studies have been found related to the effects of fatigue due to firefighting activity on the functional balance of firefighters.

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