EFFECT OF FATIGUE AND PROTECTIVE CLOTHING ON FUNCTIONAL BALANCE OF FIREFIGHTERS

P. Hur[1], K.S. Rosengren[2], G.P. Horn[1,3], D. Smith[3] and E.T. Hsiao-Wecksler[1]

[1] Mechanical Science & Eng [2] Kinesiology and Psychology [3] Illinois Fire Service Institute
University of Illinois at Urbana-Champaign, Urbana, IL, USA
E-mail: ethw@uiuc.edu Web: www.mechse.uiuc.edu/research/hsiao-wecksler/

INTRODUCTION

This study investigated the effect of fatigue and load carriage on balance. Occupations such as structural firefighters (FFs) must perform hard work wearing personal protective equipment (PPE) consisting of specialized clothing and a self-contained breathing apparatus (SCBA) to protect themselves. However, the use of PPE can potentially hinder FFs due to increased heat stress and fatigue rate and impaired mobility. This study was designed to assess the effect of firefighting activity (FFA) and PPE on balance. Specifically, we developed a new functional balance test protocol, and investigated changes in balance due to PPE ensembles and 18 min of strenuous simulated FFA.

METHODS

Forty-nine male FFs (ages 18-50) participated in this study. Subjects were divided into control (n=29) and intervention (n=20) groups. The control group (standard PPE) wore PPE typically used by US firefighters, i.e., helmet, heavily insulated hood, bunker gear, and rubber boots. The intervention group (enhanced PPE) wore PPE designed with an industrial partner that included: 1) a lighter helmet, 2) more breathable hood, 3) bunker gear with reduced insulation, maximum breathability, and a passive cooling system to assist with heat transfer; and 4) lightweight leather/Kevlar boots. Both PPE ensembles meet current guidelines for thermal protection and breathability. Both groups wore identical SCBA packs and masks.

To assess the effect of PPE ensemble and FFA, subjects were evaluated at three testing periods: initially in normal clothing (baseline), before FFA in PPE (pre-activity), and after FFA in PPE (post-activity). FFA consisted of 18 min of alternating work-rest cycles that included four simulated firefighting activities in a burn facility that contained live fire. Post-activity balance testing occurred within 1-2 min after completing the simulated FFA.

To assess functional balance, the subject began on a raised platform (15 cm (H)), stepped down and walked on a narrow plank (3m (L), 15 cm (W), 4 cm (H)), stepped up and turned around within a defined space (61×61 cm^2) on a second raised platform (10 cm (H)), and walked back to stop within a defined space (61×61 cm^2) on the original platform. Subjects were instructed to perform the task as quickly as possible, but safely. The task was made more challenging by placing an overhead obstacle (a lightweight rod) across the center of the pathway and set at 75% subject height. The rod was designed to fall away if contacted directly. The subject performed 2 trials with no obstacle, 4 with the obstacle, and finally 2 no obstacle trials. Each trial was timed by two investigators. Average time per trial was penalized by 5s for a major error (rod fall) and 2s per minor error (touch rod or floor, failure to turn or stop within defined space).

Performance times were calculated by summing the four adjusted trial times per obstacle condition.

Three-way repeated-measures ANOVA tests were used to assess the effect of different PPE group, testing period, and obstacle presence on the performance time. Statistical analyses were run on SPSS (SPSS Inc., Chicago, IL; v15).

RESULTS AND DISCUSSION

Significant increases in performance times were found due to testing period ($p<0.001$), obstacle presence ($p<0.001$) and the interaction between the two ($p<0.001$), Figure 1. No significant differences in time were found due to PPE (standard versus enhanced), or any interactions with PPE gear ($p>0.05$).

Performance times increased significantly between baseline and pre-activity ($p<0.001$), but not from pre- to post-activity. These results suggest that the use of PPE (baseline to pre-) significantly impacted balance by increasing the performance time; however, 18 min of simulated FFA did not affect balance performance. Previous studies also found that PPE impairs FF balance performance (Kincl, 2002; Punakallio, 2003). We are not aware of other studies that have investigated the effect of FFA on balance.

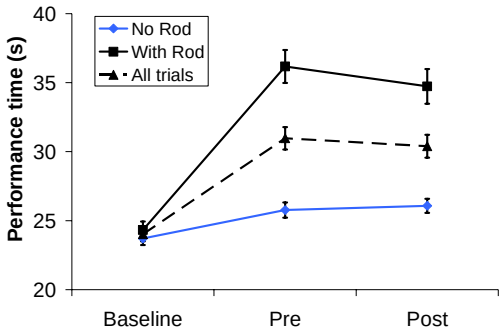

Fig 1. Mean time with standard error bars

Adding the challenge of walking under an obstacle reduced speed and increased errors. Performance time increased substantially with the addition of both the obstacle and PPE.

Although not statistically significant, performance scores for enhanced PPE declined slightly between pre- and post-activity, whereas standard PPE scores increased slightly (Figure 2). These results suggest that the enhanced gear may have some positive effect on balance performance. It is also possible that subjects were learning to move in enhanced gear during the study. The intervention gear is quite different from the traditional PPE, which is closer to the standard PPE ensemble.

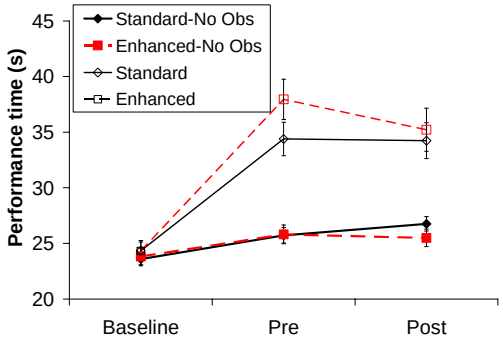

Figure 2. Gear effect with and without obstacle

SUMMARY/CONCLUSIONS

The effects of fatigue and personal protective equipment on balance performance were investigated. To assess balance performance, a new functional balance protocol was developed. Wearing any PPE was found to significantly impair balance performance. Balance performance times, however, were not significantly affected by a short bout of strenuous FFA or modified PPE.

REFERENCES

Kincl, L.D. et al. (2002) *Appl Occup Environ Hyg*, **17**(4):256-66.

Punakallio, A. et al. (2003) *Aviat Space Environ Med*, **74**(11):1151-56

Acknowledgements: US Dept of Homeland Security (#EMW-2006-FP-02459). Thanks to the 20 student assistants on this project.