Qualitative and Quantitative Determination of Impaired Movement in Protective Clothing

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Impaired movement is seen in most instances where protective clothing is worn. It is caused by garment bulk, stiffness, low stretch, poor fit and friction between fabric layers. Unlike conventional garments, protective clothing is usually constructed to provide very a generous fit. Therefore, the methods used for the determination of range of motion in conventional garments are not appropriate for assessing protective clothing. ASTM F 1154 Option B provides standardized practices for qualitatively evaluating the functionality of chemical protective ensembles (CPE) through the use of specified movements (ASTM, 2004). The results provide a qualitative evaluation of the performance characteristics of individual ensembles, however, the results do not permit comparisons across different types of CPE. Garment bulk, often seen in protective clothing, resulting from thickness or extra ease at arms and legs may greatly interfere with movement. The barrier materials used in protective clothing may also be rigid and further limit movement. When work must be accomplished by straining clothing through compression, bending, stretching, and shearing actions or by sliding one fabric against another, energy that could be used to accomplish a task is wasted (Watkins, 1995). Clothing made of different materials, even in a similar design, is expected to result in different levels of impairment to body movement. Quantitative examination of the differences involves well controlled human wear trails and measurements of subjective responses (ASTM, 2007).

The purpose of the current study was to compare the qualitative and quantitative methods of assessing impaired movement in protective clothing and to better understand the magnitude of the effect on movement and overall work performance associated with the wearing of CPE.

Methods: Four clothing ensembles, Fig. 1, including one control garment system and three types of CPE worn on top of the control were selected for this study. The control garment system consisted of 100% cotton shirt and pants. All three CPE had a similar design, hooded coverall with a front zipper. Two of them, V and M were for civilian and industrial use, while the third one, G was a military CPE.

Figure. 1. Tested CPE

Qualitative evaluation of mobility related performance was conducted in accordance with ASTM F 1154. The investigator showed the participant (one healthy male, age 38) an illustration of a well-defined action and demonstrated the action. The participant then performed the action and was questioned regarding restriction of movement in the garment while performing the action. In total, eight well-defined actions were performed by the participant.

Next, fifteen healthy males completed four sessions of walking on a treadmill at 3.5 mph, 4% for 60 minutes in the four clothing ensembles (Wen et al., 2015). Impaired movement was quantified at 5-minute intervals by monitoring the subjective ratings provided by the participants of restriction to their arms and legs and their overall rating of perceived exertion (RPE).

Results & Discussion: The results from qualitative and quantitative evaluations are shown in Table 1 and Figure 2 (Restriction to legs). The qualitative assessment provided an overview of the general acceptance of each CPE, while the quantitative method found differences in the magnitude of restrictions caused by the garments. M and G restricted arm and leg movements at a higher level than either the Control or V garments. Subjects' comments on the sources of restrictions included stiffness of M, heaviness and bulkiness of G, frictions between legs in M and G, and the restriction caused by the sweat-wetted control garment underneath the CPE.

Table 1. Qualitative assessment of clothing function during movements

CPE	Control	V	M	G
Kneeling	*EE*	*EE*	*EE*	*E*
Duck squats	*EE*	*E*	*EE*	*E*
Body bends	*EE*	*EE*	*EE*	*E*
Overhead arm extensions	*E*	*E*	*E*	*EE*
Torso twists	*EE*	*EE*	*EE*	*EE*
Cross body arm reaches	*E*	*E*	*EE*	*E*
Walking	*EE*	*EE*	*EE*	*EE*
Crawling	*E*	*N*	*E*	*N*
Overall restricted movement of arms	*SR*	*SR*	*SR*	*SR*
Overall restricted movement of legs	*SR*	*SR*	*SR*	*SR*

EE: extremely easy *N: neutral (not easy not difficult)*
E: easy *SR: slightly restricted*

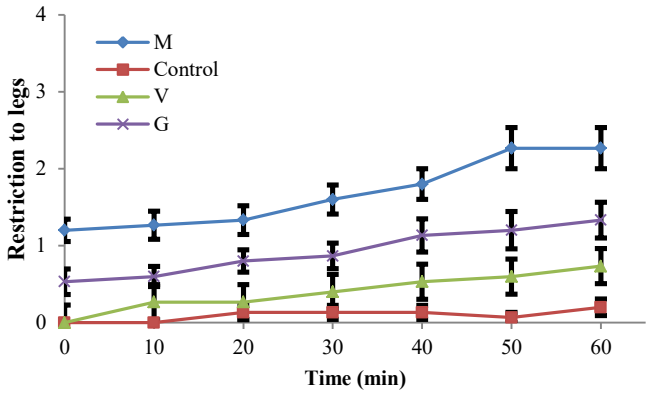

Figure. 2. Restriction to leg movement

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References:

American Society for Testing and Materials. (2004). ASTM F 1154 *Standard Practice for Qualitatively Evaluating the Comfort, Fit, Function, and Integrity of Chemical-Protective Suit Ensembles.* West Conshohocken, PA: American Society for Testing and Materials.

American Society for Testing and Materials. (2007). ASTM F 2668 *Standard Practice for Determining the Physiological Responses of the Wearer to Protective Clothing Ensembles.* West Conshohocken, PA: American Society for Testing and Materials.

Watkins, S. M. (1995). *Clothing: The Portable Environment* (2nd ed.). Ames, IA: Iowa State University Press.

Wen, S., Petersen, S., McQueen, R. & Batcheller, J. (2015). Modelling the physiological strain and physical burden of chemical protective coveralls. *Ergonomics, 58*(12), 2016-2031.