Applying a comprehensive evaluation method in Military PPE : A systematic review

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Introduction

Military personal protective equipment (PPE) is a generic term for soldiers' uniforms, weapons and associated accessories. Although military PPE is worn to protect soldiers from high risk of injury, it negatively hinders solders' mobility that could cause combat capabilities in military operations (Williams & Rayson, 2006). Therefore, it is critical to offer both necessary performance and satisfactory wearability to soldiers via military PPE. With the goal in mind, researchers have put efforts in assessing diverse dimensions of wearability of military PPE – e.g., physiological reactions (De Maio et al., 2009), joint range of motion (ROM) (Brown et al., 2018), usability (Bossi et al., 2016), ergonomic fit and size (Dabolina & Lapkovska, 2018) and subjective evaluation. Despite a considerable amount of work that have been done, no comprehensive standard method has been established yet for the assessment of wearability with regards to military PPE. To this end, we aimed to a) conduct a systematic review of current literature on the relevant topic and b) identify an opportunity to propose a direction for comprehensive wearability assessment of military PPE.

Methods

For a systematic review of literature, we used Google Scholar as a database search engine. The range of publication year was set from 2000 to October, 2021. Keywords consisted of the three levels (Table 1). Only when at least one related keyword was included in the title, abstract, and the body of the paper did the search go on, which was filtered by the Boolean operator "AND." Literature that met the following conditions were only selected for review: Those that were categorized to be research papers and technical reports; discussed the effects of military PPE on humans, and written in English. Exceptionally, we included non-English papers when the abstracts were written in English, in which the assessment methods were clearly indicated. On the other hand, we filtered out the literature that had no access to the full text, contained the evaluation of PPE targeting non-humans, investigated only wearing attitudes toward PPE, and dealt with only protective functions of PPE (no wearability).

Table 1. Keywords used for literature search

Level 1	Level 2	Level 3
wearability	personal protective equipment	military
evaluation	PPE	army
		soldier

Results & Discussions

After searching databases, a total of 2,999 articles were identified. After removing 1,941 duplicates and examining 1,058 titles and abstracts, 104 potentially relevant articles were retained. After that, 19 articles were additionally excluded adhering to the inclusion criteria. As a result, a total of 85 papers were reviewed in this study, among which 29 papers on military PPE (34.1%) and 22 papers on firefighting PPE (25.9%). About medical PPE were 15 papers found (17.6%), while seven evaluated chemical PPE (8.2%). Six police PPE-related papers were reviewed (7.1%), Level 1 Level 2 Level 3 wearability personal protective equipment military evaluation PPE army soldier and the remaining six papers covered marine inundation suits and fall-protective suits, as well as PPE for construction workers (7.1%). Evaluation indexes extracted from literature that satisfies the inclusion criteria were categorized by the following four categories including anthropometric, biomechanical, physiological and usability evaluation. A total of 256 analyses was included in 85 papers reviewed, consisting of 128 usability evaluation (50.0%), 76 physiological analysis (29.7%), 41 biomechanical analysis (16.0%), and 11 anthropometric analysis (4.3%) (Fig. 1).

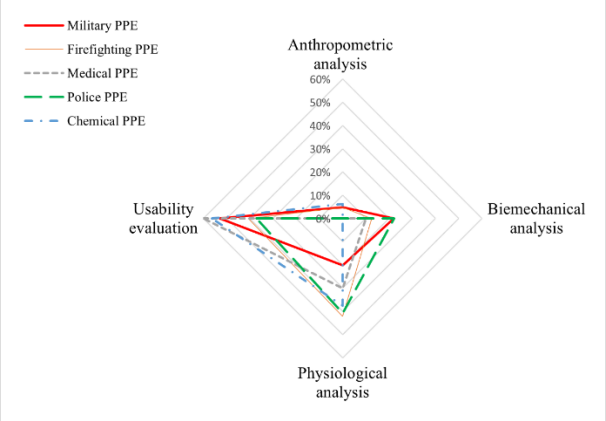

Figure 1. Distribution of evaluation indices by PPE category

Further, we organized the methodological strategies found in the reviewed papers into the two groups: those that adopted a single method and hybrid methods in data analysis. 49 of the 85 papers adopted a single method (56.5%), while 36 implemented hybrid methods (43.5%). 30 among 36 papers using hybrid methods included usability to assess effectiveness, efficiency, satisfaction, and a lab-scale quantitative evaluation of the PPE's effect on humans (83.3%). Highlighted below are some of the key findings from this study:

• Anthropometric analysis was rarely performed in previous studies for PPE evaluation.
• Evaluation methods tended to be biased to one or two functions by PPE for specific occupations.
• Usability evaluation was a most common repertoire in hybrid methods in PPE research.
• It is recommended to conduct a comprehensive evaluation of wearability in all four categories including anthropometric, biomechanical, physiological and usability, in order to gain a holistic view of the matter.

For effective evaluation of PPE wearability, it is crucial to conduct comprehensive analyses. Particularly, anthropometric components – e.g., ergonomic fit and comfort should not be overlooked in the efforts. ISO 13688 (2013) outlines anthropometric recommendations for all PPE should consider, which offers guidance for size adjustment systems or appropriate size ranges for PPE's wearers with diverse body sizes and shapes. We hope that the outcomes of this study urge researchers in the field of Textiles and Apparel to be aware the relative dearth of anthropometric evaluation in current literature and continue performing active research in this important area to offer balanced perspectives in the PPE research communities.

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