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Factors affecting airport apron workers' preference on cooling vests

Albert P.C. Chan [a], Y. Yang [a,*], Michael C.H. Yam [a], Edmond W.M. Lam [a], J.Y Hu [b]

[a] Department of Building and Real Estate, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China
[b] Institute of Textiles and Clothing, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China

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ABSTRACT

The aim of the current study is to evaluate airport apron worker's preferences using two types of cooling vests to identify the factor affecting the preferences for one vest over another. A total of 112 airport apron (43), construction (36), horticultural and cleaning workers (33) participated in two rounds of surveys to evaluate their perceptions of the cooling vests across 18 attributes. For the 17 subjective attributes (except "dislike–like"), the cluster analysis revealed four categories of subjective attributes, while the factor analysis extracted four underlying factors: thermal comfort, fabric hand feel, usability, and tactile comfort. The results of the analysis of variance indicated that airport apron workers were less satisfied with the cooling vests than the other outdoor workers. Multiple linear regression analysis on the resultant preference "dislike–like" of airport apron workers (the dependent variable) and the four underlying factors (the independent variables). The results revealed that usability significantly determined the preference of airport apron workers on cooling vests (adjusted $R^2 = 0.84$, $p < 0.001$). Given the underlying factor affecting workers' preference on cooling vests, the current study provides a practical guidance to optimize the designs of personal cooling vests in view of usability issues for airport apron workers.

1. Introduction

Occupational workers in many industries, such as glass and calcium carbide manufacturing, mining operations, farming operations, iron, steel and nonferrous foundries, and airport apron service sectors, commonly endure an extremely hot environment (Da Costa, Baptista, & Diogo, 2012). Many risk factors associated with heat stress include the thermal environment, the nature of work, the characteristics of the worker, and clothing properties (Rowlinson, YunyanJia, Li, & Chuanjing Ju, 2014). Heat stress not only damages the health of workers, but also potentially reduces their productivity (Lucas, Epstein, & Kjellstrom, 2014). The Hong Kong International Airport is located in a typical subtropical region where the summer is hot and humid. During the day on August 2014, the reported maximal air temperature and relative humidity of the Hong Kong International Airport can be high as 36.3 °C and 97%, respectively (The Hong Kong Observatory, 2014). Similar to other airports located in the tropical and subtropical regions (e.g., Changi airport in Singapore), the environmental condition of the airport apron is primarily associated with the local hot weather. The artificial climate is another stressor, leading to large hot spot areas arising from concrete runways, airport buildings (Jusuf, Wong, Hagen, Anggoro, & Hong, 2007), and the operating equipment around the planes (Noweir & Bafail, 2008). The Hong Kong International Airport thus may have a high surface temperature during the daytime because of a large amount of heat absorbed by concrete areas and airport buildings (Jusuf et al., 2007). Moreover, heat from operating vehicles and equipment for ground services operations can further yield a stressful environment to airport apron workers (Noweir & Bafail, 2008). In addition to these environmental stressors, excessive heat production may be generated in the body because of the increased workloads during the travel peak season of summer vacation (Noweir & Bafail, 2008). As a consequence, the level of heat stress can be high in the airport apron service industry.

There are different environmental engineering, administrative, and personal protective controls to minimize the deleterious effects of heat stress. An effective approach to controlling thermal stress is to provide a personal clothing ensemble with an auxiliary body cooling system to generate a cooler microclimate (Nunneley, 1970). Various kinds of personal cooling ensembles (e.g., ice vest, air- or water-cooled vests, and phase change material vest) have been proven effective in alleviating physiological and/or subjective strain and improving physical performance in the heat (Choi, Kim,

* Corresponding author.
E-mail addresses: albert.chan@polyu.edu.hk (A.P.C. Chan), jackieyang8852@yahoo.com.hk (Y. Yang), michael.yam@polyu.edu.hk (M.C.H. Yam), edmond.wm.lam@polyu.edu.hk (E.W.M. Lam), junyan.hu@polyu.edu.hk (J.Y Hu).

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& Lee, 2008; Hadid, Yanovich, Erlich, Khomenok, & Moran, 2008). However, their effectiveness in promoting the well-being of occupational workers and their job performance is yet to be determined, particularly in the field of airport apron service industry. In view of this, the current study evaluated the airport apron worker's perceptions of two types of personal cooling vests and the factors that affect preferences in relation to those cooling vests.

2. Method[1]

2.1. Field study

The field studies evaluated the subjective assessment of outdoor workers from three industries, namely, construction, horticulture and cleaning, and airport apron service, when wearing the two types of cooling vests. Three field studies were conducted per industry and each field study involved two wear trials. Each wear trial, lasting 1 h or 2 h, required participants to carry out their regular tasks while wearing vest A and vest B. The khaki-colored vest A, weighing a total weight of 2.3 kg, consisted of a fire-resistant vest and four pieces of non-toxic frozen gel pads. The total weight of the ultramarine-colored vest B was around 1.0 kg, including a fire retardant vest, three pieces of non-toxic frozen gel pads and two detachable small fans with four 1.5 V AA alkaline batteries.

In each field study, participants were randomly divided into two groups. For the first wear trial in the morning, one group wore cooling vest A, while the other group wore cooling vest B. The two groups exchanged the vest types during the second wear trial in the afternoon. All participants were required to complete the two wear trials. Each trial lasted around 3 h. A total of 112 participants employed by different companies and industries participated in the nine field studies. A total of valid 205 sets of data were obtained after eliminating 19 sets of invalid data. The field studies for airport apron workers were conducted with three airport apron service companies in the Hong Kong International Airport in the summer of 2012. A total of 43 male airport apron workers participated in the two wear trials, while 67 sets of valid questionnaires were obtained.

Prior to the wear trials, participants were briefed about both there search objectives and procedures and asked to sign consent forms. Basic personal information, including age, gender, nationality, height, weight, years of working experience, and occupation, was collected. Upon the completion of each wear trial, participants filled out a questionnaire designed to evaluate 18 subjective perceptions towards the two types of cooling vests. The 18 items of paired subjective attributes were presented in a seven-point scale, in which two opposite adjectives represented a rating of one and seven, respectively. The–paired adjectives went from clammy to dry,[2] from sticky to not adhesive, from airtight to breathable, from damp to dry, from heavy to light, from hot to cool, from scratchy to not scratchy, from prickly to not prickly, from itchy to not itchy, from rough to smooth, from stiff to pliable, from movement restricted to movement allowed, from tight to loose, from uncomfortable to comfortable, from dislike to like, from impractical to practical, from job performance interference to no job performance interference, and from unsafe to safe (Chan, Yang, Wong, Lam, & Li, 2013). The Chinese-language version of the questionnaire was provided to local workers, and the English version to non-local workers. Three textile experts in the research team verified the translations of each language. A heat stress monitor (measured by QUESTemp°36^{TM}, Australia) was placed near to the subjects to measure the environmental parameters including wet bulb globe temperature (WBGT). The airport apron workers were required to wear a reflective vest outside the cooling vest. The study was approved by the Human Subjects Ethics Subcommittee of the authors' institution.

2.2. Statistical analysis

Internal consistency of the subjective measurements was examined by the reliability test (i.e., Cronbach's alpha). Analysis of variance (ANOVA) was performed to assess whether there were any differences in subjective perceptions between airport apron workers and the other outdoor workers. The sample size for cluster analysis and factor analysis was 205 sets of data based on the nine field studies in the three industries, while 67 sets of data from airport apron service industry were used for the regression analysis. The difference in subjective attributes between the two cooling vests perceived by airport apron workers was examined using the Wilcoxon signed-rank test.

Cluster analysis is a statistical technique that is used to sort data or variables into similar sets or groups (Ketchen & Shook, 1996), which has been widely used to investigate the relationships among human psychological perceptions on clothing (Li, 2001; Wong, Li, & Yeung, 2002). It was employed to group the 17 subjective attributes (all but "dislike–like"). Following data standardization via Z scores, Ward's approach (Ward, 1963) was employed as the hierarchical cluster method to search the proximity matrix and classify the two individual elements with the smallest distance value (Borgen & Barnett, 1987). The Squared Euclidean Distance (SED) was used to describe the closeness between subjective attributes (Wong et al., 2002). The results of the cluster analysis provide the overall pattern of relationships among the subjective attributes, while detailed information about the structure and relationships among them and the relative contribution of each cluster are still unknown (Wong et al., 2002). A further investigation, therefore, was undertaken through factor analysis.

Factor analysis was used to extract the underlying factors (Chan et al., 2004; Choi, Chan, & Chan, 2011) from 17 items of subjective attributes (all but "dislike-like") to identify the strongest predictors (Chan, 1996; Lam, Chan, & Chan, 2008) that influence the preference for cooling vests of workers. Results of Kaiser-Meyer-Olkin (KMO = 0.882) and Bartlett's test of sphericity ($p < 0.001$) indicated that the data were suitable for factor analysis. The direct oblimin rotation (delta = 0) method was used to extract the underlying factors under the assumption that they might be probably related to one another.[3]

Regression analysis was conducted to explain the relationship between the underlying variables and the dependent variable of the subjective attribute (dislike – like) in the airport apron service industry. Follow-up tests were conducted prior to the multiple linear regression analysis, which was aimed at evaluating the authentic factors that affect the preference of airport apron workers for cooling vests, to ensure that the data satisfied the conditions required by the method. Multicollinearity diagnostics were used to indicate whether the independent variables were multicollinear. All underlying factors and dependent variable were tested for case-

[1] The detailed protocol of field study was introduced in Chan et al. (2013). This paper forms part of the research project titled "The effectiveness of personal cooling equipment for protecting workers from heat stroke while working in a hot environment", from which other deliverables will be produced with different objectives/scopes but sharing common background and methodology. Thus only a part of data had been used in this paper.

[2] Clammy-Dry describes the wetness of clothes/cooling vests, while Damp-Dry means the skin wetness.

[3] This assumption is supported by the results of a working paper (Chan et al., The application of a structural equation model to evaluating the usability of a hybrid cooling vest: a pilot study), in which the usability of the cooling vest was found related to its perceived cooling effect (i.e., thermal related sensations).