# Title page

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# Evaluating the usability of a commercial cooling vest in the Hong Kong industries


## Abstract

**Purpose** –The provision of appropriate personal cooling vests is recognized as an effective measure to combat heat stress. However, personal cooling vests are not widely implemented in the Hong Kong industries. The current study aims to evaluate the usability of a hybrid cooling vest that is associated with the success of its application in industrial settings.

**Materials and methods** – A self-administrated questionnaire focusing on 10 subjective attributes of cooling effect, ergonomic design, and usability of a hybrid cooling vest was administered with 232 occupational workers in the construction, horticultural and cleaning, airport apron services and kitchen and catering industries.

**Results** – A structural equation model estimated by analysis of moment structures was constructed to evaluate the usability of the cooling vest, as influenced by cooling effect and ergonomic design. Results showed that cooling effect (path coefficient = 0.69, $p < 0.001$) and ergonomic design (path coefficient = 0.55, $p < 0.001$) significantly affect the usability of the cooling vest.

**Conclusions** – The structural equation model is feasible to examine the complex nature of the structural relationships among the subjective perceptions on personal cooling vests. The empirical findings furnish sound evidence for further optimization of the hybrid cooling vest in terms of cooling effect and ergonomic design for occupational workers.



**Key words**: Cooling effect, ergonomic design, occupational workers, structural equation model


## 1. Introduction

Construction workers, agricultural farmers, airport ground services workers and restaurant kitchen workers commonly encounter extremely hot environmental conditions [1,2]. Workers undertaking physical activities to prolonged exposure to thermal environment may sustain heat-related illnesses that further elicit moral and economic issues [3,4]. In this regard, government authorities and the industry promulgate and implement a series of fundamental practice notes, guidelines, and programs to assist practitioners in taking necessary precautions against heat stress. Three major types of precautionary measures have been documented, namely, environmental engineering, administrative, and personal engineering controls. Environmental engineering controls are often employed to minimize the environmental hazards. Administrative controls are assigned by the employer to reduce the magnitude, duration, or frequency of worker's exposure to risk factors [5]. However, the former controls (e.g., provision of fans) may be restricted by the working conditions [6], and the later one (e.g., adjustment in work and rest schedule) is often dependent on worker's compliance and consistent supervisory enforcement

[7]. Personal engineering control (e.g., personal protective equipment) is an alternative to protect individuals from potential hazards in such circumstance when environmental engineering and/or administrative controls are less feasible and effective in reducing these risks to acceptable levels [8].

Wearing appropriate personal cooling vests has been recognized as an effective measure to facilitate a cooling microenvironment around the body [6] and further to alleviate human heat strain [9,10]. In addition to the merits of these personal cooling vests, their drawbacks have been received increasing concern by researchers and practitioners. For instance, the cooling agents such as cooling packs or auxiliary cooling suppliers may induce additional burden [11], while inappropriate design of the cooling garment may probably restrict body movement [10,12]. These problems possibly limit a wider application of personal cooling vests to occupational settings.

For occupational workers, personal cooling vests serve as functional apparel that should be designed to protect the wearer's body from a stressful environment, but not to impede work performance. The design of such occupational clothing depends on common criteria such as protection, functionality, performance, comfort, style, and usability [13,14]. Usability serves as a high priority in clothing design [15,16], which is one of the most important factors that wearers consider in purchasing a product [17]. However, little attention has been paid to the evaluation of the usability of protective functional clothing [16,18,19]. Especially, there is a lack of comprehensive investigation with regard to the usability of personal cooling vest. To bridge this research gap, the current pilot study aimed to assess the usability of a specific cooling vest among occupational workers across four industries, namely, construction, horticultural and cleaning, airport apron services, and kitchen and catering. The evaluation of the usability of personal cooling vests will provide deeper implications for improving clothing design prior to a wider application to occupational workers.

## 2. Methods

### *2.1. Research model*

Usability evaluation has long been considered a key procedure in the design process of smart clothing [16] and technological products [20]. It is necessary to explore the relationship between usability and product design features throughout the product design process [21,22]. Further Han et al. [20] and Han and Yang [22] developed a usability model to illustrate that product usability can be determined by product design variables with equation (1). This model is further extended to consider a broad range of subjective perceptions on the products [23,24]. It enables designers and developers to understand how product design features affect its usability and to promote its design prior to wide applications [25,26].

$$\textbf{Usability} = \textbf{F(Product design variables)} \qquad \textbf{(1)}$$

Regarding the features of functional work apparel, task-oriented or professional designs are of overriding importance [27] to provide excellent functions without impeding workers' mobility and performance. Personal cooling vest can be regarded as a kind of work apparel that is designed for protecting the body from different environmental influences [27] and improving work efficiency and comfort [28]. The critical design requirement of personal cooling vest thus should be fulfilled by its ability to protect the body from extreme hot environment and to minimize ergonomic problems [29]. In view of this, cooling effect and ergonomic design are considered as key design variables for personal cooling vests in this study.

Cooling effect associated with attenuated thermal strain is the instinct feature of personal cooling vests. The cooling effect of various cooling vests has been comprehensively assessed by a number of studies which demonstrate that properly designed cooling vests can attenuate thermoregulatory, cardiovascular and psychological strain and further improve human performance in hot environment [6, 9, 10, 31]. The subjective perceptions on cooling effect are commonly expressed as emotional or affective experience of hot or cold and wet or dry [32]. Such thermal – wet sensation could influence workers' willingness to wear the cooling vest [11].

Ergonomic design of protective clothing allowing flexible movement and avoiding excessive weight is also essential for practical use [29]. Inappropriate ergonomic design of clothing may restrict the freedom of body movement and cause inconvenient heaviness and discomfort [33,34]. A cooling vest might create ergonomic problems because its stiff and bulky cooling system would add excessive load on the body [35]. It would further impose additional force requirements, such as the displacement, expansion, bending, and compression of the clothing as the wearer moves [36]. These ergonomic problems will increase musculoskeletal pain, early fatigue [37] and impair task performance [38].

One aspect of the usability of personal cooling vest can be expressed as the effectiveness [39] of achieving its functionality, such as protection from heat stress. Satisfaction with a specific context of use is another important aspect of usability, which expresses the users' comfort and positive attitudes toward the use of the system [40]. The subjective aspect of usability is emphasized because products that do not consider usability would not be accepted by users [26]. In view of the subjective aspect, the usability of cooling vests can be expressed as the level of comfort, ease of use [18], durability [19], acceptability [21], effectiveness, and satisfaction with the use of product functionality [39].

The research model in the current study (Figure 1) is based on the usability model developed by Han et al. [20] and Han and Yang [22]. It is used to examine how cooling effect and ergonomic design may affect the usability of a hybrid cooling vest. This model illustrates the causal relationships among three latent variables, namely, cooling effect, ergonomic design, and the usability of the cooling vest. In this causative relationship, two exogenous variables, namely, a) cooling effect ($\xi_1$), and b) ergonomic design ($\xi_2$), are assumed to influence one endogenous variable: usability ($\eta_1$). The model consists of four observed exogenous indicators ($X$ variables), namely, thermal sensation ($X_1$) and wetness sensation ($X_2$) for cooling effect, as well as weight ($X_3$) and movement ($X_4$) for ergonomic design. The six observed endogenous indicators ($Y$ variables) for usability are durability ($Y_1$), overall comfort ($Y_2$), convenience ($Y_3$), acceptability ($Y_4$), perceived effectiveness of protection from heat stroke[1] ($Y_5$), and satisfaction ($Y_6$).

### *2.2. Cooling vest*

In the summer of 2013, the Labor Department of the Hong Kong Special Administrative Region, in conjunction with the Occupational Safety and Health Council, launched a "Cooling Vest Promotion Pilot Scheme" across four industries, namely, construction, horticulture and cleaning, airport apron services, and kitchen and catering industries. A total of 1475 sets of cooling vests[2] had been given to the participating organizations in these four industries [41]. A commercial hybrid cooling vest that combines frozen gel pads with small internal electronic fans was selected for this scheme. Two detachable electronic fans (with a diameter of approximate 0.1 m) are embedded in the lower back of the vest. Three frozen gel packs, each with a covering area of 160 $cm^2$ and mass of 150 g, are stored inside three pockets on the belly and back of the vest. The function of the cooling vest is to enhance air ventilation by promoting convective heat loss and sweating evaporation via ventilation fans, as well as to absorb heat from the body when the frozen gel packs transform phases from solid to liquid state. The cooling vest provided an average cooling power of about 74 W for 2 hours based on the manikin test in an environmental chamber (with temperature of 35 °C, relative humidity of 65%, and air velocity of and 0.3 m/s) [42]. The total weight of cooling vest, including all auxiliary devices (i.e., batteries), is approximately 1.0 kg.

### *3.2. Sample profile*

The Labor Department and the Occupational Safety and Health Council assisted in liaison with the organizations participating in the Scheme. Occupational workers engaged from these organizations, who had gained a hands-on experience of the cooling vest, were randomly selected to participate in the questionnaire survey. A total of 232 workers from the construction, horticulture and cleaning, airport apron services, and kitchen and catering industries participated in the survey[3]. The sample comprised of 202 male workers and 30 female workers. The demographic information of the

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[1] *Perceived effectiveness of protection from heat stroke* refers to a subjective sensation of workers who consider that the use of hybrid cooling vest would be an effective measure to reduce the frequency of heat-related symptoms (e.g., dizziness, muscle cramps, vomiting, fainting, lightheadedness).

[2] The number of the cooling vest in small, middle, and large size was 298, 731, and 446, respectively.

[3] The sample size is determined by the equation $n = \frac{\frac{P[1-P]}{\frac{A^2}{Z^2}+\frac{P[1-P]}{N}}}{R^2}$, where n is the required sample size, $N$ = 1475 is the number of cooling vests distributed under the Scheme, $P$ = 0.5 is the estimated variance in population, $A$ = 7% is the precision desired, $Z$ = 1.96 for confidence level at 95%, $R$ = 0.90 is the estimated response rate. Thus, $n$ = 214. Similarly, the sample size in each industry was determined by the same method. In fact, more than 230 workers were recruited in the questionnaire survey.

participants is shown in Table 1.

### *2.3. Questionnaire survey*

Prior to the questionnaire survey, workers were given the cooling vests to try on during summer time (July to September) in 2013. The wear trials aimed to gather the experiences of occupational workers in wearing the cooling vest during their usual work activities. All the wear trials were conducted by the participants and their companies independently. The workers were encouraged to wear the cooling vest in hot weather (e.g., when *Very Hot Weather Warning* was issued by the Hong Kong Observatory). They were allowed to take off the cooling vest and to replace the cooling accessories (e.g., batteries, and frozen gel packs) at any time during wear trials. The process of wear trials was not the scope of this research. The questionnaire survey was administered across four industries between September and October 2013 after the workers have gone through the wear trial. The study was approved by the Human Subjects Ethics Sub-committee of the authors' host organization.

Sensory perceptions are powerful tools for judging individual descriptors on perceived sensations [32]. The questionnaire survey mainly focused on evaluating the subjective attributes of cooling effect, ergonomic design, and usability. Upon their completion of the basic demographic information sheet, the workers were asked to rate 10 items of subjective attributes described as opposite adjectives on a five-point Likert scale [28]. The attributes describing cooling effect included thermal sensation and wetness sensation, whereas those describing ergonomic design were weight and freedom of movement. The attributes for usability included six items, namely, durability, overall comfort, convenience, acceptability, perceived effectiveness of protection from heat stroke, and satisfaction. The meanings of scales 1 to 5 represented the following: from *hot* to *cold* (thermal sensation), from *wet* to *dry* (wetness sensation), from *very heavy* to *very light* (weight), from *highly restricted* to *highly flexible* (freedom of movement), from *very nondurable* to *very durable* (durability), from *very uncomfortable* to *very comfortable* (overall comfort), from *very inconvenient* to *very convenient* (convenience), from *totally unacceptable* to *totally acceptable* (acceptability), from *very ineffective* to *very effective* (perceived effectiveness of protection from heat stroke), *and* from *very unsatisfied* to *very satisfied* (satisfaction). A total of 221 valid questionnaires were obtained.

### *2.4. Data analysis*

A factorial multivariate analysis of covariance (MANCOVA) was performed to measure the relationship between two or more dependent variables (i.e., subjective perceptions) and two or more independent variables (i.e., occupations, gender) by removing the effects of uncontrolled variations (i.e., age, work experience). This exercise was conducted using SPSS version 19.

The key contribution of the structural equation model was the incorporation of the wearers' perception of cooling effect, ergonomic design, and usability of the cooling vest. Analysis of moment structures (AMOS version 22) was employed to estimate the measurement model and the structural model using a correlation matrix with maximum-likelihood [43]. To evaluate the measurement properties (reliability and validity) of the constructs, the measurement model was estimated through conducting confirmatory factor analysis [44]. The latent variables were measured for the observed indicators in the measurement model, and the causal relationships among these latent variables were tested in the structural model [43]. In the measurement model, the standardized factor loading of each observed variable should be greater than 0.5; otherwise, the observed variable would be excluded [45]. Reliability test of the latent variables was conducted by using SPSS version 19. Cronbach's $\alpha$ indicates low internal consistency reliability at values smaller than 0.6 [46]. Construct reliability (*CR*) and convergent validity (*AVE*) were established if *CR* was greater than 0.6 and if *AVE* was greater than 0.5 [47]. For discriminate validity, the variance extracted for each construct should be greater than its squared correlations with other constructs [47]. The structural equation model was used to specify the phenomenon in terms of exogenous and endogenous variables and various causal effects [48]. The overall fit of the model was evaluated based on $\chi^2$, goodness of fit index (GFI), adjusted goodness of fit index (AFGI) and root mean squared residual (RMR). Generally, a small $\chi^2$ indicated good fit. GFI and AGFI values that were close to 1 also indicate the good fit of the model. Generally, an RMR value that was lower than 0.05 means that the data fitted the model well when the model was analyzed with the correlation matrix [49]. Additionally, the mean score for each construct was first calculated by determining the arithmetic average of the respective items and then averaging the resultant mean score, whereas the standard deviation (*SD*) for each construct was calculated by the square root of the variance that was the average of the squared differences of their mean [50].

## 3. Results

### *3.1. Results of factorial MANCOVA*

Differences in subjective sensations among occupations and gender are shown in Table 2. The workers in the kitchen and catering industry were more pleasant in the sensations of overall comfort, convenience, acceptability, effectiveness of protection from heat stroke, and satisfaction than those in the airport apron services industry and/or horticulture and cleaning industry. Male workers were less pleasant in skin wetness sensation than female workers. In terms of the interaction effect between occupation and gender, male construction workers were more satisfied in overall comfort than male horticultural and cleaning workers. Female workers in the kitchen and catering industry were more pleasant in the sensations of overall comfort, convenience, acceptability, and effectiveness of protection from heat stroke than those in the airport apron services industry and/or horticulture and cleaning industry. In the horticulture and cleaning industry, male workers were less satisfied in skin wetness sensation than females. In the kitchen and catering industry, female workers were more pleasant in overall comfort, acceptability, and effectiveness of protection from heat stroke than males.

### *3.2. Measurement model*

The results showed that all standardized loadings on the relative constructs (except *convenience*, the loading of which was only 0.49) were greater than 0.5 ($p < 0.001$). Thus, *convenience* was detached and only the other nine items were included in the confirmatory factor analysis again. The overall fit of the model was significant ($\chi^2 = 66.79$, $df = 24$, $p < 0.001$). The resulting goodness-of-fit statistics revealed that comparative fit index (CFI) was 0.94, GFI was 0.94, AGFI was 0.88, RMR was 0.03, and root mean square error of approximation (RMSEA) was 0.09. Therefore, the measurement model is generally acceptable.

As shown in Table 3, all standardized factor loadings ($\lambda$) on the relative constructs were greater than 0.5 ($p < 0.001$). The value of $\alpha$ suggested that reliabilities of the latent variables ranged from 0.62 to 0.83, thereby confirming that the measurement model was acceptable and valid. *CR* for each construct was greater than 0.7, and *AVE* for convergent validity was greater than 0.5. Discriminant validity was also obtained because the variance extracted for each construct was greater than its squared correlations with the other constructs. The results related to the reliability and validity of the scale confirmed the overall measurement quality. Additionally, the mean and *SD* for each construct are shown in Table 3. The mean scores for the constructs *cooling effect* and *usability* only achieved moderate levels based on a 5-point Likert scale (3.07 ± 0.35 for *cooling effect*, and 3.02 ± 0.21 for *usability*), whereas for the construct *ergonomic design,* a lower score than satisfactory level was observed (2.79 ± 0.14).

### *3.3. Structural model and model modification*

A structural equation model was used to generate $\chi^2$ of 73.56 with 25 degrees of freedom ($p < 0.001$). Regarding the sensitivity of the model to a large sample size, model fit was judged using alternative fit indexes that were within the ranges for model acceptance GFI (0.93), AGFI (0.88), and CFI (0.93) [43,51]. The value of RMR was 0.045, which indicated a generally good fit. To optimize the structural model, the largest modification index for the error terms of effectiveness and satisfaction (namely, 24.00) suggested that the assumption of zero correlation between the terms can be rejected. As a result, $\chi^2$ decreased to 47.30 with 24 degrees of freedom ($p = 0.003$). The goodness-of-fit index improved, where GFI was 0.96, AGFI was 0.92, CFI was 0.97, RMR was 0.04, RMSEA was 0.06, and its PCLOSE was 0.156. The results revealed that 78% of the variance of usability was explained by cooling effect and ergonomic design. Accordingly, the final model illustrated in Figure 2 showed a good fit. Cooling effect had a positive causal effect on the usability of the cooling vest ($\gamma_1 = 0.69$, p < 0.001). Meanwhile, ergonomic design had a positive causal effect on the usability of the cooling vest ($\gamma_2 = 0.55$, $p < 0.001$). The rationally justifiable path between the error terms of *effectiveness* and *satisfaction* added to the model revealed a correlation coefficient of 0.37 ($p < 0.001$).

## 4. Discussion

Occupational workers' perceived usability of the hybrid cooling vest is predicted with higher explicative power from cooling effect than that from ergonomic design (path coefficient is 0.69 for *cooling effect – usability* and 0.55 for *ergonomic design – usability*, Figure 2). Thermal and wetness sensations perceived by occupational workers can be beneficial to ascertain the cooling effect of the personal cooling vest in real work settings [12]. The *hot – cool* sensation of the hybrid cooling vest was considered as *neutral* for occupational workers with a rating of 3.30, and the vest was *somewhat wet* with a rating of 2.80 on the *wet – dry* sensation. These results indicated that the cooling effect of the hybrid cooling vest might not be superior. It thus is interfered that the cooling effect of ventilation fan and/or frozen ice pack incorporated into the hybrid cooling vest remains uncertain.

Ergonomic design plays a significant role in determining the usability of the personal cooling vest. Ergonomic considerations have become increasingly important for user acceptance and practical application of clothing [11,52]. Havenith and Heus [35] highlight the importance of incorporating ergonomic testing into the overall evaluation of protective clothing. However, few studies have conducted a comprehensive ergonomic assessment on personal cooling vests. In the present study, the hybrid cooling vest was considered as *heavy* for occupational workers with a rating of 2.88 on the *heavy – light* sensation, whereas it was likely to restrict workers' movement with a rating of 2.69 on the *highly restricted – highly flexible* sensation. As a result, the ergonomic design of the hybrid cooling vest was not satisfactory. These results indicated that the hybrid cooling vest might create potential ergonomic problems such as imposing additional burden and impairing the movements of workers. The hybrid cooling vest with the weight of approximately 1 kg was heavy for those workers perhaps because of their relatively small body size (i.e., average height of 167.5 cm and weight of 67.3 kg). The motions of occupational workers usually include manual material handling, lifting, standing, squatting, and crouching [53]. These movements tended to be restricted by the friction between the body and the cumbersome cooling vest including but not limited to expansion, stretching (when lifting objects), bending and compressing (when squatting) [36]. Decreased mobility on the human body may further limit the usage of the cooling vest [54].

Potential improvement of the usability of the hybrid cooling vest can be made based on its thermal and ergonomic features. A comprehensive design of this hybrid cooling system should focus on the enhancement of its cooling effect. Enlarging the power of the electronic fans might be a means to enhance cooling power of the cooling system. Without increasing excessive weight of frozen gel packs, replacing the phase change materials with a higher melting temperature and a larger latent heat might contribute to extending cooling duration of the system. Smart clothing design for the hybrid cooling vest should be produced with consideration of workers' anthropometric dimensions and tasks.

It is recognized that the current pilot study only examines the usability of a specific cooling vest. Based on the structural equation model, the full study should be launched to generalize the comprehensive findings of factors affecting the usability of different types of personal cooling vests. Moreover, the evaluation model should be refined to account for logistic problems, such as the frequency of replacing the cooling accessories. For instance, some occupational workers perceived that the cooling effective time for the exhausted battery power and the melted ice packs of this hybrid cooling vest was approximately 75 min [55]. Consequently, frequent replacement of the cooling accessories may cause inconvenience and further impede work efficiency; this condition might restrict the functionality of the cooling vest for a prolonged duration, and thus affect the usability of cooling vests. In addition to subjective measurements on the usability and design features of personal cooling vests, objective measurements on these facets should be conducted for a comprehensive optimization of product design [20]. Regarding the design of the study protocol, the procedures of wear trials in terms of the measurements of environmental conditions, work routines, and wearing durations should be established. Last but not the least, the differences in subjective perceptions on personal cooling vests between males and females should be further explored in future studies.

## 5. Conclusions

Evaluating the usability of personal cooling vest can verify whether it fulfills its designed purpose and whether it is suitable for the users. The present study attempts to evaluate the usability of a cooling vest based on the measurements of cooling effect and ergonomic design perceived by occupational workers across four industries (i.e., construction, horticulture and cleaning, airport apron service, and kitchen and catering). The current finding provides a fresh insight to researchers and practitioners for understanding structural relationships between usability and design variables of the cooling vest. The hybrid cooling vest for occupational workers can be developed by improving its usability based upon the enhancement of its cooling effect and ergonomic design prior to its wide application in occupational settings. Properly designed cooling vest may encourage occupational workers to wear it in the hostile environment so that their heat strain can be alleviated and their work performance will not be impeded. The tailor-made ergonomic design should be developed based on the body size and the range of motion of the Hong Kong occupational workers. The current finding suggests that it is of importance to balance the need of improving the cooling effect and optimizing the ergonomic design.

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**Figure captions**

Figure 1 The research model

Figure 2 The structural equation model

Note: ***$p < 0.001$

**Table list**

Table 1 Demographic information of participants

Table 2 Results of a factorial multivariate analysis of covariance (Mean and *SD*)

Table 3 Measurement model results

Table 1 Demographic information of participants

| Characteristics \ Industry | Construction industry (*N* = 68) | Horticulture and cleaning industry (*N* = 56) | Airport apron services industry (*N* = 61) | Kitchen and catering industry (*N* = 47) | Total (*N* = 232) |
|---|---|---|---|---|---|
| Age (years) | 45.1 ± 10.6 | 46.5 ± 12.5 | 40.8 ± 11.1 | 44.4 ± 9.1 | 44.2 ±1 1.1 |
| Height (cm) | 167.6 ± 7.2 | 164.9 ± 7.2 | 169.2 ± 7.3 | 168.4 ± 6.1 | 167.5 ± 7.1 |
| Weight (kg) | 68.6 ± 9.9 | 65.1 ± 11.8 | 67.9 ± 11.8 | 67.4 ± 8.7 | 67.3 ± 10.7 |
| Work experience in relevant industry (years) | 11.9 ± 7.9 | 10.1 ± 9.7 | 11.1 ± 7.7 | 19.3 ± 11.7 | 12.8 ± 9.7 |

Table 2 Results of a factorial multivariate analysis of covariance (Mean and *SD*)

| Dependent variable | Main effect of occupation[a] | | | | Main effect of gender[a] | |
|---|---|---|---|---|---|---|
| | Construction industry | Horticulture and cleaning industry | Airport apron services industry | Kitchen and catering industry | Male | Female |
| Thermal sensation | 3.24 (0.37) | 3.27 (0.11) | 3.24 (0.14) | 3.69 (0.26) | 3.26 (0.06) | 3.46 (0.24) |
| Wetness sensation | 2.94 (0.31) | 2.85 (0.09) | 2.81 (0.12) | 3.23 (0.22) | 2.75 (0.05) | 3.17 (0.20)* |
| Weight | 3.05 (0.40) | 2.68 (0.12) | 2.91 (0.15) | 2.64 (0.29) | 2.86 (0.06) | 2.77 (0.26) |
| Freedom of movement | 2.99 (0.40) | 2.61 (0.12) | 2.48 (0.15) | 2.78 (0.29) | 2.67 (0.06) | 2.76 (0.26) |
| Durability | 2.77 (0.36) | 2.70 (0.11) | 2.36 (0.14) | 3.13 (0.26) | 2.61 (0.05) | 2.88 (0.23) |
| Overall comfort | 3.11 (0.38) | 2.78 (0.11) | 2.82 (0.14) † | 3.83 (0.27) † | 2.98 (0.06) | 3.29 (0.24) |
| Convenience | 3.24 (0.45) | 2.94 (0.13) † | 2.76 (0.17) † | 3.87 (0.32) † | 3.13 (0.07) | 3.27 (0.29) |
| Acceptability | 3.11 (0.41) | 2.82 (0.12) † | 3.02 (0.16) † | 3.83 (0.30) † | 3.05 (0.06) | 3.34 (0.27) |
| Effectiveness of protection from heat stroke | 3.08 (0.37) | 3.00 (0.11) † | 3.08 (0.14) † | 3.92 (0.27) † | 3.19 (0.06) | 3.36 (0.24) |
| Satisfaction | 2.59 (0.40) | 2.74 (0.12) † | 2.78 (0.15) † | 3.59 (0.29) † | 3.00 (0.06) | 2.85 (0.26) |
| | Interaction effect between occupation and gender[a,b] | | | | | |
| Skin wetness | | | | | Horticulture and cleaning industry | |
| | | | | | 2.62 (0.11) | 3.09 (0.15) |
| Overall comfort | Male | | | | Kitchen and catering industry | |
| | 3.13 (0.09) | 2.71 (0.13) | | | 3.14 (0.13) | 4.52 (0.53) |
| | Female | | | | | |
| | | 2.86 (0.18) | 2.69 (0.27) | 4.52 (0.53) | | |
| Convenience | Female | | | | | |
| | | | 2.57 (0.32) | 4.50 (0.63) | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Acceptability | Female | | | | Kitchen and catering industry | |
| | | 2.81 (0.20) | | 4.49 (0.58) | 3.18 (0.14) | 4.49 (0.58) |
| Effectiveness of protection from heat stroke | Female | | | | Kitchen and catering industry | |
| | | 2.83 (0.18) | | 4.48 (0.52) | 3.36 (0.12) | 4.48 (0.52) |

† Significant difference between kitchen and catering industry and other occupations (*p*<0.05).

* Significant difference between male and female (*p*<0.05).

Note: [a] Covariates appearing in the model are evaluated as: Age = 43.92 years, Work experience in relevant industry = 12.72 years.

[b] Interaction effect is shown when significant difference is detected.

Table 3 Measurement model results

| Construct | Item | $\alpha$ | $\lambda$ | $\delta$ | $p$ | $AVE$ | $CR$ | Construct correlation (Squared construct correlations) | | | $M$ ($SD$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Cooling effect | Ergonomic design | Usability | |
| Cooling effect | Thermal sensation | 0.641 | 0.69 | 0.28 | <0.001 | 0.66 | 0.79 | 1 | - | - | 3.07 (0.35) |
| | Wetness sensation | | 0.68 | 0.21 | <0.001 | | | | | | |
| Ergonomic design | Weight | 0.619 | 0.50 | 0.47 | <0.001 | 0.67 | 0.79 | 0.23(0.053) | 1 | - | 2.79 (0.14) |
| | Freedom of movement | | 0.94 | 0.08 | <0.001 | | | | | | |
| Usability | Durability | 0.831 | 0.50 | 0.24 | <0.001 | 0.61 | 0.88 | 0.77 (0.59) | 0.60 (0.36) | 1 | 3.02 (0.21) |
| | Overall comfort | | 0.77 | 0.38 | <0.001 | | | | | | |
| | Acceptability | | 0.83 | 0.21 | <0.001 | | | | | | |
| | Effectiveness of protection from heat stroke | | 0.60 | 0.36 | <0.001 | | | | | | |
| | Satisfaction | | 0.71 | 0.33 | <0.001 | | | | | | |

Note: $\alpha$=Cronbach's $\alpha$; $\lambda$=standardized factor loading; $AVE$ is average variance extracted, $AVE = (\sum\lambda^2)/(\sum\lambda^2 + \sum\delta)$; $CR$ is composite reliability, $CR = ((\sum\lambda)^2)/((\sum\lambda)^2 + \sum\delta)$, where $\delta$ is error variance.