

## Evaluation of Different PPE Ensembles in terms of Sensation, Usability, Satisfaction and Preference

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**Abstract:** The purpose of this study is to assess the subjective responses on uncomfortable sensation, usability, overall satisfactory level and preference while wearing five types of personal protective equipment (PPE) ensembles. Ten subjects exercised on a treadmill, worked on a computer, and moved a mannequin in a simulated environment, replicating a health care worker's routine. Results show that the subjective discomfort perceptions, usability, overall satisfactory level and preference are different for the different ensembles. The perceived thermal, wet and overall uncomfortable sensation on the entire body was significantly correlated with those under the mask. Overall uncomfortable sensations both under the mask and in the entire body significantly influenced the overall satisfactory level of ensembles. This paper discusses how the air-tightness, weight and construction may be responsible for the usability difference between PPE. The fitness of the mask is a significant factor affecting the overall uncomfortable sensation under the mask and overall satisfactory level of the PPE ensemble.

**Keywords:** Personal protective equipment, uncomfortable sensations, usability, satisfactory level, preference.

### 1. Introduction

In hospital and field settings, the use of personal protective equipment, ranging from surgical scrub suit, surgical cap, impervious gown or apron with full sleeve coverage, goggles or face shield, shoe covers, gloves and N-95 or N100 respirators, is mainly recommended to control infection and limit outbreaks of serious infectious diseases such as SARS and avian influenza (H5N1) [1,2]. PPE is the most effective strategy [3-7], therefore an array of PPE are widely available in the market. However, the selection of the PPE is generally based on the filtration efficiency of mask or barrier effectiveness of personal protective clothing (PPC), without due consideration of wearer acceptance.

In evaluating the effectiveness of PPE, wearer acceptance should be considered and the factors related to wearing masks, includes comfort, interferences with vision, communication and job performance, resistance to breathing, fatigue and confidence in the device's effectiveness, are recommended [8]. However, studies have investigated only several aspects of subjective strain such as respirator constraint [9], thermal sensation, skin moisture [10], visual impairment and the acceptable duration of wear [11]. Other studies have examined the subjective responses of wearing PPE

ensemble in chemical [12] and asbestos industries [13, 14] and in two short physically simulated demanding tasks [15]. These studies concluded that PPE may significantly influence clothing comfort, heat perception, breathing difficulty, skin moisture and overall favor even during work in a "nature" environment or in a real working situation. Two main reasons were the collocation and weight of the equipment. A recent study has examined the usability of different protective clothing commonly worn by health-care workers taking care of patients at Hong Kong hospitals [15]. The study found that putting on - taking off different clothing took different times, implying the usability differences between PPC. Furthermore, the study discussed that the weight, fabric thickness and construction of clothing might be responsible for the usability differences between PPC. However, the studies discussed only cover PPE ensemble used in the chemical and asbestos industries or protective clothing without masks used in areas of infection control alone. Few studies have covered PPE ensemble with clothing and facial protective equipment used in areas of infection control. Other factors affecting the uncomfortable sensations and overall satisfactory level of PPE ensemble such as the air-tightness of PPE and the fitness of the mask have not

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been investigated. Also, it is necessary to observe the relationship between specific subjective responses.

The purposes of this study were to evaluate the subjective responses on the uncomfortable sensations, usability, overall satisfactory level and overall preference while wearing five types of PPE, and to explore relationship between whole body and under the mask on thermal, wet and overall uncomfortable sensations, as well as the subjective factors affecting discomfort sensation, satisfactory level, and preference.

## 2. Methodology

### 2.1 Participants

The experimental protocol was approved by the Human Subjects Ethics Sub-Committee of the Hong Kong Polytechnic University prior to beginning the experiment. The participants gave informed consent to take part in this study.

The participants were 20-24-yr old healthy males (five) and females (five), and all were nursing students. They were recruited from the School of Nursing at The Hong Kong Polytechnic University. The physical characteristics (mean  $\pm$  SD) were 22.4  $\pm$  0.55 years of age, 171.8  $\pm$  3.42 cm height, 61.08  $\pm$  4.72 kg body mass, 1.68  $\pm$  0.08 m<sup>2</sup> body surface area in the male subjects, and 22  $\pm$  1.41 years of age, 157.4  $\pm$  6.22 cm height, 47.17  $\pm$  3.18 kg body mass, 1.41  $\pm$  0.06 m<sup>2</sup> body surface area in the female subjects.

### 2.2 PPE Tested

Figure 1 illustrates the five ensembles used in this experiment, designated PPE 1-5. Each is described below:

PPE 1: 100% polyethylene barrierman (DuPont Tyvek) (F1), a commercially available pure cotton surgical scrub suit worn inside barrierman (S1), an N95 respirator (3M 1860) (3M Canada Company) and a disposable face shield;

PPE 2: a waterproof breathable protective gown with a head cover (F2), a surgical scrub suit worn inside gown (S2), and a respirator with exhaust valves and ventilation pipes (respirator A). This was custom made for this study;

PPE 3: A protective apron without sleeves (the same material as gown of PPE 2) (F2), a half-sleeved surgical scrub suit (described by the designer as made of a material with antibacterial and antiviral functions) (S3), and a polypropylene mask with two exhaust holes (Mask B). This was custom made for this study.

PPE 4: A commercially available nowoven surgical gown (Winner Medical Group, F3), a S1 and a surgical mask (Winner Medical Group);

PPE 5: A conventional pure cotton surgical gown (from a public hospital in Hong Kong) (F4), a S1, a surgical mask (Winner Medical Group) and disposable goggles.

In addition to the above, on each occasion each volunteer wore a pair of disposable gloves, a cap (except for PPE 2) and a pair of spun-bonded polypropylene shoe covers. Total weights (g) (mean  $\pm$  SD) of the ensembles were 538.4  $\pm$  21.8, 1019.2  $\pm$  23.9, 520.0  $\pm$  16.8, 424.2  $\pm$  18.4 and 857.4  $\pm$  33.3 for PPE 1 to PPE 5 respectively.

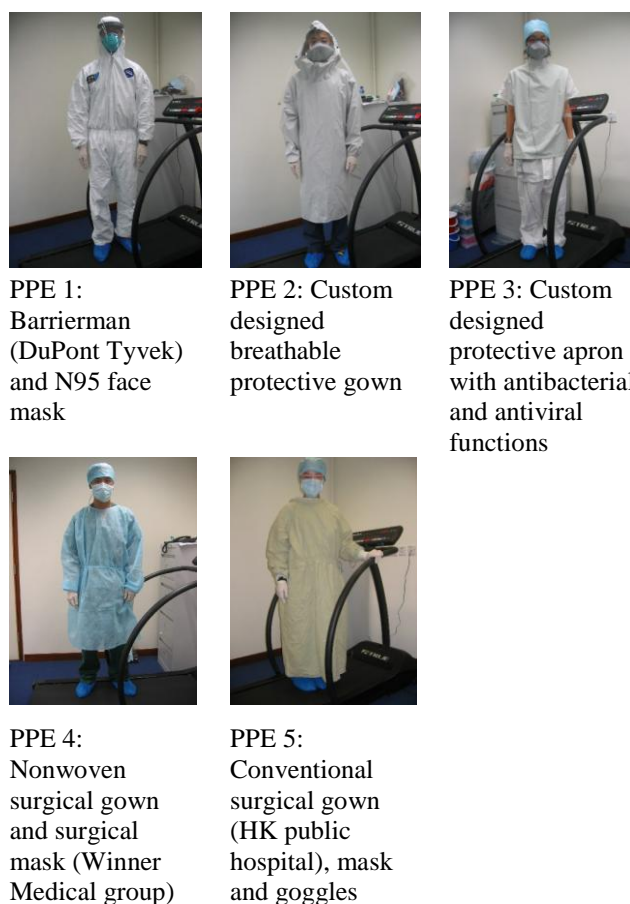


Figure 1 Five different types of personal protective equipment ensembles used in this experiment.

These five types of protective clothing were selected for the test because these include conventional types being used in health care settings in Hong Kong (PPE 1, 4 and 5) and newly devised types (PPE 2 and 3). The physical properties of the fabrics are listed in Table 1.