Topic A7: Thermal comfort

CHANGE IN THERMAL SENSATION AND THERMAL COMFORT AS A RESULT OF USING N95 FILTERING FACEPIECE RESPIRATORS UNDER INFLUENCE OF TEMPERATURE

Chen-Peng CHEN*, Shun-Hua HO, Hui-Chen WEI, and Yi-Chun LIN

Department of Occupational Safety and Health, China Medical University, No. 91 Hsueh-Shih Road, Taichung 40402, Taiwan

*Corresponding email: chencp@mail.cmu.edu.tw

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INTRODUCTION

N95 filtering facepiece respirators (N95 masks) are commonly used to protect workers from inhalation of airborne particulates in different environmental settings. However, their use in areas of sub-tropical weather, where elevated temperature (temp) and humidity are frequently encountered in summer, is often accompanied by sensation of sultriness, discouraging the users to wear them correctly or to consider them as a viable option in respiratory protection. This study investigated the change in subjective thermal perception when wearing N95 masks of two distinct facepiece designs in different temperatures. The gender as a factor was also evaluated.

METHODOLOGIES

Twenty participants (10 males and 10 females) were evaluated for their subjective thermal perception when using N95 masks in a climatic chamber pre-set at a temp of 19, 22, 25, 28, 31, or 34^{o}C and a relative humidity of 65%. In each session, the participants first sat in the chamber for 30 min for acclimation to the thermal environment, and then each put on either a cup-shaped (cup mask) or a three-flap foldable N95 mask (foldable mask). The participants then resumed the sedentary position for another 30 min to re-acclimatize. The vote of thermal sensation (TSV), thermal comfort (TCV), and thermal acceptability (TAV) were taken at an interval of 5 min from the beginning till the end of acclimation. These perceptions were evaluated to describe (Hwang et al., 2009):

- Thermal sensation toward the environment, gauged using the 7-point ASHRAE scale of TSV, in which a vote of +3, +2, +1, 0, -1, -2, and -3 represented a sensation of hot, warm, slightly warm, neutral, slightly cool, cool, and cold sensation, respectively;
- Thermal comfort of the participants, measured on a 6-point scale of TCV, in which a vote of +3, +2, +1, -1, -2, and -3 indicated a very comfortable, comfortable, slightly comfortable, slightly uncomfortable, uncomfortable, and very uncomfortable level, respectively;
- Thermal acceptance of the indoor condition, measured using a dichotomous scale of TAV, with the vote of +1 and -1 reflecting acceptable and unacceptable perception respectively.

The data were analyzed for the temp of thermal neutrality and through predicted mean vote−percentage of predicted dissatisfied (PMV−PPD) modeling for the range of temp to define the 90% thermal acceptability and comfort zone. The TSV, TCV, and TAV were also analyzed in pair by the Spearman's correlation to illustrate the interaction between different types of thermal perception under the influence of respirator use.

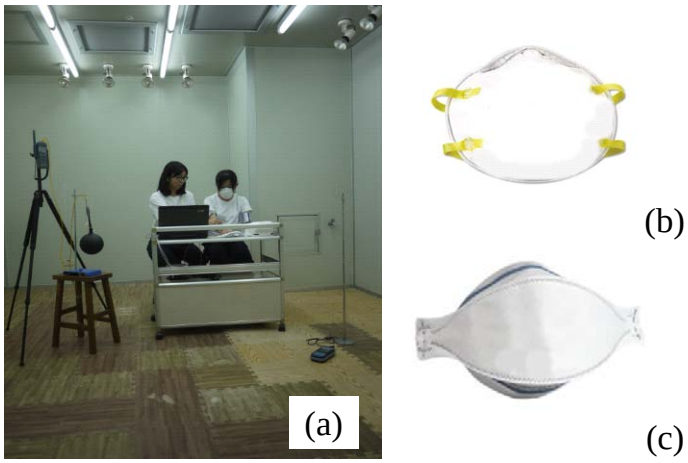

Figure 1. Climatic chamber and N95 masks used in evaluating impact of respirator use on thermal perception: (a) climatic chamber and equipments used in environmental monitoring; (b) cup-shaped N95 mask; (c) three-flap foldable N95 mask.

RESULTS AND DISCUSSION

The use of N95 masks added to the warm sensation of the study participants toward the thermal condition in the climatic chamber. The thermal sensation of the participants was significantly altered by the use of masks when the temp exceeded 28^{o}C, and the alteration increased with increasing temp, particularly among the males. The range of temp in the chamber by which the participants perceived the environment as thermally comfortable reduced when having the mask on, with the 90% thermal comfort zone narrowing down from 21.5-29.0 to 21.5-27.1^{o}C for the males and from 21.0-31.5 to 21.3-30.0^{o}C for the females (Figure 2). The thermal comfort of the females was less influenced with the use of N95 masks. In addition, the 90% thermal acceptability zone among the females when wearing the masks (21.6-31.2^{o}C) was 1.4^{o}C greater than its counterpart reported for the males (20.9-29.1^{o}C). These results suggested a preference of warmer sensation among the females and thus a greater thermal acceptability for using the masks.

The temp of thermal neutrality for the foldable mask (26.1^{o}C) was slightly higher than the level determined for the cup mask (25.7^{o}C), indicating a better adaptation of the users to the foldable mask, possibly owing to its characteristic facial flexibility. When the sensation gauged was confined to the space within the nose cup of the mask, the acceptability zone dropped approximately 1.9-4.0^{o}C from those defined for the overall thermal environment. As the results of correlation analysis shows, both the TAV and TCV were correlated to the TSV more significantly when the thermal stimulus was inside the respirator (r = −0.48 and −0.65, respectively) than when the stimulus was from the overall thermal environment (r = −0.27 and −0.40)(Table 1). These findings demonstrated that the use of respirators was a significant source of thermal dissatisfaction when the respirators were used in a warm environment. Furthermore, thermal adaptation was difficult to achieve when using a mask and thus discomfort increased continuously as the duration of use extended.

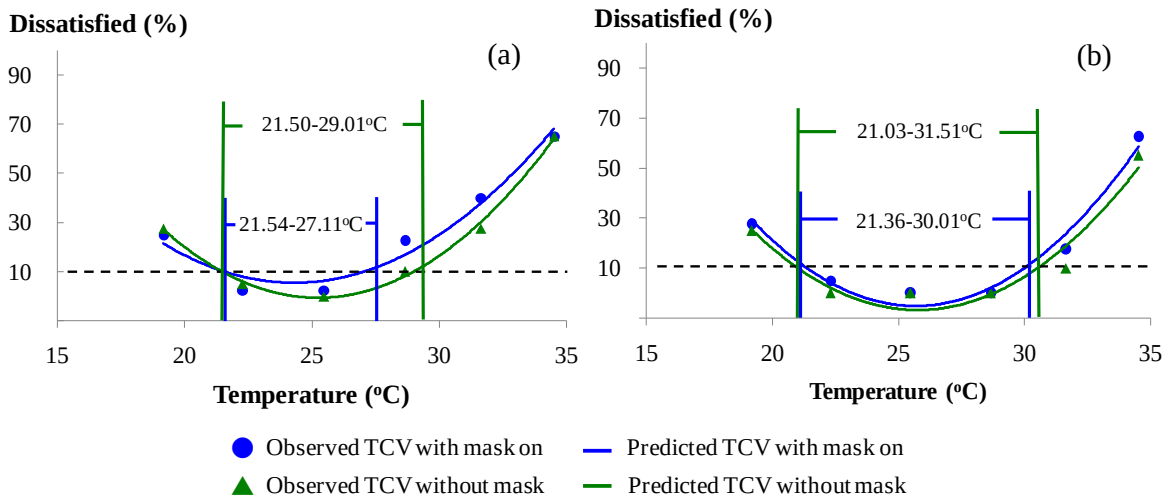

Figure 2. Distribution of thermal comfort vote (TCV) observed among (a) males and (b) females and range of temperature for 90% thermal comfort zone as predicted from percentage of dissatisfaction.

Table 1. Paired correlation between different thermal perceptions manifested in thermal sensation vote (TSV), thermal comfort vote (TCV), and thermal acceptability vote (TAV) toward overall thermal environment versus toward space confined within nose cup of N95 mask as analyzed by Spearman's correlation.

	Overall thermal environment		N95 mask-confined space	
	Correlation coefficient (r)	Significance level (p)	Correlation coefficient (r)	Significance level (p)
TSV vs. TCV	−0.399	< 0.001	−0.653	< 0.001
TSV vs. TAV	−0.271	< 0.001	−0.483	< 0.001
TCV vs. TAV	0.697	< 0.001	0.653	< 0.001

CONCLUSIONS

The use of respirator in hot environment might significantly alter the user's perception toward the thermal environment, thus caution should be exercised to prevent thermal stress. To alleviate the thermal discomfort from using a respirator, the users should consider a mask of greater flexibility and reduce the duration of each single use.

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