Thermal comfort evaluation of medical gowns using sweating thermal manikin

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Introduction Gowns are the second most utilized piece of personal protective equipment (PPE) after gloves in a healthcare setting, yet markedly less research has been conducted on them (Kilinc, 2015; Stewart et al., 2020). Heat stress in medical gowns has been a critical issue (Bogdan et al., 2011; Zwolinska & Bogdan, 2012; Yánez Benítez et al., 2020). Studies on the assessment of thermal comfort/heat stress in medical gowns have obtained confronting results (Xu et al., 2014; Aslan et al., 2013; Pamuk et al., 2008). It could be caused by the limitations of existing studies: 1) Rare study has considered both thermal and evaporative resistance (Rct, Ret) of medical gowns; 2) The standardized measurement of Rct and Ret uses a static manikin (ASTM F1291, 2016; ASTM F2370, 2016), which does not consider the effect of body movement in real wear situation; 3) Only values of the whole clothing are reported, which may neglect the difference at local body parts. Therefore, the purpose of this study was to evaluate the thermal comfort of typical medical gowns using a thermal manikin under both static and dynamic conditions and at both whole-clothing and local-body levels. This study provides enhanced understanding of the thermal comfort of medical gowns and guidance on the material selection, design improvement, and test requirements of medical gowns.

Method and Analysis Four typical nonwoven medical gowns of different protection levels were studied: Sirus 4—protection level 4 as per Association for the Advancement of Medical Instrumentation (AAMI) standard; Aurora 4—protection level 4; Sirus 3—protection level 3; and Isolation Gown—protection level 2. They have similar apron like design with long sleeves, and same XL size except the medium-sized Isolation Gown due to sourcing availability. Their thermal insulation and evaporative resistance were measured per standard ASTM F1291 and F2370 with the manikin standing still as well as walking at a speed of 30 double steps per minute to simulate real wear situation. Both whole clothing and local body values were reported for surface air layer and each gown (Rct, Rct, l, Ret, Ret, l). The effect of body movement was analyzed using paired sample *t*-test with a significance level of 0.05.

Results and Discussion As shown in Figure 1, the Rct of medical gowns ranged from 0.13 to 0.20 $℃·m^2/W$ and from 0.11 to 0.15 $℃·m^2/W$ under static and dynamic conditions respectively. Ret ranged from 19.28 to 48.21 $Pa·m^2/W$ and from 15.36 to 21.73 $Pa·m^2/W$ under static and dynamic conditions respectively. Because of the similar design and material, gowns with higher Rct values also had higher Ret values. Gowns with higher protection level have higher Rct and Ret due to their reinforced materials with increased thickness and pore density. Statistic analysis showed a significant effect ($p<.05$) of body movement on Rct and Ret. The reduction of Rct was lower compared to that of Ret, and had a smaller range of 17.5%-28.7%, while Ret reduced more with a larger range of 20.3%-54.9%.

Local Rct and Ret showed huge variance across different body sections because of the surface geometry of human body and how the gown draped on it. Both Rct,l and Ret,l had similar distribution to the Rct,l of Aurora 4 as shown in Figure 1. Lower Rct,l, as low as 0.09 ℃·m^2/W, was found at the arms and legs, and higher Rct,l, as high as 0.78 ℃·m^2/W, was found at places like underarm where heat loss was blocked by the torso, and places like back and upper thigh where the gown was overlapped, and because it was tightened at the waist, the ventilation at these areas was lowered under dynamic condition. Statistic analysis showed a significant effect (p<.05) of body movement on both Rct,l and Ret,l. That could be explained by the highly increased ventilation through the openings at the bottom of gowns on a walking manikin.

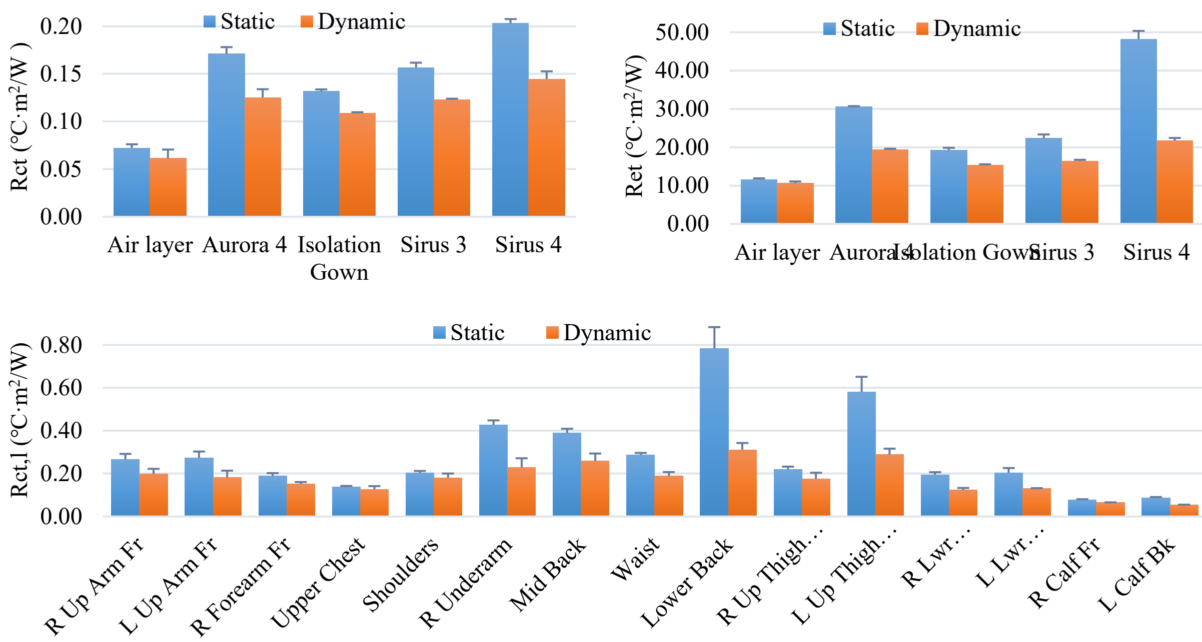

Figure 1. Static and dynamic Rct (upper left), Ret (upper right), and Rct,l for Aurora 4 (below)

Conclusions Typical disposable medical gowns with higher protection levels have higher thermal and evaporative resistance under both static and dynamic conditions because of their reinforced materials. There is a large variance of local thermal and evaporative resistance across different body sections, which indicates the report of a whole-clothing value won't provide enough information. Body movement can cause significant reduction of both thermal and evaporative resistance, with higher impact on evaporative resistance. Therefore, the measurement of them under dynamic conditions should be included and required in their testing standards. To improve the thermal comfort of medical gowns, the effects of body geometry (local differences), movement, and their potential interaction should always be considered.

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