It's Getting Hot in Here: Assessing Thermal Responses of Different Clothing Ensembles for Wheelchair Users Using Thermal Camera

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Introduction

In the United States, more than 3 million people are full-time wheelchair users (csr 1688, 2021). Sitting in a wheelchair for long periods of time can create heat that builds up over time, especially where the back meets the chair. This can be assessed and remedied through a thermal comfort study which can lead to design changes or problem solving, helping an individual to feel more comfortable and in turn more confident in their environment. Sales, Pereira, Aguilar, and Cardoso (2017) used infrared thermography to evaluate the thermal response of different wheelchairs. The uses of infrared thermography are employed in everyday life along with the various activities such as sports as seen in other past studies (O, 2015; Lee and Jin, 2019).
The purpose of this study was to investigate the heat generated by an individual in a wheelchair wearing different clothing ensembles using an infrared camera (thermal camera). This allows for a better understanding both statistically and visually of radial heat transfer when sitting in a wheelchair. The results of this study add to a relatively small data base that could potentially improve the design and function of wheelchairs or adaptive clothing for wheelchair users.

Method

This exploratory, preliminary study used a FLIR thermal camera to collect data and capture thermal images of an individual wearing four different shirt ensembles after sitting in wheelchair. The four ensembles included 1)100% cotton long sleeve t-shirt was used as a base layer; 2) a base layer t-shirt with a 100% cotton flannel shirt; 3) a base layer t-shirt with a 100% polyester fleece; and 4) a base layer t-shirt with a 100% nylon winter coat that contained a 100% polyester fill.

Data was collected by having the subject don the base layer t-shirt before a thermal image was taken with both their back and the wheelchair back in view. After the initial image, the subject fully seated in the wheelchair for five minutes in a stationary and relaxed position. Once the five minutes were completed, another thermal image was taken in the same position as the before photo. Breaks were taken before and after each trial, leaving time for temperatures to stabilize. The same procedure was followed for a total of three additional ensembles.

The data collection continued after the thermal images were captured. Regions of interest (ROIs) were placed around the back of the test subject along with the back of the wheelchair.

ROIs allowed for the FLIR software to calculate a variety of numbers for analysis, mainly the mean temperature. Once the ROIs were placed (Figure 1 and 2), the image and data were exported, and the data was combined into one file.

Results and Discussion

Paired *t*-tests and ANOVA with post hoc Tukey tests were used to analyze the data between the different conditions. A paired *t*-test was used to compare the before and after temperature differences that were gathered from the back of the ensemble and from the back of the wheelchair. Results showed significant differences in temperature for all measurements except the back of the base layer ensemble, post- (M = 30.96, SD = .13) and pre- (M = 30.68, SD = .351), $t(2) = 1.492$, p = .274.

There was a statistically significant difference between ensemble means for the chair temperature differences as determined by one-way ANOVA, ($F(3,8) = 4.281$, $p = .044$). A Tukey post hoc test revealed that there is a statistically significant difference in temperature between flannel (5.34 ± .81 degrees, $p = .046$) when compared to fleece (3.20 ± .27 degrees). There was also a statistically significant difference between the back ensembles temperature differences as determined by one-way ANOVA, ($F(3,8) = 45.869$, $p < .001$). A Tukey post hoc test revealed that there is a statistically significant difference in pre-post-temperature differences between the base ensemble (.28 ± ..33 degrees) and flannel (2.69 ± .61 degrees, p<.001), fleece (3.85 ± .40 degrees, p<.001), and winter (3.62 ± .24 degrees, p<.001). There is a statistically significant difference between the flannel (2.69 ± .61 degrees, $p = .038$) and fleece (3.85 ± .40 degrees) ensembles, but not winter. In addition, there is not a statistically significant difference between fleece and winter ensemble temperature differences.

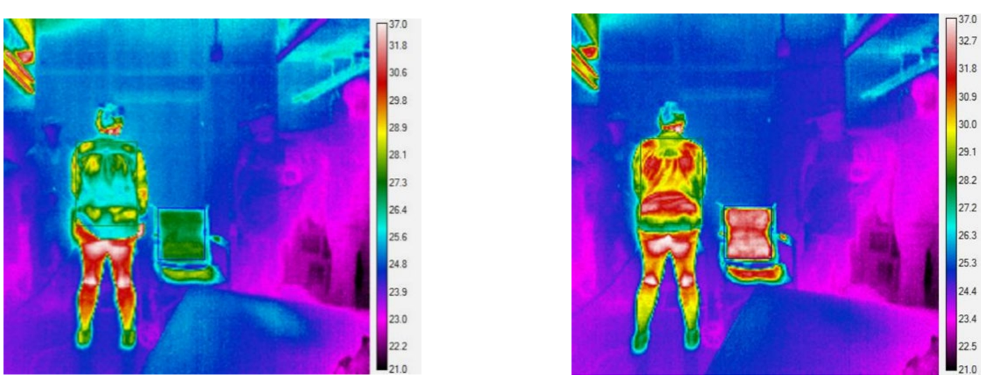

Figure 1 and 2. Thermal Images with ROIs and Temperature Scale of before and after wheelchair use (respectively), captured using the thermal camera

Conclusions and Limitations

Each clothing ensemble with different material types and number of clothing layers created significantly different heat generation on wearer's back and heat transfer on the back of the chair. This study provides an example of how the thermal camera can be used to investigate thermal responses of human subjects and clothing in different settings. This study also provides evidence that there is a need for research in this field to help provide a better understanding of heat transfer and heat generation in wheelchair users. More research utilizing thermal cameras to map heat patterns and accumulation during wheelchair use could influence selection of fabrics and support designers in creating clothing to better accommodate the wearer's thermal needs. The creation of more functional improvements to garments such as this can lead to better adaptive clothing options in other spaces, as well as wheelchair products.

Limitations include number of subjects, short period testing time, and number of clothing ensembles. Future research should be conducted to address those limitations as well as adding other activities or movements to simulate a more accurate daily life scenario. Along with this, there is ability to investigate different types of garments besides shirts and jackets.

References

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