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Editorial Open Access

Physiological Model Controlled Sweating Thermal Manikin: Can it replace human subjects?

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Sweating thermal manikins are extensively used to assess clothing before performing human trials. Because thermal manikins cannot simulate human physiological responses and psychological perceptions, a recent hot research on incorporating various physiological models with thermal manikins has been highlighted. Can such physiological model regulated sweating manikins replace human subjects?

A thermal manikin is an instrument which simulates an average human being in terms of body dimensions. The first thermal manikin was introduced in 1940s by the US Army [1]. It was a one-segment copper manikin. Afterwards, more advanced ones such as multi-segment, sweating and moveable male and female manikins have been developed as new technologiesadvance [2-5]. The idea of incorporating a human physiological model with a sweating manikin was first proposed in 2005 [6]. The National Renewable Energy Laboratory (Golden, CO) designed such a physiological model controlled manikin ADAM and used it to evaluate liquid cooling garments. The controlling system is comprised of three units: the sweating manikin, the physiological control model and the empirical thermal comfort model. In this study, the comparison of data from model controlled manikin and physiological data from subject tests was not accomplished due to various reasons such as different test conditions were used. Nevertheless, the comfort and thermal sensations obtained from the model controlled manikin showed expected trends.

Richards et al. [7] introduced the development of coupling a human physiological model (i.e., the Fiala model [14]) with a heated sweating cylinder. A good agreement has been seen between the model controlled cylinder data and human subject data. However, the human subjects had a cooler skin temperature than the Fiala physiological model controlled sweating cylinder. Later, Psikuta et al. [8-9] further developed a single-sector and a multi-sector thermophysiological human simulator, respectively. Such simulators were validated by comparing data from human subject experiments performed under different air temperatures (15-37.5 °C). They found that the single-sector human simulator was able to simulate such human thermophysiological responses as core body temperature and mean skin temperature at steady-state conditions. However, for the multi-sector human simulator, there were big discrepancies between simulated mean skin temperature, core temperature and data from the human subjects. Redortier and Voelcker [10] addressed the challenges of incorporating a multi-segment thermophysiological model (i.e., Xu's 6-segment model [15]) to control the Newton sweating thermal manikin. The whole model-manikin system presented reasonable results. Later they validated this model regulated sweating manikin for sports exercises. The initial results showed significant discrepancy between the manikin and human subjects. Burke and Blood et al. [12-13] validated the performance of a physiological model controlled Newton thermal manikin by comparing the data from simulation studies and historical human subject data. The model controlled manikin showed higher core temperatures (sometimes the differences were larger than 1.0 °C) than values on human subjects. The local mean skin temperature simulations were good, but big variations were found on mean local skin temperatures at the face and the upper arm. In addition, the physiological model controlled manikin presented better mean skin temperature results at an air temperature of 30 °C than those conducted at other air temperatures such as 20 and 10 °C.

It has been well established that the aforementioned physiological controlled sweating manikins act similar to a real human. Such model regulated manikins showed reasonable results on both physiological responses and psychological perceptions. Also, they are useful in presenting the dynamic interactions among environment, clothing and the human body. However, large discrepancies between manikin and human subject data were registered among all of them. Improvements should be made in terms of manikin construction updates and model validation needs. Future physiological model controlled manikin may represent a certain group of human beings. However, considering the well-recognized differences of physiological and psychological responses between individuals, we still believe that such thermoregulatory model controlled sweating manikins can never completely replace human subjects.

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