Match maker: how to compare thermoregulatory responses in groups of different body mass and surface area

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There is a long and rich history of research comparing thermoregulatory responses between groups of different sex, age, and health. Direct measurements of body temperature, whole body, and local sudomotor activity are the basic tools used by thermal and exercise physiologists to understand and interpret group differences in central and peripheral thermoregulation. A qualitative appreciation for how differences in physical characteristics and fitness between groups can impact thermoregulation drove the historical adoption of imperfect matching solutions meant to isolate factors of interest. A popular example, such as matching relative exercise intensity to control for fitness, does not seem necessary for making unbiased comparisons (6). The >30 yr time span of excellent reviews on the topic of sex differences in thermoregulation (5, 7) represents well the enduring problem: how should thermoregulatory responses be compared between any two groups with inherent or chance differences in physical characteristics that influence thermoregulation?

In this issue of the *Journal of Applied Physiology*, Cramer and Jay (1) provide for the first time a clear quantitative explanation for the important independent influences of body mass and body surface area on thermoregulatory outcome measures of change in body core temperature (ΔT\textsubscript{re}) and local sweating rate (LSR) during exercise in two compensable environments (25–35°C, 35% relative humidity). They also provide the necessary methodology for selecting an exercise intensity that remedies the historically confounding effects of body morphology. Briefly, the greater heat sink of individuals with larger body mass in their study (~92 kg, LG) resulted in a smaller ΔT\textsubscript{re} at any absolute rate of metabolic heat production (H\textsubscript{prod}, W) compared with smaller individuals (~68 kg, SM). Despite this fact, whole body sweating rates (WBSR) were the same because the absolute evaporative sweating requirement (E\textsubscript{req}, W) was identical for both groups, as previously described (4). As a consequence of having a smaller body surface area in SM (1.8 m\textsuperscript{2}) compared with LG (2.1 m\textsuperscript{2}), LSR was significantly higher in SM (LSR expressed as a rate in surface area units by convention). On the surface, outcomes make it appear that LG is less susceptible to heat stress than SM (lower ΔT\textsubscript{re}), but whether LG sweats at the same rate (WBSR) or less (LSR) than SM depends on which sweating measure is chosen for comparison. It is equally puzzling to decide how best to fairly compare the LSR threshold (T\textsubscript{re} onset) and sensitivity (LSR slope) between LG and SM in this scenario. The remedy that Cramer and Jay (1) provide for the inconsistent measurement outcomes is to prescribe exercise intensity as either watts per kilogram to control for the effects of body mass on ΔT\textsubscript{re} (heat sink) or as E\textsubscript{req} (W/m\textsuperscript{2}) to control for the effects of surface area on LSR. When LG and SM were compared by matching for watts per kilogram and watts per square meter, differences in ΔT\textsubscript{re} and LSR disappeared. Figure 1 summarizes how to select exercise intensity to control for ΔT\textsubscript{re} (H\textsubscript{prod}; W/kg), WBSR (E\textsubscript{req}; W), or LSR (E\textsubscript{req}; W/m\textsuperscript{2}) when a factor distinct from body mass and surface area is suspected to independently influence central or peripheral thermoregulation.

One obvious application of this research is that it will allow an improved isolation of the factors known or suspected to genuinely influence thermoregulation, thus ultimately enhancing the science and understanding of group differences in human thermoregulation. Good examples include comparisons between groups of different body size, such as men vs. women and especially children vs. adults. A less obvious application is that their methods might also be used to help fairly isolate and understand factors responsible for heat illness susceptibility. For example, absolute workload tests (H\textsubscript{prod}, W) for assessing heat intolerance (i.e., ΔT\textsubscript{re} response) (2) might further be improved by use of a more standardized test (H\textsubscript{prod}, W/kg) that removes the influence of body mass from the observation.

A minor limitation of this study is that not everyone interested in comparing thermoregulation between groups will be well versed or practiced in the use of the biophysics equations necessary for applying some of the methods. For example, although absolute H\textsubscript{prod} expressed in watts or watts per kilogram is a fairly straightforward set of calculations, the string of necessary biophysical calculations needed to use the required evaporative heat loss, or E\textsubscript{req}, can be daunting for anyone unaccustomed to their use and meaning. However, an excellent review on this subject (3) will educate readers and provides all the formulas necessary for easy input and automated output using an Excel module or similar software package. In addition, although it is likely that the approach described (Fig. 1) will improve comparisons between groups made during uncompensable heat stress also, it remains possible that smaller vapor pressure gradients between skin and air will suppress sweating and alter the anticipated group differences that otherwise require correction during compensable heat stress (1, 3, 5).

**Fig. 1.** Correct exercise intensity selection for unbiased comparisons of thermoregulatory responses in groups of different body mass and surface area. ΔT\textsubscript{re}, change in body core temperature; H\textsubscript{prod}, metabolic heat production; WBSR, whole body sweating rates; E\textsubscript{req}, evaporative sweating requirement; LSR, local sweating rate.

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In summary, thermoregulatory responses between any two groups with inherent or chance differences in body mass and surface area can be fairly compared in accordance with the matching methods described by Cramer and Jay (1) (Fig. 1). Widespread application of these techniques is recommended when attempting to isolate and describe the unique role(s) that sex, age, health, and other factors play in affecting thermoregulation.

ACKNOWLEDGMENTS

The opinions or assertions contained herein are the private views of the authors and should not be construed as official or reflecting the views of the Army the Department of Defense.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

Author contributions: S.N.C. drafted manuscript; S.N.C. edited and revised manuscript; S.N.C. approved final version of manuscript.

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