FRONT MATTER: DISCOVERY

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A new approach for comparing thermoregulatory responses of subjects with different body sizes

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The time-dependent assessment of human thermoregulatory responses during exercise, such as changes in core temperature and sweating, are commonplace in research laboratories worldwide. Moreover, researchers wishing to identify potential impairments in these responses due to factors such as obesity, age, disease and injury, must typically adopt a between-group experimental design.

In such studies, the exercise intensity administered must be carefully selected to ensure that any differences in the change in core temperature and/or sweating during exercise are caused by the factor under investigation and not by an underlying bias within their experimental design. Traditionally, aerobic fitness (VO_{2max}) has been considered a potent modulator of thermoregulatory responses to the extent that metabolic heat production should be normalized to elicit a fixed relative exercise intensity ($\%VO_{2max}$) when comparing core temperature and sweating responses between different individuals or groups. Quite recently, however, several studies have shown that for physiologically compensable combinations of activity and climate, exercise at a fixed $\%VO_{2max}$ leads to systematically greater sweat rates in aerobically-fit individuals secondary to the greater rate of evaporation needed to balance the higher rate of metabolic heat production associated with their greater absolute rate of oxygen consumption.[1-3] Furthermore, mass and body surface area-matched participants with dissimilar levels of VO_{2max} exercising at the same rate of heat production have demonstrated the same changes in core temperature and whole-body and local sweat rates despite a very different $\%VO_{2max}$.[3,4] These observations led to the conclusion that in order to perform an unbiased comparison of thermoregulatory responses between independent groups, body mass and body surface area must be matched and the same absolute rate of heat production (in W) must be administered. It follows that any differences in core temperature or sweating subsequently observed could be attributed to an independent influence of the physiological factor under examination. An excellent example is the assessment of the independent influence of sex on changes in core temperature and sweating reported by Gagnon and Kenny.[5]

However, matching independent groups for physical characteristics is oftentimes arduous, and occasionally impossible, such as when comparing thermoregulatory responses of children and adults. This *Discovery* article highlights a recent study[6] that proposes a new experimental method that solves this dilemma. As the cooking time of a turkey must be altered according its mass, we firstly hypothesized that exercise intensity should be chosen to ensure the same rate of internal heat production is generated per unit body mass (i.e. in W/kg) between all individuals. Using two groups of individuals matched for age, sex and acclimation status, and with identical operational parameters for sweating control (i.e., same esophageal temperature onset threshold and thermosensitivity for sweating), but vastly different in terms of total body mass (~65 kg vs. ~90 kg), we showed that at fixed absolute rates of heat production of 500 W and 600 W, changes in core temperature were systematically altered by body size (smaller changes in larger individuals). On the other hand, when exercise intensity was administered to generate the same rate of heat production per unit of total body mass (i.e. in W/kg) at ambient air temperatures as high as 35°C, the difference in core temperature change previously observed between large and small individuals was eliminated.[6]

While the absolute rate of sweat production (in g/min) is determined by the absolute evaporative requirements for heat balance (E_{req}; in W),[2] which is primarily governed by absolute heat production, local sweat rate is typically measured over a fixed surface area (in mg/cm^2/min) using a ventilated sweat capsule. As such, we secondly hypothesized that for a given absolute E_{req}, local sweat rate would be systematically greater in smaller individuals. The prevailing rationale was that the same absolute volume of sweat secreted over a smaller body surface area would

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Abbreviations: E_{req}, Evaporative requirement for heat balance; VO_{2max}, Maximum rate of oxygen consumption; $\%VO_{2max}$, Relative exercise intensity (percentage of maximum oxygen consumption).

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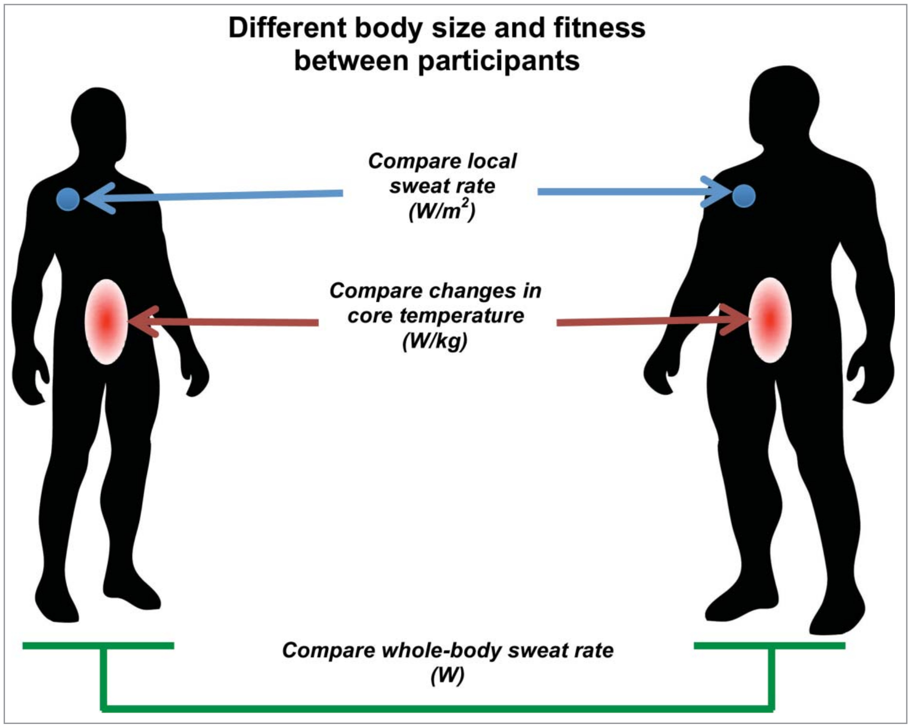

Figure 1. Proposed methods for selecting heat production (in brackets) for comparing local sweat rate in mg/cm^2/min, changes in core temperature in °C, and whole-body sweat rate in g/min or L/h.

logically lead to a greater amount of sweat per square centimeter. Therefore in order to avoid a biased difference in local sweat rate between groups of unequal body surface area, sweating responses should be compared using an exercise intensity eliciting the same rate of heat production (and therefore E_{req}) per unit surface area (in W/m^2). We demonstrated, again using 2 groups that were matched for all pertinent factors except body size (body surface area: ~1.8 m^2 vs. ~2.1 m^2), that mean local sweat rate was systematically higher in the smaller group during exercise at a fixed absolute E_{req} (in W), but these differences were abolished once an exercise intensity was used to elicit the same E_{req} per unit body surface area (in W/m^2).[6]

To compare differences in time-dependent thermoregulatory responses between groups unmatched for body size and fitness, our final conclusions were, irrespective of %VO_{2max}: 1) changes in core temperature should be assessed using a fixed heat production per unit mass; 2) local sweat rate should be assessed using a fixed heat production per unit body surface area; and 3) absolute whole-body sweat rates should be assessed using a fixed absolute heat production (**Fig. 1**). We propose that these methods should now be adopted to re-evaluate some factors that may have been traditionally considered to mediate an independent influence on changes in core temperature and local sweat rate during exercise without concern that any underlying differences in body size and fitness may potentially confound the observed responses. An example of one such factor is developmental age; while lower local sweat rates have been reported in pre-pubertal relative to late-pubertal boys,[7] heat production (and therefore E_{req}) per unit body surface area was lower due to the utilization of a fixed %VO_{2max} approach and concomitant differences in surface area-to-mass ratio, despite similar aerobic fitness levels.

An important final caveat is that the present methodology currently applies only to physiologically compensable environments under which the complete evaporation of secreted sweat occurs. The optimal experimental approach for evaluating the thermoregulatory influence of between-group factors under conditions that either elicit decrements in sweating efficiency, and/or are physiologically uncompensable, still needs to be determined. This work is ongoing.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

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