The biophysical and physiological determinants of sweating during heat stress

Accompanying video: https://youtu.be/h4p5JrIJ8VE?t=293

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Traditionally, steady-state sweat rates were proposed to be the consequence of the absolute core temperature attained during heat stress, with factors (e.g. skin temperature, heat acclimation, etc.) modifying this relationship. However, mounting evidence supports the evaporative heat balance requirements as the determinant of steady-state sweat rates during compensable heat stress. By definition, the evaporative heat balance requirement is the net difference in heat energy generated by the body that is not transferred to external work or biological processes, and the heat liberated through "dry" avenues by radiation, conduction and convection. If the environment permits 100% sweating efficiency, that is, all sweat secreted evaporates from the skin surface, then manipulations of the evaporative heat balance requirement by modifying exercise intensity or dry heat exchange will result in proportional changes in sweating, irrespective of body temperature or partial and complete heat acclimation. Using the circadian rhythm model to induce natural differences in core temperature, Ravanelli et al. (1) demonstrated that the evaporative requirements for heat balance determined the steady-state sweat rate response during compensable heat stress, independent of core and skin temperatures. While sweating may be proportional to the evaporative requirements for heat balance during compensable heat stress, partial and complete heat acclimation should increase the upper limit for heat dissipation through permitting a great maximum skin wettedness, thereby expanding the range of compensable conditions while also enabling greater evaporative heat loss during periods of uncompensable heat stress. As demonstrated in Ravanelli et al. (2), despite a progressive reduction in baseline core temperature with training (i.e. partial) and complete heat acclimation, steady-state sweat rate was marginally higher on the arm but not the back during compensable heat stress for the same evaporative requirements for heat balance. However, partial and complete heat acclimation resulted in increased sweating and a reduced change in core temperature during uncompensable heat stress confirming that enhanced heat dissipation is best observed during conditions which challenge the upper limits of heat loss potential. Moreover, it is the engagement in frequent physical training which requires sweating to maintain heat balance that expands the upper limit of heat dissipation, and not simply a result of a higher fitness (3). Collectively, our most modifiable heat loss pathway, sweating, may be regulated by means other than how hot we get, but rather by a mechanism which satisfies the biophysics of heat exchange.

References

1. **Ravanelli N**, **Coombs G**, **Imbeault P**, **Jay O**. Thermoregulatory adaptations with progressive heat acclimation are predominantly evident in uncompensable, but not compensable, conditions. *Journal of Applied Physiology* 127: 1095–1106, 2019.
2. **Ravanelli N, Imbeault P, Jay O**. Steady-state sweating during exercise is determined by the evaporative requirement for heat balance independently of absolute core and skin temperatures. *Journal of Physiology* (2020). doi: 10.1113/JP279447.
3. **Ravanelli N, Gagnon D, Imbeault P, Jay O**. A retrospective analysis to determine if exercise training-induced thermoregulatory adaptations are mediated by increased fitness or heat acclimation. *Experimental Physiology* (2020). doi: 10.1113/EP088385.

Questions

1. The human body can lose heat through 4 primary avenues. What are they and what is the conceptual heat balance equation?

2. Sally wants to exercise inside under the same conditions at the same intensity in the morning and in the afternoon. Assuming no change in mechanical efficiency between each time of day, and thus the same heat production, will Sally sweat more in the morning or afternoon?

3. What physiological adaptations occur to promote a greater maximum skin wettedness?

4. Consider an athlete who frequently exercises in cool conditions, but must engage in competition in a hot and humid environment. Discuss how you would prepare this athlete, and how you would best evaluate their thermoregulatory capacity to ensure your plan is working to mitigate thermal strain.