The human engine: How to keep it cool

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We don't usually think of ourselves in that way, but each of us is an engine, running on sustainable energy. It differs from ordinary engines in more than just the fuel. The human engine cannot be shut off, for instance: it keeps idling even if no work is required. That is needed to keep the system going, to keep our heart pumping, for example, and to keep the temperature around 37 °C. Because – and here is another difference – our human engine works only in a very small temperature range.

It's interesting to look at this a bit more quantitatively. Our daily food has an energy content of 8 to 10 MJ. That, incidentally, is equivalent to a quarter of a litre of gasoline, barely enough to keep our car going on the highway for about 2 minutes. Those 8 to 10 MJ per day represent just about 100 W on a continuous basis. Only a small fraction is needed to keep our heart pumping, as we can easily estimate from a pDV consideration (p being on the order of 10 kPa and DV on the order 0,1 litre, with a heart beat frequency around 1 Hz).

In the end, those 100 W are released as heat: by radiation, convection and evaporation. Under normal conditions, sitting behind our desk in our usual clothing in an office at 20 °C, radiation and convection are the leading terms, and evaporation gives only a small contribution. Until we start doing external work, on a home trainer, for example. The energy consumption goes up, and so does the heat production. Schematically, the total energy consumption Ptot and the external work Pwork is shown in the figure, where an efficiency of 25% has been assumed. Thus, if we work with a power of 100 W, we increase the total power by 400 W, and the heat part by 300 W.

Now the body must try to keep its temperature constant. That's not trivial: if we don't change clothing, or switch on a fan to make the temperature gradients near our skin somewhat larger, the radiation and conduction terms cannot change much. They are determined by the difference between the temperature of our skin and clothing on the one hand, and the ambient temperature on the other. When working hard, we raise that difference only slightly: due to the enhanced blood stream, our skin temperature will get closer to that of the inner body. But the limit is reached at 37 °C.

Fortunately, there is the evaporation term. Sweating is our rescue. And drinking, of course. Each additional 100 W of released heat that has to be compensated by evaporation, requires a glass of water per hour: 0,18 litre/h, to be precise. The various terms are, again schematically, shown in the figure.

One conclusion: Heavy exercise needs evaporation. Don't try to swim a 1000 m world record if your pool is heated to 37 °C. You might not live to collect your prize: Where would the heat go?

Article available at http://www.europhysicsnews.org or http://dx.doi.org/10.1051/epn:2003405