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Computer modelling of energy turnover and body temperatures in elite cyclists during climbing: steep, steeper, Angliru; cold, colder, Gavia

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Abstract

Climbing very steep mountain roads (e.g. Monte Zoncolan, Angliru) or high passes with sub- zero temperatures at the summit (e.g. Gavia, Stelvio) imposes intense stress on the physiological system during professional bicycle races. Previously we simulated energy conversion and heat transfer in the human body during bicycle racing with computer models [1]. In this presentation climbs are simulated on increasingly steeper slopes to investigate how the body copes with the large heat generation. Ascents and descents at low temperatures are also simulated, suggesting that unexpected temperature profiles may emerge in the body.

A computer model for the whole human body, consisting of 25 compartments (e.g. leg muscles and brain), was implemented by us previously [1]. The calculations of heat transport via the blood and by evaporation, radiation and convection from the skin were done based on equations developed for NASA to simulate astronauts during space travel [2]. This computer model is still relatively simple, but enables fast simulations and is freely available [3]. The model was used previously to simulate a mountain time trial to Alpe d'Huez in the Tour de France, showing that about 1600 Watt of heat was generated in the winner's muscles. The computer model predicts that during this time trial the temperature in the leg muscles may reach around 39.8 oC in five minutes. The brain reaches 39 oC within fifteen minutes [1].

New simulations suggest that if no breeze or fan is cooling the skin during a maximal effort on a stationary bicycle, brain temperature rises above 40 0C within 15 min. To investigate how the lower speed on steeper slopes diminishes the cooling capacity of the body in elite cyclists, simulations were compared of mountain time trials on increasingly steep climbs. Note that these simulations reflect predictions for typical fit individuals, but may not be applicable to athletes who are ill, dehydrated, prone to heat stroke or (ab)using substances that affect thermoregulation or skin vasodilation. In the simulation of a flat time trial at 48 km/hour, brain temperature rose to 39.0 0C. For slopes of 10, 20 and 25 % the speed dropped to 18, 10 and 8 km/hour, respectively, given the same external power. Brain temperature was predicted to reach 39.1 0C, 39.2 0C and 39.25 0C, respectively, showing only a modest increase for steeper climbs. Next an ascent and descent of a high mountain with a temperature at the top of -4 0C was simulated (Figure 1). The results suggests that due to vasoconstriction in the cold skin, the large heat generation in the muscles leads to a much higher brain temperature under cold conditions. When the descent starts and clothing is inadequate, peripheral temperatures decrease to very low values and brain temperature falls precipitously. These simulation conditions mimick a stage in the Giro d'Italia in 1988 crossing the Passo Gavia, where riders were reported to suffer severely from the cold, and some were forced to seek refuge during the descent.

Although computer models of the human physiological system are not perfect, simulations of top performances in cycle racing give surprising insights, e.g. on body temperature dynamics, and generate hypotheses for further experimental testing

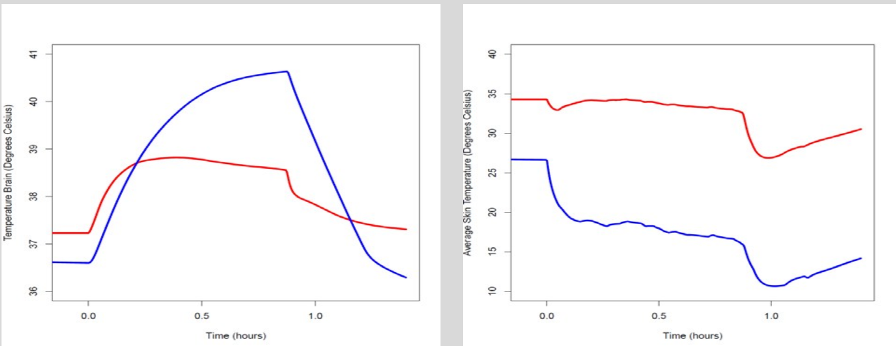

Figure 1. Simulation of a climb to the summit of the Passo Gavia from Ponte di Legno followed by descent. Red line: 18 0C at the summit, blue line : -4 0C. Skin temperature is averaged over the body. The cyclist starts climbing at t=0.

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