Simulating the physiology of athletes during endurance sports events: modelling human energy conversion and metabolism

BY JOHANNES H. G. M. VAN BEEK¹,²,³,*, FARAHANIZA SUPANDI¹, ANAND K. GAVAI²,³, ALBERT A. DE GRAAF⁴, THOMAS W. BINSL³,⁵ AND HANNES HETTLING³

¹Section Medical Genomics, Department of Clinical Genetics, VU University Medical Center, van der Boechorststraat 7, 1081 BT Amsterdam, The Netherlands
²Netherlands Consortium for Systems Biology, PO Box 94215, 1090 GE Amsterdam, The Netherlands
³Centre for Integrative Bioinformatics, VU University Amsterdam, De Boelelaan 1081A, 1081 HV Amsterdam, The Netherlands
⁴TNO Quality of Life, PO Box 360, 3700 AJ Zeist, The Netherlands
⁵Crosslinks BV, Willemskade 18c, 3016 DL Rotterdam, The Netherlands

The human physiological system is stressed to its limits during endurance sports competition events. We describe a whole body computational model for energy conversion during bicycle racing. About 23 per cent of the metabolic energy is used for muscle work, the rest is converted to heat. We calculated heat transfer by conduction and blood flow inside the body, and heat transfer from the skin by radiation, convection and sweat evaporation, resulting in temperature changes in 25 body compartments. We simulated a mountain time trial to Alpe d’Huez during the Tour de France. To approach the time realized by Lance Armstrong in 2004, very high oxygen uptake must be sustained by the simulated cyclist. Temperature was predicted to reach 39°C in the brain, and 39.7°C in leg muscle. In addition to the macroscopic simulation, we analysed the buffering of bursts of high adenosine triphosphate hydrolysis by creatine kinase during cyclical muscle activity at the biochemical pathway level. To investigate the low oxygen to carbohydrate ratio for the brain, which takes up lactate during exercise, we calculated the flux distribution in cerebral energy metabolism. Computational modelling of the human body, describing heat exchange and energy metabolism, makes simulation of endurance sports events feasible.

Keywords: whole body modelling; metabolic pathways; heat transport; muscle power; skeletal muscle metabolism; mathematical model

*Author for correspondence (hans.van.beek@falw.vu.nl).


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