Limits to sustained energy expenditure

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The maximum rate of energy expenditure is inversely related to the duration it is measured over. Very high rates exceeding 20x BMR can be maintained for minutes, and levels above 10x BMR maintained for several hours. These levels can only be performed by drawing on stored energy reserves. The maximum sustained energy expenditure is the level of expenditure that can be sustained for protracted periods of days and weeks, without the need to draw on fat stores, and is hence also the maximum rate of sustained energy intake. It is generally measured using the doubly–labelled water method. The main theory regarding what imposes these limits, in humans, is that there is an alimentary constraint on the level of food uptake (maximum sustained intake) that imposes an upper maximum on expenditure of around 2.5x BMR. However, there are numerous studies showing some groups (such as cyclists and swimmers) routinely exceed this supposed constraint, expending energy for weeks at a time at around 4x BMR. These data seem inconsistent with the fixed alimentary limit idea. There is a rich literature in animals regarding the factors imposing limits on maximal sustained energy intake and expenditure. Two theories have dominated the animal literature: one is the alimentary limit (as applied in humans) and the other is the heat dissipation limit theory. The latter suggests animals are constrained in their maximal intake and energy expenditure by their capacity to dissipate heat, thereby avoiding hyperthermia. A series of studies using the lactating mouse as a model system strongly support the heat dissipation limit hypothesis over the alimentary limit hypothesis. In short when lactating mice are exposed to the cold they increase their maximum sustained energy intake and produce more milk and larger offspring. This could be because the offspring in the cold have greater demands and these demands push the female mouse to work harder. To address this potential effect studies have been performed where the female mouse is shaved to increase her heat dissipation capacity without impact on the offspring demands. These studies show similar elevated maternal intake and greater milk production. Such observations have been repeated in other small rodents. The heat dissipation limit theory has thus become the dominant idea in the animal literature for the factor imposing limits on the maximal sustained intake/expenditure. Yet surprisingly this idea has not transferred over into the human and sports literature. This is all the more surprising because elevated heat dissipation capacity in cyclists (due to forced convection) and in swimmers (due to forced

convection and the high heat dissipation capacity of water) provides an explanation for their ability to sustain higher maximal energy expenditures than individuals engaged in other sports.