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Comparative Biochemistry and Physiology, Part A 140 (2005) 477–486

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Scaling the daily oscillations of breathing frequency and skin temperature in mammals

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Received 10 November 2004; received in revised form 16 February 2005; accepted 17 February 2005

Abstract

Among mammals, the peak–trough difference (PTD) of the circadian pattern of body temperature (T_b) drops very little with the increase in body mass (W), despite the large increase in heat capacitance and thermal inertia. We asked whether this might be contributed by systematic differences in the circadian pattern of breathing frequency (f) and skin temperature (Tskin), which are parts of the control mechanisms of heat loss. Measurements had been conducted on animals of eight species, chosen to cover a four-fold range in W, while resting and awake. The oscillation of f preceded that of T_b in 7 of the 8 species, and its acrophase did not correlate with W. The daily mean and PTD of f scaled with W in a similar manner (respectively, W^{-23} and $W^{-0.29}$), the PTD averaging about 20% of the daily mean. The circadian oscillations of Tskin, measured in specimens of five species at three locations (abdomen, ear and thigh), were in phase with T_b. Neither the PTD nor the acrophase of Tskin changed systematically with W. The differences between T_b and Tskin (means, peaks and troughs) decreased significantly with W; on average, the T_b–Tskin difference scaled to $W^{-0.19}$. In conclusion, the relative amplitudes and the acrophase of Tskin and f did not show systematic inter-species differences. The progressive increase of Tskin with W could be a factor in maintaining the PTD of T_b within a narrow range among mammals of very different size.

Keywords: Allometry; Body temperature; Breathing pattern; Circadian patterns; Control of breathing; Heat dissipation; Peripheral blood flow; Temperature control

1. Introduction

In mammals, with the exception of Monotremata, Marsupials and Chiroptera, and of some rodents experiencing daily torpor, the circadian oscillation of body temperature (T_b) has a peak–trough difference (PTD) of about 0.5–2 °C (Refinetti and Menaker, 1992; Mortola and Lanthier, 2004). Allometric scaling has indicated that the PTD of T_b [PTD(T_b)] either does not significantly change (Refinetti and Menaker, 1992; Refinetti, 1999) or drops slightly with the increase in body weight (W) (Aschoff, 1982; Mortola and Lanthier, 2004). Because the mean value of T_b does not systematically vary with W (Peters, 1983; Schmidt-Nielsen, 1984), also the relative PTD(T_b), which is the ratio between the PTD and the daily mean value of T_b, changes little with W (Mortola and Lanthier, 2004). A similar conclusion has been reached with respect to the daily oscillations of oxygen consumption ($\dot{V}O_2$). In fact, the PTD of $\dot{V}O_2$ changed with W as the mean value did ($\dot{V}O_2$ proportional to $W^{0.75}$; Stahl, 1967). Therefore, for both T_b and $\dot{V}O_2$, the amplitudes of the circadian oscillations are a constant fraction of the daily means (Aschoff, 1982; Mortola and Lanthier, 2004).

Large species have greater thermal inertia than smaller species, because, with the increase in W, the capacity for heat increases. Hence, the fact that the relative PTDs are inter-species constant not only for heat production (represented by $\dot{V}O_2$) but also for T_b can be reconciled only by assuming that the circadian control of heat loss changes

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doi:10.1016/j.cbpb.2005.02.010