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Comparative Biochemistry and Physiology, Part A 142 (2005) 389 – 396
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Temporal relationships of 21 physiological variables in horse and sheep

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Received 18 March 2005; received in revised form 18 June 2005; accepted 8 July 2005
Available online 14 November 2005

Abstract

Daily or circadian oscillation has been documented in a variety of physiological and behavioral processes. Although individual variables have been studied in great detail, very few studies have been conducted on the temporal relationships between the rhythms of different variables. It is not known whether the circadian pacemaker generates each and every rhythm individually or whether most rhythms are simply derived from a few clock-controlled rhythms. As a first step in elucidating this issue, 21 physiological variables were recorded simultaneously in horse and sheep. The results indicated that, in both species, different variables exhibit different degrees of daily rhythmicity and reach their daily peaks at different times of the day. The variables exhibiting strongest rhythmicity were locomotor activity, rectal temperature, and plasma concentrations of melatonin and glucose. Comparison of rhythmicity and acrophase in the various rhythms allowed inferences to be made about mechanisms of causation.

Keywords: Acrophase; Blood pressure; Circadian rhythm; *Equus caballus*; Heart rate; Locomotor activity; Melatonin; *Ovis aries*; Rectal temperature

1. Introduction

Daily oscillation in the levels of physiological variables has been described in a variety of species for a multitude of variables, including locomotor activity, body temperature, heart rate, blood pressure, hormonal secretion, and urinary excretion (Dunlap et al., 2004; Refinetti, 2005). Although individual variables have been studied in great detail–with characterization of rhythmic parameters such as mean level, amplitude, period, phase, and wave form–, very few studies have been conducted on the temporal relationships between the rhythms of different variables. In a classic article from 1979, Halberg et al. (1979) presented a figure depicting the acrophases (times of peak) of the rhythms of 62 variables measured in the domestic mouse. The most impressive feature of the figure was the revelation that different rhythms peak at different times of the day, so that one can find at least one rhythm in the body peaking at any given time of the day. This raises the issue of internal order in organisms—that is, how the various processes in the body relate to each other. If one rhythm lags behind another, is it because it is caused by the earlier rhythm? Does the circadian pacemaker generate each and every rhythm individually, or are most rhythms simply derived from a few clock-controlled rhythms?

Unfortunately, Halberg's figure is mostly of historical and heuristic value because the different variables were measured cross-sectionally on different animals and often in different laboratories (Halberg et al., 1979). Longitudinal monitoring of multiple variables simultaneously in individual subjects has occasionally been conducted in the past 30 years (Fischette et al., 1981; Honnebier et al., 1992; Jilge, 1985; Johnson et al., 1992; Kräuchi and Wirz-Justice, 1994; Lefcourt et al., 1999; Meinrath and D'Amato, 1979; Moore-Ede et al., 1977; Robinson and Fuller, 1999; Scales et al., 1988), but only a few variables were monitored in each study. Although the detailed study of rhythmic properties of individual variables can provide significant advances in the understanding of individual functions, the simultaneous study of many variables is a necessary step in the path to the understanding of the multiple temporal relationships of physiological processes. Thus, in the present study, we monitored simultaneously 21 different rhythms in individual horses and sheep. We chose horses and sheep as subjects not only for comparative purposes

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1095-6433/$ - see front matter © 2005 Elsevier Inc. All rights reserved.
doi:10.1016/j.cbpa.2005.07.019