Comp. Biochem. Physiol., 1974, *Vol.* 47**A**, *pp.* 799 *to* 802. *Pergamon Press. Printed in Great Britain*

SHORT COMMUNICATION

DIFFERENTIAL IN RECTAL AND CHEST MUSCLE TEMPERATURE DURING AROUSAL IN *EPTESICUS FUSCUS* AND *MYOTIS SODALIS* (CHIROPTERA: VESPERTILIONIDAE)

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(*Received* 16 *April* 1973)

Abstract—1. Chest muscle warms slightly faster than rectal temperature (T_r) during arousal in *Eptesicus fuscus* and *Myotis sodalis*.

2. Chest muscle temperature (T_c) to T_r differential rises slightly more rapidly in *M. sodalis* than in *E. fuscus*.

3. T_c at mean minimum T_r required for flight in *M. sodalis* is 23·8°C, while T_c at mean minimum T_r required for flight in *E. fuscus* is 30·1°C.

4. During arousal in both species, differential warming occurs both anterior and posterior to the diaphragm as well as between the deep chest area and the adjacent flight muscles.

INTRODUCTION

MINIMUM rectal temperatures (T_r) required for flight in many species of bats have been recently summarized (Studier & O'Farrell, 1972). Available data can be grouped into several chiropteran species which can initiate flight at T_r of roughly 25°C or less and fail to raise their T_r above that level in ambient temperatures (T_a) below the minimum T_r required for flight. Other bats appear to require a T_r of about 30°C for initiation of flight whereupon their T_r rises rapidly to about 37°C. A redistribution of blood flow occurs during arousal in hamsters (Lyman & Chatfield, 1950) such that parts of the body anterior to the diaphragm warm significantly faster than the posterior portions. This phenomenon has been generalized for nonvolant hibernators (Lyman, 1970) and suggested for some bats (Hayward *et al.*, 1965; Kulzer, 1967). Since bat flight muscle is metabolically extremely active tissue, there is considerable interest in determining if chest muscle temperature (T_c) warms at the same rate as T_r. As an initial study directed at this question, I presently report differentials in temperature during arousal in *Eptesicus fuscus*, a representative of the group of bats requiring a high T_r for initiation of flight of about 28°C (O'Farrell & Bradley, 1968), and *Myotis sodalis*, a species which initiates flight at a low T_r of about 21°C (Humphrey, see Studier & O'Farrell, 1972).

MATERIALS AND METHODS

Bats studied were eleven *Eptesicus fuscus* collected in northeastern Illinois on 13 and 14 January 1973 and eight *Myotis sodalis* collected in central Kentucky on 3 and 4 March 1973. Adult bats of both sexes were studied within 1 day of capture. Most *M. sodalis* were studied in their hibernaculum. Ambient temperatures during arousal ranged from about 4 to 12°C. Rectal and chest temperatures were taken at 1-, 2- or 3-min intervals during arousal using a quick-registering Scholtheis rectal thermometer or a Yellow Springs Instruments (YSI) flexible rectal probe and a YSI hypodermic probe read through a YSI Model 44 Telethermometer. The hypodermic probe was carefully inserted into the left pectoral muscle mass. Arousal was initiated by insertion of the probes. Bats were loosely covered with a cloth throughout the period of arousal in most cases. Individual bats provided up to 19 T_c and T_r values during arousal. Data were analyzed using parts of the MIDAS programs (Statistical Research Laboratory, University of Michigan) on an IBM Model 366/67 Computer.

RESULTS AND DISCUSSION

The relationships of T_c and T_r are depicted in Fig. 1. Most bats of both species exhibited chest temperatures which only slightly exceeded T_r. These relationships are found in the following equations:

$$\underset{\quad(0{\cdot}0195)\quad(0{\cdot}399)}{T_c = 1{\cdot}049T_r + 0{\cdot}757}, \quad N = 80, \tag{1}$$

and

$$\underset{\quad(0{\cdot}0517)\quad(0{\cdot}861)}{T_c = 1{\cdot}196T_r - 1{\cdot}666}, \quad N = 45, \tag{2}$$

where equation (1) refers to *Eptesicus fuscus* and (2) to *Myotis sodalis*. Numbers in parentheses under values for slopes and intercepts are standard errors of the means. Since in neither case do the 95 per cent confidence intervals for the slopes include 1·0, chest muscle warms significantly faster, albeit slightly faster, than T_r in both species. Additionally, the coefficient relating rate of rise of T_c compared to T_r in *M. sodalis* (1·196) is significantly greater than in *E. fuscus*, where $t = 2{\cdot}66$, N = 124, $P < 0{\cdot}01$. Although the intercepts of equations (1) and (2) are different by means of *t*-tests ($t = 2{\cdot}55$, $N = 124$, $P < 0{\cdot}02$), the 95 per cent confidence limits for both intercepts include the origin.

At the mean minimum T_r required for flight in *E. fuscus* (28°C, O'Farrell & Bradley, 1968), normal chest muscle temperature is 30·1°C or 2·1°C higher than T_r. At the mean minimum T_r required for flight in *M. sodalis* (21·3°C, Humphrey, see Studier & O'Farrell, 1972), normal T_c is 23·8°C or 2·5°C higher than T_r.

As also seen in Fig. 1, one or two individuals of each species showed a marked deviation from average values wherein T_c rose much more rapidly than T_r at intermediate T_r. Upon inspection of these individuals, it was determined that the hypodermic probe had slipped through the chest muscle mass and into the chest cavity. There appears to be a marked differential of blood flow between the deep chest and overlying flight muscles as well as a difference in flow anterior and posterior to the diaphragm.

As indicated previously (see Bradley & O'Farrell, 1969; O'Farrell & Bradley, 1970, etc.), bats capable of flight at low T_rs are individuals of species which are

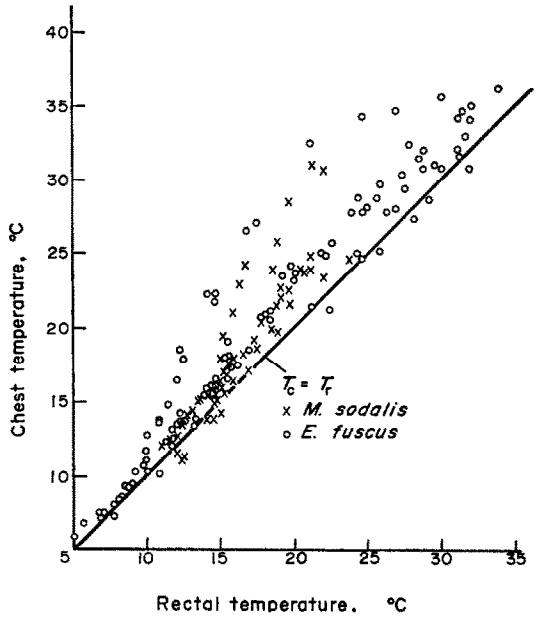

FIG. 1. Chest temperatures (T_c) and rectal temperatures (T_r) during arousal in *Myotis sodalis* (×) and *Eptesicus fuscus* (○).

periodically active throughout the winter outside their hibernaculum or arouse and move to other locations within their hibernaculum more frequently than bats which require higher T_rs for initiation of flight. By lowering body temperature to ambient temperature differentials, bats capable of flight at low T_rs should net a considerable energy savings. The metabolic machinery in the flight muscles of these bats is capable of operating with excellent efficiency in a temperature régime which is abnormally low and broad in comparison to other mammalian systems.

Acknowledgement—I thank Dr. Roy Horst for the loan of the YSI telethermometer and hypodermic probe.

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Key Word Index—Muscle; arousal; temperature; bats; *Eptesicus fuscus*; *Myotis sodalis*.