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The effect of feeding on the respiratory activity of the sloth

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Abstract

The aim of the present study was to confirm whether feeding influences the resting breathing rate and to observe possible alterations in blood gas and pH levels produced by feeding in unanesthetized sloths (*Bradypus variegatus*). Five adult male sloths (4.1 ± 0.6 kg) were placed daily in an experimental chair for a period of at least 4 h for sitting adaptation. Five measurements were made for each sloth. However, the sloths one, two and five were studied once and the sloths three and four were studied twice. Breathing rate was determined with an impedance meter and the output signal was digitized. Arterial blood samples were collected for blood gas analysis with a BGE electrolytes analyzer and adjusted for the animal's body temperature and hemoglobin content. The data are reported as mean ± SD and were collected during the resting period (8:00-10:00 h) and during the feeding period (16:00-18:00 h). The mean breathing rate increased during mastication of ymbahuba leaves (rest: 5.0 ± 1, feeding: 10 ± 1 bpm). No significant alterations were observed in arterial pH (rest: 7.42 ± 0.05, feeding: 7.45 ± 0.03), PCO_2 (rest: 35.2 ± 5.3, feeding: 33.3 ± 4.4 mmHg) or PO_2 (rest: 77.5 ± 8.2, feeding: 78.4 ± 5.2 mmHg) levels. These results indicate that in unanesthetized sloths 1) feeding evokes an increase in breathing rate without a significant change in arterial pH, PCO_2 or PO_2 levels, and 2) the increase in breathing rate produced by feeding probably is due to the act of mastication.

Key words
- Sloth
- *Bradypus variegatus*
- Feeding
- Respiratory activity
- Breathing rate
- Arterial blood pH
- PCO_2 and PO_2 levels

The control of ventilation is influenced by several factors. Among the most important are the levels of pH, PCO_2 and PO_2 in arterial blood. Additional factors include physical exercise, emotions, vocalization, and feeding. The latter involves mastication and the transport of food to the esophagus for swallowing and digestion (1). Feeding thus requires the coordination of breathing with these other motor activities (2-4).

There are some studies in humans regarding the influence of feeding on breathing rate and on arterial blood gas and pH levels (5,6). In newborns, feeding, or more specifically the act of swallowing, decreased breathing rate and tidal volume (5). In another study, Durand et al. (6) showed that feeding depresses the ventilatory response to CO_2. In adults, feeding also alters respiration, with the act of mastication bringing about a rise in the breathing rate (3,4).

The three-toed sloth (*Bradypus variegatus*) is a mammal belonging to the order Xenarthra, and is characterized by a low

breathing rate (7,8). Recent studies on unanesthetized sloths of this species have shown that the highest breathing rate occurred when the animals were feeding (Santos MSB, unpublished data). There are also reports that feeding produces a rise in heart rate and blood pressure, with values being maintained throughout the entire period of feeding activity (Duarte DPF, unpublished data). This differs from the response observed in other animals such as cats (9).

Therefore, the aim of the present study was to confirm whether feeding influences the resting breathing rate and to observe possible alterations in the blood gas and pH levels produced by feeding in unanesthetized sloths.

Five adult male sloths were used for this study after permission was obtained from IBAMA (License No. 075/98 DIFAS). Their body weights (4.1 ± 0.6 kg, mean ± SD) and temperatures (29.4 ± 1.5ºC) were within normal limits. They were maintained in a well-ventilated room with water and fresh leaves of ymbahuba (*Cecropia* sp) supplied *ad libitum*.

The sloths were subjected to a surgical procedure in which the common carotid artery was chronically cannulated under local anesthesia induced with 10 ml 2% procaine hydrochloride (LAFEPE, Recife, PE, Brazil). The common carotid artery was used because sloths have a rete mirabile in their limbs that makes cannulation of peripheral blood vessels difficult. Breathing rate and arterial pH, PCO_2 and PO_2 levels were measured 48 h after surgery.

One week prior to the experimental procedure, the sloth was placed daily in an experimental chair (10) for a period of at least 4 h for adaptation. The sitting position is the preferred posture of this animal when in captivity (10,11). Furthermore, the chair permits freedom of movement of the head and upper limbs, facilitating feeding.

The breathing rate was determined using two surface electrodes (MEDITRACE, Buffalo, NY, USA) positioned bilaterally on the thorax between the fifth and eighth intercostal spaces and coupled by cable to an impedance meter (Impedance Converter, model 2991, Biocon Inc., Culver City, CA, USA). To record ventilation, the output of this impedance meter was coupled to a DI-205 module, which was connected to a DI-200 PGH A/D converter board (DATAQ Instruments, Inc., Akron, OH, USA) inserted into a microcomputer (IBM-clone 486). This apparatus permitted visualization of the ventilatory signal and its recording on a diskette using WINDAQ-200 acquisition software (DATAQ). The sampling rate was 100 Hz.

Blood samples for pH and blood gas measurements were collected from the cannulated common carotid artery. The analyzer was adjusted for body temperature and hemoglobin content of the sloth. Each collection consisted of three samples of 0.5 ml of arterial blood drawn into sterile heparinized syringes. The syringes were capped immediately to ensure they were airtight and were then submitted to analysis with a model IL 1400 BGE electrolytes analyzer (Instrumentation Laboratory, Milan, Italy). The mean value obtained for the three 0.5-ml samples was used for each arterial pH and blood gas measurement.

The experimental procedures for data acquisition were performed in an acoustically and thermally (26ºC) isolated room where the animal was maintained in the experimental chair (10) with fresh leaves of ymbahuba available *ad libitum*. The experiments were carried out during a resting period (8:00-10:00 h), when the sloth usually does not accept available food, and during a time (16:00-18:00 h) when most of the activity normally takes place (Duarte DPF, unpublished data). During the feeding period, the animal was studied in the oral processing phase, or more specifically, when it was masticating.

Five impedance records of ventilatory activity were obtained over a period of ap-

proximately 2 h. The records, which lasted 5 min and were separated by 30-min intervals, were stored on diskettes for subsequent analysis. Following each impedance record, arterial blood samples were collected, pH was measured and blood gas analysis immediately performed. The WINDAQ playback software (DATAQ) was used to identify the ventilatory cycles and store them in Microsoft Excel, which enabled rapid and accurate calculation of the number of ventilatory cycles per minute.

Mean and standard deviations of breathing rate and arterial pH, PCO_2 and PO_2 levels were calculated using the Statistics for Windows program. As the number of samples obtained for each sloth was not the same at rest and during feeding, the Student *t*-test for unpaired data was used to compare the mean values of each variable. Results are reported as mean ± SD and the acceptable level of significance was set at $P<0.05$.

The results obtained for individual unanesthetized sloths at rest and during feeding are shown in Table 1, and summarized data are presented in Table 2. Feeding significantly increased breathing rate; however, arterial pH, PCO_2, and PO_2 were unaltered by this activity (Table 2).

Studies of human newborns show that feeding decreases tidal volume and breathing rate (12), responses that are specifically associated with the act of swallowing (5). In adults, on the other hand, feeding induces an increase in breathing rate that is related to the act of mastication (3,4) and results from a decrease in both inspiratory and expiratory time (3). We found that the breathing rate of sloths was also increased during feeding activity that involved mastication (Table 2). Similarly, it has been previously shown that the increase in breathing rate in the sloth is related to reductions in inspiratory and expiratory time (Santos MSB, unpublished data). Thus, it is possible that the increased breathing rate found in sloths during feeding activity may be due to the same factors that promote the increase in breathing rate observed in adult humans.

It is possible that the increased breathing rate observed during feeding was also associated with the effects of the sitting position on ventilatory function. In this posture, the substantially large abdominal contents of the sloth could displace the diaphragm upward (Silva EM, unpublished data) and decrease the tidal volume. Thus, to compensate for a reduced pulmonary expansion, breathing rate would increase to maintain total ventilation. However, in our study, both resting and feeding data were collected only from animals in the sitting position. Therefore, posture should not influence the increase in breathing rate produced by feeding.

Due to the low metabolic rate of the sloth (13), one might suggest that the elevation in

Table 1. Individual breathing rate (BR) and arterial pH, PCO_2 and PO_2 of unanesthetized sloths (*Bradypus variegatus*) at rest and during feeding.

Animal	Condition	BR (breaths/min)	pH	PCO_2 (mmHg)	PO_2 (mmHg)
Sloth 1	Rest	4 ± 1	7.47 ± 0.02	35.4 ± 0.9	83.6 ± 9.8
Sloth 2	Rest	4 ± 0	7.39 ± 0.05	42.2 ± 0.4	67.1 ± 3.9
Sloth 3	Rest	5 ± 1	7.38 ± 0.12	33.7 ± 0.8	84.4 ± 8.1
Sloth 4	Rest	6 ± 1	7.46 ± 0.27	29.6 ± 2.4	74.7 ± 2.0
Sloth 3	Feeding	9 ± 1	7.42 ± 0.21	37.9 ± 1.7	79.1 ± 8.5
Sloth 4	Feeding	10 ± 1	7.48 ± 0.26	29.1 ± 3.7	83.1 ± 10.8
Sloth 5	Feeding	11 ± 1	7.44 ± 0.10	32.9 ± 1.0	72.9 ± 3.0

Data are reported as means ± SD. N = 5 animals.

Table 2. Breathing rate (BR) and arterial pH, PCO_2 and PO_2 of unanesthetized sloths (*Bradypus variegatus*) at rest and during feeding.

Variables	Rest (N = 4)	Feeding (N = 3)
BR (breaths/min)	5.0 ± 1.0	10.0 ± 1.0*
pH	7.42 ± 0.05	7.45 ± 0.03
PCO_2 (mmHg)	35.2 ± 5.3	33.3 ± 4.4
PO_2 (mmHg)	77.5 ± 8.2	78.4 ± 5.2

Data are reported as means ± SD. Five measurements were made for each sloth.
*$P<0.05$ *vs* rest (Student *t*-test for unpaired data).

breathing rate is a mechanism activated to maintain arterial pH, PCO_2, and PO_2 during feeding-induced increases in energy demand. The possibility that feeding could evoke an increase in metabolic demand was put forth by Tamura et al. (14), who described the effects of feeding in severely handicapped individuals suffering from cerebral palsy and epilepsy.

On the basis of the present results obtained for unanesthetized sloths, we conclude that 1) the act of feeding evokes an increase in breathing rate without a significant change in arterial pH, PCO_2 or PO_2 levels, and 2) the increase in breathing rate produced by feeding probably results from mastication.

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