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Cardiovascular responses to locomotor activity and feeding in unrestrained three-toed sloths, *Bradypus variegatus*

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Abstract

Heart rate (HR) and systolic (SBP), diastolic (DBP) and mean (MBP) blood pressure were recorded by biotelemetry in nine conscious unrestrained sloths for 1 min every 15 min over a 24-h period. The animals were allowed to freely move in an acoustically isolated and temperature-controlled (24 ± 1ºC) experimental room with light-dark cycle (12/12 h). Behavior was closely monitored through a unidirectional visor and classified as resting (sitting or suspended), feeding (chewing and swallowing embauba leaves, *Cecropia adenops*), or locomotor activity around the tree trunk or on the room floor. Locomotor activity caused statistically significant increases in SBP (+8%, from 121 ± 22 to 131 ± 18 mmHg), DBP (+7%, from 86 ± 17 to 92 ± 10 mmHg), MBP (+8%, from 97 ± 19 to 105 ± 12 mmHg), and HR (+14%, from 84 ± 15 to 96 ± 15 bpm) compared to resting values, indicating a possible major influence of the autonomic nervous system on the modulation of cardiac function during this behavior. During feeding, the increase in blood pressure was even higher (SBP +27%, from 119 ± 21 to 151 ± 21 mmHg; DBP +21%, from 85 ± 16 to 103 ± 15 mmHg; MBP +24%, from 96 ± 17 to 119 ± 17 mmHg), while HR remained at 14% (from 84 ± 15 to 96 ± 10 bpm) above resting values. The proportionally greater increase in blood pressure than in HR during feeding suggests an increase in peripheral vascular resistance as part of the overall response to this behavior.

Key words
- Tree-toed sloth
- Heart rate
- Blood pressure
- Locomotor activity
- Feeding behavior

In mammals, different aspects of behavioral activity are associated with a wide variety of physiological changes. These include alterations in blood pressure (BP), heart rate (HR), and blood flow to and from those tissues and organs that participate in neural and hormonal functions (1-5). Sleep, for example, is an activity accompanied by a fall in BP (6). Sloths are slow-moving mammals that, besides sleeping or resting for up to 20 hours a day (7), show low levels of motor activity. These animals seem to have high levels of sympathetic discharge (8) and exhibit some aberrant reactions to certain commonly used drugs (9).

The aim of the present study was to determine the effect of locomotor activity and feeding on BP and HR in unrestrained three-toed sloths (*Bradypus variegatus*). Biotelemetric measurements of BP were obtained for nine adult sloths (four males and two females weighing on average 4.4 ± 0.6 kg), over a period of 48 h. In three other males the trials were interrupted after 26 h for technical reasons such as blood clotting and loss of the BP signal. Biotelemetry has the advantage that the animals are conscious, unrestrained and require no handling during the experiments and provides a continuous recording of hemodynamic functions.

The nine sloths were obtained from the forest in the vicinity of Recife, PE, Brazil, and kept in the vivarium of the University for two weeks prior to the experiment. Body temperature and weight were measured daily, and the animals were observed for different aspects of their behavior as described by Silva (10). On the day before surgery, the sloths were shaved in those regions on which silver plate electrodes were to be attached to record the electrocardiogram (EKG). Heart rate was measured from lead II and was used as an indicator of post-surgical stress. The right common carotid artery was cannulated under local anesthesia induced by 10 ml 2% lidocaine (Xylocaine®; Astra Química do Brasil, São Paulo, SP, Brazil) administered subcutaneously as described by Duarte at al. (8). The cannula was filled with heparinized physiological saline (Liquemine®; Roche, Rio de Janeiro, RJ, Brazil) and then sealed. The carotid artery was chosen because of the presence of a rete mirabile in the limb vessels of the animals which prevents peripheral cannulation. After a 24-h period, EKG electrodes were applied and their position was maintained by dressing the animals in a tight-fitting jacket. The jacket also carried a BP biotelemetry transmitter previously calibrated and connected to the arterial cannula. The animal was released into an acoustically isolated experimental room with a unidirectional visor for observation. The room contained a large branched tree trunk for the animal to climb. The sloth was able to move around freely, and food (fresh embauba leaves, *Cecropia adenops*) and water were available *ad libitum*. The artificial light-dark period was 12/12 h (light on at 6:00 h) and room temperature was maintained at 24 ± 1ºC. The animal's behavior was closely monitored through the visor for 1 min at intervals of 15 min and classified as resting (sitting or suspended), feeding (chewing and swallowing the embauba leaves supplied), or showing locomotor activity on the tree trunk provided or on the floor of the room, which was covered with sand. Every 15 min the observer recorded the behavior that was taking place during the 1-min monitoring period.

BP signals sampled at 200 Hz were collected over a 24-h period, during which the animal's behavior was also observed. The systolic (SBP) and diastolic (DBP) blood pressure were recorded beat to beat using the Windaq 200 Calculate software (Dataq Instruments, Akron, OH, USA) and analyzed with the Microsoft Excel software. Mean blood pressure (MBP) was calculated as DBP plus one third of the difference between SBP and DBP.

Data are reported as means ± SD. HR values before and after surgery were compared by the Student *t*-test for paired data, while SBP, DBP, MBP, and HR values at rest and during locomotor activity, and before and during feeding, were compared by the Student *t*-test for unpaired data. The level of significance was set at $P < 0.05$.

The cannulae were removed at the conclusion of the study and, after a period of recovery, the sloths were released back into the wild. The experiments were carried out with previous approval of the Ethics Committee of Centro de Ciências Biológicas, Universidade Federal de Pernambuco and with license from Instituto Brasileiro do Meio Ambiente (IBAMA, No. 075/98, DIFAS).

HR during resting behavior before (70 ± 17 bpm) and after (73 ± 16 bpm) surgery did not differ significantly ($P > 0.05$, paired Student *t*-test), suggesting that the animals were unstressed. Locomotor activity (Figure 1A) was recorded on 35 occasions representing 2% of the total number of 1485 observations. This rate was much lower than the 13% reported by Silva (10) for sloths in captivity. However, this difference of 2% *vs* 13% in locomotor activity may be accounted for by the different methodologies employed in the two studies.

Sunquist and Montgomery (11) reported that the genus *Bradypus* does not have a cyclic pattern of diurnal and nocturnal activity. On the other hand, Moura Filho et al. (12) found a reduction in activity at the end of the dark period. Studies carried out by Silva (13), recording the EKG by short range biotelemetry and observing motor activity in sloths maintained in the laboratory, showed that motor activity increased at the beginning of the night (maximum at 20:00 h) and was correlated with an increase in HR.

In the present study, locomotor activity (Figure 1A) evoked significant increases (P < 0.05, unparied Student *t*-test) in SBP (121 ± 22 to 131 ± 18 mmHg; +8%), DBP (86 ± 17 to 92 ± 10 mmHg, +7%), MBP (97 ± 19 to 105 ± 12 mmHg, +8%), and HR (84 ± 15 to 96 ± 15 bpm, +14%). The relatively larger increase in HR compared to BP indicates that the autonomic nervous system has a major effect on the modulation of heart function in these animals.

Various studies of different species have shown a close correlation between HR levels and locomotor activity (14-16). In cats (14), domestic rabbits (15), and wild rabbits (16), it has been shown that physical activity causes more noticeable effects on HR than BP. Thus, although sloths are much less active than other mammals, during those times when they display locomotor activity their cardiovascular responses are similar to those of other species.

Feeding behavior was observed on 104 occasions and resulted in significant increases (P < 0.001, unpaired Student *t*-test; Figures 1B and 2) in SBP (119 ± 21 to 151 ± 21 mmHg, +27%), DBP (85 ± 16 to 103 ± 15 mmHg, +21%), MBP (96 ± 17 to 119 ± 17 mmHg, +24%), and HR (84 ± 15 to 96 ± 10 bpm, +14%). During feeding, there was abundant salivation and the elevated levels of BP remained high while it persisted.

The ingestion and digestion of food by mammals is associated with many physiological alterations including those in the nervous, cardiovascular and endocrine systems. Alterations in the cardiovascular system before, during and after feeding have been investigated in various animals. Experiments on cats (5) and rabbits (15) have demonstrated that the presentation of food to the animal without its subsequent consumption does not bring about any changes in either BP or HR. Our results indicate that the situation is the same in *B. variegatus*, i.e., that the availability of food *ad libitum* or the presentation of embauba leaves to the ani-

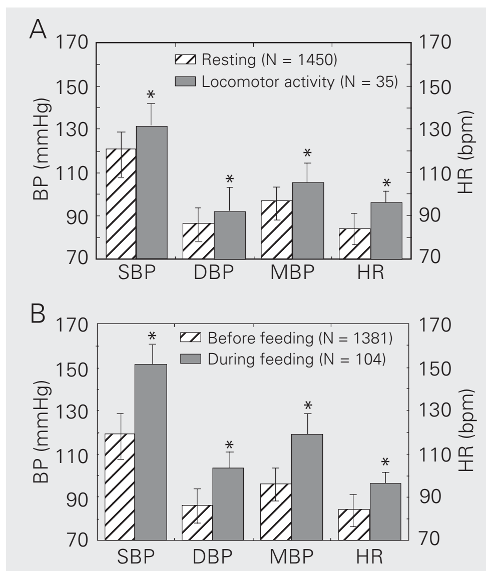

Figure 1. Systolic (SBP), diastolic (DBP) and mean (MBP) blood pressure and heart rate (HR; mean ± SD) of *Bradypus variegatus* at rest and during locomotor activity (A) and before and during feeding (B). N = number of measurements. *P < 0.05 compared to the resting condition (Student *t*-test).

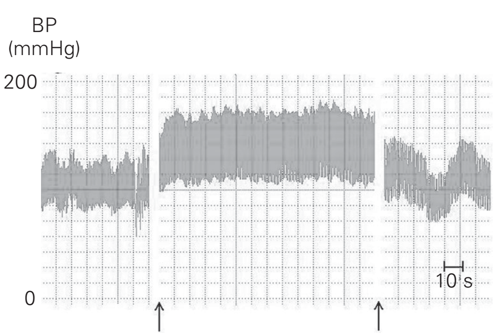

Figure 2. Typical blood pressure (BP) tracing for an unrestrained three-toed sloth during feeding (between arrows).

mals *per se* does not induce a change in cardiovascular parameters.

In dogs (1-2,17), baboons (3), calves (4), cats (5), rabbits (15), and sheep (18) a transitory rise in both HR and BP has been noted at the beginning of feeding. Although these alterations occur rapidly and are transitory, they clearly demonstrate that the autonomic nervous system is directly implicated in the cardiovascular adjustments that take place during feeding. In dogs, at the beginning of feeding (1,17), HR and BP rise by 79 and 33%, respectively, compared with control values. In sheep (18), HR and BP increase by 75 and 50%, respectively, when feeding starts. These responses, which are probably mediated by a generalized stimulation of the sympathetic nervous system, are also observed in cats (5), albeit to a lesser extent (HR +16% and BP +17%). Feeding is also associated with changes in renal function, indicating that this behavior brings about alterations in a wide variety of different centrally controlled response patterns. The results of the present study on feeding-induced cardiovascular alterations in sloths demonstrate a pattern similar to that observed in cats (5), i.e., a slightly higher elevation in BP than in HR. This provides evidence that an increase in peripheral vascular resistance contributes to the rise in BP observed in sloths.

In the study of sheep cited above, Blair-West and Brook (18) not only observed increases in HR and BP similar to those seen in other species (1,4,5,15,17), but also noted the production of copious amounts of saliva. This resulted in a reduction in renal blood flow with the consequent retention of sodium and water, and a reduction in the circulatory volume with a rise in plasma renin concentrations (18). It has also been demonstrated that the act of feeding causes the release of antidiuretic hormone in sheep (19). Similarly, the consumption of fresh leaves by *B. variegatus* causes both a rise in BP and an associated increase in salivation. This would also appear to be related to the participation of the hypertensive hormones renin, angiotensin and antidiuretic hormone, which are related to salivation. The secretion of these hormones is adjusted so as to maintain an elevated BP during feeding.

The role of the arterial baroreceptors in cardiovascular adaptations during feeding has also been examined. Studies have demonstrated that their participation in the response to feeding is species dependent. Matsukawa and Ninomiya (5) suggested that the baroreceptors are not involved in the reflex increase in HR and sympathetic activity in the renal system that occurs in the first stage of feeding in conscious cats, but do affect renal nerve activity during the final stages of ingestion. Afferents from the arterial baroreceptors exert an inhibitory influence on the discharge of renal activity, particularly when BP is high. This provides evidence that central activation via the efferent sympathetic system acts on the kidneys and heart to adjust the cardiovascular and feeding responses of these animals (5). Buchholz et al. (20) demonstrated that the rise in BP and renal activity during feeding was potentiated in rats denervated by lesioning of the solitary tract nucleus, indicating that in these animals the elevation in BP induced by feeding is buffered by baroreceptors.

Because our experiments were carried out on sloths with records collected during 1-min period at 15-min intervals, we were unable to obtain continuous profiles of BP recordings immediately before feeding started. We thus cannot entirely rule out the existence of a viscero-autonomic reflex induced by feeding that could reduce BP, decrease baroreceptor activity, and consequently increase sympathetic activity. However, the fact that BP and HR levels remained elevated throughout the feeding period supports our conclusion that the baroreceptors seem to participate minimally in the buffering of BP in this behavioral response of the three-toed sloth (*Bradypus variegatus*).

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