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SHORT COMMUNICATION

What makes the heart of *Boa constrictor* (Squamata: Boidae) beat faster?

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ABSTRACT. Body size is highly correlated with metabolism, which in turn influences physiological rates such as heart rate. In general, heart rate is negatively influenced by the size of animal's body, but there is insufficient data corroborating this pattern in snakes. This study evaluated how body size affects heart rate in captive *Boa constrictor* Linnaeus, 1758. We measured the heart rate of 30 snakes using digital palpation and evaluated how this rate is influenced by body mass and sex using Analysis of Covariance (ANCOVA). The heart rate of the snakes was 58.8 ± 6.7 bpm (beats per minute). Body size, estimated as log-transformed body mass, negatively influenced heart rate ($F_{1,28}$ = 10.27, p = 0.003, slope = -0.00004, R^2 = 0.27), but sex had no effect ($F_{1,27}$ = 0.07, p = 0.80). In conclusion, this result corroborates the negative relationship between body size and heart rate for snakes and reinforces the influence of related metabolic characteristics, such as body size, on the physiological parameters of snakes.

KEY WORDS. Body size; heart rate; intraspecific variation; metabolism, physiology; snakes.

The heart rate of snakes is influenced by diverse factors such as temperature (Lillywhite et al. 1999, Kik & Mitchell 2005, Rutskina et al. 2009), the digestive process (Wang et al. 2001, Enok et al. 2013), activity pattern (Wang et al. 2001), and pregnancy (Birchard et al. 1984), among others. One particular trait of animals, body size, is strongly and negatively correlated with metabolic rates (Clarke & Johnston 1999, Gillooly et al. 2001). Metabolic rates influence heart rate and other physiological responses. Large vertebrates have slower heart rate when compared with smaller ones (Lillywhite et al. 1999, Schmidt-Nielsen 2002), a pattern that has been confirmed for some Australian snakes (Seymour 1987) and Burmese pythons (Enok et al. 2014). In one study conducted on snake embryos (Du et al. 2013) the heart rate was higher in small species than in larger ones. However, general laws governing cardiovascular functions and body size may have exceptions, and for this reason it is important to evaluate whether or not they apply to different species (Enok et al. 2014). This is particularly true for snakes, a group for which the relationship between heart rate and body size remains relatively unexplored.

Boa constrictor Linnaeus, 1758 (Boidae), popularly known as the common boa, occurs from Mexico to northern Argentina (Vanzolini et al. 1980). This snake is commonly reared in captivity as a pet (Puorto & França 2009). Even though the heart rate of *B. constrictor* has already been documented, previous studies are based on small samples (Clark & Marx 1960, Valentinuzii et al. 1969a, b) that did not allow for a statistical evaluation of the relationship between heart rate and body size. One additional study, by Wang et al. (2001), evaluated the influence of diet and forced activity on the heart rate of this species.

According to Raske et al. (2012), information about heart rate, respiratory rate, and body temperature may improve the clinical treatment of ectothermic vertebrates. This study aimed to investigate the heart rate of captive common boas and to evaluate whether it is influenced by body size, a characteristic that is associated with metabolism.

We kept 30 captive *B. constrictor* at the Núcleo Regional de Ofiologia da Universidade Federal do Ceará (NUROF-UFC) at a room temperature (29.1 ± 1.4°C) and humidity (62 ± 7%). Each snake was maintained in an individual wooden box and offered water *ad libitum*. The experimental group, composed of 19 females and 11 males, was kept without food for about 15 days before the experiment started. This fasting period is important to control for the influence of the digestion process on heart rate (Enok et al. 2013).

We immobilized the animals using a herpetological hook and measured their heart rate (HR) by digital palpation. Heart rate was recorded as the number of beats per minute (bpm). Even though most modern studies have used another method to measure heart rate, which includes a surgically inserted catheter filled with heparinized saline connected to a pressure transducer (Wang et al. 2001, Enok et al. 2014), we have found that our method produces similar results (see discussions below for more details). Furthermore, digital palpation is easier to perform, cheaper, and safer for the subjects. Safety is an important concern in the care of exotic animals (Raske et al. 2012) such as *B. constrictor*. We measured the heart rate of active individuals because anesthesia may result in greater variations of this measurement (Blouin-Demers et al. 2000). Since we measured the heart rate of active individuals using palpation, our results reflect the maximal or active, not resting, HR. The body mass of each snake was measured in grams (g) using a digital balance.

Initially, we employed Analysis of Covariance (ANCOVA) with $\log_{10}$(HR) as a dependent variable (response), and gender and mass as independent variables (explanatory), because there was an unequal ratio of males and females in the sample. ANCOVA assumptions (linearity and equal slopes) were valid. Next, we performed a simple linear regression to evaluate the effects of mass on HR. Residuals of the regressions were checked for normality and their relationship with fitted values, in order to confirm their validity. The level of significance used in these comparisons was 5% ($p < 0.05$). Descriptive statistics are presented as mean ± standard deviation. Analyses were performed in the software R ver. 3.0.2 (R Core Team 2013).

The mass of the snakes was 816.8 ± 572.3 g and their HR was 58.8 ± 6.7 bpm. Sex did not influence HR ($F_{1,27} = 0.07$, $p = 0.80$), but mass had a negative effect on it ($F_{1,28} = 10.27$, $p = 0.003$, slope = -0.00004, $R^2 = 0.27$) (Fig. 1).

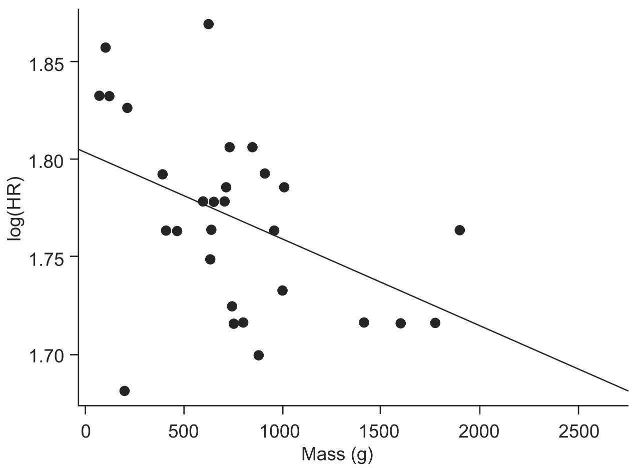

Figure 1. Relationship between body mass (g) and $\log_{10}$-transformed heart rate, measured as beats per minute in 30 individuals of *Boa constrictor* from Núcleo Regional de Ofiologia da Universidade Federal do Ceará.

Our results for *B. constrictor* corroborate the general pattern reported in the literature of a negative correlation between heart rate and body size (Lillywhite et al. 1999, Schmidt-Nielsen 2002), demonstrating that metabolic related measurements are good predictors of vital rates in this species. Our data on the heart rate of *B. constrictor*, unlike previous studies, is based on a large sample, and for this reason it might be more relevant for veterinary use (Raske et al. 2012).

A negative relationship between heart rate and body mass had been previously reported in reptiles, and more specifically snakes (Seymour 1987, Lillywhite et al. 1999, Enok et al. 2014). Seymour's results are restricted to Australian snakes and were obtained from a small sample size (only 13 individuals in nine different species). The heart rate of Burmese pythons, *Python bivittatus* Kuhl, 1820, is negatively related with body size (Enok et al. 2014), but the HR values obtained for this species are lower than for *B. constrictor*. This may be due to differences in mass between the two species. *P. bivittatus* is heavier than *B. constrictor*, corroborating the pattern of a negative relationship between HR and body size reported by Seymour (1987). However, the body mass of many individuals of *P. bivittatus* investigated by Enok et al. (2014) was greater than the body size of *B. constrictor* used in our study. Also, the differences found between both studies could be due to the methodology used by Enok et al. (2014): they kept the animals under minimum disturbance and measured their resting HR.

The heart rate values found in this study were similar to the values found by Wang et al. (2001) for *B. constrictor* in conditions of forced activity and similar temperature (28 ± 5°C). In their data the animals were encouraged to strike and bite (61.4 ± 1.5 bpm, where 1.5 is standard error). The HR of the snakes in our study was measured in the NUROF-UFC while the animals were active (most of them sibilating and constricting the hands of the researchers during the measurements). Therefore, the similarity between our results and Wang et al.'s (2001) was expected because animals in both studies were similarly active and were in equivalent environmental conditions. The heart rate of *B. constrictor* from the NUROF-UFC was higher than in the specimen evaluated by Clark & Marx (1960). Differences in environmental temperature may explain this difference, because this variable is known to influence heart rate (Lillywhite et al. 1999, Kik & Mitchell 2005, Rutskina et al. 2009).

The similarity in mean and standard error values obtained in similar environmental and activity situations in our study and in Wang et al.'s (2001) (mean = 58.8 and 61.4 bpm; and standard error = 1.50 and 1.49, respectively) indicates that the manual method of measuring HR seems to be useful for estimating patterns of heart rate in common boas. However, it was difficult to perform in large snakes with strong muscles and a deep body cavity. The manual method is valuable when it is not possible to use more sophisticated methods such as electrocardiogram (e.g., Valentinuzii et al. 1969a, b, Rutskina et al. 2009, Stuginski et al. 2011), Doppler blood flow detector (e.g., Raske et al. 2012), or pressure transducers (Wang et al. 2011, Enok et al. 2014). According to Raske et al. (2012), safe and inexpensive measurements of heart rate may be valuable for exotic animal medicine.

Stuginski et al. (2011) also found no relationship between HR and sex in *Crotalus durissus* Linnaeus, 1758. Sexual changes in the HR of snakes may occur due to pregnancy, which increases heart rate (Birchard et al. 1984). Common boas were maintained in individual cages in NUROF-UFC since their arrival and they exhibited no signs of pregnancy.

In conclusion, the heart rate of captive *B. constrictor* was negatively influenced by body size. This study, in addition to offering HR parameters of the model species for comparative purposes for veterinarians, also reinforces the influence of variables related to metabolism on physiological rates such as the heart rate of snakes.

LITERATURE CITED

Birchard GS, Black, CP Schuett GW, Black V (1984) Influence of pregnancy on oxygen consumption, heart rate and hematology in the Garter Snake: implications for the "cost of reproduction" in live bearing reptiles. **Comparative Biochemistry and Physiology Part A: Physiology 77**(3): 519-523. doi: 10.1016/0300-9629(84)90221-4

Blouin-Demers G, Weather PJ, Shilton CM, Parent CE, Brown GP (2000) Use of inhalant anesthetics in three snake species. **Contemporary Herpetology 4**: 1-7.

Clarke A, Johnston NM (1999) Scaling of metabolic rate with body mass and temperature in teleost fish. **Journal of Animal Ecology 68**: 893-905. doi: 10.1046/j.1365-2656.1999.00337.x

Clarke GK, Marx TI (1960) Heart rate of unanesthetized snakes by electrocardiography. **Copeia 1960**(3): 236-238.

Du W, Ye H, Pizzato L, Shine R (2013) Patterns of interspecific variation in the heart rates of embryonic reptiles. **PLOSOne 6**(12): e29027. doi:10.1371/journal.pone.0029027

Enok S, Simonsen LS, Wang T (2013) The contribution of gastric digestion and ingestion of amino acids on the postprandial rise in oxygen consumption, heart rate and growth of visceral organs in pythons. **Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology 165**(1): 46-53. doi: 10.1016/j.cbpa.2013.01.022

Enok S, Slay C, Abe AS, Hicks JW, Wang T (2014) Intraspecific scaling of arterial blood pressure in the Burmese python. **Journal of Experimental Biology 217**: 2232-2234. doi:10.1242/jeb.099226

Gillooly JF, Brown JH, West GB, Savage VM, Charnov EL (2001) Effects of size and temperature on metabolic rate. **Science 293**: 2248-2251. doi: 10.1126/science.1061967

Kik MJL, Mitchell MA (2005) Reptile cardiology: a review of anatomy and physiology, diagnostic approaches, and clinical disease. **Seminars in Avian and Exotic Pet Medicine 14**(1): 52-60. doi: 10.1053/j.saep.2005.12.009

Lillywhite HB, Zippel KC, Farrell AP (1999) Resting and maximal heart rates in ectothermic vertebrates. **Comparative Biochemistry and Physiology Part A: Physiology 124**(4): 369-382. doi: 10.1016/S1095-6433(99)00129-4

Puorto G, França FOS (2009) Serpentes não peçonhentas e aspectos clínicos dos acidentes, p. 125-131. In: Cardoso JLC, França FOS, Wen FH, Malaque CMS, Haddad Jr V (Ed.) **Animais Peçonhentos do Brasil.** São Paulo, Sarvier FAPESP, 2nd ed.

R Core Team (2013) **R: A language and environment for statistical computing.** Vienna, R Foundation for Statistical Computing.

Raske M, Lewbart GA, Dombrowski DS, Hale P, Correa M, Christian LS (2012) Body temperature of selected amphibian and reptile species. **Journal of Zoo and Wildlife Medicine 43**(3): 517-521. doi: 10.1638/2011-0244R.1

Rutskina IM, Litvinov NA, Roschevskaya IM, Roshchevskii MP (2009) Temperature adaptation of the heart in the Grass Snake (*Natrix natrix* L.), Common European Viper (*Vipera berus* L.), and Steppe Viper (*Vipera renardi* Christoph) (Reptilia: Squamata: Serpentes). **Russian Journal of Ecology 40**(5): 314-319.

Schmidt-Nielsen K (2002) **Animal Physiology. Adaptation and Environment.** Cambridge, University Press, 5th ed., 613p.

Seymour RS (1987) Scaling of cardiovascular physiology in snakes. **American Zoologist 27**(1): 97-109.

Stuginski DR, Fernandes W, Grego KF (2011) Parâmetros eletrocardiográficos de cascavéis (*Crotalus durissus*, Linnaeus, 1758) em cativeiro. **Archives of Veterinary Science 16**(3): 31-37.

Valentinuzzi ME, Hoff HE, Geddes LA (1969a) Electrocardiogram of the snake: effect of the location of the electrodes and cardiac vectors. **Journal of Electrocardiology 2**(3): 245-252.

Valentinuzzi ME, Hoff HE, Geddes LA (1969b) Observations on the electrical activity of the snake heart. **Journal of Electrocardiology 2**(1): 39-50.

Vanzolini PE, Ramos-Costa AMM, Vitt LJ (1980) **Repteis das caatingas.** Rio de Janeiro, Academia Brasileira de Ciências, 161p.

Wang T, Taylor EW, Andrade D, Abe AS (2001) Autonomic control of heart rate during forced activity and digestion in the snake *Boa constrictor*. **Journal of Experimental Biology 204**: 3553-3560.

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