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Topical Review

Scaling Relationships Among Heart Rate, Electrocardiography Parameters, and Body Weight

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Although heart rate (HR) is one of the most important clinical parameters determined via physical examinations, little information is available on the normal HR in dogs, which may be related to the high variability of body weight (BW) in this species. HR is determined by the discharge rate of the sinus node, which is dependent on the autonomic nervous system and the release of catecholamines. The allometric relationship between BW and HR in different species has been described as inversely proportional; however, this relationship has been refuted. Certain authors have reported that the relationship between HR and BW in dogs is based on temperament as well as sympathetic autonomic stimulation of the sinus node in small breeds compared with large breeds. The aim of this study was to analyze the effects of weight, sex, age and temperament on the HR, heart rate variability and serum catecholamine (epinephrine and norepinephrine) levels in dogs. We evaluated 48 adult dogs of both sexes and various breeds and ages and divided the dogs into 5 BW groups: <5 kg ($n = 8$), 5-10 kg ($n = 10$), 10-25 kg ($n = 10$), 25-45 kg ($n = 10$), and >45 kg ($n = 10$). The measured parameters were HR, breath rate (BR) and body temperature. We also performed an ambulatory electrocardiogram and electrocardiography (ECG) test for 24 hours (Holter monitor) and determined the serum levels of the catecholamines epinephrine and norepinephrine. We observed correlations between HR and sex; differences among the weight groups with respect to ECG variables and epinephrine levels; and differences among the temperament categories for certain clinical parameters, such as HR and BR. Age affected the R wave amplitude, and an allometric relationship was not observed between HR and BW in the dogs. Our results indicated that weight was associated with variations in the ECG variables; age and sex were associated with variations in HR; and temperament had a significant influence on the HR and BR of the dogs.

Introduction

In mammals, the specific metabolic rate (i.e., the metabolic rate per unit mass) decreases with increasing body size. Thus, metabolic rates are higher in small animals (such as mice) and lower in large animals (such as elephants). This inverse relationship occurs because the increased relative need for oxygen and blood flow in small animals results in significantly elevated heart rates (HRs).[1]

The association between metabolic rate and body weight (BW) has been widely studied, and metabolic rates are considerably higher in birds than expected based on direct proportionality alone.[2] Because an animal's rate of metabolic heat production is associated with the rate at which heat is dissipated through its body surface area (BSA), BSA appears to be more appropriate for expressing the relationship between size and specific metabolic rate.[3,4]

The autonomic nervous system is defined as the peripheral motor system and subdivided into the sympathetic and parasympathetic nervous systems, which maintain homeostasis in the body.[5] The sympathetic control of the heart is mediated by adrenergic receptors, which are activated through the release of norepinephrine and epinephrine. Adrenergic receptor activation affects HRs by increasing the frequency of the pacemaker and the conduction velocity, thereby reducing the refractory period. Moreover, cardiac contractility is increased, and the overall effects are increased HR and stroke volume.[6]

The parasympathetic effects on the heart are mediated by the neurotransmitter acetylcholine, which activates muscarinic cholinergic receptors. Parasympathetic activation efficiently reduces cardiac pacemaker frequency and cell-to-cell conduction velocity and increases the refractory period, thereby decreasing HRs.[7]

The analysis of heart rate variability (HRV) enables the observation of cardiac cycle fluctuations that occur over short or long periods and the noninvasive and selective observation of autonomic function.[8] The discovery of the relationship between the autonomic nervous system and cardiovascular morbidity promoted a greater number of studies on the increased sympathetic activity and reduced parasympathetic activity found in cardiovascular system diseases as well as the development of quantitative

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markers of cardiac autonomic activity, with HRV emerging as the most promising marker.[9,10]

Research on behavior and psychology in animals is of increasing interest because of its relevance to animal welfare. An emotion is an intense response to a short-duration event, and emotions are controlled by several different mechanisms simultaneously. Emotions are based on the activation of neural circuits in the brain that have evolved to provide greater cognitive and social assessment of the surrounding environment.[11]

The aim of this study was to investigate the relationship between HR and BW as well the influence of BW on clinical parameters, electrocardiography (ECG) variables (P wave, QRS complex, and T wave) and HRV. Additionally, we analyzed the influence of sex, age and temperament on HR, HRV and serum catecholamine (epinephrine and norepinephrine) levels in dogs.

Materials and Methods

Animals

This project was approved by the Ethics Committee on Animal Use under protocol number 41/2013-CEUA.

We evaluated 48 adult dogs of both sexes and various breeds and ages. The animals were divided into 5 BW groups, according to the information obtained through a consultation with the American Kennel Club, which considers the following weight ranges small, medium and large. We divided the animals according to BW, aiming not to group animals of different sizes in the same group, but rather animals of similar sizes in the same group so that the size did not interfere in our results. To evaluate the influence of BW on HR: group 1: <5 kg (8 animals), group 2: 5.1-10 kg (10), group 3: 10.1-25 kg (10), group 4: 25.1-45 kg (10) and >45.1 kg (10). Information on the diet and physical activity was obtained from the owners.

The inclusion criteria for the dogs used in the study were animals that were not receiving any kind of medicine or drug and animals that, according to the owners, did not present any kind of disease. All animals that received any kind of continuous medication and animals whose health was compromised in any way were excluded from the study.

The animals used in the study presented ideal body scores according to the size of the breed. No athlete dogs or dogs that were overweight or underweight were selected to avoid compromising the results.

Allometric scaling appears to govern HR across species; accordingly, logarithmic equations have been proposed to represent the relationship between HR and BW, such as $HR = 241 \times BW^{-.25}$.[12,13] We used this equation to evaluate the relationship in this study.

BSA was calculated as follows: $BSA\ (m^2) = (10.1 \times BW^{0.67}) \times 10^{-4}$, where BW is measured in grams.

The evaluation of temperament was performed as follows:

(1) After a period of acclimation lasting approximately 10 minutes, the demeanor of each dog was assessed via simple observations (hands-off). Dogs were scored as appearing calm-relaxed, nervous-aggressive, or excited-restless.
(2) The dogs' owners completed a questionnaire regarding the demeanor and temperament of the animals at home and in relation to animals and people who were not part of their household environment.

To classify the animals according to temperament, we used the information obtained from the questionnaires in tandem with our own observations regarding their behavior during their stay in the hospital (at first before handling and later during handling) to obtain the data for the study. These pieces of information were considered and the animals were divided in groups according to temperament.

In this study, when we mention HR Behavior, we point toward how the HR values (high HR or low HR) behave in each particular category under analysis (temperament: restless and unquiet animals tend to have higher HRs?; gender: do males or females have higher HRs; age: older animals tend to have lower HRs?) and whether there are significant differences for the variables under study. We have inserted a description of HR behavior in the study.

Experimental Design

Clinical Evaluation

After weighing, the dogs were sent along with their owners to the cardiac evaluation room.

The examination was always conducted in the same room, and the temperature was maintained between 20°C and 22°C by automatic air conditioning. HRs were counted over a period of 1 minute of cardiac auscultation and simultaneous palpation of the femoral pulse at the end of the routine physical examination (hands-on) immediately before the measurement of rectal temperature, which was performed using an electronic digital thermometer.

Ambulatory Electrocardiographic Examination

The dogs were subjected to ECG examination using a computerized ECG[1] that consisted of an electronic circuit that was connected externally to a computer, which was installed with standard software. After the ECG examinations, the ECG parameters were analyzed using the software.

The animals were confined manually. Each dog was positioned in the right lateral decubitus position on a table, with the forelimbs and hindlimbs maintained at right angles to the longitudinal axis of the spine. Electrodes were placed on the skin over the elbow and stifle as standardized by.[14] Three bipolar leads (I, II, and III) and 3 augmented unipolar leads (aVR, aVL, and aVF) were recorded. After the ECG recording, the results were interpreted from lead II by analyzing the following parameters: HR (bpm), electrical axis in the frontal plane (by measuring the algebraic sum of the QRS deflections in lead I and lead III) (degrees), and waves and intervals (P wave = duration [ms] and amplitude [mV]; PR interval [ms]; QRS = duration [ms]; R wave = amplitude [mV]; QT [ms]; polarity of T-wave [positive, negative, or biphasic]; and ST [elevation, depression, or isoelectric]).

Hormonal Determination of Serum Catecholamines: Epinephrine and Norepinephrine

To analyze the epinephrine and norepinephrine levels, blood samples (5 mL) were collected by venipuncture, placed in tubes for biochemical examination and centrifuged within 30 minutes after collection. Serum was aliquoted and stored at −20°C until hormone determination. The concentrations of catecholamines in the serum were determined and quantified by enzyme immunoassay using the Canine Noradrenaline and Epinephrine ELISA Kit (MyBioSource[2]). The final values after conversion were expressed in pg/mL.

Dynamic Electrocardiogram Examination (Holter)

The ECG recordings over 24 hours (Holter monitoring) were performed last and included the continuous recording of 3 ECG channels in the modified pre-cordial leads (V1, V3, and V5) using a digital apparatus (Cardio Light[3]) with an electromagnetic design