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# Sleeping respiratory rates in apparently healthy adult dogs

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ABSTRACT

Respiratory rate monitoring of cardiac patients is recommended by many cardiologists. However, little objective data exist about respiratory rates in apparently healthy dogs when collected in the home environment. We measured sleeping respiratory rates (SRR) in apparently healthy dogs and compared sleeping and resting respiratory rates (RRR) with a cross-sectional prospective study. Participants collected 12–14 one-minute SRR over a period ranging from 1 week to 2 months on 114 privately owned adult dogs. Selected participants simultaneously collected RRR. Mean within-dog average SRR ($SRR_{mean}$) was 13 breaths per minute (breaths/min). No dog had $SRR_{mean}$ >23 breaths/min; three dogs had instantaneous SRR measurements >30 breaths/min. Dogs had higher $RRR_{mean}$ (19 breaths/min) than $SRR_{mean}$ (15 breaths/min) ($P < 0.05$). Canine $SRR_{mean}$ was unaffected by age, bodyweight or geographic location. Data acquisition was considered relatively simple by most participants. This study shows that apparently healthy adult dogs generally have $SRR_{mean}$ <30 breaths/min and rarely exceed this rate at any time.


## 1. Introduction

Left-sided congestive heart failure (CHF) is a syndrome characterized in dogs by development of pulmonary congestion and edema secondary to severe left heart disease (Kittleson, 2010). Clinical signs of CHF include coughing, orthopnea, and/or varying degrees of tachypnea, ranging from mild subtle signs with slowly progressing CHF to marked signs with severe and acute CHF (Kittleson, 2010). Diagnosis of CHF often relies on results from several tests, and traditionally requires the demonstration of severe cardiac disease, radiographic evidence of pulmonary interstitial or alveolar opacity and consistent clinical signs. However, even radiologists show only fair-to moderate agreement when assessing radiographs for presence of radiographic patterns consistent with pulmonary edema, pleural effusion or a final radiographic diagnosis of CHF (Hansson et al., 2005, 2009; Schober et al., 2010).

Over the last two decades, biomarker changes have been proposed as adjunct diagnostic tests for identification of CHF in dogs (Haggstrom et al., 1994; MacDonald et al., 2003; Boswood et al., 2008; Oyama et al., 2008), however, no studies exist demonstrating their clinical utility in this setting and a recent study found that N-terminal pro-Brain Natriuretic Peptide (NT-proBNP) did not reach significance in a final multivariable regression model for predicting CHF (Schober et al., 2010). In that same study, resting respiratory rate (RRR) proved the most sensitive and specific single diagnostic test for identifying CHF as a cause of clinical signs in dogs with heart disease and was an independent variable in predicting CHF in multivariable regression analysis (Schober et al., 2010). A further study demonstrated that resolution of the CHF resulted in a reduction in respiratory rate into pre-CHF ranges (Schober et al., 2011). Thus, respiratory rate has the potential of being a more sensitive, albeit unspecific, indicator of developing or recurring CHF than radiographs, coughing, other more overt clinical signs or even biochemical biomarkers. Continued, frequent monitoring of this clinical variable could allow more timely therapeutic intervention or modulation in animals with known prior history of CHF or severe subclinical heart disease (e.g. those with marked left atrial enlargement). Many veterinary cardiologists currently recommend monitoring respiratory rates in subclinical canine and feline cardiac patients to help determine either the onset of CHF in a previously subclinical patient, or to monitor effectiveness of CHF therapy in patients with prior history of CHF (personal communication). Anecdotally, veterinary clinicians have suggested that a sleeping respiratory rate (SRR) <30 breaths/minute excludes CHF as a cause of clinical signs; however, to the best of the authors' knowledge, no data exist confirming this threshold value.

Therefore, we sought to characterize SRR in apparently healthy adult dogs. Additionally, we compared SRR and resting respiratory rate (RRR) in a subset of these subjects.

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## 2. Materials and methods

### 2.1. Data

We recruited pet owners (most commonly clinicians and veterinary students) with apparently healthy dogs to collect SRR from their pets by emailing class lists at several veterinary schools, emailing the membership of the Veterinary Information Network, and asking colleagues, acquaintances, clients and friends to provide data on their pets. Data collection began in December 2009 and ended in October 2010. Participants were recruited from various regions of the United States, Sweden, Italy and Israel. Institutional approval was not sought, as this study was purely observational, voluntary and non-invasive, and as such, required no institutional approval.

We excluded dogs with either a history or any clinical evidence of cardiac disease, other severe systemic diseases and age <6 months. Participants' pets did not undergo individual physical examinations, echocardiographic evaluation or any other diagnostic tests prior to inclusion, but required an owner history of cardiovascular health and a physical examination by their regular veterinarian within the previous 12 months. Additionally, because no dog underwent a comprehensive cardiovascular evaluation prior to inclusion, we contacted all participants 18–24 months after data submission to determine if their pets (A) had developed any signs of cardiac or respiratory disease in the intervening period and (B) had an unremarkable cardiac auscultatory examination in the intervening period.

Participants collected 12–14 measurements of respiratory rate from their pets in their home environment during "deep sleep" by counting breaths for one minute. Owners were instructed to avoid measuring SRR when pets were in "active motor sleep" (paddling, twitching, or vocalizing periods). No more than two measurements per day were allowed (therefore, the most rapid data acquisition would take 1 week), and there was no upper limit to the time over which collection could occur. During periods of data collection, animals were to be kept in a "thermoneutral" environment, meaning that extremes of heat and cold should be avoided, but temperature ranges that would be acceptable were not specified, and participants did not record ambient room temperatures at the time of collection.

Participants recorded date of birth (approximated if not known), gender and reproductive status, bodyweight, body condition score, breed and respiratory rates. A subgroup of participants also rated the difficulty of data collection on a 4-point scale. An additional subgroup of participants also recorded resting respiratory rates (RRR) during the same collection period (i.e. the period between the first and last SRR measurement), to allow within-animal comparison of SRR and RRR. These participants were recruited sequentially starting part-way through the study. No specific selection criteria were used to identify these participants, and RRR data collection was considered "optional". "Resting" was defined as conscious relaxed recumbency not immediately following extreme exercise or strenuous activity and not during periods of excitement. Participants measured RRR for a minimum of 10 observations, in using a protocol identical to that for SRR.

### 2.2. Statistical method

We provided descriptive statistics for the variables of interest, including the within-dog mean SRR ($SRR_{mean}$) and standard deviation ($SRR_{sd}$), as well as the maximum and minimum within-dog SRR. These variables were calculated as follows: a within-dog mean, standard deviation (SD), maximum and minimum SRR and coefficient of variation (CV) were calculated from each of the 12–14 measurements provided by the owners. These within-dog averages were then examined by means of box-and-whisker plots to describe the data distribution for the between-dog SRR means, SD, maxima, minima, and CV for the entire sample population. We performed simple linear regression analysis to examine the effect of age and bodyweight on SRR after analyzing the data for Normality using a Shapiro–Wilk test, and log-transforming data that failed to demonstrate Normality. We examined the plots of the standardized residuals against the predicted values, and the Normal probability plots of the residuals to confirm normality, homoscedasticity and linearity of the data. To compare the effect of geographical location on SRR we performed a Kruskal–Wallis analysis, with Bonferroni-corrected rank sum tests (for subsequent pair-wise comparisons).

To examine the possibility of significant increases or decreases in SRR over the collection period for each participant, we examined the intra-dog coefficients (slopes) of the regressed data. A slope not different from zero would suggest that there was no systematic increase or decrease in SRR over the collection period. We examined within-dog slopes by a one sample *t*-test to determine if the average slope differed from zero.

Finally, we compared SRR with RRR in a small subset of dogs with a Wilcoxon signed-ranks test.

We set an experiment-wise error rate at $\alpha = 0.05$. Because we performed five separate statistical tests, for each test we set the comparison-wise error rate at $\alpha = 0.01$. All analyses were performed using commercial statistical software (Statistix 9.0, Analytical Software, Tallahassee, FL).

## 3. Results

We obtained data on 114 dogs ranging from 3 to 49 kg (median: 22 kg). The dog breeds represented by more than four individuals consisted of "mixed breed" ($n = 34$), Labrador ($n = 12$), Cavalier King Charles Spaniel ($n = 12$), Border Collie ($n = 8$) and Golden Retriever ($n = 5$). Sixty-nine dogs were female and 45 dogs were male. Dog ages ranged from 7 to 183 months (median: 59 months). Date of birth for one dog was not available. Using a 5-point scale for body condition, 12 dogs were considered thin, 82 were considered normal, 10 were considered overweight, and no dogs were considered either emaciated or obese (data were not provided for 10 dogs). The data distribution across the four locations is shown in Table 1. Five participants provided less than 12 data points for their dogs. In one of the dogs only nine data points were provided and examination of these data showed an escalating SRR over the period of collection. No comments were provided by the participant for the abbreviated collection, and we elected to exclude this subject from the analysis, even though the $SRR_{mean}$ and maximum SRR of this subject were within the 95% confidence interval for the remaining 113 dogs.

We emailed all 114 participants approximately 18–24 months after the original data collection period to determine whether any of the dogs included in the study had developed cardiac or

**Table 1**
Geographical distribution of dogs used to acquire sleeping respiratory rates.

| Geographical location | Dogs | |
|---|---|---|
| | Male | Female |
| USA | 25 | 30 |
| Israel | 5 | 8 |
| Sweden | 4 | 25 |
| Italy | 11 | 5 |
| Total | 45 | 68 |