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Original Article

Respiratory rate of clinically healthy cats measured in veterinary consultation rooms

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ABSTRACT

Respiratory rate is commonly recorded during physical examinations. However, reference intervals are only available for resting and sleeping respiratory rates in cats at home. This observational study aimed to establish reference intervals for the respiratory rate in clinically healthy adult cats at primary-care veterinary clinics. Respiratory rates were recorded from 131 cats, in 6 primary-care veterinary clinics, by observation under four circumstances: by the investigator in the consultation room prior to and during a physical examination, by the owner at home when the cat was resting or sleeping, and by the investigator when watching a video-film of the cat recorded by the owner at home.

The respiratory rate of the 88 clinically healthy adult (≥12 months) cats in the consultation room ranged 28–176 breaths/min (median 64) with a calculated reference interval of 32–135 breaths/min. Based on video-recordings, the resting ($n = 32$) and sleeping ($n = 38$) respiratory rates of the same cats were determined: median 27 (range 16–60) breaths/min and median 20 (range 9–28) breaths/min, respectively, which were lower than the respiratory rates recorded in the consultation room (both $P < 0.0001$). We conclude that the reference intervals proposed for cats in textbooks reflect the resting respiratory rate at home. These values are inappropriate for using in the veterinary consultation room, because based on such reference intervals, many cats would erroneously be categorized as having tachypnea. Since the resting and sleeping respiratory rates at home show less variation, owners should be encouraged to film their pets before they visit their veterinarian.

Introduction

Respiratory rate is one of the most commonly assessed physiologic parameters taken by veterinarians on a daily basis, in each species, including cats. Increased respiratory rate can be caused by numerous physiologic and pathologic disorders, such as stress, hyperthermia, pain and diseases of several organ systems (Sigrist et al., 2011). Identifying a respiratory rate as increased (i.e. tachypnea) requires a reference interval, derived from a large cohort of healthy cats. Two studies have reported the respiratory rates of cats with subclinical and clinical heart disease in the home environment (Ljungvall et al., 2014; Porciello et al., 2016). Additionally, one study describes the effect of hospital visits on the respiratory rate and other physiologic variables in 30 apparently healthy cats (Quimby et al., 2011). However, a reference interval for respiratory rates of cats in veterinary consultation rooms is lacking. Our impression is that the reference intervals recommended in textbooks (20–40 breaths/min) is inappropriate for use in outside home environments (Rijnberk and Stokhof, 2008).

Therefore, we sought to establish reference intervals for the respiratory rate in cats outside the home environment. We counted the respiratory rates of apparently clinically healthy, client-owned cats brought to primary-care veterinary clinics in the consultation room and had owners count and video-record respiratory rates at home. We hypothesized that respiratory rates of clinically healthy cats at home would be lower than in the consultation room during a veterinary examination.

Materials and methods

Animals and inclusion criteria

Healthy client-owned cats were enrolled in this prospective descriptive field study. Cats were considered to be clinically healthy based on their medical files, medical history, general appearance and physical examination. If cats did not have a physical examination at the time of respiratory rate evaluation, we considered them as *assumed healthy* based on their medical files, general appearance and their owners' opinion. Physical examination consisted of evaluation of the respiratory rate, respiratory type and respiratory effort, assessment of the femoral pulse

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(quality, rhythm and frequency), the hair-coat, the skin, the mucous membranes and the lymph nodes. In addition, abdominal palpation and thoracic auscultation were carried out in each animal. Rectal temperature was measured only in some cats. The respiratory rate was measured by inspection only (hands-off), without restraint or manipulation, prior to the onset of physical examination, when the cat was still in its carrier in the consultation room. Examination of the hair-coat and the skin included screening for flea infestation using a flea comb in each cat.

Exclusion criteria were the presence of a known disease, pregnancy, lactation, abnormalities found during the physical examination, and purring while taking the respiratory rate. The respiratory rate of cats that underwent surgery (e.g. neutering) and/or anesthesia were taken at home at least 2.5 weeks after the event to minimize the effect of any factors on the respiratory rate, such as pain and discomfort.

Age, gender, breed and the reason for visiting the veterinarian were recorded. The gender at the time of the first respiratory rate collection was used. Cats were classified either as adult (≥12 months of age) or as young (<12 months).

Data collection

Data collection took place in 6 primary-care veterinary clinics, in the cities and outskirts of Amsterdam and Utrecht in the Netherlands over a period of 3 months between May and August 2016. All clinics had one waiting room and 1–2 consultation rooms with ongoing consultations. Patients included dogs, cats and small exotic animals. None of the veterinary clinics took special measures to comfort their feline patients (e.g. by using feline facial pheromones, a separate waiting room or feline consultation hours).

Data collection on each individual cat occurred in two locations (in the veterinary clinic and at home) and in both locations under two circumstances. In the veterinary clinic, the respiratory rate was obtained by a single investigator (ED) before any handling (such as physical examination) of the cat took place (1st measurement, referred to hereafter as 'ambulatory' rate). During this measurement the cat was still in its carrier or transporter and had not been handled. Thereafter, each cat was examined by the attending veterinarian. If the circumstances allowed (e.g. no sniffing by the cat or no handling by the veterinarian/technician blocking the investigator's view), counting the respiratory rate was repeated during this examination (2nd measurement). This second measurement took place always before measuring rectal temperature or performing additional investigations (such as blood pressure measurement or blood sampling).

Ambulatory respiratory rates were recorded only if counted for at least 15 s. If the investigator could repeat the respiratory rate counting under the same circumstances, the two measurements were averaged.

Immediately after completing the veterinary visit, the investigator asked each pet owner to record a video-film of at least 15 s of their cat using their mobile phone at home when the cat was sleeping (or resting) in sternal or lateral recumbency (3rd measurement), and to count the respiratory rate for 30 s immediately after filming while the cats were still sleeping or resting (4th measurement). Owners were asked to count the respiratory rate without touching their cats (i.e. the same way as it was done at the veterinary clinics), preferably when the cats were sleeping. Owners who had difficulties observing their cats sleeping were allowed to record resting respiratory rates. Owners were asked to avoid collecting data when the cat was obviously purring. Additionally, each owner received a one-page printed letter with instructions about how and when to record and count the respiratory rate of her/his cat, and where to send the video-recording (electronically) and the data. The owners were specifically asked to note whether the measurement was of a sleeping or a resting cat.

This study was purely observational and required no extra handling of the cats than already planned for the original consult, therefore no institutional approval was acquired. All owners signed an informed consent.

Statistical methods

All statistical analyses in this study were performed with commercially available statistical software (SPSS v23.0; IBM Statistics, IBM and MedCalc Statistical Software version 18, MedCalc Software bvba). P values < 0.05 were considered statistically significant.

D'Agostino-Pearson tests were used to investigate whether the data were normally distributed. If the data showed no normal distribution, logarithmic transformation was done, and the same test was run again to evaluate normal distribution of the transformed data. Data are presented as median and range. Comparisons between measurements was performed using a Wilcoxon signed rank test.

Effects of age and gender on the respiratory rate were analyzed with regression analysis (general linear regression) on the log-transformed data. MedCalc statistical software was used to investigate if reference intervals could be modelled for different age groups, based on the method described by Altman (Altman, 1993).

Table 1
Characteristics of the study population.

Age	Adult cats clinically healthy (n = 88) Median (range)	Adult cats assumed healthy (n = 18) Median (range)	Young cats clinically healthy (n = 24) Median (range)	Young cats assumed healthy (n = 1)
	5.1 (1.0–17.0) years	3.2 (1.1–17.1) years	4.0 (3.0–11.4) months	10.6 months
Sex				
Female neutered	41	10	4	
Male neutered	41	7	2	
Female intact	5		9	
Male intact	1	1	9	1
Breed				
Domestic shorthair	71	12	7	1
British shorthair	2	2	3	
Siamese	2			
Bengal	1		4	
Maine coon	1		1	
Ragdoll		1	1	
Persian shorthair	1			
Norwegian forest	1			
Birman	1			
Oriental shorthair	1		1	
Savannah			1	
Mixed breed	8	3	6	
Reason for consultation				
Vaccination	75		14	
Dental examination		14		1
General health check	4			
Neutering	1		4	
Dental cleaning	3			
Removal of sutures	1		1	
Deworming		1		
Tick removal		1		
Nail clipping			1	
Grooming	1			
Microchip placement		1		
Recheck appointments	3	1	4	

Reference intervals were estimated by using the following methods: (1) for normally distributed parameters by calculating the mean ± 1.96 standard deviation of the original data, or of the logarithmically transformed data if they were normally distributed after transformation, and thereafter back-transformed to the original units; or (2) using a non-parametrical percentile method for all other data that were not normally distributed (even after logarithmic transformation; Bland, 2015; CLSI, 2008).

Results

We screened 142 cats and excluded 11, based on the predefined exclusion criteria: one because of lactation, six because of a cardiac murmur and four because of evidence of disease (diabetes mellitus, $n = 1$; hyperthyroidism, $n = 1$; chronic renal failure, $n = 1$; upper airway infection, $n = 1$). Therefore, the study population consisted of 131 cats, of which 106 were adult (≥12 months) and 25 were young (<12 months). Of the adult population 88 cats were classified as clinically healthy and 18 assumed healthy. The population characteristics and the reasons for the veterinary consultations are shown in Table 1.

All cats in the current study showed costo-abdominal or shallow breathing, without respiratory noise (i.e. stridor or stertor). One cat showed intermittent open mouth breathing at the beginning of the consultation, but had no other clinical abnormalities detected on physical examination.

Ambulatory, sleeping and resting respiratory rates did not differ between healthy and the assumed healthy cats ($P = 0.088$, $P = 0.287$, $P = 0.480$, respectively); however, we used only the data from healthy cats for calculating reference intervals. Data from the assumed healthy and the young cats were included only in the comparisons between the two observers (i.e. owner versus investigator).

The ambulatory respiratory rate in the 88 clinically healthy adult cats ranged between 28 and 176 breaths/min, with a median of 64 breaths/min (Fig. 1). Reference intervals for ambulatory respiratory rate in adult cats were 32–135 breaths/min (90% confidence intervals [CI] 29–36 and 120–150, respectively).

Repeated measurement of the ambulatory respiratory rate during handling (physical examination) was completed in 22 clinically healthy adult cats. The median age of these cats was 6.4 years, with a range of 1.7–16.1 years. After handling, ambulatory respiratory rates (median 32 breaths/min, range 32–141 breaths/min) did not differ from those before handling ($P = 0.651$). However, we noted individual differences: three cats (14%) showed no change, eleven cats (50%) showed an increase and eight cats (36%) showed a decrease in respiratory rate during handling

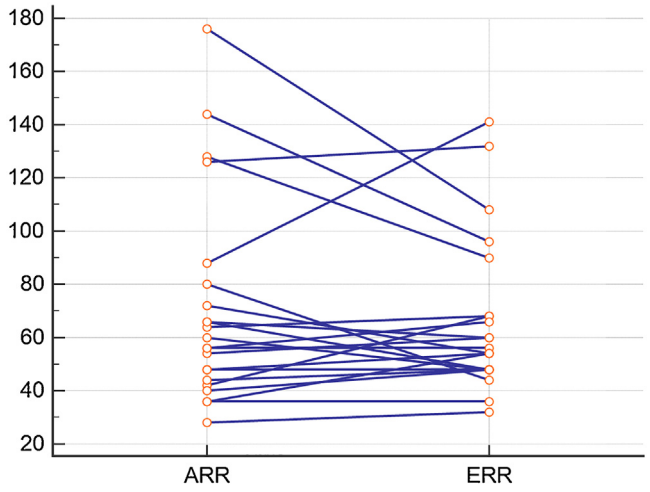

Fig. 2. Conjoined dot plot of respiratory rates of 22 clinically healthy adult cats before (ambulatory respiratory rates, ARR) and during physical examination (examination respiratory rates, ERR) at the veterinarian's consultation room. Examination resulted in increased ($n = 11$), decreased ($n = 8$) or unchanged ($n = 3$) respiratory rates. Respiratory rates changed from 28 to 176 breaths/min (median 28 breaths/min) before handling to 32 to 141 breaths/min (median 32 breaths/min) during physical examination ($P = 0.651$). The greatest increase was 53 breaths/min and the greatest decrease was 68 breaths/min.

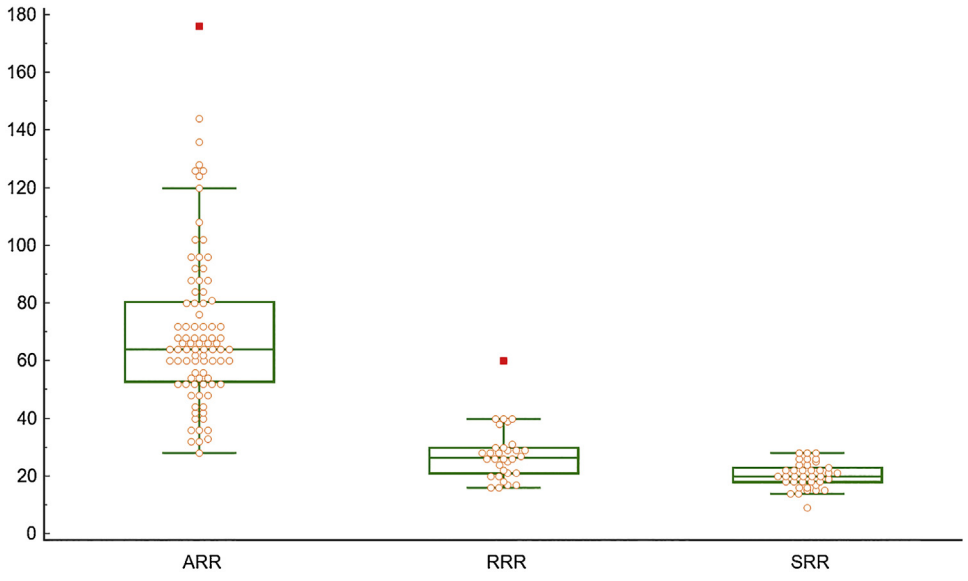

Fig. 1. Box and whisker plots showing (left to right) the ambulatory respiratory rates (ARR) of 88 clinically healthy adult cats (median 64 breaths/min; range 28–176 breaths/min); resting respiratory rate (RRR) of 32 clinically healthy adult cats at home, based on video-films recorded by the owners (median respiratory rate 27 breaths/min; range 16–60 breaths/min); sleeping respiratory rate (SRR) of 38 clinically healthy adult cats at home, based on video-films recorded by the owners (median respiratory rate 20 breaths/min; range 9–28 breaths/min). The central box represents the values from the lower to upper quartile (25–75 percentile); the middle line represents the median; and the vertical line extends from the minimum to the maximum value, excluding 'outlier' values which are displayed as separate points. An outlier was defined as a value that is smaller than the lower quartile minus 1.5 times the interquartile range, or larger than the upper quartile plus 1.5 times the interquartile range (inner fences). A distant outlier (red square) is defined as a value that is smaller than the lower quartile minus 3 times the interquartile range, or larger than the upper quartile plus 3 times the interquartile range (outer fences).

(Fig. 2). The greatest increase was 53 breaths/min and the greatest decrease was 68 breaths/min.

Of the 131 owners, 113 (86%) obtained a video-recording at home and sent it to the investigator. Of these, only five (4%) were unusable for evaluation at first submission. Data from assumed healthy and young (<12 months) cats were excluded from the following analysis. Therefore, we evaluated 70 video-recordings of 88 clinically healthy adult cats: 38 documented sleeping and 32 documented resting respiratory rates at home. Resting respiratory rate at home ranged from 16 to 60 breaths/min with a median of 27 breaths/min (Fig. 1). Resting respiratory rate exceeded 40 breaths/min in only one cat. Reference intervals for resting respiratory rate were 14–48 breaths/min (with a 90% CI of 12–17 and 41–56 breaths/min, respectively). Sleeping respiratory rates at home ranged from 9 to 28 breaths/min with a median of 20 breaths/min (Fig. 1). Reference intervals for sleeping respiratory rate were 11–29 breaths/min (90% CI 9.6–13.7 and 26.8–30.9).

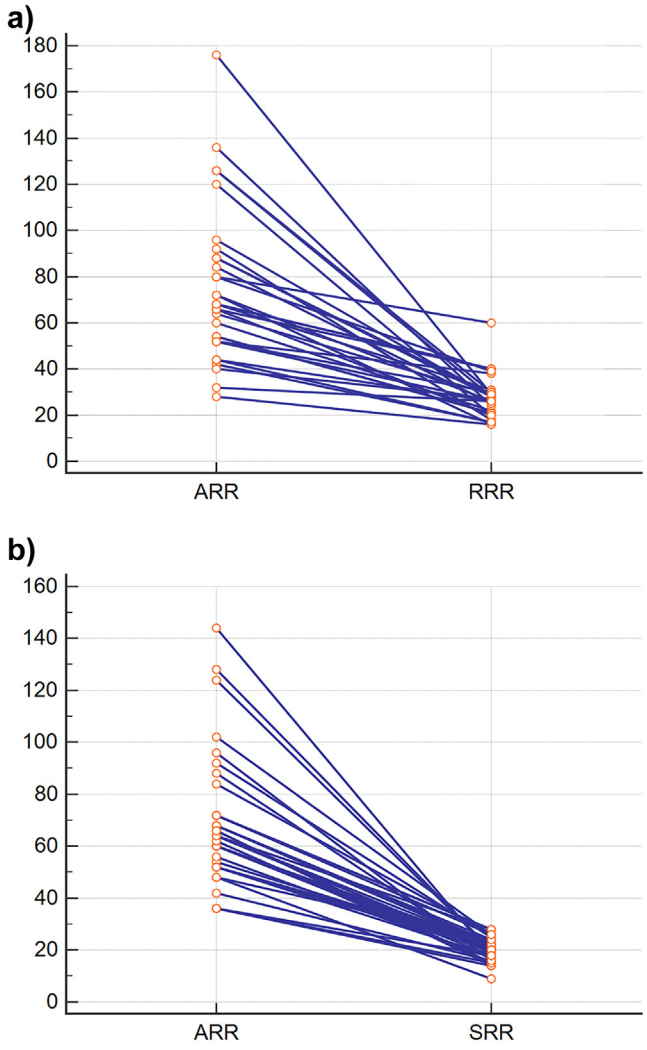

Fig. 3. A. Conjoined dot plot showing the difference in the respiratory rates of 32 clinically healthy adult cats in the consultation room (ambulatory respiratory rates, ARR) and at home when the cats were resting (resting respiratory rate, RRR). The ambulatory respiratory rates are higher ($P < 0.0001$) and show less variation compared to the resting rates. B. Conjoined dot plot showing the difference in the respiratory rates of 38 clinically healthy adult cats in the consultation room (ARR) and at home when the cat was sleeping (sleeping respiratory rate, SRR). The ambulatory respiratory rates (ARR) were higher ($P < 0.0001$) and showed less variation than the sleeping rates.

Ambulatory and resting respiratory rates, and ambulatory and sleeping respiratory rates of clinically healthy adult cats differed significantly ($P < 0.0001$ for both comparisons; Fig. 3).

Neither ambulatory nor resting respiratory rates of clinically healthy adult cats correlated with age ($P = 0.717$ and $P = 0.420$, respectively). Consequently, we could not model different reference intervals for cats of different age categories. Ambulatory, resting and sleeping respiratory rate of clinically healthy adult cats showed no gender-related associations ($P = 0.244$, $P = 0.022$ and $P = 0.962$, respectively).

The owners of 28 of the 131 cats (21%) provided resting or sleeping respiratory rate counts of their cats at home by direct hands-off observation. These measurements did not differ from measurements obtained by the investigator from corresponding video-recordings on group level ($P = 0.362$), but in some instances, we noted marked inter-observer variability (Fig. 4). Differences between the two observers (owner and clinician) in the resting respiratory rate ranged from −21 to +10 breaths/min (median difference: 0 breaths/min); differences in the sleeping respiratory rate ranged from −4 to +11 breaths/min (median difference: 1.8 breaths/min).

Discussion

Our study shows that healthy cats have higher respiratory rates in the consultation room prior to any handling, compared to the resting or sleeping respiratory rates in the same cats at home. Furthermore, the reference intervals based on these data for respiratory rates in clinically healthy adult cats in the consultation room extend from 32 to 135 breaths/min. This suggests that using commonly proposed reference intervals is inappropriate when measuring respiratory rate during a physical examination.

A high respiratory rate at the veterinarian's consultation room can be explained with a higher excitement level when awake (compared to sleeping) and when stressed by being taken to a veterinary clinic (as opposed to being at home). Differences in excitement levels in cats between home and hospital environments have been demonstrated in several studies, and showed not only a considerable individual variation, but also remarkable

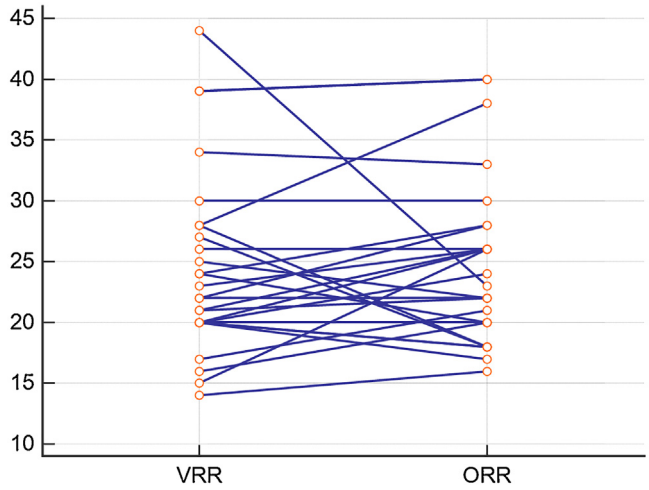

Fig. 4. Conjoined dot plot showing the difference between the recorded respiratory rate (video respiratory rate, VRR; filmed by owner, counted by the investigator) and the observed respiratory rate (ORR; direct observation by the owner). The data points indicate resting or sleeping respiratory rates of cats at home. Though no statistically significant difference between the two groups was found ($P = 0.362$), in many cases there is a clinically relevant difference between the findings of the two observers ranging from −21 to +11 breaths/min.

differences within the same cat among various visits (Belew et al., 1999; Abbott 2005; Quimby et al., 2011). In a recent study, a mean increase in respiratory rate of 12 breaths/min, with a range of −30 to +108 breaths/min, was observed at the veterinary hospital compared to respiratory rates counted at home (Quimby et al., 2011). The same study reported a median respiratory rate of 58 breaths/min (range 18–192) in the consultation room and an at-home respiratory rate of 50 breaths/min (range 24–84) of the 28 observed cats (Quimby et al., 2011). These findings are similar to those we observed. Though the respiratory rates in the previous study were measured with visual observation both in the home environment and at the veterinary clinic, all cats had undergone a blood pressure measurement and a cardiac auscultation immediately before recording of the respiratory rates (Quimby et al., 2011). Conversely, we performed the base line observation prior to removing the cat from the carrier. Nevertheless, the respiratory rates we measured after performing a physical examination did not differ from those measured at baseline, suggesting that in most cats, the timing of the in-clinic measurements might not be important.

The high and wide range of respiratory rates of healthy cats recorded in veterinary clinics can be explained with the difficulty of recognizing panting in cats, which, unlike dogs, often keep their mouth closed. Once the respiratory rate exceeds 50–60 breaths/min in cats, the duration of inspiration and expiration becomes equal (Jennings and Szlyk, 1985). Compared to dogs, cats have a smaller range and an earlier transition from the resting situation (i.e. when the duration of expiration exceeds that of the inspiration) to the stage when expiration and inspiration are of equal duration (Iscoe et al., 1983; Jennings and Szlyk, 1985). After this transition point, dogs start panting (Iscoe et al., 1983).

The respiratory rate of a cat in a consultation room might also be influenced by factors such as travel time from home to the clinic, whether the cat had an indoor or outdoor lifestyle and the demeanor of the cat during veterinary examination and in the home environment. Because of the large number of possible combinations of these factors in any cat, we chose not to investigate these aspects.

The reported respiratory rates of 30 healthy cats (18–192/min) at a veterinary hospital (Quimby et al., 2011) are similar to the respiratory rates of 103 cats (20–180 breaths/min) in a different study, referred for emergency consultations because of respiratory distress (Sigrist et al., 2011), and similar to the respiratory rates of the present study in clinically healthy adult cats (28–176 breaths/min). These findings suggest that a single respiratory rate measurement in a consultation room is of limited clinical value.

After a physical examination most cats experienced a change in the ambulatory respiratory rate. However, the direction (decreasing or increasing) and the magnitude of change was unpredictable.

Adult cats in our study had a median sleeping respiratory rate of 20 breaths/min and it never exceeded 30 breaths/min, consistent with previous observations which showed that most healthy cats have a mean sleeping respiratory rate of <30 breaths/min (median 19 breaths/min, range 9–37 breaths/min; Ljungvall et al., 2014). As the previous study demonstrated, we also found that the sleeping respiratory rates were lower than the resting respiratory rates. This can be explained by the fact that awake cats can respond to external stimuli (e.g. noise), which in turn can lead to an increased respiratory rate.

One of the limitations of the present study is that in most cats the respiratory rates at the two different locations (i.e. at home and at the veterinary clinic) were not measured on the same day. Taking measurements on the same day might reduce the alterations in respiratory rate caused by environmental factors (such as ambient temperature) or day-to-day variability of the cats' demeanor.

We did not educate owners about how to measure respiratory rates and many owners found it hard to identify the breathing movements at home. The low number of responses to our request to count respiratory rates at home reflects this problem, as only 28 of the 131 cat owners (21%) managed to count the respiratory rate of their cats at home. Additionally, the counts provided by the owners often differed from the counts that the investigator found on the video-films that were recorded contemporaneously. In contrast, owners found filming their cat breathing easy to do: 113 of 131 owners (86%) made a video-recording. Although we found no difference between the respiratory rates counted by the owners and the rates that were counted by the investigator from the video-recordings, there were quite some clinically relevant individual differences. The differences in the resting or sleeping respiratory rates counted by the owner at home and counted from the video-recording by the investigator are unlikely to be linked to the within-cat variability since the variation in these parameters is very limited (Orem et al., 1977; Ljungvall et al., 2014). Therefore, relying on cat owners to reliably monitor respiratory rates in cats at home might result in erroneous measurements and could complicate disease management decisions. Whether training owners to measure respiratory rates would improve the accuracy remains undetermined. However, having owners record the cats for counting by clinicians or technicians might provide a valid alternative in cats where owners are unable to measure respiratory rates reliably and accurately.

We measured ambulatory respiratory rates over a minimum of 15 s instead of the widely used 30–60 s. This was necessary because the animals were moving, sniffing or vocalizing. Since rates were high, a possible multiplied measurement error was less likely to happen. To reduce this error, we used the mean of two counts of 15 s for calculating the respiratory rate whenever possible (in most cases).

The presence of subclinical disease, which could have resulted in an increased respiratory rate (such as anemia, cardiac or respiratory disease), cannot be completely excluded because no thoracic imaging (e.g. radiographs), plethysmography, fecal (parasitologic) or blood tests were performed. This is especially true for the assumed healthy cats, where not even a routine physical examination was performed. This was the reason that the respiratory rates of assumed healthy cats were excluded from the data set that was used for establishing the reference interval. However, we did not observe differences in the respiratory rates recorded from these 'assumed healthy' cats and cats that underwent physical examination.

Several studies have shown that purring cats have elevated respiratory rates (Remmers 1972; Jennings and Szlyk, 1985). A recent study on 341 cats reported that 18% of cats were purring (determined by auscultation) in the veterinarian's consultation room, irrespective of health, age or gender (Little et al., 2014). It is likely that in the current study purring in some cats remained unrecognized, influencing the (ambulatory and resting) respiratory rates. Particularly from the video-recordings it was impossible to determine with certainty whether a cat was purring.

Conclusions

Respiratory rates can be very variable and high in clinically healthy adult cats examined in veterinary clinics. The reference intervals commonly reported in veterinary textbooks propose most likely represent the resting respiratory rate in the home environment. Because the same cats have a low respiratory rate with a much smaller variability at home, veterinarians can consider relying on repeated video-recordings made prior to each scheduled office visit, for comparison, while avoiding comparisons made between these videotaped data and respiratory rate data

collected by in-clinic, hands-off inspection. This would not only spare time for the veterinarian, but would also supply more reliable information about this physiologic parameter of the animal.

Conflict of interest statement

None of the authors has any financial or personal relationships that could inappropriately influence or bias the content of the paper.

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