

# 'The Mercury Challenge': feline systolic blood pressure in primary care practice – a European survey

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*Journal of Feline Medicine and Surgery*  
2022, Vol. 24(10) e310–e323  
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DOI: 10.1177/1098612X221105844  
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## Abstract

**Objectives** The aim of this study was to collect data from a substantial number of older cats having their systolic blood pressure (SBP) measured in a variety of clinical practices, to describe the findings and assess variables that affected the duration of assessment and the values obtained.

**Methods** An international (European-based) multicentre convenience sample survey of cats  $\geq 7$  years of age attending veterinary clinics and having SBP measured as part of their clinical assessment. Information gathered included details of the cat, concomitant disease(s) or therapies, SBP results, device used, time taken to assess SBP and the demeanor of the cat.

**Results** Useable data were available from 8884 cats aged 7–26 years, from 811 clinics across 16 countries. The device used to measure SBP was Doppler in 47.4% and oscillometry in 48.5%. The demeanor of the cat was reported to be calm in 45.7%, anxious in 41.9% and nervous in 8.9%; and the duration of assessment was reported to be <5 mins in 50.4%, 5–10 minutes in 41.7% and >10 mins in 7.9%. Concomitant chronic kidney disease (CKD) was reported in 21.8%, hyperthyroidism in 12.0% or both in 3.1%. The median SBP was 150 mmHg (range 80–310), with 18.6% classified as hypertensive (SBP 160–179 mmHg) and 21.1% as severely hypertensive (SBP  $\geq 180$  mmHg). The measured SBP was significantly affected by the cat's demeanor, duration of SBP assessment, presence of CKD and/or hyperthyroidism, the cat's sex and age, and the presence of concomitant therapy. The duration of SBP assessment was significantly affected by the cat's demeanor.

**Conclusions and relevance** In veterinary clinics, SBP can be measured in most cats within a short period of time using either Doppler or oscillometric equipment. The presence of CKD or hyperthyroidism was associated with significantly higher SBP values, and anxious or nervous cats had higher SBP values and took longer to obtain SBP assessments.

**Keywords:** Hypertension; blood pressure; oscillometry; Doppler

**Accepted:** 12 May 2022

## Introduction

The first reports of naturally occurring systemic hypertension in cats emerged in the late 1980s and early 1990s;<sup>1–4</sup> since then, hypertension has emerged as a major feline disease, reportedly affecting around 10% or more of cats over the age of 6–9 years presented to veterinary clinics, with a marked increase in prevalence with age.<sup>5–10</sup> While earlier experimental studies established a link between hypertension and induced renal damage,<sup>11</sup> or the administration of thyroxine,<sup>12</sup> studies of naturally occurring disease soon demonstrated that many cases of hypertension were associated with either chronic kidney disease (CKD), hyperthyroidism or, sometimes, other

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systemic diseases.<sup>1–3,13–16</sup> In contrast to human medicine where primary hypertension is common, it is currently estimated that at least 80% of feline cases are secondary hypertension, with CKD being the most commonly identified comorbidity.<sup>17–19</sup>

Indirect measurement of systolic blood pressure (SBP), using either Doppler or oscillometric equipment, has become established as the standard way to assess blood pressure (BP) and diagnose hypertension in conscious cats. However, measured BP can be affected by many different variables, including the type of equipment and how it is used (site used, technique employed, position of the cat, size of the cuff, etc), personnel involved, level of arousal of the cat and experience of the operator.<sup>20–43</sup> These factors, together with the inherent inter- and intra-variability of BP,<sup>44</sup> can make interpretation of individual BP measurements challenging. Despite these difficulties, consensus guidelines have emerged on how to measure and interpret SBP in cats,<sup>17,18</sup> although SBP values should not be interpreted independently from other clinical information.

There have been few large-scale studies on assessment of feline SBP in clinical practice and the variables that may be associated with its measurement in this setting. The current study, entitled 'The Mercury Challenge', was therefore established as a large, international, multicenter European-based convenience sample of feline SBP assessment in primary care practice. The objective was to collect data on more than 10,000 cats  $\geq 7$  years of age, where SBP was being measured as part of their clinical assessment, to describe the findings and to look at different variables that might have affected SBP measurement and the values obtained.

## Materials and methods

A web-based questionnaire was designed and hosted on a dedicated website ([www.mercurychallenge.ceva.com](http://www.mercurychallenge.ceva.com)) to collect data on cats that were having SBP measured as part of their clinical examination (Figure 1). Clinics were encouraged to follow the American College of Veterinary Internal Medicine (ACVIM) guidelines for evaluation of BP,<sup>17</sup> and were given the option of entering up to five individual SBP measurements (with the mean being automatically calculated), but they could also enter any number of values between 1 and 5. Additional data collected included age, weight, breed and sex of the cat; concomitant diseases that had been diagnosed; concomitant treatments that the cat was receiving; results of SBP assessment; time taken to assess SBP; device used to measure SBP; and subjective assessment of the demeanor of the cat when measuring SBP.<sup>26</sup>

Clinics were given tick-box options to indicate the presence of concomitant diseases (specifically, previously diagnosed CKD or hyperthyroidism because of the established importance of these conditions and feline hypertension,<sup>17,18</sup> or an 'other' category, where there was

a free-text option to add further details) and concomitant therapies (similarly, some specific therapies and an 'other' category with the option to add further information; see Figure 1). Because this survey was undertaken by Ceva Santé Animale, specific questions about the use of amlodipine (licensed for the treatment of systemic hypertension in cats by Ceva Santé Animale as AMODIP) could not be asked for regulatory reasons.

The web-based questionnaire was launched in May 2018 and clinics were contacted and made aware of the initiative across Europe through representatives and newsletters from Ceva Santé Animale, and coverage in the veterinary press. Clinics willing to participate were asked to enter the details of any cat aged  $\geq 7$  years that was having its BP assessed as part of its clinical examination (with the owner's explicit permission). The goal was to record SBP assessments from  $>10,000$  cats; after this had been achieved (December 2020), the website was closed to further submissions.


### Statistical analysis

Descriptive statistics were used to summarize the collected data and inferential statistics were used to analyze factors affecting the SBP measured and the duration of SBP assessment. As the data were not normally distributed, simple non-parametric univariate analyses were undertaken as appropriate (Mann–Whitney test, Kruskal–Wallis test with Dunn's post-test pair-wise comparisons, Spearman Rank correlation and  $\chi^2$  test).

It was hypothesized that the following might all independently affect the SBP measured: the clinic; the cat's age, weight, sex, breed and demeanor; the device used; and the presence of concomitant disease or concomitant therapy. To evaluate these factors further, a linear mixed-model analysis was used to evaluate their effect on mean SBP values (after logarithmic transformation of the SBP to have normally distributed data), using these variables as fixed effects except for the clinic, which was included as a random effect. Variables with a  $P$  value  $<0.20$  in the univariable linear mixed-model analysis were used in the backward selection to build the multivariable model. Goodness of fit was assessed with the normal distribution of the residuals.

It was also hypothesized that the cat's demeanor, the device used and the SBP measured might all independently affect the duration of SBP assessment, and a proportional-odds cumulative logistic mixed model was used to assess the effect of these variables on the duration of SBP assessment. However, only cats known to have had at least five SBP recordings, along with information on the duration of SBP assessment ( $n = 4250$ ) were included in these analyses.

For all analyses, GraphPad Prism (version 9.2.0) or R software (version 4.0.4) was used, and a  $P$  value  $<0.05$  was considered to be statistically significant.



**Demographics**

Cat's Name:

Age:  or Year of Birth

Weight:   Kg or  Lbs

Sex:  Male  Female

Neutered:  Yes  No

Breed:

**Concurrent disease and treatments**

Concurrent diseases?  Yes  No

- Chronic kidney disease
- Hyperthyroidism
- Other

Concurrent treatments?  Yes  No

- ACEi
- Telmisartan
- Spironolactone
- NSAIDs
- Beta-blockers
- Pimobendan
- Carbimazole, Thiamizole, Methimazole
- Other

**Systolic Blood Pressure Measurement and Diagnosis**

Systolic Blood Pressure values:      Calculated mean:

Duration:  < 5mins  5-10 mins  > 10 mins

Device:  Oscillometry  Doppler  Other

Cat's demeanour:  Calm  
 Cooperative but anxious  
 Nervous, excited or aggressive

Diagnosis:  SBP <140 mmHg Normotensive  
 SBP 140-159 mmHg Pre-hypertensive  
 SBP 160-179 mmHg Hypertensive  
 SBP >180 mmHg Severely hypertensive

Figure 1 Overview of questions asked in the online database

## Results

### Population characteristics

A total of 10,153 SBP assessments were recorded in the database; of these, 1269 were excluded: 1146 as they were

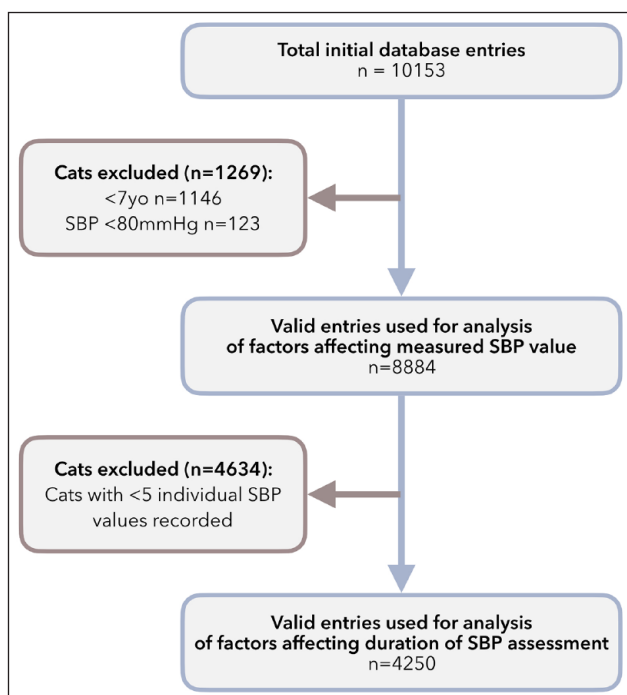
from cats aged <7 years (and therefore did not meet the inclusion criteria); and 123 as the recorded SBP was <80mmHg (range 10–79) and these entries were regarded as unreliable based on previously published data.<sup>17,18,39</sup>

This resulted in a total of 8884 unique SBP assessments, which were used as the population for subsequent analyses of factors affecting SBP values measured (Figure 2).

In 4630/8884 cases, <5 individual SBP recordings (between 1 and 4) were entered into the database, and it was impossible to determine whether at least five recordings had originally been obtained. In a further four cases, although five readings had been entered, the duration of SBP assessment had not been recorded. This resulted in 4250 cases where at least five SBP measurements were known to have been made and the duration of SBP measurement was recorded, and this population was used for analysis of factors affecting the duration of SBP measurement (Figure 2).

The demographics of the 8884 cats in the final dataset are shown in Table 1 and Figure 3. Database entries were received from a total of 811 clinics from 16 countries. The median number of entries per clinic was 6.0 (range 1–162, interquartile range [IQR] 2.0–16.0).

The age of the cats ( $n = 8884$ ) ranged from 7 to 26 years old (median 13.0; IQR 10.0–16.0). Data on body weight were available from 8517 cats, but the weights of seven cats were excluded as outliers and potentially unreliable based on published data,<sup>45–52</sup> three weighing >15 kg (range 16–59 kg) and four <1.5 kg (range 1.0–1.3). Of the remaining 8510 cats, median body weight was 4.0 kg (range 1.5–14.0; IQR 3.3–5.0).



**Figure 2** Overview of study population, excluded cases and analyses performed. SBP = systolic blood pressure

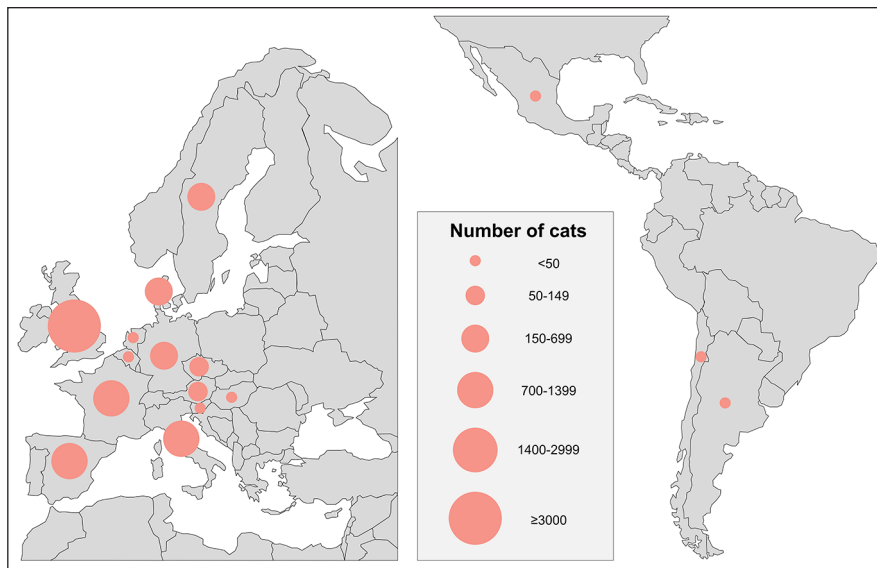
**Table 1** Demographic data of the 8884 cats included in the study

Demographic	n (%)
Country	
Argentina	16 (0.2)
Austria	139 (1.6)
Belgium	6 (0.1)
Chile	1 (<0.1)
Czech Republic	81 (0.9)
Denmark	547 (6.2)
France	800 (9.0)
Germany	599 (6.7)
Hungary	2 (<0.1)
Italy	1103 (12.4)
Mexico	9 (0.1)
Netherlands	40 (0.5)
Slovenia	2 (<0.1)
Sweden	552 (6.2)
Spain	1216 (13.7)
UK	3771 (4.2)
Breed	
Crossbred	6466 (72.8)
Bengal	50 (0.6)
British Shorthair	237 (2.7)
Burmese	72 (0.8)
Chartreux	19 (0.2)
Siamese	188 (2.1)
Maine Coon	139 (1.6)
Norwegian Forest Cat	86 (1.0)
Persian	331 (3.7)
Ragdoll	87 (1.0)
Other pedigree breed	965 (10.9)
Unknown	244 (2.7)
Sex	
Male	71 (0.8)
Male neutered	4256 (47.9)
Female	63 (0.7)
Female neutered	4335 (48.8)
Unknown	159 (1.8)

#### Individual cat SBP and associated factors

In the final population ( $n = 8884$ ), the overall median recorded SBP was 150 mmHg (range 80–310; IQR 133–174). An overview of the recorded SBP values broken down by the different categories is given in Tables 2 and 3, along with the results of simple, non-parametric statistical analyses.

The type of device used to measure SBP was specified for 8512 cats (Table 2), but of the 4305 cases where oscillometry was used, the specific type of equipment was only provided in 165 cases, which comprised petMAP ( $n = 107$ ; Ramsey Medical), Vet HDO Monitor ( $n = 35$ ; S+B medVET), SunTech or SunTech Vet20 ( $n = 21$ ; SunTech



**Figure 3** Overview of the geographic distribution of the population investigated

**Table 2** Analysis of the systolic blood pressure (SBP) reported in the 8884 cats according to different criteria

Category	Number of cats (% category)	Median SBP	IQR	Range	Analysis
<b>Sex</b>					
Male	71 (0.8)	144	129–163	90–250	Kruskal–Wallis <i>P</i> = 0.1118
Male neutered	4256 (47.9)	151	134–174	80–300	
Female	63 (0.8)	148	130–179	92–300	
Female neutered	4335 (48.8)	150	132–174	80–310	
Unknown	159 (1.8)				
<b>Breed</b>					
Pedigree	2174 (24.5)	150	132–172	80–300	Mann–Whitney <i>P</i> = 0.1223
Non-pedigree	6466 (72.8)	151	133–175	80–310	
Unknown	244 (2.7)				
<b>Device used</b>					
Doppler	4207 (47.4)	148	130–172	80–310	Mann–Whitney <i>P</i> < 0.0001
Oscillometric	4305 (48.5)	154	136–175	80–280	
Unknown	372 (4.2)				
<b>Demeanor</b>					
Calm	4074 (45.7)	144	128–166	80–310	Kruskal–Wallis <i>P</i> < 0.0001*
Anxious	3720 (41.9)	155	138–179	80–300	
Nervous	790 (8.9)	165	145–190	81–300	
Unknown	300 (3.4)				
<b>Duration of assessment (mins)</b>					
<5	4475 (50.4)	148	130–170	80–310	Kruskal–Wallis: <i>P</i> < 0.0001†
5–10	3696 (41.7)	155	136–178	80–300	
>10	706 (7.9)	154	136–180	80–300	
Unknown	7 (0.1)				
<b>Concomitant diseases reported</b>					
Total cats with concomitant disease	4629 (52.1)				
CKD alone (n = 1692) or with other disease (n = 244)	1936 (21.8)	155	136–179	80–310	Kruskal–Wallis: <i>P</i> < 0.0001†
Hyperthyroidism alone (n = 957) or with other disease (n = 111)	1068 (12.0)	160	140–181	85–300	

(Continued)



**Table 2** (Continued)

Category	Number of cats (% category)	Median SBP	IQR	Range	Analysis
CKD and hyperthyroid alone (n = 241) or with other disease (n = 35)	276 (3.1)	159	139–183	83–263	
Other disease(s)	1349 (15.2)	148	130–170	80–300	
No concomitant disease reported	4255 (47.9)	148	130–170	80–300	
Treatment					
Receiving concomitant therapy	3097 (34.9)	155	137–179	82–300	Mann–Whitney $P < 0.0001$
No concomitant therapy reported	5786 (65.1)	150	131–171	80–310	
Unknown	1				

\*Dunn's post-test comparison showed significant differences between all three categories ( $P < 0.0001$ )

†Dunn's post-test comparison showed significant ( $P < 0.0001$ ) differences between <5 mins and 5–10 mins, and between <5 mins and >10 mins

‡Dunn's post-test comparison showed significant differences ( $P < 0.0001$ ) between no disease and chronic kidney disease (CKD), hyperthyroidism and CKD + hyperthyroidism; between other disease(s) and CKD, hyperthyroidism and CKD + hyperthyroidism; and also a significant ( $P = 0.008$ ) difference between CKD and hyperthyroidism  
IQR = interquartile range

**Table 3** Details of recorded systolic blood pressure (SBP) values according to disease status and American College of Veterinary Internal Medicine SBP category in all 8884 cats

Disease status (number of cats)	Normotensive (<140 mmHg)	Pre-hypertensive (140–159 mmHg)	Hypertensive (160–179 mmHg)	Severely hypertensive ( $\geq 180$ mmHg)	Analysis
CKD (n = 1936)	547 (28.3)	499 (25.8)	415 (21.4)	475 (24.5)	$\chi^2 P < 0.0001$
Hyperthyroidism (n = 1068)	225 (21.1)	305 (28.6)	241 (22.6)	297 (27.8)	
CKD and hyperthyroidism (n = 276)	71 (25.7)	69 (25.0)	52 (18.8)	84 (30.4)	
Other disease (n = 1349)	483 (35.8)	395 (29.3)	219 (16.2)	252 (18.7)	
None reported (n = 4255)	1542 (36.2)	1223 (28.7)	726 (17.1)	764 (18.0)	
Total (n = 8884)	2868 (32.2)	2491 (28.9)	1653 (18.6)	1872 (21.1)	

Data are n (%)

CKD = chronic kidney disease

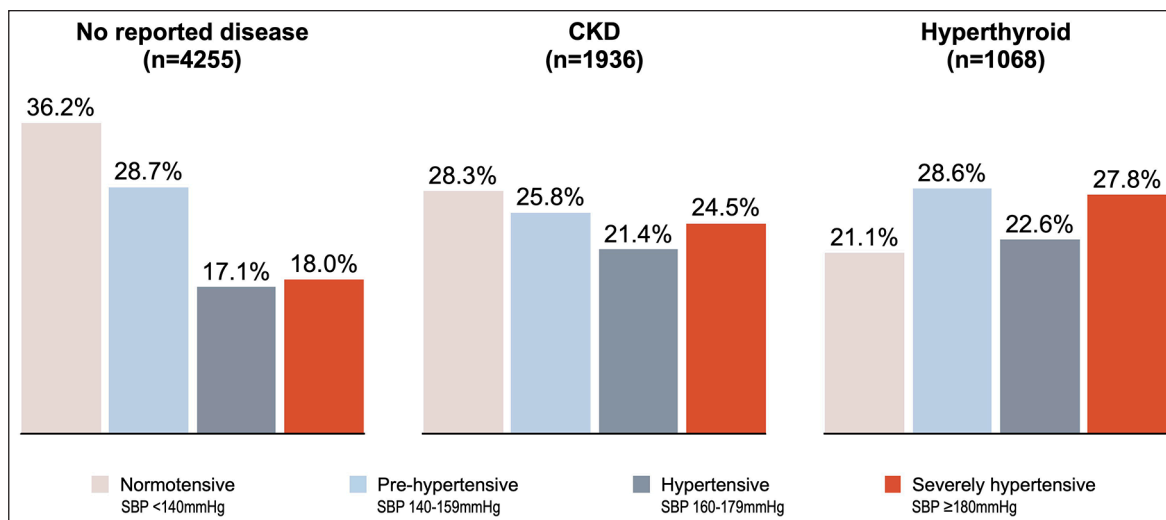
Medical), LifeVet M (n = 1; Eikemeyer) and VetTRENDS (n = 1; VetTRENDS).

Of the 3097 cats reported to be receiving systemic therapy (Table 2), 1000 were receiving antithyroid medication, 528 an angiotensin converting enzyme inhibitor, 380 telmisartan, 311 a non-steroidal anti-inflammatory drug, 106 a beta blocker, 38 pimobendan and 36 spironolactone. A total of 1066 cats were reported to be receiving 'other' systemic therapies, and although details of additional drugs were not always declared, 319 cats were reported to be receiving amlodipine, 165 glucocorticoids, 141 antibacterial drugs, 113 insulin and 90 other diuretics (furosemide or torasemide). Multiple ( $\geq 2$ ) drug therapy was reported in 682 of the cats. A number of the systemic therapies that were being administered are known to affect SBP<sup>17,18</sup> but, as full details of the drugs used, their doses, frequency of administration and duration of use were unavailable, cats were simply classified as receiving concomitant therapy or not.

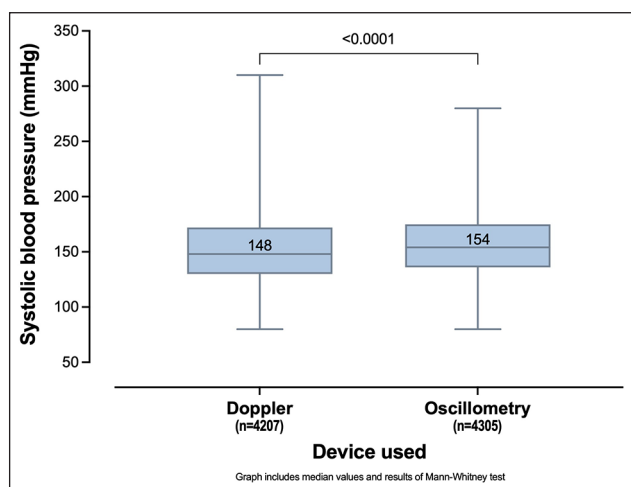
A breakdown of the cats according to the ACVIM criteria for assessing SBP<sup>17</sup> is shown in Table 3 and Figure 4.

As can be seen, there was a statistically significant higher proportion of cats with CKD and/or hyperthyroidism in the hypertensive or severely hypertensive categories ( $P < 0.0001$ ). When only cats that were not receiving any form of systemic therapy were analyzed (n = 5786), there was only a marginal effect on the results, with a slightly higher proportion of cats with CKD (47.6%) and hyperthyroidism (51.1%) falling into the hypertensive range (SBP  $\geq 160$  mmHg) and a slightly lower proportion of cats with no disease reported (34.3%) falling into this range.

Simple, non-parametric analysis of median SBP values showed significant differences according to the device used to measure SBP, the demeanor of the cat, the duration of assessment, the presence of concomitant disease and the presence of concomitant therapy (Table 2, Figures 5–9). In addition to the data shown, Spearman's correlation coefficient showed a statistically significant ( $P < 0.0001$ ) but weak correlation between SBP and age ( $r_s = 0.25$ ) and a statistically significant ( $P < 0.0001$ ) but very weak negative correlation between SBP and body weight ( $r_s = -0.07$ ).



**Figure 4** Overview of the proportion of cats falling into the different American College of Veterinary Internal Medicine-defined categories of systolic blood pressure (SBP) for those with no concomitant disease diagnosed, with concomitant chronic kidney disease (CKD) or hyperthyroidism

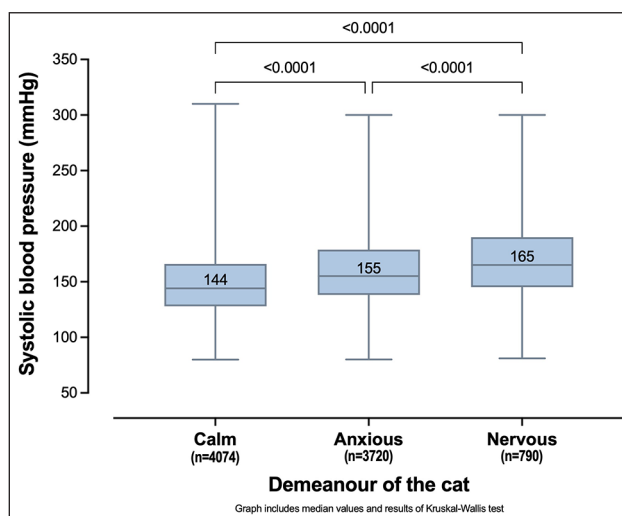


**Figure 5** Box-and-whisker plot of the association between systolic blood pressure (SBP) values and device used to measure SBP (n = 8512)

The results of further data analysis with the linear mixed model (including the clinic as a random effect) are shown in Table 4, and revealed a significant independent effect of the cat’s demeanor, duration of assessment, disease status, sex, age and presence of concomitant therapy on the SBP measured in the cats.

*Duration of SBP assessment and associated factors*

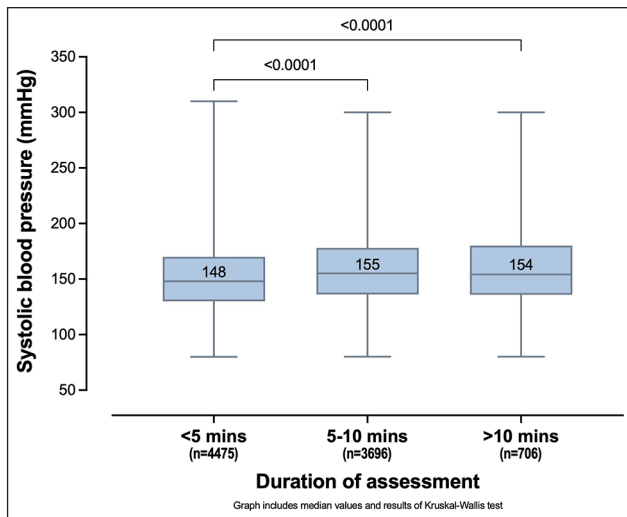
For the 4250 cats where factors associated with the duration of SBP were analyzed, results of simple non-parametric analysis of the relationship between duration



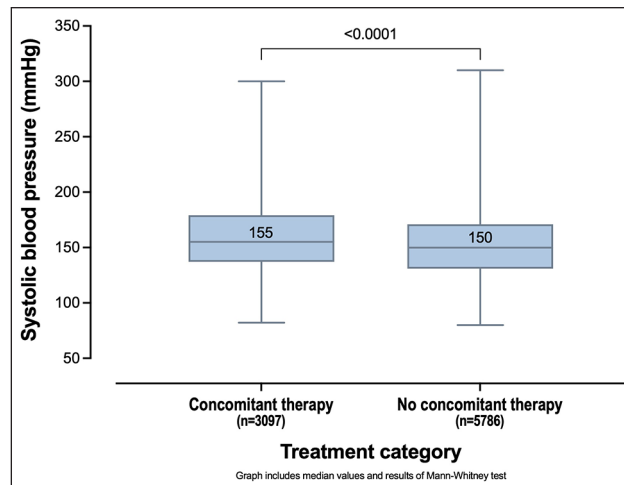
**Figure 6** Box-and-whisker plot of the association between systolic blood pressure values and cats’ demeanor (n = 8584)

and the device used to measure SBP, the demeanor of the cat and the SBP measured are shown in Table 5 and Figures 10 and 11.

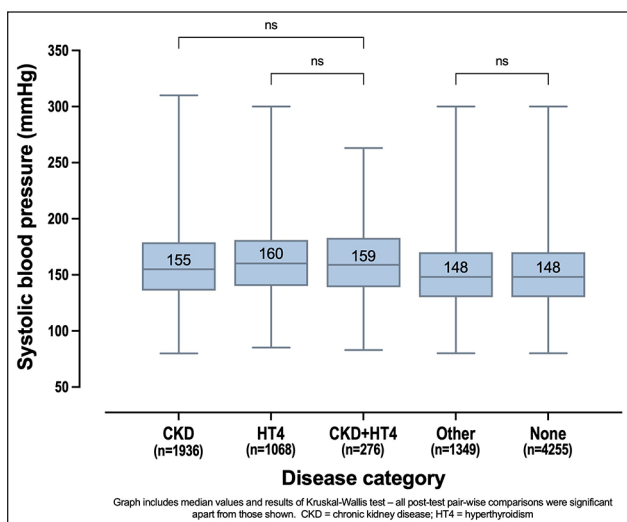
Results of the further multivariable analysis of the effect of different factors on the duration of SBP assessment (using the proportional odds cumulative logistic model) are shown in Table 6, and showed that only the demeanor of the cats statistically significantly affected the duration of assessment, with the odds of the SBP assessment taking  $\geq 5$  mins vs  $< 5$  mins being 1.55 for anxious vs calm cats and 2.42 for nervous vs calm cats ( $P < 0.001$ ).



**Figure 7** Box-and-whisker plot of the association between systolic blood pressure (SBP) values and duration of SBP assessment (n = 8877)



**Figure 9** Box-and-whisker plot of the association between systolic blood pressure values and cats' treatment status (n = 8883)



**Figure 8** Box-and-whisker plot of the association between systolic blood pressure values and cats' disease status (n = 8884). CKD = chronic kidney disease; HT4 = hyperthyroidism

### Discussion

This study represents the largest published data of feline SBP measurements to date, and the first to look at measurements conducted in primary care veterinary clinics across numerous countries. The initial aim was to collect data from only European countries, but 26 entries were received from three South American countries (Table 1 and Figure 3) and were also included in the final analyzed dataset, which comprised nearly 9000 unique cat entries. The study was designed to capture data from cats  $\geq 7$  years of age where SBP was already being measured as

part of their clinical evaluation. An age cutoff of 7 years was applied as hypertension is more common in older cats,<sup>5,10,17,18</sup> which is also in line with the International Society of Feline Medicine recommendations for routine measurement of SBP in cats.<sup>18</sup> We did not ask clinics to record the reason(s) for measuring SBP in these cats – while it may have been a screening procedure in an older cat, in others it was probably undertaken owing to the presence of underlying diseases associated with hypertension, because of suspected hypertension based on clinical presentation or as a result of monitoring pre-existing hypertension (evident as a number of cats were already receiving antihypertensive therapy).

Overall, we found that 3525 (39.7%) of the cats had a SBP  $\geq 160$  mmHg and would thus be classified as hypertensive according to current guidelines,<sup>17,18</sup> with 1872 (21.1%) falling into the severely hypertensive category (SBP  $\geq 180$  mmHg). This is a higher proportion than the 23.7% of cats aged  $\geq 9$  years reported to be hypertensive in a smaller study of SBP measurements in primary care practice in the UK,<sup>10</sup> but there were differences in the populations studied so direct comparison is not possible. Further, in our study, information was not available on the number of cats already diagnosed with hypertension or the number showing clinical signs of hypertension (eg, hypertensive ocular disease). Although our results suggest a relatively high prevalence of hypertension, not all would necessarily have been classified as hypertensive by the clinicians involved, as other factors would also have been taken into consideration (such as the conditions at the time of measurement and the repeatability of the findings).

In our study, 1564 (44.4%) of the 3525 cats with a SBP  $\geq 160$  mmHg were reported to have either concomitant CKD (n = 890, 25.2%), hyperthyroidism (n = 538, 15.3%)



**Table 4** Linear mixed-model multivariable analysis of factors influencing systolic blood pressure in the study cats, with clinic as a random effect

Parameter	Estimate	95% CI	P value
Univariate analysis			
Age (for an increase of 1 year)	0.014	0.013–0.015	<0.001
Sex (male vs female)	0.008	–0.001 to 0.017	0.075
Body weight (for an increase of 1 kg)	–0.011	–0.014 to –0.008	–0.001
Concomitant treatment (yes vs no)	0.024	0.015–0.033	<0.001
Demeanor (anxious vs calm)	0.066	0.057–0.075	<0.001
Demeanor (nervous vs calm)	0.119	0.104–0.134	<0.001
Device (oscillometry vs Doppler)	0.008	–0.007 to 0.023	0.333
Duration (5–10mins vs <5 mins)	0.036	0.025–0.047	<0.001
Duration (>10mins vs <5 mins)	0.044	0.025–0.063	<0.001
CKD + hyperthyroidism vs no disease	0.058	0.033–0.083	<0.001
CKD vs no disease	0.040	0.028–0.052	<0.001
Hyperthyroidism vs no disease	0.063	0.049–0.077	<0.001
Other disease vs no disease	0.004	–0.009 to 0.017	0.500
Pedigree vs non-pedigree	0.005	–0.006 to 0.016	0.347
Multivariate analysis (showing only significant results)			
Demeanor (nervous vs calm)	0.113	0.098–0.128	<0.001
Demeanor (anxious vs calm)	0.064	0.055–0.073	<0.001
Duration (>10mins vs <5 mins)	0.026	0.008–0.044	0.005
Duration (5–10mins vs <5 min)	0.023	0.013–0.033	<0.001
Hyperthyroidism vs no disease	0.042	0.025–0.059	<0.001
CKD + hyperthyroidism vs no disease	0.030	0.004–0.056	0.026
CKD vs no disease	0.028	0.015–0.041	<0.001
Sex (male vs female)	0.016	0.008–0.024	<0.001
Age (for an increase of 1 year)	0.013	0.012–0.014	<0.001
Concomitant treatment (yes vs no)	–0.012	–0.024 to 0.000	0.037

Clinic effect = 0.089 (0.082–0.098);  $P < 0.001$

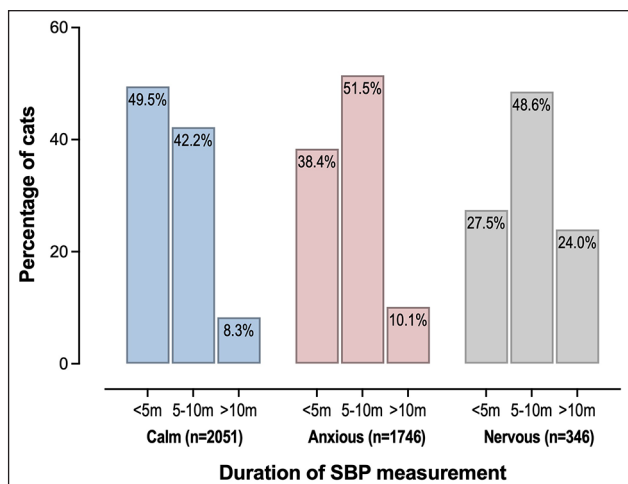
CI = confidence interval; CKD = chronic kidney disease

**Table 5** Relationship between length of time taken to assess systolic blood pressure (SBP;  $n = 4250$ ) and the cat's demeanor, the equipment used and the SBP measured

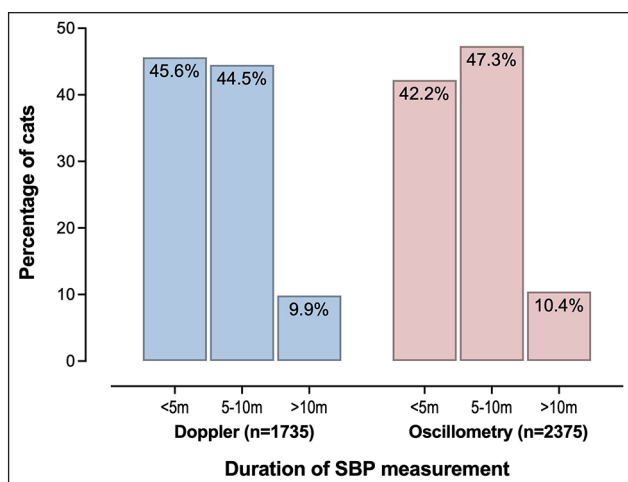
Category	Duration of SBP assessment			Analysis
	<5mins	5–10mins	>10mins	
All cats	1837 (43.2)	1975 (46.5)	438 (10.3)	
Equipment				$\chi^2 P = 0.0926$
Doppler ( $n = 1735$ )	792 (45.6)	772 (44.5)	171 (9.9)	
Oscillometry ( $n = 2375$ )	1003 (42.2)	1124 (47.3)	248 (10.4)	
Unknown ( $n = 140$ )	42	79	19	
Demeanor				$\chi^2 P < 0.0001$
Calm ( $n = 2051$ )	1015 (49.5)	866 (42.2)	170 (8.3)	
Anxious ( $n = 1746$ )	670 (38.4)	899 (51.5)	177 (10.1)	
Nervous ( $n = 346$ )	95 (27.5)	168 (48.6)	83 (24.0)	
Unknown ( $n = 107$ )	57	42	8	
Median (range) SBP	150.0 (86–277)	155.0 (80–300)	156.0 (86–300)	Kruskal–Wallis $P = 0.0006^*$

Data are  $n$  (%) unless otherwise stated

\*Dunn's post-test comparison showed significant differences between <5mins and 5–10mins ( $P = 0.0021$ ) and between <5mins and >10mins ( $P = 0.0168$ )



**Figure 10** Association between the duration of systolic blood pressure (SBP) assessment and cat demeanor (n = 4143)



**Figure 11** Association between the duration of systolic blood pressure (SBP) assessment and the equipment used (n = 4110)

or both (n = 136, 3.9%). Compared with cats with no concomitant disease, cats with CKD and/or hyperthyroidism had a significantly higher prevalence of hypertension and significantly higher median SBP values (Tables 2–4, Figures 4 and 8). Inevitably, our results underestimated the true prevalence of CKD and hyperthyroidism in the population studied, as some cats may have had diagnoses made after SBP values were obtained, and others may have had undiagnosed disease because of a lack of investigations. These are limitations of the convenience nature of the study; however, consistent with our likely underestimating the prevalence of concomitant disease, previous publications have reported hypertension to be present in around 20–60% of cats with CKD<sup>1,6,53–55</sup> and 15–85% of cats with hyperthyroidism.<sup>1,56–59</sup>

**Table 6** Proportional odds cumulative logistic mixed model for duration of systolic blood pressure (SBP) assessment (n = 4250)

Parameter	OR	95% CI	P value
Univariate analysis			
Demeanor (anxious vs calm)	1.50	1.34–1.68	<0.001
Demeanor (nervous vs calm)	2.36	1.96–2.84	<0.001
Device (oscillometry vs Doppler)	1.21	0.96–1.52	0.101
SBP (for an increase of 10mmHg)	1.03	1.01–1.05	<0.001
Multivariate analysis			
Demeanor (anxious vs calm)	1.55	1.39–1.74	<0.001
Demeanor (nervous vs calm)	2.42	2.01–2.92	<0.001

OR = odds ratio; CI = confidence interval

We chose to use a linear mixed-model multivariable approach to analyze the various factors associated with SBP values in this population of cats. We considered this to be appropriate as it allowed us to include the clinic as a random effect, accounting for the significant variability in SBP values that occurred between clinics (probably because of different selection criteria for cases, as well as differences in methodologies and techniques for measuring SBP). In performing this analysis, we not only found that disease status had a significant impact on SBP, but also that the demeanor of the cat had a marked effect on measured SBP. Smaller effects were seen with duration of SBP assessment, age, sex and treatment status (Table 4, Figures 5–9). In a previously published study of Doppler SBP assessment in 780 apparently healthy cats from rehoming centers in the UK, Payne et al<sup>26</sup> assessed the demeanor of the cats during SBP assessment and found significantly higher SBP values in cats showing more signs of arousal (anxious or nervous cats vs calm cats). We used similar descriptors to classify the demeanor of cats in our study and found very similar results. Median SBP values were approximately 10 mmHg different between calm and anxious cats, and between anxious and nervous cats (Table 4, Figure 6). This finding is important, adding weight to previous observations<sup>26</sup> and suggesting that a subjective assessment of the cat’s demeanor may be important in helping to interpret SBP values in clinical practice.

Interestingly, although the difference in median SBP values in cats assessed by Doppler and oscillometry (148 and 154 mmHg, respectively) were significantly different according to the Mann–Whitney test, they did not remain significant in the linear mixed-model analysis. There is no doubt that the type of equipment used to measure

indirect SBP can influence the values obtained, and previous studies directly comparing Doppler and oscillometric equipment in conscious cats have often,<sup>21,39,60</sup> but not invariably,<sup>23</sup> found oscillometric equipment to significantly underestimate SBP compared with Doppler. However, differences are likely to vary between different models and optimizations of oscillometric equipment,<sup>21</sup> and between different levels of operator training and experience.<sup>22</sup> Had we collected more information on the different types of oscillometric equipment used, it is possible we may have found an effect of device used on SBP measured, but none was evident in the data obtained. Further, we did not collect information on the size of cuff used, site where the cuff was applied or the position of the cat, all of which may have the potential to influence SBP results obtained.<sup>20,30,39,61,62</sup>

In contrast to the device used, sex was not found to influence median SBP values using the Kruskal–Wallis test, but in the multivariable linear mixed-model analysis the small difference between the higher values in males than females was found to be significant. While some studies have reported no effect of sex on SBP,<sup>53,63,64</sup> others have found males to have significantly higher SBP values.<sup>13,24,26</sup> Although our results also suggest a potentially higher SBP in male cats, the differences observed were very small and unlikely to be of clinical significance when interpreting SBP results.

The presence of concomitant therapy was associated with a significantly higher SBP in the cats in our study (Table 4, Figure 9), but this finding is difficult to interpret. This study was not designed to provide information on the impact or efficacy of therapies in cats already diagnosed with hypertension, and the higher SBP values in cats receiving concomitant systemic therapy might reflect either the presence of previously diagnosed hypertension and/or other underlying diseases affecting SBP.

We found a small positive relationship between age and SBP values in this study, as has been reported in previous studies.<sup>6,13,26,63–65</sup> However, whether this is an independent effect of age on SBP (as reported in humans)<sup>66</sup> or whether it may reflect the presence of undiagnosed underlying disease(s) causing secondary increases in SBP remains to be determined. Although simple correlation also suggested a negative association between body weight and SBP, as in some other studies,<sup>26,53</sup> this was not significant in the linear mixed model, suggesting the apparent association may have been a result of the confounding effect of underlying disease. Although we found no evidence of an effect of pedigree status on SBP values, we did not have enough cats from a range of different breeds to allow a meaningful between-breed comparisons. At least two studies have identified significant differences in SBP between certain breeds among healthy cats,<sup>67,68</sup> and further work is needed to investigate and quantify potential breed differences and to understand if they might affect clinical interpretation of SBP values.

This study was also designed to provide information on variables that may affect the duration of SBP assessment. Few studies have evaluated the time it takes to measure SBP in cats and yet, anecdotally and in market research surveys of veterinarians ('Feline hypertension research', FMR Global Health 2021, unpublished data), the length of time taken to measure SBP is a commonly cited reason for clinicians not undertaking assessments. In our study, analysing data for the 4250 cases where five individual SBP values had been entered (Table 5), the time taken to assess SBP was reported to be  $\leq 10$  mins in 89.7% ( $n = 3812$ ) and  $< 5$  mins in 43.2% ( $n = 1837$ ). These findings are comparable to a previous study, which reported that five Doppler SBP readings were obtained in  $< 5$  mins from 37.5% of cats.<sup>23</sup> Interestingly, in that study,<sup>23</sup> one specific oscillometric device was also evaluated and it was reported that five oscillometric readings could only be obtained from 5% of cases in  $< 5$  mins and that 55% of cases took  $> 10$  mins. In our study, although the specifics of the oscillometric devices used were largely unknown, we found no significant difference in the overall time taken between Doppler and oscillometric devices (Tables 5 and 6, Figure 11). However, in both univariate and multivariate analysis, the subjective assessment of the demeanor of the cat did have a significant influence on the duration of SBP assessment, with it taking longer to measure SBP in cats categorized as anxious or nervous than in those categorized as calm (Tables 5 and 6, Figure 10). Although the SBP measured was also significantly associated with the duration of measurement in univariate analysis, this was not significant in multivariate analysis, probably because of the relationship between demeanor and measured SBP. Several factors contribute to the overall amount of time it takes to measure SBP in a clinical setting (eg, allowing the cat time to acclimatize to the environment, repeating the assessment if there is doubt over the validity of readings, etc), but the data from this study show that the measurement of SBP itself can usually be carried out quickly in a clinical setting, although additional time may be anticipated if cats appear overtly anxious or nervous.

Despite the value of this study, several important limitations also need to be recognized. This was a convenience sample survey designed to collect a large amount of data, but it lacked detailed information on several aspects that might affect SBP values such as the environment, the cuff size and site, the position of the cat and details of the equipment used. Further, only basic information on pre-existing diseases and therapies was collected, without knowledge of whether hypertension had already been diagnosed or what conditions might have been diagnosed at the time of SBP assessment.

## Conclusions

This large study provides a substantial amount of valuable data that will help inform the clinical practice of feline BP assessment. We found evidence that, in most cats, SBP

can be measured successfully in a short period of time, irrespective of the type of equipment used. However, perhaps unsurprisingly, SBP assessment tends to take longer in cats showing higher levels of anxiety or nervousness. In this population of older cats, we found a high prevalence of potential hypertension, and the recent finding of hypertensive ocular abnormalities in 59% of cats with oscillometric SBP >160 mmHg (or diastolic pressure >100 mmHg)<sup>69</sup> illustrates the importance of undertaking SBP measurements. Further, even with severe hypertensive chorioretinopathy, significant clinical improvement is seen with adequate control of the hypertension.<sup>70</sup> As in other studies, the presence of CKD and/or hyperthyroidism was significantly associated with the presence of raised SBP values; importantly, we confirmed observations in a previous study,<sup>26</sup> which suggested that a subjective assessment of the cat's demeanor may be an important clinical aid to interpreting SBP values. Finally, our results help to confirm the value of SBP assessment in clinical practice and suggest it can be achieved successfully and quickly in most cases. The results add weight to the greater need for routine SBP assessment, especially in cats at higher risk of hypertension, to improve the generally low frequency of assessment that is currently undertaken in primary care practice.<sup>10,71,72</sup>

**Acknowledgements** The authors would like to express their sincere thanks to all the clinics, veterinarians, veterinary nurses and other staff who participated in this study and provided details of feline blood pressure measurements.


**Conflict of interest** This study was conducted by Ceva Santé Animale. CG-P, EG and TB are employees of Ceva Santé Animale, and AHS acts as a consultant for Ceva Santé Animale.

**Funding** This study was conducted by and funded by Ceva Santé Animale.

**Ethical approval** The work described in this manuscript involved the use of non-experimental (owned or unowned) animals. Established internationally recognised high standards ('best practice') of veterinary clinical care for the individual patient were always followed and/or this work involved the use of cadavers. Ethical approval from a committee was therefore not specifically required for publication in *JFMS*. Although not required, where ethical approval was still obtained, it is stated in the manuscript.

**Informed consent** Informed consent (verbal or written) was obtained from the owner or legal custodian of all animal(s) described in this work (experimental or non-experimental animals, including cadavers) for all procedure(s) undertaken (prospective or retrospective studies). No animals or people are identifiable within this publication, and therefore additional informed consent for publication was not required.

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## References

- 1 Kobayashi DL, Peterson ME, Graves TK, et al. **Hypertension in cats with chronic renal failure or hyperthyroidism.** *J Vet Intern Med* 1990; 4: 58–62.
- 2 Littman MP. **Spontaneous systemic hypertension in 24 cats.** *J Vet Intern Med* 1994; 8: 79–86.
- 3 Morgan R. **Systemic hypertension in four cats: ocular and medical findings.** *J Am Anim Hosp Assoc* 1986; 22: 615–621.
- 4 Turner JL, Brogdon JD, Lees GE, et al. **Idiopathic hypertension in a cat with secondary hypertensive retinopathy associated with a high-salt diet.** *J Am Anim Hosp Assoc* 1990; 26: 647–651.
- 5 Paepe D, Verjans G, Duchateau L, et al. **Routine health screening: findings in apparently healthy middle-aged and old cats.** *J Feline Med Surg* 2013; 15: 8–19.
- 6 Bijmans ES, Jepson RE, Chang YM, et al. **Changes in systolic blood pressure over time in healthy cats and cats with chronic kidney disease.** *J Vet Intern Med* 2015; 29: 855–861.
- 7 Jepson RE, Brodbelt D, Vallance C, et al. **Evaluation of predictors of the development of azotemia in cats.** *J Vet Intern Med* 2009; 23: 806–813.
- 8 Saignes CF and Serra E. **Feline systemic arterial hypertension: clinical study of 24 cases.** *Rev Med Vet* 1999; 150: 791–796.
- 9 Carter JM, Irving AC, Bridges JP, et al. **The prevalence of ocular lesions associated with hypertension in a population of geriatric cats in Auckland, New Zealand.** *N Z Vet J* 2014; 62: 21–29.
- 10 Conroy M, Chang YM, Brodbelt D, et al. **Survival after diagnosis of hypertension in cats attending primary care practice in the United Kingdom.** *J Vet Intern Med* 2018; 32: 1846–1855.
- 11 Klevans LR, Hirkaler G and Kovacs JL. **Indirect blood pressure determination by Doppler technique in renal hypertensive cats.** *Am J Physiol* 1979; 237: H720–H723.
- 12 Strauer BE and Scherpe A. **Experimental hyperthyroidism I. Hemodynamics and contractility in situ.** *Basic Res Cardiol* 1975; 70: 115–129.
- 13 Bodey AR and Sansom J. **Epidemiological study of blood pressure in domestic cats.** *J Small Anim Pract* 1998; 39: 567–573.
- 14 Brown SA and Henik RA. **Diagnosis and treatment of systemic hypertension.** *Vet Clin North Am Small Anim Pract* 1998; 28: 1481–1494.
- 15 Flood SM, Randolph JF, Gelzer AR, et al. **Primary hyperaldosteronism in two cats.** *J Am Anim Hosp Assoc* 1999; 35: 411–416.
- 16 Sander C, Hörauf A and Reusch C. **Indirect blood pressure measurement in cats with diabetes mellitus, chronic nephropathy and hypertrophic cardiomyopathy [article in German].** *Tierarztl Prax Ausg K Kleintiere Heimtiere* 1998; 26: 110–118.
- 17 Acierno MJ, Brown S, Coleman AE, et al. **ACVIM consensus statement: guidelines for the identification, evaluation, and management of systemic hypertension in dogs and cats.** *J Vet Intern Med* 2018; 32: 1803–1822.
- 18 Taylor SS, Sparkes AH, Briscoe K, et al. **ISFM consensus guidelines on the diagnosis and management of hypertension in cats.** *J Feline Med Surg* 2017; 19: 288–303.
- 19 Jepson RE. **Feline systemic hypertension: classification and pathogenesis.** *J Feline Med Surg* 2011; 13: 25–34.



- 20 Cannon MJ and Brett J. **Comparison of how well conscious cats tolerate blood pressure measurement from the radial and coccygeal arteries.** *J Feline Med Surg* 2012; 14: 906–909.
- 21 Cerna P, Archontakis PE, Cheuk HO, et al. **Comparison of Doppler ultrasonic and oscillometric devices (with or without proprietary optimisations) for non-invasive blood pressure measurement in conscious cats.** *J Feline Med Surg* 2021; 23: 121–130.
- 22 Gouni V, Tissier R, Misbach C, et al. **Influence of the observer's level of experience on systolic and diastolic arterial blood pressure measurements using Doppler ultrasonography in healthy conscious cats.** *J Feline Med Surg* 2015; 17: 94–100.
- 23 Jepson RE, Hartley V, Mendl M, et al. **A comparison of CAT Doppler and oscillometric Memoprint machines for non-invasive blood pressure measurement in conscious cats.** *J Feline Med Surg* 2005; 7: 147–152.
- 24 Lin CH, Yan CJ, Lien YH, et al. **Systolic blood pressure of clinically normal and conscious cats determined by an indirect Doppler method in a clinical setting.** *J Vet Med Sci* 2006; 68: 827–832.
- 25 Mandigers P. **Non-invasive blood pressure measurement in dogs and cats** [article in Dutch]. *Tijdschr Diergeneesk* 2005; 130: 198–201.
- 26 Payne JR, Brodbelt DC and Luis Fuentes V. **Blood pressure measurements in 780 apparently healthy cats.** *J Vet Intern Med* 2017; 31: 15–21.
- 27 Quimby JM, Smith ML and Lunn KF. **Evaluation of the effects of hospital visit stress on physiologic parameters in the cat.** *J Feline Med Surg* 2011; 13: 733–737.
- 28 Sparkes AH, Caney SM, King MC, et al. **Inter- and intra-individual variation in Doppler ultrasonic indirect blood pressure measurements in healthy cats.** *J Vet Intern Med* 1999; 13: 314–318.
- 29 Van Vertloo LR, Carnevale JM, Parsons RL, et al. **Effects of waiting room and feline facial pheromone experience on blood pressure in cats.** *Front Vet Sci* 2021; 8: 640751. DOI: 10.3389/fvets.2021.640751.
- 30 Whittemore JC, Nystrom MR and Mawby DI. **Effects of various factors on Doppler ultrasonographic measurements of radial and coccygeal arterial blood pressure in privately owned, conscious cats.** *J Am Vet Med Assoc* 2017; 250: 763–769.
- 31 Zeugswetter FK, Tichy A and Weber K. **Radial vs coccygeal artery Doppler blood pressure measurement in conscious cats.** *J Feline Med Surg* 2018; 20: 968–972.
- 32 Acierno MJ, Seaton D, Mitchell MA, et al. **Agreement between directly measured blood pressure and pressures obtained with three veterinary-specific oscillometric units in cats.** *J Am Vet Med Assoc* 2010; 237: 402–406.
- 33 Belew AM, Barlett T and Brown SA. **Evaluation of the white-coat effect in cats.** *J Vet Intern Med* 1999; 13: 134–142.
- 34 Binns SH, Sisson DD, Buoscio DA, et al. **Doppler ultrasonographic, oscillometric sphygmomanometric, and photoplethysmographic techniques for noninvasive blood pressure measurement in anesthetized cats.** *J Vet Intern Med* 1995; 9: 405–414.
- 35 Branson KR, Wagner-Mann CC and Mann FA. **Evaluation of an oscillometric blood pressure monitor on anesthetized cats and the effect of cuff placement and fur on accuracy.** *Vet Surg* 1997; 26: 347–353.
- 36 Caulkett NA, Cantwell SL and Houston DM. **A comparison of indirect blood pressure monitoring techniques in the anesthetized cat.** *Vet Surg* 1998; 27: 370–377.
- 37 Cerejo SA, Teixeira-Neto FJ, Garofalo NA, et al. **Effects of cuff size and position on the agreement between arterial blood pressure measured by Doppler ultrasound and through a dorsal pedal artery catheter in anesthetized cats.** *Vet Anaesth Analg* 2020; 47: 191–199.
- 38 da Cunha AF, Saile K, Beaufrère H, et al. **Measuring level of agreement between values obtained by directly measured blood pressure and ultrasonic Doppler flow detector in cats.** *J Vet Emerg Crit Care (San Antonio)* 2014; 24: 272–278.
- 39 Haberman CE, Morgan JD, Kang CW, et al. **Evaluation of Doppler ultrasonic and oscillometric methods of indirect blood pressure measurement in cats.** *Intern J Appl Res Vet Med* 2004; 2: 279–289.
- 40 Martel E, Egner B, Brown SA, et al. **Comparison of high-definition oscillometry – a non-invasive technology for arterial blood pressure measurement – with a direct invasive method using radio-telemetry in awake healthy cats.** *J Feline Med Surg* 2013; 15: 1104–1113.
- 41 Petric AD, Petra Z, Jerneja S, et al. **Comparison of high definition oscillometric and Doppler ultrasonic devices for measuring blood pressure in anaesthetised cats.** *J Feline Med Surg* 2010; 12: 731–737.
- 42 Skelding A and Valverde A. **Non-invasive blood pressure measurement in animals: Part 1 – techniques for measurement and validation of non-invasive devices.** *Can Vet J* 2020; 61: 368–374.
- 43 Skelding A and Valverde A. **Review of non-invasive blood pressure measurement in animals: part 2 – evaluation of the performance of non-invasive devices.** *Can Vet J* 2020; 61: 481–498.
- 44 Mishina M, Watanabe N and Watanabe T. **Diurnal variations of blood pressure in cats.** *J Vet Med Sci* 2006; 68: 243–248.
- 45 Campigotto A, Bernardo T, Stone E, et al. **An animal health example of managing and analyzing a large volume of data on a PC: modeling body weight and age of over 13 million cats for explanatory and predictive purposes.** *Prev Vet Med* 2020; 174: 104824. DOI: 10.1016/j.prevetmed.2019.104824.
- 46 Campigotto AJ, Poljak Z, Stone EA, et al. **Investigation of relationships between body weight and age among domestic cats stratified by breed and sex.** *J Am Vet Med Assoc* 2019; 255: 205–212.
- 47 Freeman LM, Lachaud MP, Matthews S, et al. **Evaluation of weight loss over time in cats with chronic kidney disease.** *J Vet Intern Med* 2016; 30: 1661–1666.
- 48 Greene JP, Lefebvre SL, Wang M, et al. **Risk factors associated with the development of chronic kidney disease in cats evaluated at primary care veterinary hospitals.** *J Am Vet Med Assoc* 2014; 244: 320–327.
- 49 Jukes A, Lui M, Morton JM, et al. **Associations between increased body condition score, bodyweight, age and breed with urethral obstruction in male castrated cats.** *Vet J* 2019; 244: 7–12.
- 50 King JN, Gunn-Moore DA, Tasker S, et al. **Tolerability and efficacy of benazepril in cats with chronic kidney disease.** *J Vet Intern Med* 2006; 20: 1054–1064.

- 51 Spada E, Antognoni MT, Proverbio D, et al. **Haematological and biochemical reference intervals in adult Maine Coon cat blood donors.** *J Feline Med Surg* 2015; 17: 1020–1027.
- 52 Teng KT, McGreevy PD, Toribio JLML, et al. **Risk factors for underweight and overweight in cats in metropolitan Sydney, Australia.** *Prev Vet Med* 2017; 144: 102–111.
- 53 Hori Y, Heishima Y, Yamashita Y, et al. **Epidemiological study of indirect blood pressure measured using oscillometry in clinically healthy cats at initial evaluation.** *J Vet Med Sci* 2019; 81: 513–516.
- 54 Morar D, Falcă C, Moț T, et al. **Blood pressure in cats with chronic renal failure.** *Lucrări Științifice Med Vet* 2010; 43: 319–324.
- 55 Syme HM, Barber PJ, Markwell PJ, et al. **Prevalence of systolic hypertension in cats with chronic renal failure at initial evaluation.** *J Am Vet Med Assoc* 2002; 220: 1799–1804.
- 56 Morar D, Ciulan V, Simiz F, et al. **Arterial blood pressure measured by oscillometric method in cats with hyperthyroidism.** *Lucrări Științifice Med Vet* 2014; 47: 60–64.
- 57 Watson N, Murray JK, Fonfara S, et al. **Clinicopathological features and comorbidities of cats with mild, moderate or severe hyperthyroidism: a radioiodine referral population.** *J Feline Med Surg* 2018; 20: 1130–1137.
- 58 Williams TL, Peak KJ, Brodbelt D, et al. **Survival and the development of azotemia after treatment of hyperthyroid cats.** *J Vet Intern Med* 2010; 24: 863–869.
- 59 Williams TL, Elliott J and Syme HM. **Renin-angiotensin-aldosterone system activity in hyperthyroid cats with and without concurrent hypertension.** *J Vet Intern Med* 2013; 27: 522–529.
- 60 Sander C, Hörauf A and Reusch C. **Indirect blood pressure measurement in cats with diabetes mellitus, chronic nephropathy and hypertrophic cardiomyopathy** [article in German]. *Tierarztl Prax Ausg K Kleintiere Heimtiere* 1998; 26: 110–118.
- 61 Conti LMDC, Champion T, Guberman UC, et al. **Comparison of indirect systolic blood pressure on the forelimb and hindlimb of cats.** *Rev Acad Ciênc Agrar Ambient* 2013; 11: 395–401.
- 62 De Rosa SM, Drobatz KJ and Reineke EL. **Evaluation of coccygeal and radial artery Doppler blood pressure measurements in sick cats with and without abnormalities in tissue perfusion.** *J Vet Emerg Crit Care* 2021; 31: 749–757.
- 63 Mishina M, Watanabe T, Fujii K, et al. **Non-invasive blood pressure measurements in cats: clinical significance of hypertension associated with chronic renal failure.** *J Vet Med Sci* 1998; 60: 805–808.
- 64 Sansom J, Rogers K and Wood JL. **Blood pressure assessment in healthy cats and cats with hypertensive retinopathy.** *Am J Vet Res* 2004; 65: 245–252.
- 65 Morar D, Moț T, Falcă C, et al. **The relationship between age and blood pressure in clinically healthy cats.** *Lucrări Științifice Med Vet* 2012; 45: 125–129.
- 66 Ishida A, Fujisawa M, Del Saz EG, et al. **Arterial stiffness, not systolic blood pressure, increases with age in native Papuan populations.** *Hypertens Res* 2018; 41: 539–546.
- 67 Hanås S, Holst BS, Ljungvall I, et al. **Influence of clinical setting and cat characteristics on indirectly measured blood pressure and pulse rate in healthy Birman, Norwegian Forest, and domestic shorthair cats.** *J Vet Intern Med* 2021; 35: 801–811.
- 68 Morar D, Mot T, Falca C, et al. **The antihypertensive effect of amlodipine in cats.** *Med Vet* 2011; 5: 76–81.
- 69 Cirila A, Drigo M, Andreani V, et al. **Ocular fundus abnormalities in cats affected by systemic hypertension: prevalence, characterization, and outcome of treatment.** *Vet Ophthalmol* 2021; 24: 185–194.
- 70 Young WM, Zheng C, Davidson MG, et al. **Visual outcome in cats with hypertensive chorioretinopathy.** *Vet Ophthalmol* 2019; 22: 161–167.
- 71 Higgs P, Murray JK and Hibbert A. **Medical management and monitoring of the hyperthyroid cat: a survey of UK general practitioners.** *J Feline Med Surg* 2014; 16: 788–795.
- 72 Kopecny L, Higgs P, Hibbert A, et al. **Management and monitoring of hyperthyroid cats: a survey of Australian veterinarians.** *J Feline Med Surg* 2017; 19: 559–567.