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Results of Screening of Apparently Healthy Senior and Geriatric Dogs

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Background: There is a growing interest in health care of elderly dogs; however, scientific information about physical and laboratory examination findings in this age group is limited.

Objectives: To describe systolic blood pressure (SBP), and results of physical examination and laboratory tests in senior and geriatric dogs that were judged by the owner to be healthy.

Animals: Hundred client-owned dogs.

Methods: Dogs were prospectively recruited. Owners completed a questionnaire. SBP measurement, physical, orthopedic and neurologic examination, direct fundoscopy and Schirmer tear test were performed. Complete blood count, serum biochemistry, and urinalysis were evaluated.

Results: Forty-one senior and 59 geriatric dogs were included. Mean SBP was 170 ± 38 mmHg, and 53 dogs had SBP > 160 mmHg. Thirty-nine animals were overweight. A heart murmur was detected in 22, severe calculus in 21 and 1 or more (sub)cutaneous masses in 56 dogs. Thirty-two dogs had increased serum creatinine, 29 hypophosphatemia, 27 increased ALP, 25 increased ALT, and 23 leukopenia. Crystalluria, mostly amorphous crystals, was commonly detected (62/96). Overt proteinuria and borderline proteinuria were detected in 13 and 18 of 97 dogs, respectively. Four dogs had a positive urine bacterial culture. Frequency of orthopedic problems, frequency of (sub)cutaneous masses, and platelet count were significantly higher in geriatric compared with senior dogs. Body temperature, hematocrit, serum albumin, and serum total thyroxine concentration were significantly lower in geriatric compared with senior dogs.

Conclusions and Clinical Importance: Physical and laboratory abnormalities are common in apparently healthy elderly dogs. Veterinarians play a key role in implementing health screening and improving health care for elderly pets.

Key words: Age-specific reference interval; Blood pressure; Canine; Creatinine ratio; Elderly dogs; Urinary protein.

There is a growing interest in health and wellness of elderly dogs.[1–5] Older pets represent 30–40% of patients in general practice and this proportion is likely to increase in the future as dogs live longer.[2,3] This age group has specific needs and is more prone to develop chronic illness.[2] Often, initial clinical signs are vague and difficult to recognize for the owner[2,4,5] or discarded as not important or "normal for his age."[5] Veterinary healthcare guidelines for different life stages have been developed.[1,5] The goal of these programs is to improve quality of life and longevity, through early detection and timely treatment of diseases.[1–5] Life stage categories are somewhat arbitrary and vary depending on the source. Because of a difference in life expectancy between small and large breed dogs, determination of age cutoffs for senior and geriatric dogs is difficult.[2,4,6,7] Multiple human/pet analogy charts have been proposed, in which senior and geriatric dogs are distinguished based on age and related to the ideal body weight (BW) of the animal.[2,5,8] A senior/geriatric care program should minimally include a thorough history, systolic blood pressure (SBP) measurement, extensive physical examination (PE), ophthalmic examination, and laboratory tests.[1,2,4,5] However, there is only minimal scientific information regarding abnormalities on physical and laboratory examination in senior and geriatric dogs.[4,9–12] A recent health screening study in middle-

Abbreviations:

ALP	alkaline phosphatase
ALT	alanine aminotransferases
BCS	body condition score
BW	body weight
CKD	chronic kidney disease
HPF	high power field
MCS	muscle condition score
PE	physical examination
RI(s)	reference interval(s)
SBP	systolic blood pressure
sCreat	serum creatinine concentration
STT	Schirmer tear test
USG	urine specific gravity
UPC	urinary protein:creatinine ratio

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The study was performed at the Department of Medicine and Clinical Biology of Small Animals, Faculty of Veterinary Medicine, Ghent University, Salisburylaan 133, 9820 Merelbeke, Belgium.

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aged and old cats performed by our group confirmed that abnormalities are common in elderly cats and emphasized the need for regular health checks and age-dependent laboratory reference intervals (RIs).[13,14] The same might be true for dogs.

The current study aimed to prospectively evaluate senior and geriatric dogs that were apparently healthy for their owners and to report on the presence of abnormal findings on SBP measurement, PE, ophthalmic, neurologic, and orthopedic examination and routine blood and urinalysis. We hypothesized that owners often fail to recognize potentially pathologic abnormalities or consider them as normal for the dog's age.

Materials and Methods

Animals

One hundred dogs without currently known health issues were recruited prospectively. Owners were informed about the study by means of social media and by posters and brochures at the University of Ghent and multiple general veterinary practices in Flanders (Belgium) and the Netherlands. Age of inclusion depended on estimated ideal BW (based on body condition scoring[15,16]), with a previously published human/pet age analogy chart as a guide (Fig. 1).[5] Dogs could not be included if year of birth was unknown. To evaluate age effect, dogs were divided into 2 age groups based on the same chart[5]: group 1 (senior) and group 2 (geriatric). We aimed to have an approximately equal number of senior and geriatric dogs and a maximum of 8 dogs per breed to avoid a possible breed effect on the results. Sex was not a recruitment criterion. All examinations were free of charge for the owner.

To be accepted for inclusion, dogs had to be "healthy for the owner;" that is, in the owner's opinion, the dog did not have any problem for which veterinary care was needed. This was then considered "apparently healthy" for the owner. Dogs needed to be free of medication for at least 2 months before inclusion. Preventive medication (vaccination, deworming) was allowed until 2 weeks before consultation. Interested owners were contacted by telephone or email by 1 author (AW) to evaluate suitability of the candidate (age, medication, health status according to owner), and an information brochure was provided. Dogs that were not deemed suitable were excluded, and the others were invited for the health screening consultation. All dogs were fasted for 12 hours, and water was offered at libitum.

The study was completed at the Department of Small Animal Medicine and Clinical Biology, Ghent University, between February and June 2013. All dogs were privately owned, the owners signed an informed consent, and the study was approved by the local and national ethical committees (EC2012/181).

Study Protocol

All procedures were performed in the same order by the same author (AW) without sedation or anesthesia.

Owners completed a questionnaire related to health, living environment, activity, behavioral changes (canine cognitive dysfunction rating scale[17]), nutrition, vaccination, parasite control, and medical history (Appendix S1). The questionnaire was reviewed with the owner, and additional questions were asked if required. During this time, the dog was allowed to freely explore the examination room. Dogs with a recent history of medication or when significant illness was suspected based on the history and

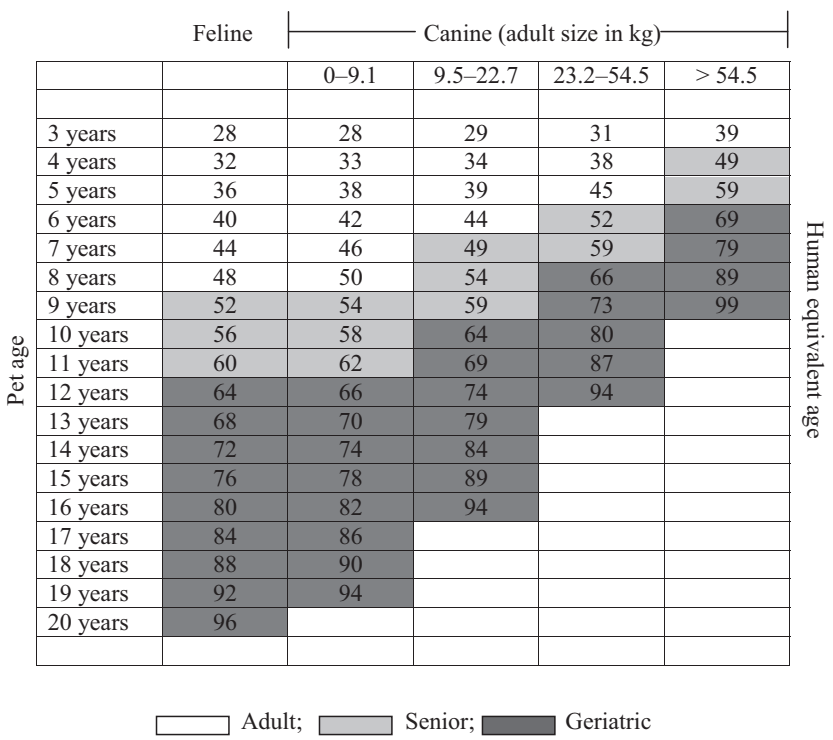

Figure 1. Human/pet analogy chart (modified from Fortney WD: Implementing a Successful Senior/Geriatric Health Care Program for Veterinarians, Veterinary Technicians, and Office Managers. Vet Clin North Am Small Anim Pract 2012;42:823–834. Adapted with permission).

observation (eg obvious polyuria/polydipsia (>100 mL/kg/d), cachexia) were excluded.

The SBP was measured by Doppler ultrasonic technique according to the ACVIM guidelines.[18] Hypertension and hypotension were defined as SBP ≥160 mmHg and <80 mmHg, respectively.[18–21]

A standard PE was performed including assessment of body condition score (BCS) on a 9-point scale and muscle condition score (MCS),[15,16] rectal examination, and digital vaginal examination in females. A standard orthopedic[22,23] and neurologic[24] and brief ophthalmic[25] examination was additionally performed. Bilateral tear production was evaluated with a Schirmer tear test (STT) strip, and a production of ≥15 mm per minute was considered normal.[25] Direct fundoscopy was performed, paying special attention to signs secondary to systemic hypertension, such as retinal hemorrhage or detachment, subretinal edema, or tortuous vessels.[26]

Six milliliters of blood was taken from the jugular vein, and 10 mL of urine was collected by ultrasound-guided cystocentesis. To obtain serum, coagulated tubes were centrifuged within 30 minutes at 2431 x *g*. All samples were preserved at 4°C and analyzed the day of collection.[a]

A CBC[b] and serum biochemistry profile[c] were performed and serum total thyroxine concentration was measured with a previously validated immunoassay.[d,27]

Urinalysis consisted of measurement of urine specific gravity (USG) with a manual refractometer; urinary pH and urinary protein:creatinine ratio (UPC[e]); urinary dipstick[f] ; sediment evaluation; and bacterial culture.[g] Sediment was prepared by centrifuging 5 mL of urine for 3 minutes at 447 x *g*, after which 4 mL of the supernatants was removed. Sediment was resuspended by flicking the tube several times, and 1 unstained drop was placed on a clean glass slide and covered with a coverslip.[28] The presence of cells, crystals, and casts was evaluated microscopically within 30 minutes of collection. Crystalluria and presence of casts were evaluated semiquantitatively and expressed per high power field (HPF) (40xobjective) as absent, mild (<1/HPF), moderate (1-3/HPF), or severe (≥3/HPF). Microscopic hematuria and pyuria was defined as more than 5 red blood cells and white blood cells per HPF, respectively.

With the owner's consent, fine needle aspiration and cytology of (sub)cutaneous masses were performed.

Statistical Analysis

All statistical analyses were performed with the statistical software package SAS.[h] Differences between the 2 age groups were analyzed by a linear fixed effects model for continuous variables and a Wilcoxon rank sum test for ordinal variables. Binary variables were analyzed by logistic regression. Spearman's rank correlation coefficient was used to evaluate association between variables. Associations between continuous variables were explored by linear regression. The level of significance was set at 5%.

The study was set up to have a power of 80% to find a significant effect for systolic blood pressure when the relative difference, that is, difference divided by standard deviation, equals 0.60, by a two-sided *t*-test at the 5% significance level and assuming a 2 : 3 ratio for the sample sizes in the 2 groups.

Results

Study Population

The age criteria were met by 131 dogs, 30 were excluded after initial contact by telephone or email because of recent medication/anesthesia (n = 5), pregnancy (n = 1), hypothyroidism (n = 1), maximum amount of dogs per breed was met (n = 10), and to prevent overrepresentation of geriatric dogs (n = 13). One dog was excluded after questionnaire review because of recent medication. One hundred privately owned dogs, 41 senior and 59 geriatric, were accepted for inclusion. Population consisted of 50 females (10 intact, 40 neutered) and 50 males (26 intact, 24 neutered). Eighty-four were purebred dogs (1 to 8 dogs per breed), and 16 were crossbred. Forty-five dogs belonged to students or staff. Age and BW of the complete population and age groups are presented in Table 1.

Questionnaire

Ten owners reported their dog was "getting a bit older," 5 were reported to sleep more, 13 were more prone to stiffness or lameness, 14 were deaf or hearing less, and in 7 dogs the owner had noticed a decreased sight. None of the dogs had a cognitive dysfunction score rating scale compatible with canine cognitive dysfunction syndrome.[17]

Four geriatric dogs were reported to urinate larger amounts and to drink slightly more (<100 mL/kg/d). Four dogs had urinary incontinence (2 senior males, 1 geriatric male, and 1 geriatric, neutered female), 4 dogs soiled the house during the night (n = 3, all geriatric, 1 intact male, 2 neutered females) or when excited (n = 1, geriatric intact female), and 1 had pollakiuria. None of the owners realized that polyuria, periuria, or pollakiuria might be associated with or a consequence of a medical condition.

Ninety-nine dogs received mainly commercial food (71 dry food, 12 dry and canned food, 16 > 50% raw meat) and 1 dog received a home-made diet. Twenty-eight dogs were fed an age-specific diet, 3 were on a diet for neutered animals, 6 were on a low-fat or reduction diet, and 6 were on a specific diet for sensitive skin (n = 1), dental support (n = 1), joint disease (n = 2), or intestinal sensitivity (n = 2). Of the dogs that were on a low-fat or reduction diet, half of the dogs had overweight (BCS >5) and 1 had underweight (BCS 3/9).

For dogs not belonging to veterinarians (n = 90), yearly visits to the veterinarian were reported for 67 dogs, 8 dogs were reported to go more often, and 15 dogs went less frequently. Last health visit was less than 6 months ago in 50% of the dogs (45/90). Vaccination in accordance with recent guidelines[29] and quarterly deworming were performed in 77 and 58 dogs, respectively. External parasiticides were applied regularly in 75 dogs, from time to time in 23 and never in 2 dogs. Teeth were brushed frequently (once or twice a week) in 3 dogs, infrequently in 12 dogs, and never in 85 dogs.

Blood Pressure Measurement and Physical and Ophthalmic Examination

The descriptive statistics for SBP and some of the PE findings are summarized in Table 1.

Fifty-three dogs had SBP exceeding 160 mmHg, 36 of which were equal to or exceeding 180 mmHg (maximum 274 mmHg). In 13 hypertensive dogs (range 171–

Table 1. Descriptive statistics for all included dogs and for the 2 age groups. All variables are normally distributed and are expressed as mean ± standard deviation.

	RI	Study Population (n = 100)	Senior Dogs (n = 41)	Geriatric Dogs (n = 59)	*P*-value
Age (years)[a]	/	9.6 ± 2.4	7.9 ± 1.8	10.8 ± 2.0	/
Body weight (kg)	/	27.6 ± 17.9	27.2 ± 19.4	27.8 ± 16.9	.86
SBP	80–160 mmHg[18–21]	170 ± 38	169 ± 36	171 ± 39	.89
Heart rate	60–120 beats/min[30]	108 ± 23	111 ± 26	106 ± 21	.24
RR	10–30 breaths/min[30]	72 ± 59	74 ± 71	70 ± 51	.72
Body temperature[a]	38–39.2°C[30]	38.8 ± 0.4	38.9 ± 0.4	38.8 ± 0.4	.044
STT left eye	≥15 mm/min[25]	19.6 ± 3.8	19.8 ± 4.2	19.5 ± 3.5	.77
STT right eye	≥15 mm/min[25]	19.0 ± 3.5	19.3 ± 3.7	18.8 ± 3.5	.48
Hematocrit[a]	43–59%	48.3 ± 4.8	49.8 ± 4.1	47.2 ± 5.0	.0064
Leukocytes	6000–16,000 /μL	7667.1 ± 2577.9	7680.0 ± 2912.3	7658.1 ± 2344.0	.97
Thrombocytes[a]	164,000–510,000/μL	310,030 ± 101,717	280,268 ± 86887	330712 ± 106735	.014
Sodium	143–154 Eq/L	147.7 ± 2.1	148.0 ± 1.8	147.5 ± 2.3	.27
Potassium	4.2–5.6 mEq/L	4.6 ± 0.4	4.5 ± 0.4	4.6 ± 0.4	.13
Total calcium	4.0–5.7 mEq/L	5.2 ± 0.2	5.2 ± 0.2	5.2 ± 0.2	.96
Phosphorus	3.0–5.8 mg/dL	3.4 ± 0.9	3.4 ± 0.9	3.4 ± 0.9	.71
Urea	6.0–57 mg/dL	30.3 ± 9.7	28.0 ± 8.7	31.8 ± 10.1	.052
Creatinine	<(60 + BW)/88.4 mg/dL	0.9 ± 0.2	0.9 ± 0.2	0.9 ± 0.2	.50
Total protein	5.3–8.0 g/dL	6.6 ± 0.5	6.6 ± 0.5	6.6 ± 0.4	.40
Albumin[a]	2.2–4.4 g/L	4.0 ± 0.4	4.1 ± 0.3	3.9 ± 0.4	.015
Cholesterol	114–390 mg/dL	249.8 ± 75.6	236.5 ± 60.9	259.1 ± 83.7	.14
Triglycerides	2–152 mg/dL	86.8 ± 143.6	86.5 ± 107.8	86.9 ± 164.8	.99
AST	<50 U/L	33.9 ± 10.8	34.8 ± 11.4	33.2 ± 10.4	.48
ALT	<70 U/L	66.4 ± 61.2	63.8 ± 44.2	68.2 ± 71.0	.72
ALP	<111 U/L	108.6 ± 152.1	101.4 ± 157.7	113.5 ± 149.2	.70
GGT	<9 U/L	6.5 ± 10.0	5.5 ± 3.3	7.3 ± 12.8	.39
Glucose	54.9–89.8 mg/dL	82.8 ± 7.2	82.8 ± 9.0	81.0 ± 7.2	.29
Total thyroxine[a]	0.5–3.4 μg/dL	2.0 ± 0.8	2.3 ± 0.9	1.9 ± 0.7	.0078
Urinary pH	4.5–7.0	7.0 ± 1.1	7.0 ± 1.2	7.0 ± 1.0	1.0
USG		1.031 ± 0.012	1.033 ± 0.010	1.030 ± 0.012	.13
UPC	<0.5	0.3 ± 0.6	0.3 ± 0.5	0.3 ± 0.6	.57

RI, reference interval; SBP, systolic blood pressure; RR, respiratory rate; STT, Schirmer tear test; AST, aspartate transaminase activity; ALT, alanine transaminase activity; ALP, alkaline phosphatase activity; GGT, γ-glutamyl transpeptidase activity; USG, urine specific gravity; UPC, urinary protein:creatinine ratio.

[a]Variables significantly different between age groups.

264 mmHg), SBP was remeasured later on the same day. Four of these were normotensive the second time, and only 1 dog still had SBP exceeding 180 mmHg (181 mmHg). There was a negative linear relationship between SBP and BW ($P = .021$): for each increase in BW with 1 kg, SBP decreased with 0.5 mmHg. Overweight, age, and sex did not have a significant effect on SBP.

Body and muscle condition score are presented in Table 2. Three of 39 overweight dogs and the 2 underweight dogs had mild-to-moderate muscle wasting. Both BCS and MCS were not significantly different between the 2 age groups. There was a significant association between being neutered and overweight ($P = .011$).

One dog was bradycardic (56 beats per minute) and 1 was severely tachycardic (200 beats per minute), which normalized at the end of the examination.[31] Three dogs had an irregular heart rhythm, other than sinus arrhythmia. A systolic heart murmur was detected in 22 animals (8 senior, 14 geriatric), with the following intensity: grade 1/6 (n = 4), 2/6 (n = 7), 3/6 (n = 8), and 4/6 (n = 3). The difference between the 2 age groups was not significant, but the odds of systolic murmur was significantly decreasing with increasing weight (OR = 0.95, 95% CI 0.92–0.99, $P = .0077$). Lung auscultation was normal in 86 dogs and increased bronchovesicular sounds were observed in 14 dogs, 12 of which were panting. Tracheal reflex was positive in 30 dogs. None of the dogs had a palpable thyroid gland.

Findings of oral examination are summarized in Table 2. All of the dogs with gingivitis had calculus. Halitosis was present in 36 dogs, and all of these had calculus with or without gingivitis. Teeth were brushed in 11 dogs with calculus.

Fourteen dogs had body temperature exceeding 39.2°C (maximum 39.7°C), none of the dogs had values below 38°C. There was a significant positive correlation between heart rate and body temperature ($rho = 0.43$; $P < .001$). Seventeen dogs had local lymphadenopathy. Thirteen dogs had submandibular lymphadenopathy and concurrent calculus and gingivitis, 2 dogs had a reactive popliteal lymph node (cutaneous inflammation and presumed insect bite in affected animals), and 2 dogs had mild prescapular lymphadenopathy. Abdominal palpation was tense in 19 dogs and painful in 2.

Table 2. Body condition score, severity of muscle wasting, and oral examination findings in the global population and the 2 age groups.

	Global Population (n = 100)	Senior Dogs (n = 41)	Geriatric Dogs (n = 59)
Body Condition Score[a]			
<4	2	2	0
4–5	59	24	35
>5	39	15	24
Muscle wasting			
Absent	87	38	49
Mild	10	2	8
Moderate	3	1	2
Severe	0	0	0
Dental calculus			
Not obvious	12	6	6[b]
Mild	37	17	20
Moderate	30	10	20
Severe	21	8	13
Gingivitis			
Absent	51	23	28
Mild	28	10	18
Moderate	18	7	11
Severe	3	1	2

[a]Body conditions score on a 9-point scale.

[b]One dog had multiple dental treatments and had only 1 tooth left.

None of the dogs had a palpable abdominal mass or organomegaly.

Two geriatric intact dogs had a unilateral enlarged and firmer testicle. One dog had testicular prostheses. Eleven male dogs had signs compatible with balanoposthitis, and 8 of these were intact. Symmetrical mild prostatic enlargement was present in 6/26 intact male dogs; in 12/26, the prostate was located abdominally; and in 7/26, palpation was normal. Rectal examination did not reveal any other abnormalities. Palpation of the mammary glands revealed 1 small mammary nodule in a senior intact female dog and 2 female dogs had undergone a unilateral mastectomy (1 partial, 1 complete). Digital vaginal examination was possible in 40 of 50 female dogs and revealed a small vaginal mass in 1 intact geriatric dog.

Fifty-six dogs had at least 1 (sub)cutaneous mass, ranging from 1 to 9 per dog. There was a total of 151 (sub)cutaneous masses, 29 of which were warts. Geriatric dogs had significantly more masses (mean 2.1 ± 2.5 masses per dog) than senior dogs (0.7 ± 1.2 masses per dog; $P = .0017$). Cytology was not performed (21/56 dogs) on small warts, eyelids, or when owner refused puncture. Ten samples were not diagnostic. One or more lipomas were found on 23 dogs. Nine dogs had 1 or more follicular cyst(s). Two dogs were diagnosed with cutaneous mastocytoma, which was histologically confirmed as a grade II mastocytoma in 1. One dog had a basal cell carcinoma on the ear, 3 had cytology suggestive of sebaceous gland adenoma, and 2 dogs had cytology suggestive for a sarcoma. Histology of 1 of the suspected sarcomas revealed an inflamed epithelioma.

Orthopedic examination could be performed in 98 dogs and was normal in 36. Twenty-four dogs showed abnormalities on 1 limb, and 38 dogs had 2 or more limbs affected. The most frequently affected joint was the hip with uni- and bilateral painful or decreased extension, flexion, or both in 44 dogs. Marked lameness on a front limb was noted in 6, on a hind limb in 1, and on multiple limbs in 4 dogs. There were significantly more orthopedic problems in the geriatric group ($P = .0068$), the odds for orthopedic problems was not associated with BW, and there was no significant association between orthopedic problems and being overweight.

Neurologic examination could be performed in 98 dogs and was normal in 80 cases. Four dogs had decreased or absent patellar reflexes (1 unilateral, 3 bilateral), 7 showed discomfort when manipulating cervical spine (n = 5) or dorsiflexion of the tail (n = 2). One dog had a mild ataxia, related to previous surgery for a herniated disk. Two dogs did not respond to loud auditory stimuli, both of them were reported deaf by the owner.

In 98 dogs, STT could be performed. Results <15 mm/min were found bilaterally in 4 and unilateral in 6 dogs. Two dogs had readings of <10 mm/min. One dog had unilateral conjunctivitis with a superficial corneal ulcer and decreased tear production (10 mm/min). There was no significant difference in STT between the 2 age groups. Lens opacification (sclerosis or cataract) was present in 66 dogs. Opacification was mild in 35, moderate in 27, and severe in 4 dogs. Fundoscopic examination could be performed in 96 dogs, abnormalities secondary to hypertension were not found, and inspection was hampered by lens opacification in 13 dogs.

Laboratory Variables

Descriptive statistics for laboratory variables are presented in Table 1 and the number of animals within, below, or above the RI in Table 3.

Mild, nonregenerative anemia was present in 11 dogs, being mild in 8 dogs (hematocrit ≥40%). Fifteen of the 23 leukopenic dogs had total leukocyte count above 5000/μL, and only 3 dogs had values ranging from 3000–4000/μL. Twelve of the leukopenic dogs had normal differential leukocyte counts, 5 had lymphopenia, and 6 showed a mild-to-moderate decrease in mature neutrophils. Two of 4 dogs with thrombocytopenia had platelet aggregates on their blood smear, suggesting pseudothrombocytopenia.

For the 32 dogs with increased serum creatinine (sCreat), USG is shown in Table 4.[32] In 1 dog, USG was not available. Urea was increased in only 1 dog, this dog also had an increased sCreat and USG of 1.020 and was borderline proteinuric. Six dogs with an increased sCreat and USG below 1.030 were hypertensive. Two of them had SBP between 160 and 180 mmHg and none of those were proteinuric, 4 had SBP of 180 mmHg or more, and 1 of these dogs had borderline proteinuria. Linear regression showed a

Table 3. Distribution of laboratory variables of the global population below, within, and above the reference interval.

		Below RI		Within RI	Above RI	
Variable	RI	n	Minimum	n	n	Maximum
Hematocrit	43–59%	11	30.7	89	0	/
Leukocytes	6000–16,000/μL	23	3430	76	1	22,270
Thrombocytes	164,000–510,000/μL	4	112,000	94	2	811,000
Sodium	143–154 mEq/L	1	142	99	0	/
Potassium	4.2–5.6 mEq/L	11	3.6	88	1	5.9
Chloride	106–118 mEq/L	0	/	96	4	121
Total calcium	4.0–5.7 mEq/L	0	/	99	1	5.8
Phosphorus	3.0–5.8 mg/dL	29	1.4	71	0	/
Urea	6.0–57 mg/dL	1	4.33	98	1	72
Creatinine	<(60 + BW)/88.4 mg/dL	/	/	68	32	1.5
Total protein[a]	5.3–8.0 g/dL	0	/	98	0	/
Albumin[a]	2.2–4.4 g/L	0	/	88	10	4.8
Cholesterol	114–390 mg/dL	1	108	97	2	603
Triglyceride	2–152 mg/dL	0	/	93	7	1285
AST	<50 U/L	/	/	88	12	
ALT	<70 U/L	/	/	75	25	456
ALP	<111 U/L	/	/	73	27	981
GGT	<9 U/L	/	/	76	14	89
Glucose	54.9–89.8 mg/dL	0	/	85	15	94.9
Total thyroxine	0.5–3.4 μg/dL	1	<0.5	96	3	4.8

RI, reference interval; BW, body weight in kg; AST, aspartate transaminase activity; ALT, alanine transaminase activity; ALP, alkaline phosphatase activity; GGT, γ-glutamyl transpeptidase activity.

[a]Two samples could not be analyzed because of hyperlipidemia.

Table 4. Distribution of urine specific gravity in the global population, the 2 age groups, and dogs with increased serum creatinine.[a]

	Global Population (n = 99)	Senior Dogs (n = 40)	Geriatric Dogs (n = 59)	Dogs with Increased Serum Creatinine
USG ≥1.030	57	26	31	17
USG >1.013–1.030	36	13	23	10
USG 1.007–1.013	6	1	5	4

[a]>(60 + body weight in kg)/88.4 mg/dL.

USG, urine specific gravity.

Table 5. Degree of increase in activity of liver-derived enzyme activities in serum in the global population, described as a function of the upper reference limit.

Variable	Number of Dogs with Value above RI	Number of Dogs 1-<2 Times URL	Number of Dogs 2-<3 Times URL	Number of Dogs ≥3 Times URL
AST	12	12	0	0
ALT	25	19	3	3
ALP	27	16	6	5
GGT	14	12	0	2

RI, reference interval; URL, upper reference limit; AST, aspartate transaminase activity; ALT, alanine transaminase activity; ALP, alkaline phosphatase activity; GGT, γ-glutamyl transpeptidase activity.

significant positive relationship between sCreat and BW (slope: 0.27; $P = .0045$).

Increase in activity of liver-derived enzyme activities in serum was quite common and mostly minor (Table 5). Mild hyperglycemia was present in 15 dogs, and none of these had glycosuria. Serum total thyroxine concentration was increased in 3 senior dogs and decreased in 1 senior dog. The latter dog had an increased thyroid stimulating hormone level and was diagnosed with hypothyroidism. It had a BCS of 8/9, was rather passive for the owner, and had SBP of 186 mmHg and proteinuria. It also had hypertriglyceridemia and mildly increased liver enzyme activities. Hypertriglyceridemia was present in 7 dogs, with 1 having concurrent hypercholesteremia. Two dogs were known to have hypertriglyceridemia and were fed a low-fat diet. One of these still had severely increased triglycerides (>8 times upper limit of RI), and the other only had a very mild hypertriglyceridemia. There was a weak but significant association between cholesterol and triglycerides (*rho* = 0.22; $P = .025$) and between cholesterol and BCS (*rho* = 0.27; $P = .0075$).

Cystocentesis was performed in 97 dogs, 1 dog had an empty bladder, and 2 dogs urinated on the table; only USG was recorded. Results for USG are presented in Table 4.[32] Urinary sediment analysis was performed in 96 samples. Microscopic analysis revealed crystalluria (62/96), presence of free lipid droplets (79/96), spermatozoids (14/96), bacteria (5/96), microscopic hematuria (32/96), and pyuria (5/96). Mild-to-moderate amounts of casts were seen in 28/96 dogs (hyaline n = 23;

granular n = 2; hyaline and granular n = 3). Crystalluria was mild in 37, moderate in 18, and severe in 7 dogs. Amorphous crystals were most commonly detected (51/62). Struvite crystals were noted in the remaining dogs. There was no significant association between food type and presence of urinary crystals. Four dogs (2 female neutered, 2 male intact; 1 senior, 3 geriatric) had a positive urinary culture for *Escherichia coli* and sediment analysis revealed bacteriuria and pyuria in all 4 dogs. In 1 male dog without treatment, a follow-up sample could be obtained 14 days later and the culture was negative.

UPC distribution according to the ACVIM consensus statement[33] is presented in Table 6. Of the dogs with borderline proteinuria, 2 had a positive urinary culture, 5 had microscopic hematuria, 1 had an increased sCreat and USG of 1.020, 2 had an increased sCreat and USG ≥1.030, and 15 had normal sCreat. In the dogs with overt proteinuria, 1 had a bacterial cystitis, 1 had mild pyuria, and 4 had microscopic hematuria. Twelve dogs with overt proteinuria had a normal sCreat, and 1 had an increased sCreat and concentrated urine (USG ≥1.030). Ten dogs with borderline proteinuria and 10 dogs with overt proteinuria had SBP ≥ 160 mmHg. There was a weak but significant correlation between SBP and proteinuria (*rho* = 0.22; *P* = .030). There was no significant difference in UPC between the 2 age groups and there was no significant association between UPC and BW.

Urinary pH ranged from 5 to 7.5 in 68/97 dogs and was >7.5 (maximum 9) in 29/97 dogs. Only 1 dog with bacterial cystitis had alkaline urine (pH 8.5). Results of urinary dipstick analysis are summarized in Table 7. Of the dogs with confirmed bacterial cystitis, 2 had a trace and the other 2 were leukocyte esterase positive. The protein dipstick was negative in 1 borderline proteinuric dog. All other dogs with borderline or overt proteinuria had at least a trace of protein on dipstick. On the other hand, urinary dipstick reported a trace or even protein positivity in, respectively, 22 and 25 cases with UPC <0.2.

Table 6. Distribution of the complete population and age groups across the 3 proteinuria categories according to the ACVIM consensus statement of Lees et al.[33]

	Global Population (n = 97)	Senior Dogs (n = 39)	Geriatric Dogs (n = 58)
UPC <0.2	66	25 (64.1%)	41 (70.7%)
UPC 0.2–0.5	18	10 (25.6%)	8 (13.8%)
UPC >0.5	13	4 (10.3%)	9 (15.5%)

UPC, urinary protein:creatinine ratio.

Table 7. Results of urinary dipstick analysis in the global population (performed on 97 animals).

	Negative	Trace	Positive
Hemoglobin	79	4	14
Bilirubin	16	45	36
Urobilinogen	60	37	0
Leukocyte esterase	92	3	2
Nitrite	96	1	0
Acetone	97	0	0
Glucose	97	0	0
Protein	20	26	51

Age Group Comparison

Platelet count (*P* = .014) and frequency of orthopedic problems (*P* = .0068) and (sub)cutaneous masses (*P* = .0017) were significantly higher in geriatric compared with senior dogs. Hematocrit (*P* = .0064), serum albumin (*P* = .015), serum total thyroxine concentration (*P* = .0078), and body temperature (*P* = .044) were significantly lower in geriatric dogs. The other variables did not differ significantly between the 2 age groups.

Discussion

Older pets are becoming increasingly important in everyday practice. Guidelines and care programs have been developed,[1,2,5] but prospective studies that have recorded abnormalities and their significance are scarce.[9–11] This study describes an extensive health screening in a population of elderly dogs "apparently healthy" for their owner. Defining health is a challenge. The authors aimed to select a study population that could reflect the elderly dog population that may be presented for health screening in general practice.

Three recent prospective health screening studies on elderly dogs were published. Potentially clinically important laboratory and abdominal ultrasound abnormalities were reported in 54.7 and 64.2% of elderly, clinically normal Golden Retrievers, respectively.[9] Another study was conducted in 45 elderly dogs, involving history, PE, and urinary dipstick. At least 1 previously unrecognized problem was noted in 80% of the dogs.[10] In the latter study, inclusion criteria did not include being healthy for the owner and abnormalities were more frequently noted when compared to the present study. The third study reported on pre-anesthetic screening of 101 dogs older than 7 years, where a new diagnosis was made in 30 dogs.[11] Direct comparison between the present and the previously published studies is difficult because of different inclusion criteria and study protocols. However, both present and previous studies demonstrate that health issues are common in elderly dogs and that screening helps to identify these previously unknown health issues. Whether this earlier detection leads to improved quality of life or longevity remains to be proven.

The owner plays a pivotal role in successful health care, but is often unable to recognize early clinical signs.[2,10] In the current study, none of the owners considered excessive water intake as being pathologic or more than 100 mL/kg/d. However, 1 dog diagnosed with chronic kidney disease (CKD) appeared to be drinking more than 200 mL/kg/d when owners were asked to measure water intake at home. Also, micturition disorders were not regarded as potentially

important. It has been demonstrated that early signs of CKD were often present many months before diagnosis, but did not encourage the owner to consult a veterinarian.[34] Therefore, veterinarians should educate pet owners to detect and report clinically relevant abnormalities in their (elderly) pet.[2] Also, thorough history taking is crucial to obtain this information and should ideally be based on a questionnaire.[2,10]

Prevalence of overweight in the current study is in line with recent reports in adult dogs, that is, 34–59%.[35–40] Prevalence of overweight increases with age,[36–38] but a decrease after the age of around 10 years is reported in some studies.[35–37] There was no significant difference between the 2 age groups in our study. Neutering was significantly associated with overweight in the current and previous studies.[35–37] A prevalence of underweight between 4.2 and 11% has been reported in the adult dog population,[35,38,40,41] which is slightly higher than in the current study. The discrepancy between BCS and MCS in some of these dogs underlines the importance of evaluating muscle mass and body fat separately, as these scoring systems are not directly correlated.[16]

Raw meat-based diet is a popular feeding type nowadays,[42] which is confirmed by our data. An association has been made with nutritional imbalances, risk of pathogen transmission and other illnesses, and a raw meat-based diet is therefore not generally recommended.[42–46] As in the study by Davies, only the minority of these dogs (28%) were fed an age-adapted diet.[10] Low-fat or weight reduction diets were only fed to 6%, although 39% of dogs were considered to be overweight.[15] This emphasizes that improved owner awareness of normal canine body condition and regular nutritional assessment by veterinarians are important.[16,36,41,47]

Although prevalence of hypertension in healthy dogs is reported to be low,[48,49] in the current study hypertension was frequently encountered. The findings in our study are in contrast with a study on 33 healthy geriatric dogs (mean 130 $\pm$ 20 mmHg).[50] In contrast to the latter study, we did not exclude animals with laboratory abnormalities, heart murmur, or obesity and thus, it is likely that in our study more dogs had occult underlying diseases for secondary hypertension. However, in the current study, an obvious underlying cause for hypertension could not be defined, except for 1 dog with hypothyroidism.

The most likely explanation for the high prevalence of hypertension is white-coat hypertension, which is described in dogs, cats, and humans.[51–55] Indeed, none of the hypertensive dogs had ocular signs of target organ damage, which has been described in 62% of dogs with systemic hypertension.[26] We tried to limit the white-coat effect by measuring SBP in a quiet environment, after an acclimatization period and with the owner present if possible. However, we only had a single measurement in most of the animals. A recent study in three-year-old beagles revealed a gradual decrease in SBP and a normalization of hypertension in all animals after 4 to 5 measurements, each on a different day.[51] This emphasizes the importance of stress and thus white-coat hypertension, but also the fact that an acclimatization period of 5–10 minutes might not be sufficient in dogs in contrast to what is reported for cats.[54]

Technical artifacts during measurement seem an unlikely explanation, because the ACVIM guidelines[18] were respected and all measurements were taken by the same trained author (AW). Although all measurements were preferably performed with dogs in recumbency, some dogs were allowed to sit (n = 20) or stand (n = 5) to reduce stress and measurements were taken with the cuff at the level of the right atrium.[18] A recent study reported a significantly higher mean SBP and less repeatable measurements in dogs in a sitting positing compared with lateral recumbency.[56] Although the position could be a cause for some of the increased measurements in our study, the fact that these animals did not tolerate recumbency could also indicate more stress.

Our findings underline that canine SBP results should be interpreted with caution. If hypertension is suspected, multiple measurements are required to confirm the presence of systemic hypertension. In dogs with predisposing conditions such as CKD and hypercortisolism, or with signs consistent with end-organ damage, SBP measurement should be performed. However, the role of routine SBP measurement in all aged dogs is less clear than in feline patients.[57] Screening of dogs $\geq$10 years old is advised by some authors,[18] but care should be taken to avoid stress, to rely on multiple measurements, ideally in the pet's home environment, and to look for signs of target organ damage.

More than half of the dogs had 1 or more palpable (sub)cutaneous mass. Malignancy was suspected based on cytology in 5% of the samples. Davies reported masses suspicious for neoplasia and warts in 18 and 11% of the aged dogs, respectively, but cytology was not performed.[10] Although the majority of masses in our study was of benign origin, cytology is advised because there is a good correlation between cytologic diagnosis and histologic diagnosis.[58] There were significantly more masses in the geriatric compared with the senior group, which was also reported in annual reports in the United States.[3]

Absence or decrease in patellar reflex in 4 dogs is most likely an age-dependent neurologic decline, as was previously described in dogs.[59] Stiffness or lameness was reported by few owners, even though abnormalities on orthopedic examination were commonly encountered. Because orthopedic problems can have an important effect on comfort of dogs, it is important for veterinarians to detect, and if necessary treat, musculoskeletal abnormalities. Similarly, dental disease can affect the dogs comfort. Dental disease is a common finding in the general pet population,[12,60] especially in elderly animals.[61,62] Because we only performed visual oral inspection on conscious dogs, we cannot comment on the presence of periodontitis. Although dental hygiene can be improved by brushing teeth especially if performed frequently,[63] this was never performed in 85% of the dogs.

Tear production is reported to decrease with age in adult dogs.[64] In our population, there was no significant

difference between senior and geriatric dogs. Nevertheless, mean tear production of our general population is slightly lower than in previous studies with dogs with mean age 4 years.[64,65] In 2 dogs, the tear production was <10 mm/min, which could be compatible with keratoconjunctivitis sicca, but both these dogs did not have other clinical signs compatible with this disease.[66] The 1 dog with the corneal ulcer had unilateral mucoid discharge and a tear production of only 10 mm/min, indicative for keratoconjunctivitis sicca.

Routine monitoring of clinicopathologic data is important in the management of older animals.[67] Ideally, the trend should be followed for an individual animal, so that small, but clinically significant changes can be detected, even when they are still within the RI. This approach, preferably with subject-based RIs,[68] can help to detect chronic disease in an early stage. For the laboratory variables that were outside the RI (Table 2), some of the abnormal values could truly be the result of occult disease, but the RI may not be appropriate for this age group as well.[14] Animals between 1 and 7 years of age of different breeds and sizes were used as reference population, which may be inappropriate for assessment of elderly dogs. Age-dependent RIs might be warranted, but a major challenge is the selection of an appropriate reference population because older dogs might suffer from subclinical disease.

Fourteen dogs with increased sCreat did not have concentrated urine, which could indicate renal origin. In only 1 dog, CKD IRIS stage II could be confirmed based on repeated urine and blood analyses. For the other dogs, no follow-up information was available, so CKD could not be confirmed. The need for re-evaluation of RIs for sCreat depending on age, size, and breed has been reported before,[69–73] but it is beyond the scope of this study to investigate this matter. In agreement with the significant positive linear relationship between sCreat and BW in the current study, the upper limit of the sCreat RI for small dogs was previously reported to be substantially lower than for larger dogs.[72]

Crystalluria, mostly amorphous crystals, was detected in more than half of the dogs, and none of them showed signs of lower urinary tract disease. This is very similar to recent findings in elderly cats.[13] In contrast, crystalluria was only detected in 2.8% of dogs in a previous study on aged Golden Retrievers.[9] Another recent study reported crystalluria (mainly struvite) in 44% of dogs fed with different kinds of dry diets.[74] In our study, there was no association between food type and the presence of crystals, in contrast to what has been reported in cats.[75] All crystals observed in our study can be observed in healthy animals and it is generally accepted that crystalluria is not always associated with disease.[76,77] Therefore, mild crystalluria by itself is no indication to start feeding calculolytic diets.[77]

As expected, the urinary dipstick was associated with a high number of false positives to detect proteinuria.[28,76] Proteinuria affects up to 25% of elderly people and is not considered a physiologic age-related change, but the consequence of an underlying pathology.[78,79] In 18.6% of these dogs, renal proteinuria was detected (7 overt, 11 borderline).[33] The reader is referred to Marynissen et al. for more information regarding proteinuria in this population.[i] There was a weak, but significant positive correlation between proteinuria and SBP. This correlation was stronger in previously described studies,[80,81] possibly because of the high prevalence of stress-related hypertension in the current study. In our study, proteinuria was not significantly higher in geriatric compared with senior dogs, in contrast to a similar study in cats.[13]

Of the dogs with *Escherichia coli* cystitis, 3 dogs were asymptomatic and 1 dog had pollakiuria, unreported, and regarded as unimportant by the owner. Because all dogs had >1000 bacteria/mL and urine was obtained by cystocentesis, sample contamination is very unlikely.[82] Asymptomatic bacteriuria is most commonly described in patients with underlying, predisposing diseases (eg diabetes mellitus).[82] However, a recent study reported subclinical bacteriuria in 3/140 dogs, all young female, presenting for elective surgery.[83] *Escherichia coli* is most commonly isolated in animals with asymptomatic bacteriuria.[83,84] Three of these dogs were treated and in the other dogs bacteriuria was transient. Transient asymptomatic bacteriuria has been described earlier,[85] and the need for antimicrobial treatment in asymptomatic dogs is questioned. In the present dogs, we did initiate treatment in 3 cases, because all of them also showed pyuria.[86] Further research is needed to define risk populations and the necessity of treatment of asymptomatic bacterial cystitis in dogs.

Based on the screening performed in 100 dogs, we diagnosed cutaneous mastocytoma in 2, a mammary nodule in 1, CKD in 1, hypothyroidism in 1, and bacterial cystitis in 4 dogs. Also, many other dogs showed physical or laboratory abnormalities (eg overweight, orthopedic problems, dental calculus, increased sCreat) that warranted further diagnostics or treatment. The veterinarian and owner play a pivotal role in recognition of clinical signs, nutritional evaluation, and modification and implementation of adequate preventive medicine. Further diagnostic investigation, treatment, follow-up, or both were advised in several animals because of the presence of hypertension, heart murmur, or laboratory abnormalities. This was communicated to the owners and regular veterinarian as most owners elected to do further examinations or follow-up at their regular veterinarian. Also, the dogs were only evaluated at a single time point. The lack of further diagnostics and follow-up information limits the authors to estimate the importance of some of the physical and laboratory abnormalities. Further, the fact that veterinary students or staff were owner of 45 dogs is a potential selection bias. Because all examinations were free of charge for the owner, this might have influenced some owners to withhold potentially important information that might lead to exclusion. We tried to avoid this study limitation by taking an extensive history. Because 83% of participating owners reported veterinary visits at least once a year, this population mostly represents animals that receive regular health care with motivated owners.

Nevertheless, this study clearly indicated the value and the need for regular health checks of apparently healthy elderly dogs to improve early disease detection and allow early therapeutic intervention. Health screening programs should minimally comprise thorough history (questionnaire), extensive PE, and complete blood and urine examinations. Systolic blood pressure measurement is definitely advised in dogs with an underlying disease that is associated with hypertension. Routine blood pressure measurement in elderly dogs should be interpreted cautiously and multiple measurements are required, because of possible white-coat hypertension. Blood examination frequently revealed mild abnormalities for which further examination was necessary to determine its clinical relevance. To improve the interpretation of geriatric laboratory screening, the development of age-dependent RIs for certain variables is warranted.

In conclusion, PE and laboratory abnormalities are common in apparently healthy elderly dogs. Veterinarians play a pivotal role in improving health care for elderly pets by stimulating and performing regular health screening and by raising owner awareness for potentially important, but unnoticed, clinical signs in aging dogs.

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Off-label Antimicrobial Declaration: Authors declare no off-label use of antimicrobials.

Footnotes

[a] MEDVET Algemeen Medisch Laboratorium Diergeneeskunde, Antwerp, Belgium
[b] Advia 2120i, Siemens, Brussels, Belgium
[c] Architect C16000, Abbott, Wiesbaden, Germany
[d] Immulite 2000 systems, Siemens, Brussels, Belgium
[e] Iricell IQ, Instrumentation Laboratory, Zaventem, Belgium
[f] iCHEM velocity stick, Beckman Coulter, Suarlée, Belgium
[g] BioMerieux Media Square, Brussels, Belgium
[h] SAS version 9.2, SAS Institute Inc., Cary, NC
[i] Marynissen S., Willems A., Paepe D. et al. Proteinuria in apparently healthy elderly dogs (abstract). Proceedings of the 48th European Conference Voorjaarsdagen, Research Award; 2015 Apr 9-11. Amsterdam, The Netherlands.

References

1. Bartges J, Boynton B, Vogt AH, et al. AAHA canine life stage guidelines. J Am Anim Hosp Assoc 2012;48:1–11.

2. Metzger FL. Senior and geriatric care programs for veterinarians. Vet Clin North Am Small Anim Pract 2005;35:743–753.

3. State of pet health website. State of pet health 2013 report, Banfield Pet hospital. In: 2013, http://www.stateofpethealth.com/state-of-pet-health. Accessed April 02, 2016.

4. Epstein M, Kuehn NF, Landsberg G, et al. AAHA senior care guidelines for dogs and cats. J Am Anim Hosp Assoc 2005;41:81–91.

5. Fortney WD. Implementing a successful senior/geriatric health care program for veterinarians, veterinary technicians, and office managers. Vet Clin North Am Small Anim Pract 2012;42:823–834.

6. Galis F, Van Der Sluijs I, Van Dooren TJM, et al. Do large dogs die young? J Exp Zool B Mol Dev Evol 2007;308B:119–126.

7. Greer KA, Canterberry SC, Murphy KE. Statistical analysis regarding the effects of height and weight on life span of the domestic dog. Res Vet Sci 2007;82:208–214.

8. Bellows J, Colitz CMH, Daristotle L, et al. Common physical and functional changes associated with aging in dogs. J Am Vet Med Assoc 2015;246:67–75.

9. Webb JA, Kirby GM, Nykamp SG, Gauthier MJ. Ultrasonographic and laboratory screening in clinically normal mature golden retriever dogs. Can Vet J 2012;53:626–630.

10. Davies M. Geriatric screening in first opinion practice – results from 45 dogs. J Small Anim Pract 2012;53:507–513.

11. Joubert KE. Pre-anaesthetic screening of geriatric dogs. J S Afr Vet Assoc 2007;78:31–35.

12. Diez M, Picavet P, Ricci R, et al. Health screening to identify opportunities to improve preventive medicine in cats and dogs. J Small Anim Pract 2015;56:463–469.

13. 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.

14. Bellows J, Colitz CMH, Daristotle L, et al. Defining healthy aging in older dogs and differentiating healthy aging from disease. J Am Vet Med Assoc 2015;246:77–89.

15. Laflamme D. Development and validation of a body condition score system for dogs. Canine Pract 1997;22:10–15.

16. Freeman L, Becvarova I, Cave N, et al. WSAVA nutritional assessment guidelines. J Small Anim Pract 2011;52:385–396.

17. Salvin HE, McGreevy PD, Sachdev PS, Valenzuela MJ. The canine cognitive dysfunction rating scale (CCDR): A data-driven and ecologically relevant assessment tool. Vet J 2011;188:331–336.

18. Brown S, Atkins C, Bagley R, et al. Guidelines for the identification, evaluation, and management of systemic hypertension in dogs and cats. J Vet Intern Med 2007;21:542–558.

19. Stepien RL, Rapoport GS, Henik RA, et al. Comparative diagnostic test characteristics of oscillometric and Doppler ultrasonographic methods in the detection of systolic hypertension in dogs. J Vet Intern Med 2003;17:65–72.

20. Stepien RL. Pathophysiology of systemic hypertension and blood pressure assessment. In: Ettinger SJ, Feldman EC, eds. Textbook of Veterinary Internal Medicine, 7th ed. St. Louis, MO: Elsevier Saunders; 2010:577–582.

21. Waddell LS. Hypotension. In: Ettinger SJ, Feldman EC, eds. Textbook of Veterinary Internal Medicine, 7th ed. St. Louis, MO: Elsevier Saunders; 2010:585–588.

22. Arthurs G. Orthopaedic examination of the dog 1. Thoracic limb. In Practice 2011;33:126–133.

23. Arthurs G. Orthopaedic examination of the dog 2. Pelvic limb. In Practice 2011;33:172–179.

24. Jeffery N. Neurological examination of dogs 1. Techniques. In Practice 2001;23:118–130.

25. Mitchell N. Approach to ocular examination in small animals. In Practice 2011;33:146–154.

26. LeBlanc NL, Stepien RL, Bentley E. Ocular lesions associated with systemic hypertension in dogs: 65 cases (2005-2007). J Am Vet Med Assoc 2011;238:915–921.

27. Singh AK, Jiang Y, White T, Spassova D. Validation of nonradioactive chemiluminescent immunoassay methods for the analysis of thyroxine and cortisol in blood samples obtained from dogs, cats, and horses. J Vet Diagn Invest 1997;9:261–268.

28. Wamsley H, Alleman R. Complete urinalysis. In: Elliott J, Grauer GF, eds. BSAVA Manual of Canine and Feline Nephrology and Urology. Quedgeley, Gloucester: British Small Animal Veterinary Association; 2007:87–116.

29. Welborn LV, DeVries JG, Ford R, et al. 2011 AAHA canine vaccination guidelines. J Am Anim Hosp Assoc 2011;47: 1–42.

30. Rijnberk A, Stokhof A. Algemeen Onderzoek. In: Rijnberk A, Van Sluijs F, eds. Anamnese en lichamelijk onderzoek bij gezelschapsdieren, tweede druk. Antwerpen: Standaard Uitgeverij; 2005:59–77 Dutch.

31. Côté E. Electrocardiography and cardiac arrythmias. In: Ettinger SJ, Feldman EC, eds. Textbook of Veterinary Internal Medicine. St. Louis: Elsevier Saunders; 2010:1187–1195.

32. Stockham SL, Scott MA, eds. Urinary system. In: Fundamentals of Veterinary Clinical Pathology, 2nd ed. Iowa: Blackwell Publishing; 2008:415–494.

33. Lees GE, Brown SA, Elliott J, et al. Assessment and management of proteinuria in dogs and cats: 2004 ACVIM Forum Consensus Statement (small animal). J Vet Intern Med 2005;19:377–385.

34. Bartlett PC, Van Buren JW, Bartlett AD, Zhou C. Case-control study of risk factors associated with feline and canine chronic kidney disease. Vet Med Intern 2010;2010:9.

35. McGreevy PD, Thomson PC, Pride C, et al. Prevalence of obesity in dogs examined by Australian veterinary practices and the risk factors involved. Vet Rec 2005;156:695–702.

36. Lund E, Armstrong PJ, Kirk CA, Klausner JS. Prevalence and risk factors for obesity in adult dogs from private US veterinary practices. Intern J Appl Res Vet Med 2006;4:177–186.

37. Mao J, Xia Z, Chen J, Yu J. Prevalence and risk factors for canine obesity surveyed in veterinary practices in Beijing, China. Prev Vet Med 2013;112:438–442.

38. Colliard L, Ancel J, Benet JJ, et al. Risk factors for obesity in dogs in France. J Nutr 2006;136:1951S–1954S.

39. Holmes KL, Morris PJ, Abdulla Z, et al. Risk factors associated with excess body weight in dogs in the UK. J Anim Physiol Anim Nutr 2007;91:166–167.

40. Courcier EA, Thomson RM, Mellor DJ, Yam PS. An epidemiological study of environmental factors associated with canine obesity. J Small Anim Pract 2010;51:362–367.

41. Courcier EA, Mellor DJ, Thomson RM, Yam PS. A cross sectional study of the prevalence and risk factors for owner misperception of canine body shape in first opinion practice in Glasgow. Prev Vet Med 2011;102:66–74.

42. Michel KE. Unconventional diets for dogs and cats. Vet Clin North Am Small Anim Pract 2006;36:1269–1281.

43. Freeman LM, Michel KE. Evaluation of raw food diets for dogs. J Am Vet Med Assoc 2001;218:705–709.

44. Freeman LM, Chandler ML, Hamper BA, Weeth LP. Current knowledge about the risks and benefits of raw meat based diets for dogs and cats. J Am Vet Med Assoc 2013;243:1549–1558.

45. Schlesinger DP, Joffe DJ. Raw food diets in companion animals: A critical review. Can Vet J 2011;52:50–54.

46. Cornelissen S, De Roover K, Paepe D, et al. Dietary hyperthyroidism in a Rottweiler. Vlaams Diergeneeskundig Tijdschrift 2014;83:306–311.

47. Baldwin K, Bartges J, Buffington T, et al. AAHA nutritional assessment guidelines for dogs and cats. J Am Anim Hosp Assoc 2010;46:285–296.

48. Remillard RL, Ross JN, Eddy JB. Variance of indirect blood-pressure measurement and prevalence of hypertension in clinically normal dogs. Am J Vet Res 1991;52:561–565.

49. Bodey AR, Michell AR. Epidemiological study of blood pressure in domestic dogs. J Small Anim Pract 1996;37:116–125.

50. Meurs KM, Miller MW, Slater MR, Glaze K. Arterial blood pressure measurement in a population of healthy geriatric dogs. J Am Anim Hosp Assoc 2000;36:497–500.

51. Schellenberg S, Glaus TM, Reusch CE. Effect of long-term adaptation on indirect measurements of systolic blood pressure in conscious untrained beagles. Vet Rec 2007;161:418–421.

52. Marino CL, Cober RE, Iazbik MC, Couto CG. White-Coat effect on systemic blood pressure in retired racing greyhounds. J Vet Intern Med 2011;25:861–865.

53. Hoglund K, Hanas S, Carnabuci C, et al. Blood pressure, heart rate, and urinary catecholamines in healthy dogs subjected to different clinical settings. J Vet Intern Med 2012;26: 1300–1308.

54. Belew AM, Barlett T, Brown SA. Evaluation of the white-coat effect in cats. J Vet Intern Med 1999;13:134–142.

55. Franklin SS, Thijs L, Hansen TW, et al. White-coat hypertension new insights from recent studies. Hypertension 2013;62:982–987.

56. Rondeau DA, Mackalonis ME, Hess RS. Effect of body position on indirect measurement of systolic arterial blood pressure in dogs. J Am Vet Med Assoc 2013;242:1523–1527.

57. Stepien RL. Systemic hypertension. In: Bonagura JD, Twedt DC, eds. Kirk's Current Veterinary Therapy XV. Missouri: Elsevier Saunders; 2014:726–730.

58. Ghisleni G, Roccabianca P, Ceruti R, et al. Correlation between fine-needle aspiration cytology and histopathology in the evaluation of cutaneous and subcutaneous masses from dogs and cats. Vet Clin Pathol 2006;35:24–30.

59. Levine JM, Hillman RB, Erb HN, deLahunta A. The influence of age on patellar reflex response in the dog. J Vet Intern Med 2002;16:244–246.

60. Lund EM, Armstrong PJ, Kirk CA, et al. Health status and population characteristics of dogs and cats examined at private veterinary practices in the United States. J Am Vet Med Assoc 1999;214:1336–1341.

61. Kyllar M, Witter K. Prevalence of dental disorders in pet dogs. Vet Med (Praha) 2005;50:496–505.

62. Kortegaard HE, Eriksen T, Baelum V. Periodontal disease in research beagle dogs - an epidemiological study. J Small Anim Pract 2008;49:610–616.

63. Harvey C, Serfilippi L, Barnvos D. Effect of frequency of brushing teeth on plaque and calculus accumulation, and gingivitis in dogs. J Vet Dentist 2015;32:16–21.

64. Hartley C, Williams DL, Adams VJ. Effect of age, gender, weight, and time of day on tear production in normal dogs. Vet Ophthalmol 2006;9:53–57.

65. da Silva EG, Sandmeyer LS, Gionfriddo JR, et al. Tear production in canine neonates evaluation using a modified Schirmer tear test. Vet Ophthalmol 2013;16:175–179.

66. Williams DL. Immunopathogenesis of keratoconjunctivitis sicca in the dog. Vet Clin North Am Small Anim Pract 2008;38:251–268.

67. Metzger FL, Rebar AH. Clinical pathology interpretation in geriatric veterinary patients. Vet Clin North Am Small Anim Pract 2012;42:615–629.

68. Walton RM. Subject-based reference values: Biological variation, individuality, and reference change values. Vet Clin Pathol 2012;41:175–181.

69. Ulleberg T, Robben J, Nordahl KM, Heiene R. Plasma creatinine in dogs: Intra- and inter-laboratory variation in 10 European veterinary laboratories. Acta Vet Scand 2011;53:25.

70. Lefebvre HP, Watson ADJ, Toutain PL, Brown JP. Lack of technical and biological validation of plasma creatinine in the dog: One of the difficulties in the interpretation of results. Rev Med Vet (Toulouse) 1998;149:7–14 French.

71. Kraft W, Hartmann K, Dereser R. Age dependency of laboratory values in dogs and cats. 3. Bilirubin, creatinine and protein in blood serum. Tierarztl Prax Ausg K Kleintiere Heimtiere 1996;24:610–615 German.

72. Craig AJ, Seguela J, Queau Y, et al. Redefining the reference interval for plasma creatinine in dogs: Effect of age, gender, body weight, and breed. J Vet Intern Med 2006;20:740–740.

73. Friedrichs KR. Reference intervals: An essential, expanding, and occasionally equivocal standard. Vet Clin Pathol 2010;39:131–132.

74. Gleaton HK, Bartges JW, Laflamme DP. Influence of diet on urinary pH, urine and serum biochemical variables, and blood-ionized calcium concentrations in healthy dogs. Vet Ther 2001;2:61–69.

75. Sturgess CP, Hesford A, Owen H, Privett R. An investigation into the effects of storage on the diagnosis of crystalluria in cats. J Feline Med Surg 2001;3:81–85.

76. Reine NJ, Langston CE. Urinalysis interpretation: How to squeeze out the maximum information from a small sample. Clin Tech Small Anim Pract 2005;20:2–10.

77. Adams LG, Syme HM. Canine ureteral and lower urinary tract disease. In: Ettinger SJ, Feldman EC, eds. Textbook of Veterinary Internal Medicine, 7th ed. St. Louis, MO: Elsevier Saunders; 2010:2086–2115.

78. Heidenreich S, Zierden E, Zidek W. Microalbuminuria in very old patients. Geriatric Nephrol Urol 1995;5:9–13.

79. Verma V, Kant R, Sunnoqrot N, Gambert SR. Proteinuria in the elderly: Evaluation and management. Int Urol Nephrol 2012;44:1745–1751.

80. Wehner A, Hartmann K, Hirschberger J. Associations between proteinuria, systemic hypertension and glomerular filtration rate in dogs with renal and non-renal diseases. Vet Rec 2008;162:141–147.

81. Finco DR. Association of systemic hypertension with renal injury in dogs with induced renal failure. J Vet Intern Med 2004;18:289–294.

82. Barsanti JA. Genitourinary infections. In: Greene CE, ed. Infectious Disease of the Dog and Cat, 4th ed. Missouri: Elsevier Saunders; 2012:1013–1144.

83. McGhie JA, Stayt J, Hosgood GL. Prevalence of bacteriuria in dogs without clinical signs of urinary tract infection presenting for elective surgical procedures. Aust Vet J 2014;92:33–37.

84. Smee N, Loyd K, Grauer GF. UTIs in small animal patients: Part 2: Diagnosis, treatment, and complications. J Am Anim Hosp Assoc 2013;49:83–94.

85. Wan SY, Hartmann FA, Jooss MK, Viviano KR. Prevalence and clinical outcome of subclinical bacteriuria in female dogs. J Am Vet Med Assoc 2014;245:106–112.

86. Weese JS, Blondeau JM, Boothe D, et al. Antimicrobial use guidelines for treatment of urinary tract disease in dogs and cats: Antimicrobial guidelines working group of the international society for companion animal infectious diseases. Vet Med Int 2011;2011:9.

Supporting Information

Additional Supporting Information may be found online in the supporting information tab for this article:

Appendix S1: Owner Questionnaire.