OPEN ACCESS

PAPER

High prevalence of gait abnormalities in pugs

Cecilia Rohdin,[1,2] Karin Hultin Jäderlund,[3] Ingrid Ljungvall,[1] Kerstin Lindblad-Toh,[4,5] Jens Häggström[1]

The objective of this prospective study was to determine the prevalence of gait abnormalities in a cohort of Swedish pugs by using an owner-based questionnaire targeting signs of gait abnormality and video footage showing the dog's gait. This study also evaluated associated conditions of abnormal gait, including other health disorders prevalent in the breed. Five hundred and fifty (550) pugs registered in the Swedish Kennel Club, of one, five and eight years of age, in 2015 and 2016, were included in the study. Gait abnormalities were reported in 30.7 per cent of the responses. In the majority of cases, the character of the described gait indicated a neurological cause for the gait abnormality. An association was observed between abnormal gait and age, with gait abnormalities being significantly more common in older pugs (P=0.004). An association was also found between abnormal gait and dyspnoea, with dyspnoea being significantly more common in pugs with gait abnormalities (P<0.0001). This study demonstrated that the prevalence of gait abnormalities was high in the Swedish pug breed and increased with age. Future studies on the mechanisms behind these gait abnormalities are warranted.

Introduction

Gait is a manner of coordinated limb movement, with the canine walk and trot described as symmetrical gaits.[1] Although incompletely studied, the gait of short-legged dogs, including the pug, has been described.[2] Abnormal gait can be the result of orthopaedic and/or neurological conditions. The pug breed is predisposed for specific orthopaedic conditions[3 4] and neurological problems in the breed have become increasingly recognised in the last few years.[5–14]

In a British study, lameness, as the result of orthopaedic problems, and spinal cord disorders, characterised by paresis and ataxia, were reported in 2.4 per cent versus 1.4 per cent of the pugs attending primary veterinary care.[15] The prevalence of spinal cord disorders presented from the UK[15] corresponds poorly to a Swedish report,[i] which suggested a sevenfold increase in mortality rate for ataxia, paresis and collapse in pugs compared with other breeds. Adding the attention 'wobbly pugs' are given on the internet suggests a need to systematically determine the prevalence of gait abnormalities in the breed.

The aim of this prospective study was to investigate the prevalence of gait abnormalities in a cohort of Swedish pugs by using an owner-based questionnaire targeting signs of gait abnormality. Specialist evaluation of the gait using video footage of parts of the patient population, to compare with the owners' responses, was an additional aim. The study also evaluated associated conditions of abnormal gait, including other health disorders prevalent in the breed.

Materials and methods

Data collection

An invitation to participate in the study was sent by mail to all owners of pugs registered in the Swedish Kennel Club that had dogs aged one, five or eight years in 2015. The following data were obtained from the Swedish Kennel Club register: pedigree number, the dog's name and date of birth, name and address of the owner. An online standardised questionnaire[ii] was sent to all owners who accepted the invitation. To increase the number of dogs included in the study, a second

Veterinary Record (2018) doi: 10.1136/vr.104510

[1]Department of Clinical Sciences, Swedish University of Agricultural Sciences, Uppsala, Sweden
[2]Anicura, Albano Animal Hospital, Danderyd, Sweden
[3]Department of Companion Animal Clinical Sciences, Norwegian University of Life Sciences, Oslo, Norway
[4]Department of Medical Biochemistry and Microbiology, Science for Life Laboratory, Uppsala University, Uppsala, Sweden
[5]Broad Institute of Harvard and Massachusetts, Institute of Technology, Cambridge, MA, USA

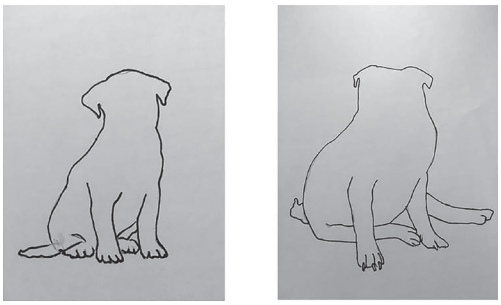
E-mail for correspondence: cecilia.rohdin@slu.se

Provenance and peer review Not commissioned; externally peer reviewed.

Received May 13, 2017
Revised September 22, 2017
Accepted November 11, 2017

[i]AGRIA insurance data. Updated dog breed statistics: 2006–2011. 2015. AGRIA Insurance Ltd, Stockholm, Sweden.

[ii]Netigate survey platform, Stockholm, Sweden.



(a) (b)

FIG 1: The following question was added to the paper-based questionnaire sent out in 2016 in the study of gait in pugs. Which sitting position does your pug prefer: (a) or (b)? Both options could be chosen.

paper-based questionnaire including the same questions as in the online version, but with one additional question (Fig 1), was sent by post to all owners of pugs that turned one, five or eight years of age in 2016 and were registered in the Swedish Kennel Club. The three age groups, rather than the whole pug population, were selected to optimise recognition of age-related gait abnormalities indicating distinct aetiologies, and to limit the amount of questionnaires/data.

Questionnaire

The investigators used a questionnaire, targeting immediate signs of unsound gait, for example, lameness, ataxia/incoordination, weakness and indirect signs of gait abnormality (eg, inability to jump, abnormal wearing of the nails and/or the skin on the dorsum of the paws) (Fig 2a, b) (Table 1). The owners could either state that their dogs had a normal gait with none of the following signs: lameness, ataxia incoordination, weakness, inability to jump or raise up, abnormal wearing of the nails and/or the skin on the dorsum of the paws, or that their dogs had an abnormal gait with signs of lameness, ataxia incoordination, weakness, inability to jump or raise up, abnormal wearing of the nails and/or the skin on the dorsum of the paws. When an abnormal gait was stated, owners were asked to define the problem as acute; less than one-month duration, or chronic; more than one-month duration.

Pugs assessed by their owners to have an abnormal gait, and pugs reported by their owners as having a normal gait but which exposed an unsound gait later in the questionnaire (by their owners' response to questions about wearing of nails and/or paws) were assessed by the authors as having an abnormal gait and included in group 1. Pugs that were not included in group 1 were described by the authors as having a normal gait (group 2).

Specific questions aimed to further characterise a possible gait abnormality and questions regarding the general health of the pug were asked. In case the pug was no longer alive, the owners were asked to provide information regarding reason/cause of death (Table 1).

For most of the questions, the respondent's answers were limited to a fixed set of responses: either a simple yes or no question, or multiple-choice questions where the respondents had several options to choose from. No preset options were available for certain questions and the owners were able to respond to them freely. The questionnaire did not offer preset options to actively respond 'do not know' and 'choose not to answer'; however, for every question there was a possibility for the owners not to respond or to respond to more than one alternative.

(a) (b)

FIG 2: In this questionnaire-based study of the gait in pugs, the owners were asked if their pug would wear their nails (a) and/or the skin (b) on the dorsum of their paws as shown in the picture.

Video footage

In addition to being asked to complete the questionnaire, the owners of all pugs were encouraged to send video footage of their pug, showing their dog walking back and forth, slowly on a leash, and also showing the dog walking from the side.[iii] Two board-certified veterinary neurologists (CR and KHJ) evaluated all videos independently, each on two separate occasions, and classified the dogs as having normal or abnormal gait. Results from the two raters were compared and in cases of disagreement the videos were examined again in normal and slow motion before arriving at a final, joint decision. The specialist's evaluation of the gait was then compared with the owner's responses in the questionnaire. A normal gait in the videos was defined as coordinated walking or trotting without signs of pacing,[2] with no visible or audible lameness or paresis and with no scuffing of the nails and/or skin on the dorsum of the paws.

Statistical analysis

The statistical analyses were performed using a commercially available statistical software program.[iv] Descriptive statistics were used for dog characteristics, gait abnormalities and presence of comorbidities. Continuous variables were reported as median and IQR. If owners had made multiple choices each single reply was included in the analysis.

[iii] https://www.youtube.com/watch?v=raIfVZba2I8&feature=youtu.be

[iv] JMP Pro V.11.2.0, Cary, NC, USA.

TABLE 1: Questions included in the questionnaire sent to owners of pugs one, five and eight years of age and registered in the Swedish Kennel Club. When limited or fixed sets of responses were available they are shown in brackets

Questions related to gait	Questions related to general health
Normal or abnormal gait? ▶ Age when abnormal gait was first noticed (six months; one, two, three, four, five, six, seven or eight years of age) ▶ Onset of abnormal gait (acute, insidious) ▶ Course of abnormal gait (constant, progressing, improving) ▶ What legs are involved in the abnormal gait? (thoracic limbs, pelvic limbs or both) ▶ Symmetrical or asymmetrical involvement of legs ▶ Ability to jump up and down a sofa ▶ Signs indicating abnormal wearing of the nails or the skin on the dorsal aspect of the paws ▶ What legs are involved in abnormal wearing of the nails and/or the skin on the dorsal aspect of paws? (thoracic limbs, pelvic limbs or both) ▶ When did the abnormal wearing of the nails and/or the skin on the dorsal aspect of the paws start? (as a puppy, at one year of age, more than six months ago, more than one year ago) ▶ Reluctance to walk on specific grounds (asphalt, parquet, gravel, grass) ▶ Use of paw protection ▶ Signs indicating pain (vocalising, reluctance to go for walks, resenting being lifted, unwilling to wear a collar, difficulty finding a resting position, avoiding specific positions, unwilling to be petted and irritable mood) ▶ Tail carriage (double curled, tight, weak) ▶ Incontinence (faecal, urinary) ▶ Incontinence seen after laying down, during playing, during eating, when excited ▶ Difficulties posturing while urinating/defecating ▶ Describe your pug's clinical sign (owner allowed to respond freely) ▶ Any previous traumatic event (owner allowed to respond freely) ▶ Veterinary examination performed due to abnormal gait, wearing of the nails and/or the skin on the dorsum of the paws ▶ Any relatives with unsound gait	Has your pug ever shown any of these signs or been diagnosed with any of these disorders? ▶ Seizures ▶ Syncope ▶ Dyspnoea Has your dog had surgery for dyspnoea? ▶ Pigmentary keratopathy ▶ Corneal ulcers ▶ Abnormal scratching around neck/ears/head ▶ Chronic skin problems ▶ Demodicosis ▶ Pug dog encephalitis ▶ Fly snapping ▶ Licking the air Is the dog alive? In case the dog is no longer alive: ▶ Was the dog euthanased or did it die? ▶ Why did the dog die/why was the dog euthanased? (gait abnormality, dyspnoea, skin problems, incontinence, epilepsy, pug dog encephalitis, eye problems, other disorder)

The chi-squared test or Fisher's exact test was used to test for differences in proportions concerning general health disorders in age groups and in gait abnormality groups. Differences in continuous variables between groups were tested using Wilcoxon test.

Possible associations between presence of gait abnormalities and dog characteristic (age, sex, weight) variables and presence of specific comorbidities (faecal and urinary incontinence, seizures, syncope, dyspnoea, pigmentary keratitis, corneal ulcer, abnormal scratching around neck/ears and head, chronic skin problems, demodicosis, pug dog encephalitis, fly snapping and licking the air) were investigated using backward stepwise multivariate logistic regression analysis. Only variables with a P value of <0.2 in the univariate regression analysis were included in the multivariate analysis. Level of statistical significance was set at $P<0.05$.

Results

Response rate

Of the 2374 invitations and questionnaires sent to selected pug owners, 26 per cent were returned. Five hundred and fifty owners specifically responded to the main question concerning gait (normal vs abnormal gait) (Fig 3).

In the 550 returned questionnaires, with responses concerning normal versus abnormal gait, the response rate for individual questions ranged from 220/550 (40.0 per cent) (signs of pain) to 528/550 (96.0 per cent) (any seizures).

General description of the study population

A detailed description on signalment and clinical variables in the entire cohort of pugs is presented in Table 2. Information about sex, weight and sitting position by age groups is presented in Table 3.

Prevalence of gait abnormality

In the responses to the questionnaire, 'a normal gait' was described by the owners in 79.6 per cent of the pugs. 'An abnormal gait for less than a month' was described in 4.4 per cent of the pugs and 'a chronic gait abnormality (>1 month duration)' in 16.0 per cent of the pugs. One hundred and twenty-eight pug owners responded that their dog wore down their nails and/or the skin on the dorsum of their paws. Fifty-seven of these 128 owners responded, in the same questionnaire, that their pug had a normal gait. Adding these 57 pugs showing indirect signs of unsound gait (wearing their nails and/or the skin on the dorsum of the paws from scuffing) resulted in a prevalence of 30.7 per cent for gait abnormalities (group 1).

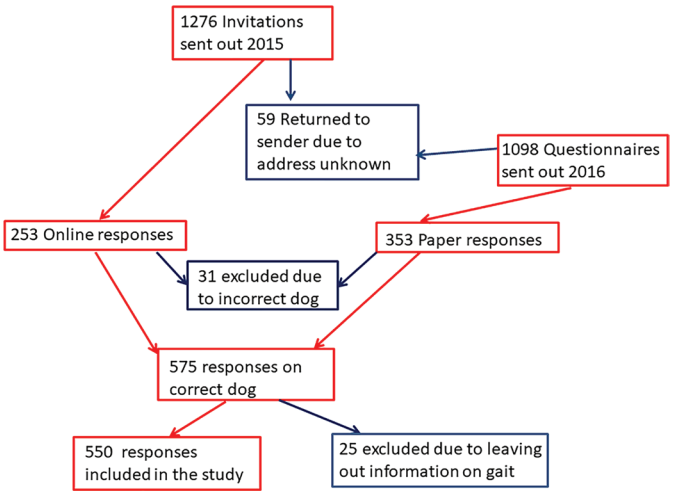


FIG 3: Flow chart over the number of responses to the questionnaires sent to owners of pugs one, five and eight years of age registered in the Swedish Kennel Club.

TABLE 2: Distribution of signalment and clinical variables in 550 pugs with a normal and an abnormal gait. Pugs with an abnormal gait included all pugs perceived by their owners to have a gait abnormality, and all pugs that were reported to wear down their nails and/or the skin on the dorsum of their paws independent of their owner's perception of the gait. Note that there was a possibility for the owner to include more than one answer or provide no response to a specific question, which is the reason why the numbers in each column may not add up to the total in the adjacent column

Variable	Total number of dogs	Normal gait	Abnormal gait
Number of pugs	550	381	169
Sex			
Female	233	176	57
Male	209	136	73
Spayed female	49	33	16
Neutered male	49	28	21
Unknown sex	10	8	2
Median age (months)	58 (IQR=69)	54 (IQR=52)	61 (IQR=39)
Median bodyweight (kg)	9 (IQR=2)	8 (IQR=1)	9 (IQR=2)
Abnormal wearing of nails	128/336 (38.1%)	–	128/165 (77.6%)
Thoracic limbs	95/118 (80.5%)	–	95/118 (80.5%)
Pelvic limbs	5/118 (4.2%)	–	5/118 (4.2%)
Thoracic and pelvic limbs	18/118 (15.3%)	–	18/118 (15.3%)
Wearing nails to the extent they bleed	21/273 (7.7%)	–	21/157 (13.4%)
Abnormal wearing of skin on paws	22/335 (6.6%)	–	22/160 (13.8%)
Abnormal wearing of skin on paws to the extent it bleeds	19/150 (12.7%)	–	19/95 (20.0%)
Incontinence			
Faecal	13/357 (3.6%)	2/195 (1.0%)	11/162 (6.8%)
Urinary	23/341 (6.7%)	7/180 (3.9%)	16/161 (9.9%)
Sitting position (a)	119/329 (36.2%)	90/195 (46.2%)	29/134 (21.6%)
Sitting position (b)	210/329 (63.8%)	105/195 (53.8%)	105/134 (78.4%)
Pain	22/199 (11.1%)	1/89 (1.1%)	21/110 (19.1%)
Double curled tail	142/351 (40.5%)	88/192 (45.8%)	54/159 (34.0%)
Unable to jump up a bed or a sofa	34/186 (18.3%)	1/58 (1.7%)	30/128 (23.4%)

Course of owner-perceived gait abnormality

The owners reported that in 63/92 (68.5 per cent) of the pugs the first signs of gait abnormality were insidious in nature, and in 36/99 (36.4 per cent) of the dogs, a progression of clinical signs was described. An insidious onset was reported in 21/32 (65.6 per cent) of the pugs with a thoracic limb involvement, and in 19/23 (82.6 per cent) of the dogs with pelvic limb involvement.

TABLE 3: Sex, bodyweight, preferred sitting position (Fig 1) and gait status by age group in 550 pugs. Pugs with an abnormal gait included all pugs perceived by their owners to have a gait abnormality, and all pugs that were reported to wear down their nails and/or the skin on the dorsum of their paws independent of their owner's perception of the gait. Note that there was a possibility for the owner to include more than one answer or provide no response to a specific question, which is the reason why the numbers in each column may not add up to the total in the adjacent column

Variable	One year	Five years	Eight years
Number of pugs	168	218	164
Sex			
Female	87 (51.8%)	86 (39.4%)	60 (36.7%)
Male	69 (41.1%)	87 (39.9%)	53 (32.3%)
Spayed female	1 (0.6%)	19 (8.7%)	29 (17.7%)
Neutered male	9 (5.4%)	24 (11.0%)	16 (9.8%)
Unknown sex	2 (1.2%)	2 (0.9%)	6 (3.7%)
Bodyweight (kg)	8 (IQR=2)	9 (IQR=2)	9 (IQR=2)
Sitting position (a)	41/78 (52.6%)	51/148 (34.5%)	27/103 (26.2%)
Sitting position (b)	37/78 (47.4%)	97/148 (65.5%)	76/103 (73.8%)
Pugs with a normal gait	144/168 (85.7%)	149/218 (68.3%)	88/164 (53.7%)
Pugs with an abnormal gait	24/168 (14.3%)	69/218 (31.7%)	76/164 (46.3%)

The clinical signs were described as progressing in 6/32 (18.8 per cent) and in 13/25 (52.0 per cent) of pugs with affected thoracic versus pelvic limbs

Characteristics of gait abnormality (group 1)

The median age when the gait abnormality started was two (2.0) years (IQR=3.5) (Fig 4). The debut of abnormal gait in the thoracic limbs was reported at a younger age (median one (1.0) year, IQR=0.5) compared with pugs with an abnormal gait affecting the pelvic limbs (median three (3.0) years, IQR=3) (P<0.001).

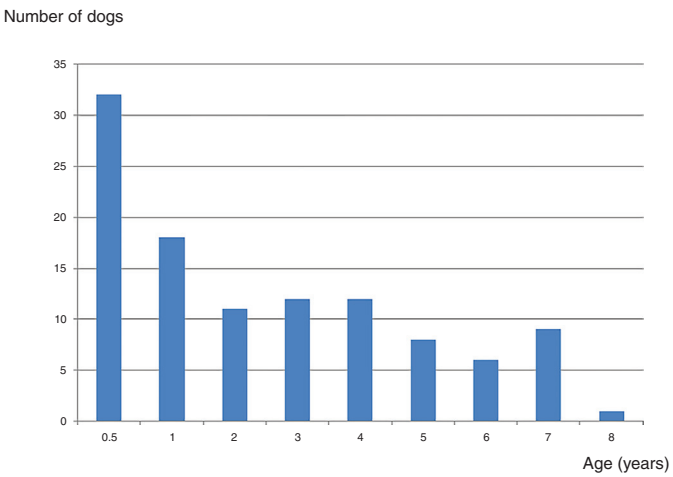


FIG 4: Distribution of age of onset of gait abnormality in this questionnaire-based study in pugs. The figure includes the 109 pugs whose owners responded to the question related to onset of gait abnormality.

TABLE 4: Distribution of general health disorders by age in 550 pugs. Number of positive answers in relation to the total number of answers for the specific question by age group

Variable	One year	Five years	Eight years	P value
Seizures	2/163 (1.2%)	23/213 (10.8%)	22/152 (14.5%)	<0.001
Syncope	3/164 (1.8%)	28/210 (13.3%)	29/153 (19.0%)	<0.001
Dyspnoea	15/162 (9.3%)	75/211 (35.5%)	60/156 (38.5%)	<0.001
Surgery for dyspnoea	3/164 (1.8%)	12/214 (5.6%)	11/152 (7.3%)	0.054
Pigmentary keratopathy	18/154 (11.7%)	69/196 (35.2%)	56/137 (40.9%)	<0.001
Corneal ulcers	22/152 (14.5%)	79/196 (40.3%)	60/140 (42.9%)	<0.001
Abnormal scratching around neck/ears/head	5/163 (3.1%)	27/210 (12.9%)	18/147 (12.2%)	0.002
Chronic skin problems	3/157 (1.9%)	20/208 (9.6%)	12/144 (8.3%)	0.008
Demodicosis	12/158 (7.6%)	17/199 (8.5%)	12/139 (8.6%)	0.95
Pug dog encephalitis	1/158 (0.6%)	2/201 (1.0%)	0/141 (0%)	0.34
Fly snapping	1/161 (0.6%)	5/211 (2.4%)	7/148 (4.7%)	0.058
Licking in the air	17/165 (10.3%)	51/214 (23.8%)	32/154 (20.8%)	0.0021

TABLE 5: Distribution of general health disorders by gait abnormality in 550 pugs with a normal and an abnormal gait. Pugs with an abnormal gait included all pugs perceived by their owners to have a gait abnormality, and all pugs that were reported to wear down their nails and/or the skin on the dorsum of their paws independent of their owner's perception of the gait

Variable	Total number of dogs	Normal gait	Abnormal gait	P value
Seizures	47/528 (8.9%)	21/369 (5.7%)	24/156 (15.4%)	0.0004
Syncope	60/527 (11.4%)	29/370 (7.8%)	29/154 (18.8%)	0.0003
Dyspnoea	150/529 (28.4%)	72/367 (19.6%)	78/159 (49.1%)	<0.0001
Surgery for dyspnoea	26/530 (4.9%)	10/367 (2.7%)	15/160 (9.4%)	0.0015
Pigmentary keratopathy	143/487 (29.4%)	81/340 (23.8%)	62/145 (42.8%)	<0.0001
Corneal ulcers	161/488 (33.0%)	96/346 (27.7%)	65/141 (46.1%)	0.0001
Abnormal scratching around neck/ears/head	50/520 (9.6%)	20/364 (5.5%)	28/153 (18.3%)	<0.0001
Chronic skin problems	35/509 (6.9%)	22/359 (6.1%)	11/146 (7.5%)	0.34
Demodicosis	41/496 (8.3%)	27/347 (7.8%)	12/149 (8.1%)	0.70
Pug dog encephalitis	3/500 (0.6%)	1/350 (0.3%)	2/147 (1.4%)	0.21
Fly snapping	13/520 (2.5%)	4/364 (1.1 %)	9/153 (5.9%)	0.0031
Licking in the air	100/533 (18.8%)	50/368 (13.6%)	49/162 (30.2%)	<0.0001

Among dogs with an abnormal gait (group 1), thoracic limb involvement 81/158 (51.3 per cent) was more commonly reported than pelvic limb involvement 28/158 (17.7 per cent, P<0.001). Of pugs with an abnormal gait, involvement of both pelvic and thoracic limbs was reported in 49/158 (31.0 per cent).

Abnormal wearing of nails and skin on dorsum of the paws

Wearing of the nails was more common in the thoracic limbs; thoracic limb involvement was reported in 113/118 (95.8 per cent) of the pugs wearing nails (P<0.001). In 56/120 (46.7 per cent) the pugs had been wearing their nails since they were a puppy, whereas 98/120 (81.7 per cent) of the pugs had been wearing their nails since one year of age. Abnormal wearing of the skin on the dorsum of the paws was most common in the thoracic limbs, and 11/17 (64.7 per cent) of the pugs who wore down the skin on the dorsum of their paws showed thoracic limb involvement. In 13/19 (68.4 per cent) the pugs had been wearing the skin on the dorsum of their paws since one year of age.

Prevalence of pain

Prevalence of pain in pugs with gait abnormality (group 1) is described in Table 2. The most common sign of pain described by the owners in association with gait abnormalities was reluctance to go for walks, 17/30 (56.7 per cent). The least common signs of pain described by the owners in association with gait abnormalities were an irritable mood, 1/30 (3.3 per cent) and an unwillingness to be petted, 2/30 (6.7 per cent).

Prevalence of general health disorders

The prevalence of general health problems was compared between one, five and eight-year-old pugs (Table 4) and between pugs with a normal gait (group 2) and pugs with a gait abnormality (group 1) (Table 5).

A significant association was found between gait abnormality perceived by the owner and age, dyspnoea and abnormal scratching around the neck/ears and head (Table 6). A significant association was also found

TABLE 6: The P values and ORs and 95% CIs for dog characteristic variables and comorbidities remaining in the final multivariate logistic regression model including owner-perceived gait abnormality (no/yes) as outcome variable in 550 pugs

Variable	P value	OR (95% CI)
Age	<0.0001	1.24 (0.72 to 0.89)
Dyspnoea	0.003	2.55 (1.55 to 4.20)
Abnormal scratching around neck/ears/head	0.0008	3.83 (1.94 to 7.60)

TABLE 7: The P values and ORs and 95% CIs for dog characteristic variables and comorbidities remaining in the final multivariate logistic regression model including gait abnormality (no/yes) as outcome variable in 550 pugs. Pugs with an abnormal gait included all pugs perceived by their owners to have a gait abnormality, and all pugs that were reported to wear down their nails and/or the skin on the dorsum of their paws independent of their owner's perception of the gait

Variable	P value	OR (95% CI)
Age	0.004	1.18 (1.09 to 1.28)
Dyspnoea	<0.0001	3.19 (2.11 to 4.85)

between abnormal gait as assessed by the authors (group 1) and age and dyspnoea (Table 7).

Prevalence of incontinence

Of 13 pugs with faecal incontinence, three (23.1 per cent) were described by their owners as having a normal gait and eight (61.5 per cent) as having a chronic gait abnormality. Of 23 pugs with urinary incontinence, nine (39.1 per cent) were described as having a normal gait and 14 (60.9 per cent) as having a chronic gait abnormality.

Reason for death/euthanasia

Forty-seven owners reported one or several causes for their dog's death/euthanasia: abnormal gait was recognised as the single, listed, most frequent cause of death/euthanasia of pugs in this study, 17/59 (28.8 per cent).

Veterinary consultation

Prevalence of owners who had sought veterinary care for their pug's abnormal gait or for wearing of the nails and/or the skin on the dorsum of the paws is described in Table 8.

Video evaluation of gait

Eighty-nine videos were sent for evaluation. Seven videos were excluded due to poor quality or other technical reasons. Twenty-three videos were not accompanied by a corresponding questionnaire, and were excluded. The remaining 59 videos included: 26 videos (44.1 per cent) of one-year-old pugs, 20 videos (33.9 per cent) of five-year-old pugs and 13 videos (22.0 per cent) of eight-year-old pugs. Forty-six of 59 (78.0 per cent) owners submitting a video recording claimed their dogs had a normal gait. Subtracting from this the number of videotaped dogs that were reported to wear their nails and/or skin on the paws (six pugs) decreased the number of pugs reported by their owners to show a normal gait from 78.0 to 67.8 per cent. The corresponding numbers for the videos analysed by the specialists were that 40 out of 59 (67.8 per cent) pugs showed a normal gait. In 16/59 (27.1 per cent) of the analysed videos, there was disagreement between owners and specialists. The specialists considered the gait as abnormal in 11 dogs, in which the owners had considered the gait as being normal. The owners assessed the gait as abnormal in five dogs, for which the authors had considered the gait as normal. In four of these five pugs, the owners described abnormal wearing of the nails. Three (3/19) pugs showed lameness as an isolated gait abnormality in the analysed videos.

TABLE 8: Prevalence of pugs whose owners, of 550 pugs, had sought veterinary care for their pug's abnormal gait, for wearing of the nails or the skin on the dorsum of the paws. Pugs with an abnormal gait included all pugs perceived by their owners to have a gait abnormality, and all pugs that were reported to wear down their nails and/or the skin on the dorsum of their paws independent of their owner's perception of the gait

Variable	Number of positive answers in relation to the total number of answers for the question
Pugs perceived by their owners of having a chronic gait abnormality	36/81 (44.4%)
Pugs with an abnormal gait	48/149 (32.2%)
Pugs wearing down their nails	31/115 (27.0%)
Pugs wearing down their nails to the extent they would bleed	9/19 (47.4%)
Pugs wearing down the skin on the dorsum of the paws to the extent they would bleed	8/18 (44.4%)

Discussion

This study showed that the prevalence of gait abnormalities in the pug breed was high and that it increased with age. Indeed, the single most common cause for death/euthanasia, reported by the owner, was an abnormal gait, which suggests gait abnormalities to be a more significant health problem than what previous, published scientific literature has suggested.[15]

In general, most causes of lameness are orthopaedic in origin, whereas most causes of paresis and ataxia are neurological. Wearing of the nails and/or on the dorsum of the paws, scuffing, is associated with neurological disorders as a consequence of proprioceptive deficits and motor dysfunction.[16–18] Although this study did not aim to differentiate orthopaedic from neurological causes for gait abnormalities, the high prevalence of wearing of nails reported in the questionnaires, and the fact that lameness was not a common finding in submitted videos, suggest that the majority of gait abnormalities in the pugs were indeed related to neurological rather than orthopaedic disorders. This is in accordance with a Swedish insurance database report, presenting a sevenfold increase in mortality rate for ataxia, paresis and collapse in the pug compared with the risk in other breeds[i]. Data from that same source did not show an increase in relative risk for general locomotor problems in pugs compared with the risk in other breeds. It has previously been shown that the insured dog population is similar to the general population of Swedish dogs.[19]

The assessment of the dog's gait was performed by the owners, likely making the results from the questionnaire less reliable. This was also suggested in the analysis of the videos, where the specialists identified more dogs with gait abnormalities than the owners did, 32.2 per cent versus 22.0 per cent. Interestingly, when adding the pugs from the videos where the owners described a normal gait but with wearing of nails and/or

skin on the dorsum of the paws, the specialists and the owners reported identical numbers of pugs with a gait abnormality.

The difficulty to evaluate locomotion, as shown in this study, has previously been described,[20] and the results from the video analysis could be questioned. It is reasonable to assume that mild or intermittent gait abnormalities might not have been appreciated by the owners or by the specialists; thus, the prevalence of gait abnormality in the breed found in this study could indeed have been underestimated. Ideally, the results in this study should be confirmed by objective gait studies, using kinetic and kinematic analysis, in the future.

For the video evaluation of the gait in the present study, we defined the normal gait in the pug as a coordinated walk or trot without pacing,[2] with no visible or audible lameness or paresis and with no wearing of the nails and/or the skin on the dorsum of the paws. Abnormal wearing of the nails and/or skin on the dorsum of the paws could not be easily identified in the submitted videos explaining why four pugs were classified as having an abnormal gait by the owners but as having a normal gait by the specialists. A relatively small proportion, 59/550 (10.7 per cent) of the responders, submitted a video footage of their dog's gait, which could have affected the result. In addition, the video analysed group of pugs were not age matched with the questionnaire-based group of pugs, and the lower proportion of submitted videos of eight-year-old pugs might have affected the result.

Pugs with a gait abnormality (group 1; 30.7 per cent of all pugs) included all pugs with an owner-reported gait abnormality (20.4 per cent) and all pugs that later in the questionnaire were reported to actually scuff, to wear down their nails and/or the skin on the dorsum of their paws. In the present study, pug owners reported abnormal gait more often in the pelvic limbs than the thoracic limbs. This finding was inconsistent with that of a gait abnormality (group 1) being more commonly reported in the thoracic limbs. Also, in almost a third of the pugs with a gait abnormality, both thoracic and pelvic limbs were affected. This inconsistency could be a result of different underlying pathology affecting the thoracic and the pelvic limbs, but could also be the consequence of owners not associating wearing of the nails and/or skin on the dorsum of the paws with abnormal gait. Furthermore, the clinical experience of the authors is that dogs with neurological gait disorders, affecting both thoracic and pelvic limbs, are easily misjudged by laymen as only affecting either or. A disorder with obvious affection of the pelvic limbs may therefore be accompanied by a subtle involvement of the thoracic limbs and vice versa. Nonetheless, neurological deficits in dogs are seen more commonly in the pelvic limbs than in the thoracic limbs in general,[21] and for pugs, vertebral anomalies, including hemivertebrae,[8 12 14 22–25] degenerative disc disease,[5 26] constrictive myelopathy[6 23] and subarachnoid diverticula (SAD),[5 7 9–11 27] are found more often in the thoracolumbar area. In most of the pugs with abnormal wearing of their nails, the wearing involved the thoracic limbs and had developed already when the dog was one year old, suggesting a congenital or an early onset underlying pathology. The possibility that the wearing of nails is the result of other unrelated causes, for example, conformation, also needs to be considered. Wearing of nails and skin on the dorsum of the paws has previously been described in pugs in association with SAD[13 28]; in these pugs, neurological signs were more pronounced in the thoracic limbs and from a young age.[13 28 29]

Our results show that the prevalence of gait abnormalities in pugs is a greater health problem than what has previously been described.[15] Clinical data from primary care veterinary practices in the UK[15] included conditions that the owners had sought medical attention care for. In the present study, the majority of the owners of pugs with a gait abnormality had not sought veterinary care for their dog's gait, wearing of the nails or incontinence. Possible explanations could be that a veterinarian is only sought if the abnormality is actually appreciated by the owner as *abnormal*, or if the gait abnormality seems associated with signs suggesting suffering (pain).

This study showed an association between abnormal gait (group 1) and age, and an association between abnormal gait and dyspnoea was also confirmed. It has previously been shown that obesity is associated with the brachycephalic airway syndrome[30] and dyspnoea might be the natural consequence of a pug that is not exercising, and therefore gains weight. Weight was however not associated with gait abnormalities and the development of a chronic gait abnormality might therefore be related to dyspnoea and chronic airway obstruction in other, yet unknown, ways. The importance of finding an association between two common health problems in a breed, for example, dyspnoea and abnormal gait, may be questioned. However, specific breed-related characteristics may predispose the pug to health problems not previously associated with the brachycephalic syndrome.

Faecal and urinary incontinence were more common in pugs with an abnormal gait in comparison to pugs with a normal gait (Table 2). The larger number of pugs with urinary incontinence cannot be explained by neutering or spaying as these were not more frequently incontinent compared with intact pugs. A possible association between gait abnormalities and incontinence in the pug needs verification.

The majority of the pugs in this study preferred a sitting position the owners associated with dog (b) (Fig 1). The sitting position in dogs with a chronic gait abnormality was almost exclusively associated with image (b). The sitting position (b) has previously been preferred by dogs with specific orthopaedic disorders,[31] referred to

as a positive 'sit-test'.[21] Sitting with fully extended stifle joints can also be observed in dogs with spinal cord disorders.[32 33] However, position (b) was also reported by more than 50 per cent of owners assessing their pugs having a normal gait and also increased with age in pugs with and without gait abnormality. It needs to be verified if the preferred sitting position (b) might be an indication of a gait abnormality in pugs.

The response rate (26 per cent) of this study might have been affected by the Swedish petition for the right of brachycephalic breeds to breathe; launched the same year the invitation was sent and supported by a large number of Swedish veterinarians, it threatened many owners of brachycephalic breeds, which might have made owner population more reluctant to participate in this study. A pilot study launched before the petition reached a response rate of 35 per cent. It has, however, been shown that a low response rate does not necessarily indicate non-response bias.[34] Suggesting all non-responders belonged to group 2, the prevalence of gait abnormality in the entire study population would have been 7.3 per cent. Additionally, although accepting to participate in the study, many owners did not complete the survey by leaving specific questions unanswered.

Since the majority of pugs in Sweden are registered in the Swedish Kennel Club,[v] the general study population is most likely representative of the Swedish pug breed. The final study population might however be biased; it could be that owners of pugs suffering from obvious gait abnormalities are more prone to respond to the questionnaire. It might also be possible that there is another population of owners who have pugs with a normal gait that have specific interests in responding, for example, breeders.

In conclusion, gait abnormalities were a common finding in the pug breed with a prevalence of 30.7 per cent. Wearing of the nails and/or skin on the dorsum of the paws, predominately in the thoracic limb, was frequently found and from a comparably young age. The aim of this study was to investigate the prevalence of gait abnormalities in the pug breed with no ambition to determine their underlying pathology or prognosis. The results presented in this article may serve as a background to future, urgent studies on underlying pathology and clinical significance of gait abnormalities in the pug breed.

Acknowledgements The authors wish to acknowledge the Swedish Mopsorden for their commitment and support and for promoting the participation in this study.

Funding The study was supported by the Swedish Kennel Club (SKK) and AGRIA's research fund.

Competing interests None declared.

[v]Statistics Sweden 2012.

References

1 FANCHON L, GRANDJEAN D. Accuracy of asymmetry indices of ground reaction forces for diagnosis of hind limb lameness in dogs. *Am J Vet Res* 2007;68:1089–94.
2 HILDEBRAND M. Symmetrical gaits of dogs in relation to body build. *J Morphol* 1968;124:353–9.
3 LAFOND E, BREUR GJ, AUSTIN CC. Breed susceptibility for developmental orthopedic diseases in dogs. *J Am Anim Hosp Assoc* 2002;38:467–77.
4 O'NEILL DG, MEESON RL, SHERIDAN A, *et al*. The epidemiology of patellar luxation in dogs attending primary-care veterinary practices in England. *Canine Genet Epidemiol* 2016;3:4.
5 BISMUTH C, FERRAND FX, MILLET M, *et al*. Original surgical treatment of thoracolumbar subarachnoid cysts in six chondrodystrophic dogs. *Acta Vet Scand* 2014;56:32.
6 FISHER SC, SHORES A, SIMPSON ST. Constrictive myelopathy secondary to hypoplasia or aplasia of the thoracolumbar caudal articular processes in Pugs: 11 cases (1993-2009). *J Am Vet Med Assoc* 2013;242:223–9.
7 FLEGEL T, MÜLLER MK, TRUAR K, *et al*. Thoracolumbar spinal arachnoid diverticula in 5 pug dogs. *Can Vet J* 2013;54:969–73.
8 GUTIERREZ-QUINTANA R, GUEVAR J, STALIN C, *et al*. A proposed radiographic classification scheme for congenital thoracic vertebral malformations in brachycephalic "screw-tailed" dog breeds. *Vet Radiol Ultrasound* 2014;55:585–91.
9 MAULER DA, DE DECKER S, DE RISIO L, *et al*. Signalment, clinical presentation, and diagnostic findings in 122 dogs with spinal arachnoid diverticula. *J Vet Intern Med* 2014;28:175–81.
10 MAULER DA, DE DECKER S, DE RISIO L, *et al*. Spinal arachnoid diverticula: outcome in 96 medically or surgically treated dogs. *J Vet Intern Med* 2017;31:849–53.
11 MEREN IL, CHAVERA JA, ALCOTT CJ, *et al*. Shunt tube placement for amelioration of cerebrospinal fluid flow obstruction caused by spinal cord subarachnoid fibrosis in dogs. *Vet Surg* 2017;46:289–96.
12 MOISSONNIER P, GOSSOT P, SCOTTI S. Thoracic kyphosis associated with hemivertebra. *Vet Surg* 2011;40:1029–32.
13 ROHDIN C, NYMAN HT, WOHLSEIN P, *et al*. Cervical spinal intradural arachnoid cysts in related, young pugs. *J Small Anim Pract* 2014;55:229–34.
14 RYAN R, GUTIERREZ-QUINTANA R, TER HAAR G, *et al*. Prevalence of thoracic vertebral malformations in French bulldogs, pugs and english bulldogs with and without associated neurological deficits. *Vet J* 2017;221:25–9.
15 O'NEILL DG, DARWENT EC, CHURCH DB, *et al*. Demography and health of pugs under primary veterinary care in England. *Canine Genet Epidemiol* 2016;3:5.
16 CARR BJ, DYCUS DL. Canine gait analysis. *Recovery & Rehab* 2016:93–100.
17 DELAHUNTA A, GLASS EN. Small animal spinal cord disease. In: DELAHUNTA A, GLASS EN, eds. Veterinary neuroanatomy and clinical neurology. 3rd edn. St Louis: Missouri, USA: Saunders-Elsevier, 2009:244.
18 GAROSI L. Examining the neurological emergency. In: PLATT L, GAROSI L, eds. Small animal neurological emergencies. London, UK: Manson Publishing/the veterinary press, 2012:21.
19 EGENVALL A, HEDHAMMAR A, BONNETT BN, *et al*. Survey of the swedish dog population: age, gender, breed, location and enrollment in animal insurance. *Acta Vet Scand* 1999;40:231–40.
20 GILLETTE RL, ANGLE TC. Recent developments in canine locomotor analysis: a review. *Vet J* 2008;178:165–76.
21 WITTE P, SCOTT H. Investigation of lameness in dogs. *In practice* 2011;33:58–66.
22 BAILEY CS, MORGAN JP. Congenital spinal malformations. *Vet Clin North Am Small Anim Pract* 1992;22:985–1015.
23 BOUMA JL. Congenital malformations of vertebral articular processes in dogs. *Vet Clin North Am Small Anim Pract* 2016;46:307–26.
24 JEFFERY ND, SMITH PM, TALBOT CE. Imaging findings and surgical treatment of hemivertebrae in three dogs. *J Am Vet Med Assoc* 2007;230:532–6.
25 WESTWORTH DR, STURGES BK. Congenital spinal malformations in small animals. *Vet Clin North Am Small Anim Pract* 2010;40:951–81.
26 CHEN AV, BAGLEY RS, WEST CL, *et al*. Fecal incontinence and spinal cord abnormalities in seven dogs. *J Am Vet Med Assoc* 2005;227:1945–51.
27 OXLEY W, PINK J. Amelioration of caudal thoracic syringohydromyelia following surgical management of an adjacent arachnoid cyst. *J Small Anim Pract* 2012;53:67–72.
28 FOSS KD, BERRY WL. What is your neurologic diagnosis? Spinal arachnoid cysts. *J Am Vet Med Assoc* 2009;234:1009–11.
29 RYLANDER H, LIPSITZ D, BERRY WL, *et al*. Retrospective analysis of spinal arachnoid cysts in 14 dogs. *J Vet Intern Med* 2002;16:690–6.
30 LIU NC, ADAMS VJ, KALMAR L, *et al*. Whole-body barometric plethysmography characterizes upper airway obstruction in 3 brachycephalic breeds of dogs. *J Vet Intern Med* 2016;30:853–65.
31 MUIR P. Advances in the canine cranial cruciate ligament. Lowa, USA: Wiley-Blackwell, 2010.
32 DEWEY CW. Myelopathies: disorders of the spinal cord in a practical guide to canine and feline neurology. In: DEWEY CW, ed. A practical guide to canine and feline neurology. Lowa, USA: Lowa state press, 2003:284.
33 THOMSON CE, HAHN CN. Hierarchial organisation in the nervous system. In: THOMSON CE, HAHN CN, eds. Veterinary neuroanatomy. 1st edn. Edinburgh: Elsevier-Saunders, 2012.

34 CHOUNG RS, LOCKE GR, SCHLECK CD, *et al*. A low response rate does not necessarily indicate non-response bias in gastroenterology survey research: a population-based study. *J Public Health* 2013;21:87–95.