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A follow-up study of exercise test results and severity of brachycephalic obstructive airway syndrome signs in brachycephalic dogs

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Abstract

To promote successful breeding against brachycephalic obstructive airway syndrome (BOAS), it is important to assess how BOAS signs progress during young adulthood and how evaluation age and ageing affect the results of chosen breeding selection tools. The aims of this study were to assess how veterinary-assessed and owner-reported BOAS signs and exercise test results change when dogs age. Eight English Bulldogs, 25 French Bulldogs, and 31 Pugs that had undergone previous evaluation were re-examined 2–3 years later. An owner questionnaire regarding BOAS signs, a veterinary assessment of BOAS severity, and exercise, ie walk tests were re-performed. In Pugs, both 6-min walking distance and 1,000-m time worsened and the initial evaluation age had a significant effect on the 1,000-m time. No significant changes were seen in the results of the French Bulldogs but a negative effect on the 1,000-m time was seen with weight gain. Exercise test statistics were not performed with regard to English Bulldogs due to low sample size. The veterinary-assessed BOAS severity class remained the same in the majority of dogs and the BOAS grade worsened mostly in those dogs that were initially evaluated at less than two years of age. Most owners reported no major changes in BOAS severity. BOAS grading and walk tests were easy to repeat and results remained relatively constant in dogs initially evaluated at over two years of age, supporting the use of these breeding selection tools. However, further, large-scale offspring studies are still needed.

Keywords: *animal welfare, brachycephalic obstructive airway syndrome, English Bulldog, French Bulldog, Pug, walk test*

Introduction

Brachycephalic obstructive airway syndrome (BOAS) is a major welfare concern in flat-faced dog breeds, such as the English Bulldog, French Bulldog, and Pug. Signs include exercise intolerance, heat sensitivity, respiratory difficulties, sleep and gastrointestinal disturbances and are directly linked to short facial and skull anatomy. In severe cases, the dogs suffer from syncope, cyanosis, and even death. (Hendricks 2004; Poncet *et al* 2005, Riecks *et al* 2007; Roedler *et al* 2013).

Although it is a commonly held opinion that signs of BOAS worsen when dogs age, the evidence is limited. Clinical signs can already be severe by 12 months of age (Knecht 1979) and the mean age for the visit to the veterinarian for evaluation due to clinical signs is 3–4 years (Lorinson *et al* 1997; Monnet 2008). Several studies have also reported outcomes and progression of BOAS signs pre- and post-upper respiratory tract surgery (Torrez & Hunt 2006; Riecks *et al* 2007; De Lorenzi *et al* 2009; Liu *et al* 2017a, 2019). However, to our knowledge, the natural progression of BOAS signs in brachycephalic dogs during adulthood without corrective surgery has not been reported.

The popularity of brachycephalic breeds has grown enormously while, simultaneously, public demand for more ethical and healthier breeding standards for these breeds has risen (Honey 2017; Ladlow *et al* 2018). In our previous studies (Lilja-Maula *et al* 2017; Aromaa *et al* 2019) we have shown sub-maximal exercise test results to correlate with the severity of BOAS which could therefore allow them to aid breeding selection. These sub-maximal exercise tests, such as the 1,000-m walk test and the 6-min walk test (6MWT), evaluate dogs' exercise capacity and recovery, both of which are major elements affected by BOAS as well as being safe and easy to perform in dogs suffering from respiratory problems since they are self-paced. Walk tests performed in human medicine, such as the 6MWT, are commonly used to evaluate exercise capacity and prognosis in patients with chronic respiratory diseases (ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories 2002; ATS Technical Standard 2014). Currently, a number of breed associations and kennel clubs use exercise tests to assess the respiratory health of brachycephalic dogs (Dutch Kennel Club 2014; Bartels *et al* 2015; Finnish Kennel Club 2018). Additionally, a recent pilot study evaluated the usability of the 6MWT to objectively assess the outcome after BOAS surgery and found that in the majority of dogs results improved post-surgery (Villedieu *et al* 2019). In addition to the exercise test, which takes into account exercise and heat intolerance, the other components of BOAS should also be evaluated when making a breeding assessment for brachycephalic dogs (Packer *et al* 2015; Lilja-Maula *et al* 2017; Aromaa *et al* 2019), in particular, the functional BOAS grade (Liu *et al* 2015) and stenosis of the nostrils (Packer *et al* 2015; Liu *et al* 2016) should also be assessed. Since BOAS is considered a progressive disease, it is crucial for the breeding assessment to be carried out at an age that will deliver the most reliable results later in life but that is still viable for breeding purposes. However, there are yet to be any data published on how exercise test results and BOAS severity assessment change over time.

The aims of this study therefore were to assess how veterinary-assessed and owner-reported BOAS signs and exercise test results change when dogs age. Evaluation of the changes in clinical BOAS assessment and exercise test results should provide more reliable recommendations regarding their optimal use as breeding selection tools, thereby shedding more light upon the natural progression of BOAS during adulthood.

Materials and methods

Ethical approval

All the study dogs were privately owned pets considered to be healthy by their owners. The study protocol was approved by the Committee of Experimental Animals of Southern Finland (no: ESAVI/11519/04.10.07/2014 and ESAVI/10906/04.10.07/2017) and every owner signed a consent form.

Study design and animals

The follow-up component of this prospective clinical study was performed at the Veterinary Teaching Hospital, University of Helsinki, Finland between June 2017 and July 2019. The English Bulldogs, French Bulldogs, and Pugs that had participated in the initial studies (Lilja-Maula *et al* 2017; Aromaa *et al* 2019) between November 2014 and May 2017 were invited to a follow-up 2–3 years later with owners being contacted via telephone. Pregnant or lactating dogs were excluded from the follow-up study, as were those that had had BOAS surgery, carried multi-drug resistant bacteria, or were incapable of performing the exercise test due to illness or motivation problems, ie non-respiratory causes such as fear or unwillingness to move with researcher. Participation in dog shows and animals' breeding history were tracked with the help of the Finnish Kennel Club public breeding database (Finnish Kennel Club KoiraNet 2020).

During the follow-up visit, an owner questionnaire regarding BOAS signs, a physical examination, including clinical BOAS grading, and exercise tests were re-performed, and haematology and biochemistry blood samples were taken as per our previous studies (Lilja-Maula *et al* 2017; Aromaa *et al* 2019). The demographics, owner-reported BOAS signs, clinical BOAS grade and exercise test results from initial studies (Lilja-Maula *et al* 2017; Aromaa *et al* 2019) are re-presented in this paper for those dogs that participated in this follow-up study.

Owner questionnaire and veterinary assessment of BOAS signs

Owners were re-interviewed regarding their dogs' daily welfare in terms of exercise intolerance, breathing, sleeping, and eating habits. The questionnaire was modified from Roedler *et al* (2013).

The veterinary-assessed BOAS grade (0 = no, 1 = mild, 2 = moderate, 3 = severe signs), modified from Liu *et al* (2015) and presented in Lilja-Maula *et al* (2017), consisted of an assessment of audible upper respiratory noise, pre- and post-exercise, and the presence of respiratory effort, dyspnoea, and cyanosis. The veterinarian carrying out the evaluation was blinded to the dogs' previous results.

Dogs graded as having no or mild BOAS signs were considered to be BOAS− while dogs with moderate or severe signs were designated BOAS+, as suggested by Liu *et al* (2015) and used in the initial studies (Lilja-Maula *et al* 2017; Aromaa *et al* 2019).

Walk tests

As previously described (Lilja-Maula *et al* 2017; Aromaa *et al* 2019) dogs were walked on a leash at their own pace along a 60-m straight corridor (room temperature 21–22°C). During walking/trotting dogs were motivated to perform their personal best but cantering or galloping was not allowed. First, the distance walked in 6 min was recorded and following that, dogs continued to walk until 1,000-m was reached. The time taken to complete the 1,000 m walk test was recorded. Respiratory rate and type, upper respiratory sounds, heart rate, and body temperature were evaluated before and after the 6-min and 1,000-m walking tests. Dogs were excluded from the test if they had dyspnoea, hyperthermia (body temperature above 39.5°C), clear motivation problems, or orthopaedic problems. After exercise, dogs' recovery (ie, body temperature, respiratory and heart rate) time was monitored at 5-min intervals until they had returned to pre-exercise levels. Time limits to pass the 1,000-m walk test were 12-min walk time for English Bulldogs (Lilja-Maula *et al* 2017) or 11-min walk time for French Bulldogs and Pugs (Aromaa *et al* 2019) and, for all, recovery in 15 min. Dogs excluded before or during the test due to breathing difficulties or hyperthermia (ie BOAS signs) were considered to have failed the test.

Statistical analysis

Descriptive statistics are presented as means (± SD) for continuous normally distributed variables or median (and range) for non-continuous or non-normally distributed variables. For recovery time comparisons (ordinal variables), the Wilcoxon matched pairs test was chosen. The change in 6MWT distance and 1,000-m test time between initial and follow-up visits was assessed using the paired *t*-test and multiple linear regression model. The multiple linear regression model was also used to analyse the change in the walking test results between two testing time-points. Age at the initial study point and percentage change in bodyweight between the initial and follow-up visit were used as covariates. Overall changes with 95%

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Table 1 Demographic data for study dogs.

		English Bulldog (n = 8)	French Bulldog (n = 25)	Pug (n = 31)
Gender				
Female		4	13	16
Male		4	12	15
Age (years; median, range)	Initial*	3.4 (2.2–5)	2.5 (1.2–4.5)	3.3 (1–5.6)
	Follow-up	6.3 (4.7–7.5)	4.6 (3.4–6.7)	5.3 (3.2–8.4)
Mean (± SD) weight (kg)	Initial*	22.9 (± 2.3)	12.2 (± 1.4)	8.8 (± 1.3)
	Follow-up	23.4 (± 1.8)	12.4 (± 1.5)	8.9 (± 1.6)
Body condition score (median, range)	Initial*	3 (2–3)	3 (3–3)	3 (3–4)
	Follow-up	3 (2–4)	3 (3–4)	3 (2–4)

* Lilja-Maula *et al* (2017) and Aromaa *et al* (2019).

confidence intervals were estimated from the models. The analyses were conducted separately for Pugs and French Bulldogs. English Bulldogs' exercise test results are presented only descriptively due to the very small sample size in the follow-up study. For group comparisons (ie differences in percentage bodyweight change between both visits between breeds) an independent sample *t*-test, without the assumption of equal variances, was used.

The normality of the model residuals of the fitted statistical models (for the 6-min and 1,000-m tests) were assessed using the Shapiro-Wilk test of normality and normal QQ plots.

Statistical analyses were conducted using GraphPad Prism Mac 8.3.0® and SAS® System for Windows, version 9.4 (SAS Institute Inc, Cary, NC, USA). *P*-values < 0.05 were considered statistically significant.

Results

Study animals

From the initial study population, 8/28 English Bulldogs, 25/44 French Bulldogs, and 31/51 Pugs were re-evaluated after 2–3 years. The demographics at first visit and follow-up visits are presented in Table 1.

The most common reasons for dogs not participating in the follow-up study were owner-related: 21 refused and 13 could not be reached. Other reasons for not participating were dog-related issues, ie nine dogs had been euthanased, six had had clear motivation problems during the exercise tests at the initial visit, six carried multi-drug resistant bacteria, four had orthopaedic or neurological problems, two had had BOAS surgery, and two were pregnant at the time of testing.

At the time of writing, 49 of the 64 dogs (77%) had Finnish Kennel Club recorded dog show results and 34/64 dogs (53%) had been used for breeding, of which 8/34 (24%) had been used prior to two years of age.

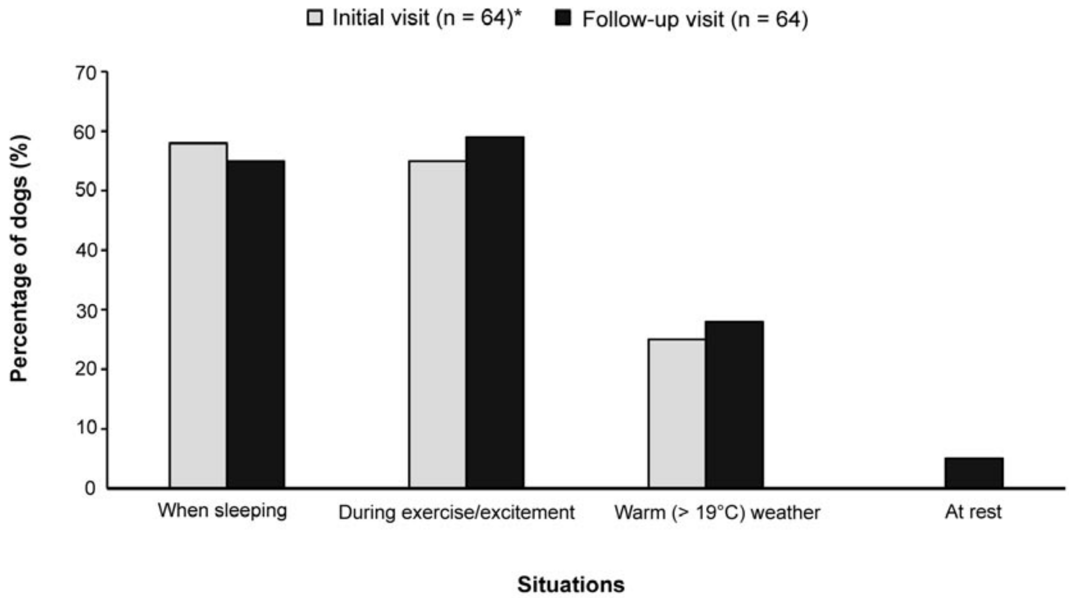
Owner questionnaire

Two owners at the initial visit and three at the follow-up (out of the 64 owners) reported respiratory-related problems affecting their dogs' welfare. Nine reported that exercise intolerance was a new problem compared to their dogs' status in the initial visit, with three noting increased upper respiratory noises at rest, and four describing syncope. However, conversely, eight of the owners that had reported exercise intolerance at the initial visit did not report it in the second visit. In all, exercise intolerance was reported in 20/64 (31%) dogs at the follow-up visit and 19/64 (30%) at the initial visit. Only one owner had reported weekly gastrointestinal signs (ie, vomiting and regurgitation) at the initial visit while, at the follow-up, three did so. When the owners were asked whether, at any point, their dogs had shown pronounced upper respiratory sounds, 50/64 (78%) reported this to be the case at the initial visit and, equally, 50/64 (78%) at the follow-up. However, seven of the owners that reported this at the initial visit did not do so during the follow-up visit. The distribution of pronounced upper respiratory sounds in different situations during the initial and follow-up visits are shown in Figure 1.

Veterinary assessment of BOAS signs

Thirty-five (English Bulldog; n = 5, French Bulldog; n = 17, Pug; n = 13) of the 64 dogs were graded by a veterinarian into BOAS− class (ie, no or mild BOAS signs) and 29/64 dogs (English Bulldog; n = 3, French Bulldog; n = 8, Pug; n = 18) into BOAS+ (ie, moderate or severe BOAS signs). A clinically meaningful change, ie a change in BOAS−/BOAS+ categorisation between both visits, was seen in 16 dogs (25%): 13 (20%) went from BOAS− to BOAS+ while three (5%) did the opposite (BOAS+ to BOAS−). The changes in veterinary-assessed BOAS severity grades between initial and follow-up visits are presented in Table 2. In those dogs that were ≤ 2 years of age at the time of the initial visit (French Bulldog; n = 10, Pug; n = 11), the BOAS grade worsened in 48% (French Bulldog; n = 3, Pug;

Figure 1



Owner-reported presence of increased upper respiratory sounds in different situations at the initial and follow-up visits in English Bulldogs, French Bulldogs and Pugs (n = 64). * Lilja-Maula *et al* (2017) and Aromaa *et al* (2019).

Table 2 Veterinary-assessed brachycephalic obstructive airway syndrome (BOAS) severity grade change from initial visit to follow-up visit in English Bulldogs, French Bulldogs and Pugs.

Change in BOAS grade (0, 1, 2, 3)	English Bulldog (n = 8)	French Bulldog (n = 25)	Pug (n = 31)	Total (n = 64)
No change	4 (50%)	19 (76%)	15 (48%)	38 (59%)
0	0	3	1	
1	3	13	5	
2	1	3	4	
3	0	0	5	
Worsened	2 (25%)	5 (20%)	10 (32%)	17 (27%)
From 0 ⟶ 1	0	1	1	
From 1 ⟶ 2	1	3	8	
From 1 ⟶ 3	1	0	0	
From 2 ⟶ 3	0	1	1	
Improved	2 (25%)	1 (4%)	6 (19%)	9 (14%)
From 1 ⟶ 0	2	0	3	
From 2 ⟶ 1	0	0	3	
From 3 ⟶ 2	0	1	0	

BOAS grade: 0 = no signs; 1 = mild; 2 = moderate; 3 = severe.

n = 7). In contrast, for those dogs that were over two years of age at the initial visit (English Bulldog; n = 8, French Bulldog; n = 15, Pug; n = 20), the BOAS grade worsened only in 16% (English Bulldog; n = 2, French Bulldog; n = 2, Pug; n = 3). Also, younger Pugs gained weight more than all the older dogs ($P = 0.0007$) or young French Bulldogs ($P = 0.05$). Similar weight gain was not observed in young French Bulldogs compared with all older dogs ($P = 0.5$). The mean percentage weight change in younger Pugs was +7.7%, younger French Bulldogs +1.1%, and in all older dogs –0.4%.

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Table 3 Mean (± SD) and range exercise test results at the initial and follow-up visits for French Bulldogs and Pugs.

	French Bulldog (n = 25)			Pug (n = 31)		
	1st visit[†]		2nd visit	1st visit[†]		2nd visit
6MWD (m)	627 (± 69)		601 (± 55)	572 (± 57)		548 (± 58)
	(435–745)		(510–710)	(400–700)		(400–640)
	n = 25	*P* = 0.11	n = 25	n = 31	*P* = 0.007	n = 30
1,000-m (min)	9.78 (± 0.95)		9.87 (± 0.86)	10.80 (± 1.32)		11.11 (± 1.02)
	(8.25–11.88)		(8.43–11.27)	(9.1–15.55)		(9.50–13.90)
	n = 24	*P* = 0.96	n = 22	n = 30	*P* = 0.14	n = 30
1,000-m recovery (m)						
≤ 5 min	3/24		9/22	4/30		5/30
≤ 10 min	11/24	*P* = 0.17	9/22	17/30	*P* = 0.67	13/30
≤ 15 min	8/24		2/22	7/30		8/30
≥ 15 min	2/24		2/22	2/30		4/30
Passing 1,000-m walk test*	19/25**		18/25**	23/30		14/30
(Number of animals)	76%		72%	77%		47%

6MWD: 6-minute walk distance.
* Passing the 1000-m test: For French Bulldogs and Pugs, time ≤ 11 min and recovery ≤ 15 min.
** Including dogs that were disqualified before or during the test due to brachycephalic obstructive airway syndrome related clinical signs and were considered to fail the test.
[†] Aromaa *et al* (2019).

Blood samples were taken from all the dogs. There were no significant changes in haematology. One Pug and one French Bulldog had a moderate (2–3 times upper limit) increase and two French Bulldogs a remarkably high (> 3 times upper limit) increase in alanine transaminase. One Pug and one English Bulldog had a mild (< 2 times upper limit) increase and one French Bulldog a moderate increase in alkaline phosphatase. All the dogs with changes in blood chemistry were clinically asymptomatic. One Pug had remarkable hypoalbuminaemia. Two Pugs had a mild increase in creatine.

Walk tests

Walk test results at the initial and follow-up visit in French Bulldogs and Pugs are presented in Table 3. At the initial visit, for English Bulldogs (n = 7, one excluded due motivation problems), the mean (± SD) results for the 6-min walking distance (6MWD) and the 1,000-m test were 541 (± 66) m and 11.53 (± 0.98) min, respectively, compared to 591 (± 34) m and 10.74 (± 0.66) min for the follow-up (n = 8). For 1,000-m test, 4/7 passed the test at initial visit and 6/8 at follow-up.

Changes in the walk test results (ie, distance and time) between the two testing time-points and the influence of the initial evaluation age or weight change to the test results in French Bulldogs and Pugs are presented in Tables 4(a,b) and 5(a,b).

Discussion

Our follow-up study showed differences in breed for the mean change in exercise test results for Pugs compared to French Bulldogs. In Pugs, both exercise test results worsened over time and the initial age at evaluation had a significant effect on the 1,000-m time change. For French Bulldogs, no significant change over time was seen for either test result, but weight gain had a negative effect on the 1,000-m time. The veterinary-assessed BOAS class stayed fairly constant and most changes for the worse were seen for those dogs initially evaluated at less than two years of age.

Owner questionnaire results regarding BOAS signs were relatively similar between initial and follow-up studies. Only a few owners reported new, severe BOAS-related signs, such as syncope, in their dogs. A low number of owner-reported BOAS signs is not a surprising finding given that 55% of dogs in our study were also evaluated by the veterinarian as having no or mild BOAS signs. However, BOAS signs may be underestimated by owners or considered to be normal for the breed (Packer *et al* 2012, 2019; Roedler *et al* 2013). Brachycephalic dog breed owners have also been shown to possess particularly close emotional bonds with their pets and despite the owner-reported disorders, the majority consider their dog to be in good health (Packer *et al* 2019). In our study, only 5% of owners reported breathing problems impinging on their dog's welfare while, on the other hand, 31% reported

Table 4(a) Multiple linear regression analysis of 6-min walking distance change (m) between initial and follow-up visit in French Bulldogs (n = 23).

	Estimate	SE	95% CI	*P*-value
Mean change	–49.10	48.65	–150.6 to 52.38	0.32
Age at initial visit	8.11	17.48	–28.36 to 44.58	0.65
Weight change (%)	–4.18	3.00	–10.44 to 2.09	0.18

Table 4(b) Multiple linear regression analysis of 6-min walking distance change (m) between initial and follow-up visits in Pugs (n = 30).

	Estimate	SE	95% CI	*P*-value
Mean change	–62.98	26.32	–116.98 to –8.99	0.02
Age at initial visit	11.76	7.44	–3.51 to 27.03	0.13
Weight change (%)	–0.12	1.28	–2.75 to 2.51	0.93

Table 5(a) Multiple linear regression analysis of 1,000-m time change (min) between initial and follow-up visit in French Bulldogs (n = 20).

	Estimate	SE	95% CI	*P*-value
Mean change	0.35	0.64	–1.00 to 1.70	0.60
Age at initial visit	–0.14	0.23	–0.62 to 0.34	0.55
Weight change (%)	0.09	0.04	0.007 to 0.17	0.04

Table 5(b) Multiple linear regression analysis of 1,000-m time change (min) between initial and follow-up visit in Pugs (n = 29).

	Estimate	SE	95% CI	*P*-value
Mean change	1.45	0.54	0.33 to 2.60	0.01
Age at initial visit	–0.37	0.16	–0.69 to –0.05	0.03
Weight change (%)	0.02	0.03	–0.03 to 0.07	0.50

exercise intolerance and 78% pronounced upper respiratory sounds. Public criticism of brachycephalic dogs has also increased between the two studies and may also have influenced owner responses.

The veterinary-assessed functional BOAS grade and BOAS class did not change in the majority (59 and 75%, respectively) of dogs. This is an encouraging finding since BOAS is mainly considered to be a progressive disease and functional BOAS assessment, although having set criteria, is largely subjective. Most changes were, as expected, for the worse but a number of individuals were graded as having less severe signs at the follow-up. This reflects the dynamic nature of BOAS and the extent to which stress and excitement can affect the clinical presentation. However, the initial evaluation age seems to be an important factor, especially in Pugs, as the BOAS grade worsened mainly in dogs evaluated at less than two years of age. Additionally, as weight gain can exacerbate signs of BOAS (Manens *et al* 2012; Packer *et al* 2015), we compared the percentage weight change in these two age groups and found younger dogs to gain more weight than their older counterparts and, furthermore, young Pugs gained more weight compared to young French Bulldogs. This finding is in keeping with previous studies that have shown that Pugs tend to be overweight (O'Neill *et al* 2016; Liu *et al* 2017b) and are ten times more likely to be obese compared with other breeds (Such & German 2015). As obesity has been shown to further compromise breathing and cause exercise and heat intolerance, it is advisable to favour a lean body condition in brachycephalic breeds (German 2006; Manens *et al* 2012). Altogether, our study gives new information regarding the natural progression of BOAS during young adulthood in those dogs that have not undergone surgery and represent the less severely affected population. As BOAS grade worsened in only 27% of dogs in our study, it can be concluded that BOAS signs do not categorically worsen in all brachycephalic dogs during adulthood. However, studies reporting the progression of BOAS signs during an entire lifespan are needed and worsening can be different in dogs with initially more severe signs of BOAS.

The sub-maximal exercise test used for breeding consists of exercise and recovery components. In our study, the limit to pass the 1,000-m test was based on our previous results (Lilja-Maula *et al* 2017; Aromaa *et al* 2019). The dog must walk 1,000 m in a maximum of 11 min (Pugs and French Bulldogs) or 12 min (English Bulldogs) and return to pre-test levels within 15 min. The recovery part considers heart rate, respiratory effort, and temperature. Using these parameters, 74% of dogs passed the test at the initial visit and 60% at the follow-up. The longer exercise, ie the 1,000-m test, seemed in our earlier study (Aromaa *et al* 2019) to reveal more clearly the signs related to BOAS compared to the 6MWT and, in the present study, the results also appeared slightly more stable in the 1,000-m test.

There were breed differences in the 6MWT distance and 1,000-m time change, with a significant change for the worse seen over time in Pugs but not French Bulldogs. However, there was a significant effect of weight gain causing an extension of time to complete the 1,000-m test in French Bulldogs. In Pugs, the change in the 6MWT distance was not significantly influenced by the initial evaluation age or weight change, but the change in the 1,000-m time was influenced by the initial age. This deterioration was emphasised in initially younger Pugs, as an increase in age at the initial visit decreased the 1,000-m time change from the initial visit. Although not significant, a similar age effect was also seen for the change in the 6MWT distance for Pugs as well as a weight gain effect for change in the 6MWT distance in French Bulldogs.

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Based on our results, the walk test seems repeatable over time in young, adult, breeding age dogs. The initial evaluation age should be taken into account and the optimal breeding assessment age for BOAS in brachycephalic dogs must be carefully considered. It could be recommended that BOAS assessment and exercise testing for breeding is not carried out prior to two years of age or should at least be done again if performed younger. Our study group represents the real population used for breeding in Finland, as the majority of dogs had participated in dog shows and half had been used for breeding at the time of article writing.

A study limitation includes the relatively small number of dogs, particularly English Bulldogs. The low numbers of these in the follow-up study was due to several different reasons. Most significantly, the English Bulldogs were slightly older at the time of initial and follow-up studies, therefore there was a greater likelihood of other health-related problems and death occurring. Due to these low numbers, only the results from Pugs and French Bulldogs underwent statistical analysis and cannot be extrapolated to English Bulldogs. It should be noted, however, that in the initial study, only seven of 26 English Bulldogs passed the 1,000-m walk test (Lilja-Maula *et al* 2017).

Animal welfare implications

The welfare aspects related to breeding of brachycephalic dogs are complex and should not focus only on respiratory problems. However, in humans, 'air hunger' is reported as being one of the most devastating feelings related to breathlessness and therefore can be regarded as a major welfare concern in brachycephalic dogs (Beausoleil & Mellor 2015). Kennel clubs around the world have woken to this issue and launched different recommendations regarding BOAS and breeding. A phenotype-based upper airway syndrome screening programme has been established in Norwich terriers in Switzerland since 2003 and a marked reduction in the severity of upper airway signs has been reported (Marchant *et al* 2019). Based on our previous studies (Lilja-Maula *et al* 2017; Aromaa *et al* 2019) and the present follow-up study, the exercise tolerance tests are safe, non-invasive, cost effective and easy to use tools for assessing the severity of BOAS. As BOAS is a multifactorial syndrome, the most reliable evaluation of individual dogs' BOAS signs is obtained by combining the exercise part with evaluation of recovery, nostril stenosis, and veterinary-assessed BOAS grade. In our studies, we have also encountered brachycephalic dogs that do not show or show only mild BOAS signs and whose signs do not progress during young adulthood. However, the question of whether any breeding selection tools used for brachycephalic breeds are sufficient to effectively battle against BOAS, remains unanswered. Furthermore, possible cross-breeds and their offspring should be evaluated for BOAS prior to further breeding.

Conclusion

Based on our follow-up study, both the exercise tests and functional BOAS grading are easily repeated in the same individual over time and the results remain fairly consistent in breeding age adults. However, it is recommended that breeding assessment for BOAS not be performed prior to two years of age, and breeders and owners should be further educated on the harmful impact of weight gain on BOAS signs. Future offspring studies on the long-term effects of any BOAS breeding schemes on brachycephalic dog health are needed.

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References

Aromaa M, Lilja-Maula L and Rajamäki MM 2019 Assessment of welfare and brachycephalic obstructive airway syndrome signs in young breeding age French Bulldogs and Pugs, using owner questionnaire, physical examination and walk tests. *Animal Welfare 28*: 287-298. https://doi.org/10.7120/09627286.28.3.287

ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories 2002 ATS statement. Guidelines for the six-minute walk test. *American Journal of Respiratory and Critical Care Medicine 166*: 111-117. https://doi.org/10.1164/ajrccm.166.1.at1102

ATS Technical Standard 2014 Field walking tests in chronic respiratory disease. *European Respiratory Journal 44*: 1428-1446. https://doi.org/10.1183/09031936.00150314

Bartels A, Martin V, Bidoli E, Steigmeier-Raith S, Brühschwein A, Reese S, Köstlin R and Erhard M 2015 Brachycephalic problems of Pugs relevant to animal welfare. *Animal Welfare 24*: 327-333. https://doi.org/10.7120/09627286.24.3.327

Beausoleil NJ and Mellor DJ 2015. Introducing breathlessness as a significant animal welfare issue. *New Zealand Veterinary Journal 63*: 44-51. https://doi.org/10.1080/00480169.2014.940410

De Lorenzi D, Bertoncello D and Drigo M 2009 Bronchial abnormalities found in a consecutive series of 40 brachycephalic dogs. *Journal of the American Veterinary Medical Association 235*: 835-840. https://doi.org/10.2460/javma.235.7.835

Dutch Kennel Club 2014 *Convenant Bulldog, breeding rules.* https://www.houdenvanhonden.nl/contentassets/27de95b0774b4730990cfae5b7c4c3e4/convenant_bulldog-breeding_rules.pdf

Finnish Kennel Club 2018 *Guideline for walking test.* https://www.kennelliitto.fi/kasvatus-ja-terveys/koiran-terveys/koiran-terveystutkimukset/kavelytestissa-arvioidaan-koiran-rasituksensietoa

Finnish Kennel Club KoiraNet 2020 https://jalostus.kennelliitto.fi/frmEtusivu.aspx?Lang=fi&R=

German AJ 2006 The growing problem of obesity in dogs and cats. *The Journal of Nutrition 136*: 1940S-1946S. https://doi.org/10.1093/jn/136.7.1940S

Hendricks JC 2004 Brachycephalic airway syndrome. In: King LG (ed) *Textbook of Respiratory Disease in Dogs and Cats* pp 310-318. Elsevier: St Louis, Missouri, USA. https://doi.org/10.1016/B978-0-7216-8706-3.50044-X

Honey L 2017 Future health and welfare crises predicted for the brachycephalic dog population. *Veterinary Record 181*: 550. https://doi.org/10.1136/vr.j5429

Knecht CD 1979 Upper airway obstruction in brachycephalic dogs. *Compendium on Continuing Education for the Practicing Veterinarian 1*: 25-30

Ladlow J, Liu NC, Kalmar L and Sargan D 2018 Brachycephalic obstructive airway syndrome. *Veterinary Record 182*: 375-378. https://doi.org/10.1136/vr.k1403

Lilja-Maula L, Lappalainen AK, Hyytiäinen HK, Kuusela E, Kaimio M, Schildt K, Mölsä S, Morelius M and Rajamäki MM 2017 Comparison of submaximal exercise test results and severity of brachycephalic obstructive airway syndrome in the English Bulldog. *The Veterinary Journal 219*: 22-26. https://doi.org/10.1016/j.tvjl.2016.11.019

Liu N-C, Adams VJ, Kalmar L, Ladlow JF and Sargan DR 2016 Whole-body barometric plethysmography characterizes upper airway obstruction in 3 brachycephalic breeds of dogs. *Journal of Veterinary Internal Medicine 30*: 853-865. https://doi.org/10.1111/jvim.13933

Liu N-C, Genain MA, Kalmar L, Sargan DR and Ladlow JF 2019 Objective effectiveness of and indications for laser-assisted turbinectomy in brachycephalic obstructive airway syndrome. *Veterinary Surgery 48*:79-87. https://doi.org/10.1111/vsu.13107

Liu N-C, Oechtering GU, Adams VJ, Kalmar L, Sargan DR and Ladlow JF 2017a Outcomes and prognostic factors of surgical treatments for brachycephalic obstructive airway syndrome in 3 breeds. *Vet Surgery 46*: 271-280. https://doi.org/10.1111/vsu.12608

Liu N-C, Sargan DR, Adams VJ and Ladlow JF 2015 Characterisation of Brachycephalic Obstructive Airway Syndrome in French Bulldogs using whole-body barometric plethysmography. *PLoS One 10*: e0130741. https://doi.org/10.1371/journal.pone.0130741

Liu N-C, Troconis EL, Kalmar L, Price DJ, Wright HE, Adams VJ, Sargan DR and Ladlow JF 2017b Conformational risk factors of brachycephalic obstructive airway syndrome (BOAS) in Pugs, French Bulldogs, and bulldogs. *PLoS One 12*: e0181928. https://doi.org/10.1371/journal.pone.0181928

Lorinson D, Bright RM and White RAS 1997 Brachycephalic airway obstruction syndrome – a review of 118 cases. *Canine Practice 22*: 18-21

Manens J, Bolognin M, Bernaerts F, Diez M, Kirschvink B and Clercx C 2012 Effect of obesity on lung function and airway reactivity in healthy dogs. *The Veterinary Journal 193*: 217-221. https://doi.org/10.1016/j.tvjl.2011.10.013

Marchant SW, Dietschi E, Rytz U, Schawalder P, Jagannathan V, Rasouliha SH, Gurtner C, Waldvogel AS, Harrington RS, Drögemüller M, Kidd J, Ostrander EA, Warr A, Watson M, Argyle D, Ter Haar G, Clements DN, Leeb T and Schoenebeck JJ 2019 An ADAMNTS3 missense variant is associated with Norwich Terrier upper airway syndrome. *PLOS Genetics*. https://doi.org/10.1371/journal.pgen.1008102

Monnet E 2008 *Brachycephalic airway syndrome*. CVC in San Diego Proceedings: San Diego, CA, USA

O'Neill DG, Darwent EC, Church DB and Brodbelt 2016 Demography and health of Pugs under primary veterinary care in England. *Canine Genetics and Epidemiology 3(1)*: 1-12. https://doi.org/10.1186/s40575-016-0035-z

Packer RMA, Hendricks A and Burn CC 2012 Do dog owners perceive the clinical signs related to conformational inherited disorders as 'normal' for the breed? A potential constraint to improving canine welfare. *Animal Welfare 21*: 81-93. https://doi.org/10.7120/096272812X13345905673809

Packer RMA, Hendricks A, Tivers MS and Burn C 2015 Impact of facial conformation on canine health: Brachycephalic Obstructive Airway Syndrome. *PLoS One 10*: e0137496. https://doi.org/10.1371/journal.pone.0137496

Packer RMA, O'Neill DG, Fletcher F and Farnworth MJ 2019 Great expectations, inconvenient truths, and the paradoxes of the dog-owner relationship for owners of brachycephalic dogs. *PLoS One 14(7)*: e0219918. https://doi.org/10.1371/journal.pone.0219918

Poncet CM, Dupré GP, Freiche VG, Estrada MM, Poubanne YA and Bouvy BM 2005 Prevalence of gastrointestinal tract lesions in 73 brachycephalic dogs with upper respiratory syndrome. *Journal of Small Animal Practice 46*: 273-279. https://doi.org/10.1111/j.1748-5827.2005.tb00320.x

Riecks TW, Birchard SJ and Stephens JA 2007 Surgical correction of brachycephalic syndrome in dogs: 62 cases (1991-2004). *Journal of the American Veterinary Medical Association 230*: 1324-1328. https://doi.org/10.2460/javma.230.9.1324

Roedler FS, Pohl S and Oechtering GU 2013 How does severe brachycephaly affect dogs' lives? Results of a structured preoperative owner questionnaire. *The Veterinary Journal 198*: 606-610. https://doi.org/10.1016/j.tvjl.2013.09.009

Such ZR and German AJ 2015 Best in show but not best shape: a photographic assessment of show dog body condition. *Veterinary Record 177(5)*: 125. https://doi.org/10.1136/vr.103093

Torrez CV and Hunt GB 2006 Results of surgical correction of abnormalities associated with brachycephalic airway obstruction syndrome in dogs in Australia. *Journal of Small Animal Practice 47*: 150-154. https://doi.org/10.1111/j.1748-5827.2006.00059.x

Villedieu E, Rutherford L and Ter Haar G 2019 Brachycephalic obstructive airway surgery outcome assessment using the 6- minute walk test: pilot study. *Journal of Small Animal Practice 60*: 132-135. https://doi.org/10.1111/jsap.12942

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