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Comparison of submaximal exercise test results and severity of brachycephalic obstructive airway syndrome in English bulldogs

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A B S T R A C T

Canine brachycephalic obstructive airway syndrome (BOAS) is a complex respiratory disease related to congenitally flattened facial and skull anatomy. BOAS causes respiratory distress, heat and exercise intolerance, and gastrointestinal signs. English bulldogs (EB) have a high prevalence of BOAS. Currently, the severity of BOAS signs in veterinary practice is assessed subjectively. To reduce BOAS in brachycephalic breeds, an objective and easy-to-use tool could help breeders select healthier animals. Exercise tests, such as the 6 min walk test (distance walked measured) or the 1000 m walk test (duration measured), could be used to assess the severity of BOAS, as exercise intolerance and impaired recovery are key features of BOAS. This study evaluated the severity of signs and anatomic components of BOAS in a group of prospectively recruited young adult EBs ($n = 28$) and investigated the correlations of the 6 min walk test or the 1000 m walk test with a veterinary assessment of BOAS severity, using an ordinal 4 level scale of respiratory signs. EBs with more severe BOAS walked a shorter distance, more slowly and their recovery from exercise took longer than those with only mild signs of BOAS. Control dogs of different breeds ($n = 10$) performed the exercise tests significantly better (i.e. longer distance, faster time and recovery) than EBs. Increases in body temperature during exercise were significantly higher in EBs than in controls. The results of this study support the use of exercise tests for objective evaluation of the severity of BOAS in EBs.

Introduction

Brachycephalic dog breeds, such as the English bulldog (EB), have congenitally flattened facial anatomy. This conformation is associated with several malformations of the head and neck, which can be classified as primary, such as elongated soft palate and stenotic nares, or as secondary due to long-term effects of increased inspiratory upper airway resistance, such as everted tonsils and laryngeal collapse (Fasanella et al., 2010; Poncet and Freiche, 2014). Clinical signs include snoring, panting, overheating, exercise intolerance, prolonged recovery from exercise, cyanosis, gastrointestinal problems and disturbed sleep patterns (Fasanella et al., 2010; Packer and Tivers, 2015), collectively referred to as brachycephalic obstructive airway syndrome (BOAS). Packer et al. (2015) have quantitatively demonstrated that the relative shortening of the muzzle dramatically increases the risk of BOAS. To reduce the prevalence of BOAS, the key lies in responsible breeding choices, as corrective surgery is helpful only at the individual level.

Many, but not all, brachycephalic dogs exhibit clinically significant signs of BOAS, such as daily respiratory distress or even dyspnoea (Packer et al., 2015). The severity of BOAS signs is currently subjectively assessed, and many owners consider these signs as 'normal for the breed' (Packer et al., 2012). An easy, non-invasive, and objective screening tool to help breeders to select healthier animals is needed. Recently, the severity of BOAS in French bulldogs was assessed using non-invasive, but broadly unavailable, whole-body barometric plethysmography (Liu et al., 2015). Although measuring the degree of facial foreshortening using the craniofacial ratio and selecting animals with a greater craniofacial ratio could help reduce the risk of BOAS, many popular brachycephalic breeds might have insufficient individuals with a 'safe' craniofacial ratio (Packer et al., 2015).

Since exercise intolerance and impaired recovery due to malfunctioning thermoregulation are key features of BOAS, exercise tests could offer a feasible and non-invasive screening test. A 1000 m fitness test is already in use in the Netherlands, where EBs intended for breeding must pass the fitness test in addition to other

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breeding requirements.[1] Another submaximal exercise test, the 6 min walk test (6MWT), is easy to perform and reproducible for screening exercise tolerance in dogs (Boddy et al., 2004; Swimmer and Rozanski, 2011; Lilja-Maula et al., 2014; Manens et al., 2014), but no studies on its use in brachycephalic breeds have been published.

The aims of this study were: (1) to describe and compare BOAS-related clinical signs and anatomical lesions in young adult EBs; (2) to evaluate their exercise tolerance by using the 6MWT and 1000 m walk test; and (3) to examine the relationship between veterinary assessed severity of BOAS and exercise test results.

Materials and methods

Ethical approval

All study dogs were privately owned, prospectively recruited pet animals, whose owners signed an informed consent. The study protocol was approved by the Committee for Experimental Animals of Southern Finland (approval number ESAVI/11519/04.10.07/2014; date of approval 7 November 2014).

Study protocol for English bulldogs

The study was performed at the Veterinary Teaching Hospital, University of Helsinki, Finland from December 2014 to June 2015. Inclusion criteria were purebred EB, age 2–5 years and no history of BOAS or orthopaedic surgery. Owners filled in an online pre-study questionnaire on their dog's physical activity and overall health. Thirty dogs with variable activity habits were chosen from the 54 answers that were received. Only one dog per owner was chosen. Two of the chosen dogs could not participate due to acute illness; thus, a total of 28 EBs were included.

At the first visit, a questionnaire of BOAS-related signs, modified from Roedler et al. (2013), was completed, clinical examinations and exercise tests were performed, and blood samples were taken. At the second visit, the dogs were anaesthetised, upper airways were visually evaluated and dual-slice helical computed tomography (CT) (Somatom Emotion Duo, Siemens AG) of the head was performed using a bone algorithm and a slice thickness of 2 mm. The dogs were premedicated with 0.2 mg/kg butorphanol (Torbutor, Richter Pharma) intramuscularly, induced after pre-oxygenation with 1 mg/kg lignocaine (Lidocain, Orion) intravenously, along with alfaxalone (Alfaxan, Dechra) to effect (approximately 2 mg/kg); after intubation, anaesthesia was maintained with sevoflurane (Sevoflurane, AbbVie) and continuous infusion of lignocaine 2 mg/kg/h.

Study protocol for control dogs

For the exercise test, 10 healthy dogs of the same age range and of small or medium-sized breeds with similar or smaller height than EBs were recruited and evaluated using the same interview and physical examination protocols as used for the EBs.

Grading of brachycephalic obstructive airway syndrome signs

A clinical veterinary assessment of BOAS severity was made on the basis of clinical examination findings according to the scale presented in Table 1. EBs graded as having no or mild signs of BOAS are referred to as the BOAS$^-$ group. EBs having moderate or severe signs are referred to as the BOAS$^+$ group.

Exercise tests

The dogs were walked at the teaching hospital along a quiet air conditioned (21–22 °C) 60 m straight corridor on a leash at their own pace first for 6 min and, after a brief break for a physical examination, continued to walk until 1000 m was reached. Heart rate (HR), respiratory rate (RR), colour of mucous membranes, severity of upper respiratory noise and body temperature were measured during the physical examination, before and immediately after the 6 min walk test and 1000 m walk test. The 6 min walk distance (6MWD) was recorded in metres (m) and 1000 m time (excluding break) in minutes (min). Recovery time after finishing the 1000 m walk test was recorded at 5 min intervals until each dog had recovered to pre-walk status (HR, RR, body temperature, general condition). Exercise tests were not performed or were discontinued if the animal was dyspnoeic prior to or during the valuation (i.e. laboured breathing with continuous stertor/stridor and use of accessory respiratory muscles) or body temperature >39.3 °C.

[1] See: Dutch Kennel Club. Convenant Bulldog Breeding Rules 2014. www.houdenvanhonden.nl/contentassets/27de95b0774b4730990cfae5b7c4c3e4/convenant_bulldog-breeding_rules.pdf (accessed 7 December 2016).

Table 1
Scoring scale of brachycephalic obstructive airway syndrome (BOAS) signs based on veterinary clinical examination findings.

	BOAS grade			
	BOAS$^-$		BOAS$^+$	
	Grade 0	Grade 1[a]	Grade 2[a]	Grade 3
Upper respiratory noise[b] at rest	0	0–1	1–2	2–3
0 = none				
1 = mild				
2 = moderate				
3 = severe				
Upper respiratory noise[b] after exercise	0	1–2	1–2	2–3
0 = none				
1 = mild				
2 = moderate				
3 = severe				
Respiratory type at rest	0	0	0–1	1
0 = normal				
1 = use of accessory respiratory muscles[c]				
Resting dyspnoea or cyanosis	0	0	0	0–1
0 = none				
1 = present				

Grade 0 = none, grade 1 = mild, grade 2 = moderate, grade 3 = severe signs.
[a] Upgrading to next BOAS grade is made in case the dog has all signs in upper range.
[b] Audible upper respiratory noise evaluated without auscultation.
[c] Accessory respiratory muscle use evident by nasal flaring and increased chest and abdominal wall movements.

Pharyngolaryngeal and nasal component of brachycephalic obstructive airway syndrome

The pharyngolaryngeal region was assessed visually before endotracheal intubation in sternal recumbency. For overall assessment of the pharyngolaryngeal obstruction level, a score was established (Table 2). Stenosis of nares was visually graded in awake animals as absent, mild, moderate or severe (Packer and Tivers, 2015). The presence of caudal aberrant nasal turbinates was evaluated as absent, minimal, mild, moderate or severe from head computed tomography scans (Grosso et al., 2015).

Statistical analyses

Descriptive statistics are presented as mean ± standard deviation (SD) for continuous, normally distributed variables, or as median and range for ordinal or non-normally distributed variables. For pair-wise comparisons, a paired *t* test was used for continuous, normally distributed variables (i.e. temperature). For group comparisons, an independent sample *t* test was used for continuous, normally distributed variables, without assumption of equal variances (i.e. 6MWD, 1000 m time). The Mann–Whitney *U* test was used for ordinal variables (i.e. recovery time, stenosis of nares, pharyngolaryngeal obstruction and severity of caudal aberrant nasal turbinates). The correlation between 6MWD and severity of BOAS (i.e. grade 0, 1, 2, 3; Table 1) was assessed using a multiple linear regression model with weight and age as covariates. A similar multiple linear regression model was used to assess the correlation between 1000 m time and severity of BOAS, and the correlation between body temperature change pre-exercise versus post-exercise and the severity of BOAS.

Table 2
Scoring scale of severity of pharyngolaryngeal obstruction based on visual evaluation.

	Pharyngolaryngeal obstruction			
	Grade 0	Grade 1[a]	Grade 2[b]	Grade 3
Elongated soft palate	0	0–1	1	1
0 = no				
1 = yes				
Everted tonsils	0	0–1	0–1	1
0 = no				
1 = yes				
Laryngeal collapse grade[c]	0	0–I	I–II	II–III

Grade 0 = no, grade 1 = mild, grade 2 = moderate, grade 3 = severe obstruction.
[a] Only one lesion allowed.
[b] Upgrading to next obstruction grade is made in case the dog has all lesions in upper range.
[c] 0 = not present, I = eversion of laryngeal saccules, II = loss of rigidity and medial displacement of cuneiform processes, III = collapse of corniculate processes (Leonard, 1960).

The models assume the two dependent variables (6MWD and the 1000 m time) to be continuous and normally distributed, which was evaluated using the Shapiro–Wilk test. These models also assume the distance between each grade to be equal. The regression coefficients (β), their significance levels and interpretations of the effect sizes are reported. All comparisons were performed as two-tailed tests. *P* values <0.05 were considered to be significant. Statistical analyses were conducted using STATA 14.0.

Results

History and clinical information

Twenty-eight EBs (13 females, 15 males) were included in the study. The median age was 3 years (range 2–5 years), the median weight was 25.1 kg (range 18.5–33.1 kg) and the median body condition score (BCS) was 3/5 (range 2–4/5).

For overall quality of life, 24/28 owners of EBs (86%) stated that their dogs had no medical or other conditions affecting their dog's daily life. In the remaining four dogs, furunculosis, eye and skin problems, osteoarthritis or vomiting/regurgitation occasionally affected the daily quality of life. No owners reported respiratory signs or exercise intolerance as factors affecting their dogs' daily quality of life, although five owners stated that their EBs had exercise intolerance (18%) and one dog had experienced a syncopal episode.

During warm weather (>19 °C), 3/28 EBs (11%) were able to walk <10 min, 12/28 (43%) 10–30 min, 8/28 (28%) 30–60 min and 5/28 (18%) over 60 min. No owners reported that their dogs needed >30 min recovery time during summer; most dogs (25/28, 89%) recovered in >15 min. Vomiting or regurgitation was reported occasionally in 14/28 EBs (50%), weekly in two EBs (7%) and daily in one EB (4%), with 11/28 (39%) not reported to experience vomiting or regurgitation. Loud upper respiratory noise was reported in 25/28 EBs (89%) while sleeping, during exercise or during warm weather. No owners reported their dogs having loud upper respiratory noise at rest. No loud upper respiratory noise at all was reported in 3/28 (11%) of EBs.

During clinical veterinary examinations, upper respiratory noise was evaluated at rest as mild in 11/28 (39%), moderate in 7/28 (25%) and severe in 3/28 EBs (11%); 7/28 dogs (25%) had no audible upper respiratory noise at rest. No remarkable changes were seen on biochemistry or haematological analyses.

Of the 10 control dogs, seven were females and three were males. The median age was 4 years (range 2–5 years), the median weight was 9.1 kg (range 6.8–20 kg) and the median body BCS was 3/5 (range 3–4/5). The breeds comprised two Cairn Terriers and one of each of a Jack Russell terrier, Miniature poodle, Cavalier King Charles spaniel, Finnish Lapphund, Standard Dachshund, Border terrier, Mudi and Cocker spaniel. On the basis of owner interviews, 8/10 control dogs had no medical or other conditions affecting their daily quality of life. In 2/10 dogs, atopy/allergy occasionally affected their daily quality of life. No upper respiratory noise was reported during exercise, warm weather or rest, although 2/10 dogs occasionally snored. No exercise intolerance was reported and all, except one with a very thick breed-specific coat (Finnish Lapphund), were able to walk over 60 min in warm weather. Gastrointestinal signs were seen occasionally in 3/10 control dogs. Physical examinations were normal in all controls.

Severity of brachycephalic obstructive airway syndrome

None of the 28 EBs were graded according to veterinary clinical examination as having no signs of BOAS, 17/28 were graded as having mild signs, 7/28 as moderate, and 4/28 as severe signs of BOAS. Altogether, 17/28 (7 females, 10 males) EBs were classified to BOAS$^-$ group and 11/28 (6 females, 5 males) to BOAS$^+$ group. All control dogs were graded as having no signs or findings typical of BOAS.

Table 3
Combined pharyngolaryngeal obstruction severity and nasal findings of brachycephalic obstructive airway syndrome (BOAS)$^+$ and BOAS$^-$ English bulldogs.

	BOAS$^+$ (n = 11)	BOAS$^-$ (n = 17)
Pharyngolaryngeal obstruction[a]		
0 = no	1	5
1 = mild	3	9
2 = moderate	6	3
3 = severe	1	0
	P = 0.02	
Stenotic nares		
0 = no	0	2
1 = mild	2	8
2 = moderate	7	5
3 = severe	2	2
	P = 0.06	
Caudal aberrant nasal turbinates		
0 = normal	0	0
1 = minimal	1	2
2 = mild	5	8
3 = moderate	4	6
4 = severe	1	1
	P = 0.76	

BOAS$^-$ = no or mild signs; BOAS$^+$ = moderate or severe signs, based on veterinary clinical examination grading.
[a] Including evaluation of soft palate, tonsils and laryngeal collapse as described in Table 2.

Pharyngolaryngeal and nasal findings in English bulldogs with brachycephalic obstructive airway syndrome

An elongated soft palate was seen in 21/28 (75%) EBs and everted tonsils in 7/28 (25%) EBs. Grade I laryngeal collapse was seen in 8/28 (29%) EBs and one dog (4%) had grade III laryngeal collapse (Leonard, 1960). No laryngeal collapse was present in the remaining 19/28 dogs (67%). Combined pharyngolaryngeal obstruction level and nasal findings of BOAS$^+$ and BOAS$^-$ EBs are presented in Table 3.

Exercise tests

Three of 28 EBs were considered ineligible for either exercise test, one because of dyspnoea at rest, and two because of body temperature >39.3 °C. Additionally, seven EBs did not proceed to the 1000 m test after the 6MWT because of body temperature >39.3 °C. Another two EBs refused to walk properly during the exercise tests; these EBs were withdrawn from the analysis. Finally, one BOAS$^-$ EB was unable to complete the 1000 m test. This dog had very severe pododermatitis and 'false paw pad' lesions (i.e. interdigital callus formation). Therefore, 23 EBs performed the 6MWT and 16 performed the 1000 m test. All control dogs were able to perform both walk tests. The exercise test results are presented in Table 4.

The severity of BOAS was negatively correlated with 6MWD (β = –40.07, P = 0.02) after controlling for weight and age. As an interpretation of this regression coefficient, a 1 U increase in BOAS severity decreased the distance by 40 m (95% CI –74.08 to –6.05 m). Similarly, for the 1000 m time, BOAS severity was positively related to time (β = 1.32, P = 0.048) after controlling for weight and age. Consequently, a 1 U increase in BOAS grade increased the walking time by 1 min 19 s (95% CI 0 min 1 s to 2 min 37 s).

Body temperature

Pre-exercise and post-exercise test body temperatures are presented in Table 5. The difference in the change of body temperature pre-6MWT versus post-6MWT was statistically significant (P = 0.02) between EBs and controls (mean of 0.43 °C increase for EBs; 95% CI 0.24 to 0.61 °C; mean of 0.07 °C increase for controls; 95% CI –0.19 to 0.33 °C).

Table 4
Results of the 6 min and 1000 m walk tests of brachycephalic obstructive airway syndrome (BOAS)+ and BOAS− English bulldogs (EBs) and controls presented as mean ± standard deviation and range.

	BOAS+ EBs		BOAS− EBs		Controls
6MWD (m)	494 ± 56 (385–585) n = 8	P = 0.059	543 ± 55 (455–655) n = 15	P = 0.002	629 ± 62 (520–705) n = 10
1000 m time (min)	13.02 ± 1.31 (11.45–14.75) n = 5	P = 0.046	11.34 ± 1.32 (9.14–14.37) n = 11	P = 0.001	9.37 ± 1.06 (8.35–11.37) n = 10
1000 m recovery[a] (number of animals)					
≤5 min	0/5		1/11		8/10
≤10 min	0/5		1/11		2/10
≤15 min	2/5		7/11		0/10
>15 min	3/5		2/11		0/10
		P = 0.06		P = 0.0001	
Combined 1000 m time in ≤12 min and recovery ≤15 min[b] (number of animals)	0/5		7/11		10/10

P values are presented between BOAS+ and BOAS− groups and between BOAS− and controls.
6MWT, 6 min walk test; 6MWD, 6 min walk distance.
BOAS− = no or mild signs; BOAS+ = moderate or severe signs, based on veterinary clinical examination grading.
[a] Recovery to pre-walk status (heart and respiratory rate, body temperature, general condition).
[b] Requirements to pass the EB fitness test (according to Dutch Kennel Club Convenant bulldog breeding rules).

The severity of BOAS increased the pre-6MWT versus post-6MWT temperature change (β = 0.23, P = 0.05) after controlling for weight and age. In other words, a 1 U increase in BOAS severity grade increased the temperature change by 0.23 °C (95% CI 0.00 to 0.47 °C). Similarly, for the post-6MWT temperature, the effect of BOAS severity was positive and significant (β = 0.27, P = 0.03) after controlling for weight and age. Consequently, a 1 U increase in BOAS grade represented an increase of 0.27 °C (95% CI 0.02 to 0.52 °C) in the post-walking temperature.

Discussion

The popularity of brachycephalic breeds has dramatically increased during the past decade, and the welfare aspects of profound brachycephaly have received public attention (Oechtering, 2010; Emmersson, 2014). The English bulldog (EB) is a breed with increased risk of BOAS (Fasanella et al., 2010; Packer et al., 2015). The aims of this study were to evaluate the severity of clinical signs and anatomical components of BOAS in a group of young adult EBs and to determine how well results of 6MWT and 1000 m walk tests correlate with severity of BOAS.

For research purposes, BOAS grade has been commonly evaluated by the frequency of owner-reported signs (Poncet et al., 2005) or by veterinary clinical evaluation (Liu et al., 2015). We chose veterinary clinical evaluation-based scoring, as it has previously been demonstrated that owners frequently do not recognise or perceive clinical signs of BOAS as problematic (Packer et al., 2012). A consensus between both authors evaluating the clinical signs of BOAS was reached by assessing several cases together. However, the evaluation always remains subjective and can vary between veterinary professionals. The anatomical components, more stenotic nares and more severe pharyngolaryngeal obstruction, were seen in our study more frequently in BOAS+ group than in BOAS− group, reflecting the association between the severity of anatomical components and clinical signs. Interestingly, we found that the severity of caudal aberrant turbinates was almost equally distributed in BOAS+ and BOAS− groups. However, BOAS is a multimodal disease and the extent to which each anatomical abnormality contributes to signs seen in individual animals can vary (Schuenemann and Oechtering, 2014; Grosso et al., 2015). We did not evaluate other obstructing components of nasal cavity, such as mucosal contact points and rostral aberrant turbinates (Oechtering et al., 2016). Both clinical signs reported by owners and components of BOAS were not as prevalent in our study as described previously (Poncet et al., 2005; Fasanella et al., 2010; Roedler et al., 2013). However, earlier studies included brachycephalic dogs evaluated or treated because of BOAS, compared with our study population, which included greater number of mild BOAS cases.

Dogs depend on nasal breathing for thermoregulation (Schuenemann and Oechtering, 2014; Oechtering et al., 2016). Brachycephalic breeds are known to be at greater risk for heat stroke due to their ineffective evaporation and inadequate airflow in the upper respiratory system (Flournoy et al., 2003; Bruchim et al., 2006). Exercise produces increased body heat (Flournoy et al., 2003). Many normocephalic breeds can tolerate high body temperatures after maximal exercise, without adverse effects (Flournoy et al., 2003; Angle and Gillette, 2011). However, we are not aware of any report of submaximal exercise-induced body temperature increases in any dog breeds. We demonstrated that the mean body temperature rise in EBs after submaximal exercise was 0.43 °C, whilst in controls it was only 0.07 °C, and that the rise in body temperature increases with severity of BOAS, reflecting the low capacity of EBs to control body temperature.

Packer et al. (2015) suggested several strategies for breeding to reduce BOAS risk, such as selecting dogs with lower risk morphologies, development of genetic testing or out-crossing. Avoiding the use of dogs with severe BOAS signs in breeding might reduce the

Table 5
Pre-exercise and post-exercise body temperatures of English bulldogs (EBs) and control dogs presented as mean ± SD and range.

	Controls (n = 10)		All EBs (n = 28)	EBs performing 6MWT (n = 23)	EBs performing 1000-m test (n = 16)
Pre-exercise °C	38.3 ± 0.32 (37.9–38.9) P = 0.55	P = 0.004	38.8 ± 0.44 (38.0–39.7)	38.7 ± 0.39 (38.0–39.2) P = 0.0001	38.6 ± 0.39 (38.0–39.1)
Post 6MWT °C	38.4 ± 0.42 (37.9–39.1)			39.1 ± 0.46 (38.4–39.9)	
Post 1000 m °C	38.5 ± 0.43 (37.9–39.1) P = 0.12[a]				39.2 ± 0.50 (38.5–40.1) P = 0.0001[a]

6MWT, 6 min walk test.
[a] P value between pre- and post-1000 m test.

prevalence of BOAS or reduce the severity of BOAS. A breeding test to choose animals with either no signs, or clinically irrelevant signs of BOAS, should be easy to perform and objective. Examination of internal airways and veterinary expert opinion on clinical signs are commonly used for diagnosis of BOAS. However, veterinary clinical evaluation is always subjective, and pharyngeal and nasal evaluation requires anaesthesia and is therefore not feasible for large-scale breeding purposes. The submaximal exercise tests are easy to perform and give an overall estimate of a dog's respiratory and exercise capacity.

Other factors, such as orthopaedic or motivation problems, or severe pododermatitis, can affect a dog's ability to perform walk tests and should be taken into account. We found that 6MWD was reduced ($P = 0.059$), and 1000 m and recovery times ($P = 0.046$ and $P = 0.06$) were increased, in EBs with BOAS than EBs without BOAS. In addition, a 1 U increase in BOAS grade significantly decreased the 6MWD by 40 m and increased the time in the 1000 m test by 1 min 19 s. These findings support the use of exercise tests as an objective means of evaluating severity of BOAS.

Since being overweight has been demonstrated to increase the risk of BOAS signs (Liu et al., 2015; Packer et al., 2015) and to reduce 6MWD (Manens et al., 2014), body weight and also age were taken into account in our regression analysis. The control dogs, when compared with EBs without BOAS, walked considerably further, faster and also recovered more quickly. The Dutch Kennel Club is already using the 1000 m test for breeding EBs. Their requirements of a maximum 12 min walk time and 15 min recovery seem reasonable in light of our findings, as none of the dogs with BOAS were able to perform the test within those limits. On the basis of our study, the recovery to pre-exercise status is essential when evaluating the performance. Many of the EBs were able to walk a similar distance or time as controls, but their recovery was considerably delayed. Since longer legs have been associated with longer walking distance (Swimmer and Rozanski, 2011), our control dogs were small or medium-sized breeds with similar or smaller height than EBs.

The age group of 2–5 years was chosen because it represents the average breeding age. Since BOAS signs are known to usually worsen with age (Hendricks, 2004; Roedler et al., 2013), for breeding purposes, 'passing' exercise test results should not be considered valid for the duration of the dog's life, but the test should be repeated after a certain period. Further studies examining the effect of a dog's ageing on results and exercise test usability in other brachycephalic breeds are needed. Breed-specific normal values should be obtained in studies with larger sample sizes.

Conclusions

The results of submaximal exercise tests, the 6MWT and the 1000 m test, correlate with clinical severity of BOAS, and these tests could provide an objective and simple way to select less affected breeding animals. The submaximal exercise-induced body temperature rise was significantly greater in EBs than in controls, further emphasising the thermoregulation problems associated with brachycephaly.

Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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