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Animal Welfare 2015, 24: 327-333
ISSN 0962-7286
doi: 10.7120/09627286.24.3.327

Brachycephalic problems of pugs relevant to animal welfare

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Abstract

Excessive breeding for brachycephaly (fore-shortened muzzle) has led to increasing problems in pugs related to brachycephalic airway syndrome (BAS). Consequently, the German Pug Club (Deutscher Mopsclub eV; DMC) established a stress test in 2009 that must be passed for breeding and requires normalised heart and respiratory rates 15 min after having covered a distance of 1 km. In this study, 42 pugs underwent the stress test under standardised conditions. Taking into account that this exercise should not be too physically demanding for any healthy dog, the results were surprising: 14 of the pugs failed, ie a failure rate of 33.3%. In addition to the stress test, the pugs were assessed according to their heart and respiratory rates at rest, which we predicted would be associated with BAS, and in this test, 21 out of 42 pugs failed. Thus, 50.0% of the pugs were in a severely compromised physical condition. A further group of seven retropugs, ie a crossbreed of pugs with a slightly longer muzzle, was included in the study to compare brachycephalic problems. All of the retropugs passed the test, even when respiratory and heart rates at rest were considered. However, the findings may not be transferable to all retropugs because of the small sample size, so further research is needed. In summary, this study has enabled the development of recommendations for future implementation of stress tests.

Keywords: *animal welfare, brachycephalic airway syndrome, physical exercise, pugs, retropugs, stress test*

Introduction

Short-muzzled dog breeds have become popular again. However, excessive breeding for brachycephaly affects the entire upper respiratory tract. Stenotic nares and elongated soft palate are the primary malformations narrowing the airways (Harvey 1982; Aron & Crowe 1985; Wykes 1991; Koch *et al* 2003; Riecks *et al* 2007). The nasal cavity is too small to allow normal post-natal growth of nasal conchae. This results in so-called aberrant conchae obstructing the nasal passage and the choanae (Oechtering *et al* 2007). Increased inspiratory effort is necessary to ensure adequate ventilation. This increased effort leads to excessive negative pressure breathing, which can cause secondary damage, such as tissue oedema, as well as everted tonsils and laryngeal saccules. Additionally, laryngeal or tracheal collapse has been observed during disease progression. Recent examinations have identified further obstructions responsible for dyspnoea. For example, the nasal vestibules are narrowed by nasal alae that are too long. Additionally, the soft palate is not only overlong but also thickened. The tongue is too long and too thick (Oechtering 2010). A study reported that 35 out of 40 brachycephalic dogs suffered from bronchial stenoses, and the pug was the most affected breed (De Lorenzi *et al* 2009). A further study suggested that brachycephalic dogs were prone to lower PaO_2, higher $PaCO_2$ and hypertension (Hoareau *et al* 2012).

Brachycephalic airway syndrome (BAS) is a combination of upper respiratory tract disorders in predisposed breeds (Oechtering *et al* 2007). According to the severity of the stenotic changes, the signs and symptoms include stertorous breathing, loud snoring, coughing, suffocation, syncope and problems when eating (Lorinson *et al* 1997). The primary clinical symptom is an inspiratory stridor (Koch *et al* 2003). Furthermore, these dogs exhibit exercise intolerance and signs of dyspnoea. Severe cases can result in cyanosis and collapse caused by hypoxia. Pugs are additionally very prone to hyperthermia because thermoregulation is limited by the short length of their noses (Oechtering 2010). The severity of symptoms related to BAS seems to have increased considerably over the last few years. Interviews with brachycephalic dog owners demonstrated that more than half of the dogs suffered from breathing disorders during sleep, causing 24% of the dogs to attempt to sleep in a sitting position and 36% to have already collapsed as a result of dyspnoea (Oechtering 2013). Moreover, many affected dogs develop signs of disease during their first three years of life (Oechtering *et al* 2007). The lack of percep-

tion of frequent and severe clinical signs of BAS as a veterinary issue by owners has problematic impacts on treatment and breeding (Packer *et al* 2012). Therapy consists of removing obstructions by means of surgical methods, such as alar-fold wedge resection or laser-assisted turbinectomy.

In Germany, a pug must successfully pass a stress test developed by the German Pug Club (Deutscher Mopsclub eV — DMC) to be classified as suitable for breeding. According to the guidelines, the pug must take a maximum of 11 min to walk 1 km. The dogs must be kept on a leash during the test, and the gait is not specified. Immediately before and after the test, which takes place at events, eg organised by the International French Bulldog Club, the pug must be examined by an independent veterinary surgeon, particularly with regard to heart rate and breath sounds. The stress test is considered to be passed successfully if the heart and respiratory rates normalise within 15 min. All tested pugs must be at least 12 months old and marked with a microchip. The British Kennel Club also responded to problems related to some breeds "requiring particular monitoring by reason of visible conditions which may cause health or welfare concerns" (The Kennel Club Limited 2013). Since 2012, such breeds must pass a health check from the show veterinary surgeon after winning Best of Breed at Crufts.

The new crossbreed Rassmo® arose from the wish to breed the pug according to its appearance in the 19th century but relieve it of brachycephalic problems. This cross between Parson Russell terriers and pugs has been legally protected since 2007. A circle of breeders was also founded in 2006 with the intention of freeing the pug from breed-typical problems. The aim was to restore the original type of pug by crossbreeding with a foreign breed, resulting in the creation of retropugs, not to develop a new breed, but rather to breed a healthy pug. This goal was achieved by crossbreeding with the Parson Russell terrier and by reducing its genome proportion in favour of the pug genome over subsequent generations.

The objective of this study was to examine the degree of BAS in pugs and retropugs by means of a standardised stress test.

Materials and methods

Study animals

We published a call for participation in the study via the German Pug Club. Owners of pugs from various breed clubs and societies answered and none of them withdrew their participation. In general, all owners who showed interest in this voluntary study signed up and expected their dog to be healthy and fit. More than half of the pugs' owners (n = 24) were members of the German Kennel Association (Verband für das Deutsche Hundewesen, VDH) while the other dogs belonged to hobby breeders.

All of the dogs were privately owned. In total, 54 dogs belonging to two different breeds were included in the study. The larger group consisted of pugs (see Figure 1), with 47 participants, 23 of which were males and 24 of which were females. The second group consisted of seven so-called retropugs (four males, three females; see Figure 2).

Stress test

The dogs included in this study underwent a stress test under standardised conditions, ie with the same speed and the same walking time, where they walked on a treadmill with a pre-set speed of 1.50 to 1.52 m s^{-1} for 11 min. Thus, the distance amounted to between 990 and 1,003 m. This procedure ensured approximately equal climatic conditions for each dog.

The treadmill was part of the gait analysis laboratory of the Clinic of Small Animal Surgery and Reproduction of the Centre for Clinical Medicine at Ludwig Maximilian University in Munich, Germany. Two treadmills were inserted into a pedestal that measured 5.7 × 1.2 × 0.28 m (length × width × height). The treadmills were 140 × 0.80 cm (length × width). It seemed to be easier for the dog to walk on the treadmill when the owner stood on the pedestal in front of it. In this way, the owner was able to reassure the dog and motivate it with food and/or toys if the need arose. While walking, the dog was additionally secured by a second person standing beside the treadmill and keeping the dog on a leash. Should an incident have occurred, such as exhaustion or loss of interest, the treadmill could have been immediately stopped.

Photographs of the nose

A face-on photograph was taken of each dog to measure the nose (see Figure 3). The ratio of nostril width (NW) to nostril length (NL) as a criterion for brachycephaly was calculated by the following formula:

• NW/NL = Segment NW/Segment NL

There are no references to nostril width ratios in the literature. To obtain comparable values of a normocephalic breed, we also took face-on photographs of ten beagles belonging to the Chair of Animal Nutrition, Ludwig Maximilian University in Munich, Germany.

Course of the experiment

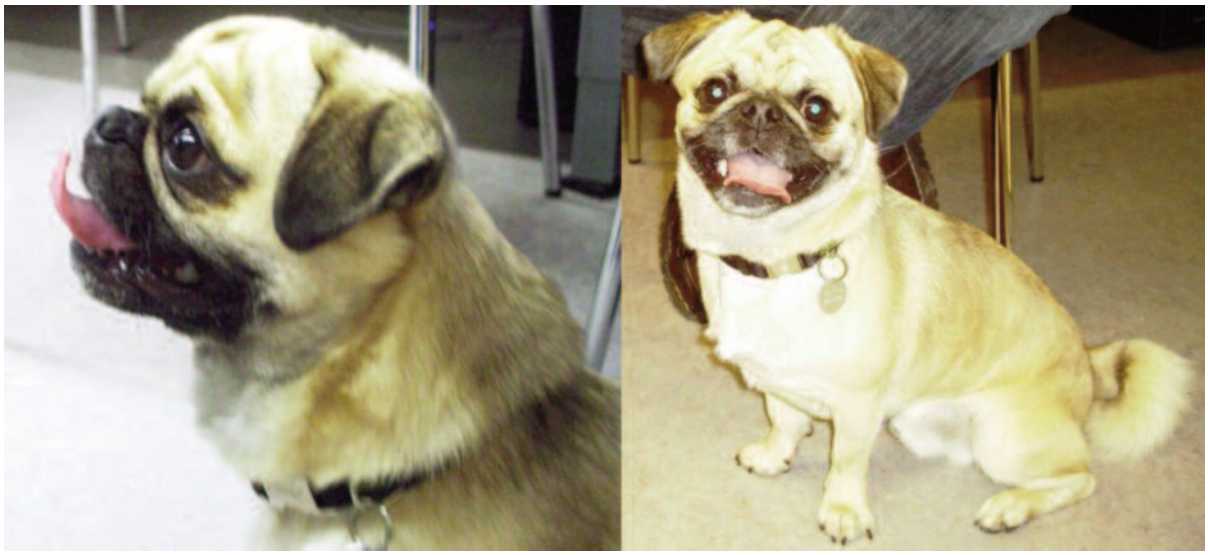
For the dogs, it was important that the stress test and all of the examinations were conducted in a calm manner. At first, the dog's ability to walk on the treadmill was tested. If no problems occurred, the dog was physically examined, and its temperature and respiratory and heart rates were recorded at rest. Once the height and weight of the dog, in addition to potential abnormal breath sounds, were documented, the stress test began. On completion, auscultation was performed to document the heart and respiratory rates after exercise. The temperature after exercise was also measured. After a recovery phase of 15 min, these three values were determined again (heart and respiratory rate after recovery as well as temperature). Finally, face-on and profile photographs were obtained of each dog.

https://doi.org/10.7120/09627286.24.3.327 Published online by Cambridge University Press

Figure 1

Profile and front of a beige pug.

Figure 2



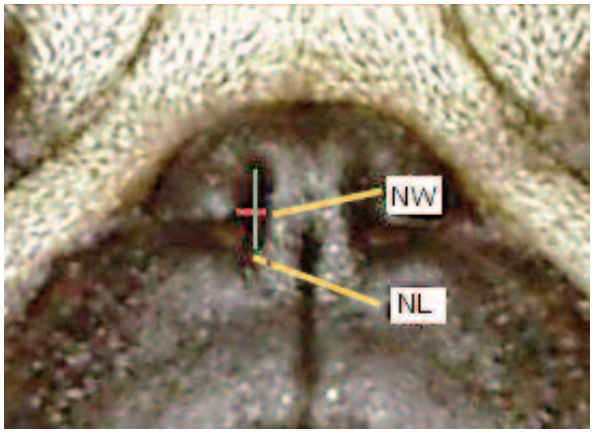
Profile and front of a beige retropug.

Statistical analysis

Statistical analyses were conducted and illustrated using the statistical software IBM SPSS 20.0. Intergroup comparisons were performed after the homogeneity of variance was verified using Levene's test.

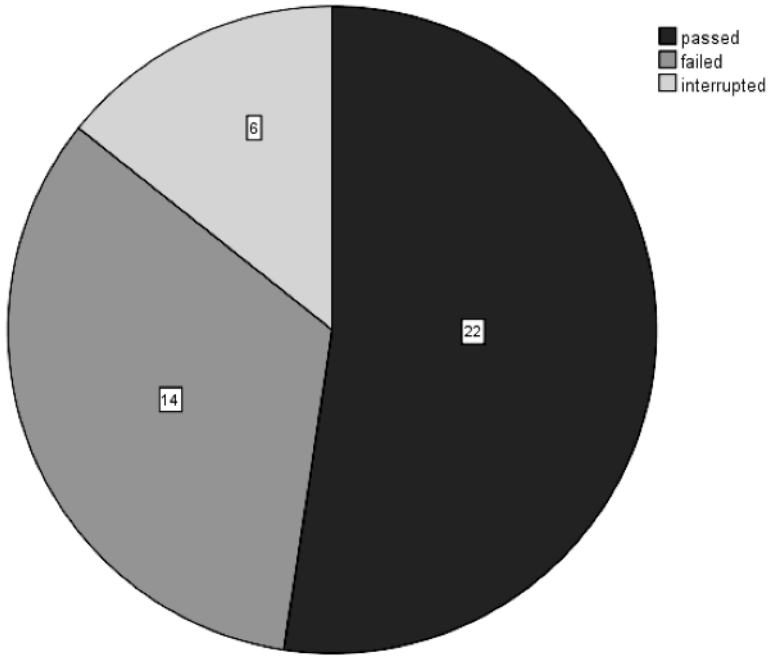
The Kolmogorov-Smirnov corrected by Lilliefors test was used to assess whether the parameters were normally distributed. Normally distributed variables were summarised as mean (± SEM) whereas in skewed variables the median, min and max were calculated. For comparison, variables were grouped into pugs and retropugs as well as dogs that passed the stress test and those that did not. Thereby, single comparisons were carried out via the student's *t*-test whereas in cases without normality the Mann-Whitney *U*-test was conducted. *P*-values ≤ 0.05 were accepted as indicating significance.

Figure 3



Photography of the nasal plane to determine the ratio of nostril width (NW) to nostril length (NL).

Figure 4



Results of the stress test in pugs, according to the guidelines of the DMC (n = 42).

Table 1 Abnormal breath sounds in pugs.

Audible abnormal breath sounds	Pugs
Absent	7
Upper chest sounds	30
Lower chest sounds	2
Upper and lower chest sounds	3
Total	**42**

Results

All of the dogs were between one and eight years old when the study was conducted. On average, the pugs were 3.4 (± 0.30) years old and weighed 9.1 (± 0.21) kg.

Five out of the 47 pugs included in the study could not become accustomed to walking on the treadmill. Thus, 42 pugs were subjected to the stress test. The test was interrupted prematurely for six dogs. Furthermore, two dogs were excluded from participation for health reasons due to BAS. Since both dogs would never have been able to pass the test on the treadmill, they were added to the 'failed' group. In total, 14 pugs did not pass the stress test. As shown in Figure 4, 22 pugs successfully passed the test.

In addition to the requirements of the DMC, the pugs were assessed according to their heart and respiratory rates at rest. Dogs with rates higher than the reference range were also classified in the 'failed' group. Five out of the six pugs in which the test was interrupted prematurely had considerably increased respiratory rates at rest. As these rates continued to increase during the stress test, the dogs were assumed to have failed because of their poor physical condition. In the other case, the owner chose to interrupt the test, although the pug would have passed the test without any problems. Two dogs fulfilled the requirements of the DMC in almost normalising their heart and respiratory rates after 15 min of recovery. However, their respiratory rates at rest were much higher than the reference range (120 per min each). Adding these two dogs and the five pugs in which the test was prematurely interrupted, the size of the 'failed' group increased to 21 dogs. Consequentially, 20 pugs passed the test.

Comparison of the 'passed' and 'failed' groups, as assessed according to the DMC guidelines, did not show any significant differences regarding respiratory rate, heart rate and body temperature at rest. However, after modification of the MDC guidelines with respect to respiratory and heart rates at rest as described above, these analyses revealed a significantly lower respiratory rate at rest (P = 0.006) in the 'passed' group than in the 'failed' group.

The next sections deal in detail with the parameters that were examined before and immediately after the stress test, as well as after a recovery time of 15 min.

The physical examination focused on respiratory auscultation. Seven out of 42 pugs did not show any abnormal breath sounds, whereas increased upper or lower airway noise or a combination of both occurred in all of the other dogs. For further details, please refer to Table 1.

Data on respiratory rate, heart rate and body temperature at rest, after exercise and 15 min after exercise are provided in Table 2

Nostrils were measured with regard to width and length using photographs. The nostril index was calculated as the ratio of nostril width (NW) to nostril length (NL). In the examined

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Table 2 Mean (± SEM) respiratory rate, heart rate and body temperature of pugs.

Category	Respiratory rate (breaths per min)		Heart rate (bpm)		Body temperature (°C)	
At rest	n = 42	52.65 (± 5.55)	n = 42	100.65 (± 2.71)	n = 42	38.54 (± 0.07)
After exercise	n = 40	102.90 (± 8.60)	n = 40	127.95 (± 2.81)	n = 40	39.12 (± 0.06)
15 min after exercise	n = 40	54.48 (± 5.44)	n = 40	98.65 (± 3.00)	n = 40	38.83 (± 0.05)

pugs, this index amounted to an average of 0.13 (± 0.01); (Table 3) which was far below the mean value calculated in the reference group of ten beagles (0.74 [± 0.05]).

Additional analysis of retropugs (n = 7)

The mean age documented in the group of retropugs was 2.7 (± 0.38) years, and the mean weight was 8.8 (± 0.38) kg. Differences in age and in weight between the pugs and the retropugs were hence minimal (and not significant).

The mean respiratory rate at rest in the retropugs group was 30.9 (± 2.09) per min. Immediately after performing the stress test, this value increased to 64.1 (± 16.14) per min and after recovery, it amounted to 29.7 (± 2.74) min. Thus, the mean respiratory rate of retropugs after recovery was lower than the initial level, and it was also significantly lower than the corresponding value in the group of pugs ($P < 0.001$).

Concerning the mean heart rate at rest, the retropugs barely differed from the pugs (96.0 [± 4.94] bpm). Immediately after the stress test, retropugs experienced an increase to 113.7 (± 6.87) bpm. Then, after recovery, the heart rate decreased again to 94.0 (± 4.76) bpm.

At rest, the retropugs had a mean body temperature of 38.9 (± 0.20)°C which showed a slight increase immediately after the stress test (39.0 [± 0.20]°C). After 15 min of recovery, the temperature decreased to 38.9 (± 0.14)°C.

On average, the retropugs presented a nostril index of 0.18 (± 0.10).

Table 3 Mean (± SEM) nostril index.

		NW/NL
Pugs	n = 32	0.13 (± 0.01)

Discussion

The aim of this study was to examine problems related to BAS in pugs by means of a standardised stress test. Since BAS is diagnosed clinically, all participating pugs were physically examined and their temperature, respiratory and heart rates were recorded at rest, after exercise and after a 15-min recovery period. The dogs were also familiarised with the treadmill before performing the standardised stress test, which was characterised by its low demands. Thus, upper respiratory tract stenosis was expected to be the only cause for failure.

According to the DMC, the pugs must take a maximum of 11 min to walk a distance of 1 km and show normalised heart and respiratory rates within 15 min of completing the exercise. To achieve this goal, the pugs that we examined in our study ran a medium to fast trot at a speed of between 1.50 and 1.52 m s^{-1} on the treadmill. Average human walking pace is around 1.25 m s^{-1}, but can be higher (Knoblauch *et al* 1996). A study among US dog walkers showed that 80.2% of participants took at least one walk of 10 min or more, and 42.3% accumulated 30 min or more from walks lasting at least 10 min each (Ham & Epping 2006). Thus, a 10-min duration of the stress test at the chosen walking pace of 1.5 m s^{-1} is relevant to the normal activity of pet dogs.

In general, the DMC guidelines do not specify the gait during the stress test. It is not rare that, consequentially, tested dogs cover the distance partly by walking and partly by galloping, and they even stop for short periods. In this way, the subject is not continuously stressed. If the dogs walk slowly or even stop, heart and respiratory rates can recover during the test. It is necessary to provide instructions regarding how to cover the distance of 1 km. A trot is recommended. It may be helpful to set a mark every 100 m and equip owners with stopwatches during testing. The speed, which must be kept at a constant rate, can be assessed more easily when the next mark has to be achieved within 1 min.

We wish to note that a distance of 1 km should not be excessively physically demanding for any healthy dog. Thus, recovery of heart and respiratory rates within 15 min is not expected to be a problem. This study demonstrated, however, that 14 of 42 pugs did not pass the stress test according to the DMC guidelines, indicating a failure rate of 33.3%. Regarding respiratory rates at rest, seven pugs displayed strongly increased values, of which five were unable to withstand the 11-min exercise. None were of an advanced age (max 4.5 years), and two weighed slightly more than the average (9.8 and 10.5 kg). Thus, a higher age or weight was not an explanation for the respiratory rates at rest. Body condition score has not been assessed in this study. Adding these seven pugs to the 'failed' group increases the failure rate to 50.0%, indicating that more than half of the pugs not only proved unsuitable for breeding but were also in very poor physical condition. This finding represents an alarmingly high proportion considering that the number of pug puppies has greatly increased recently (VDH 2011).

The DMC stress test was designed primarily for evaluating the suitability for breeding of young dogs. At a younger age, chronic effects of BAS are limited compared to older dogs that are more affected by the impact of secondary pathology. In our study, the mean age amounted to 3.4 (± 0.3) years, which lies between both extremes. However, we must take into account that a stress test only reflects the current situation and does not allow a prediction of the further development of the disease. Long-term health problems and shortened life-expectancy due to secondary pathology cannot be excluded. The stress test serves to identify dogs currently affected by BAS, and to make sure that those dogs will at least not be used for breeding. It is important that this fact is made clear by the DMC in order to prevent the test from being used as a marketing tool by breeders.

Inspiratory stridor is the main symptom of BAS (Koch *et al* 2003). Even though 35 of the 42 pugs included in this study showed abnormal breath sounds, only two were known to suffer from clinical signs of BAS. All of the other 33 pugs were considered to be healthy dogs by their owners, and some of them had already passed the DMC stress test. Moreover, assuming a normal respiratory rate at rest of between 10 and 30 breaths per min (Suter & Kohn 2006), the pugs far exceeded the reference range with a mean respiratory rate of 52.7 (± 5.55) per min.

Elevated heart and respiratory rates were expected immediately after the stress test due to higher oxygen demands during exercise. Additionally, increased body temperature normally occurs as a result of muscular activity (Klinke & Silbernagl 2003).

Heart and respiratory rates after recovery are essential for passing the DMC stress test. In total, 22 pugs were able to normalise their heart and respiratory rates within 15 min, thus passing the test, in contrast to 14 pugs that failed.

In this study, it was striking that the dogs that failed the stress test had a significantly higher respiratory rate than the dogs that passed. An implication of these findings is that pugs with respiratory rates already exceeding the normal range at rest should be categorised as 'failed'. If their respiratory rates do not reach the reference range after recovery, these pugs cannot be considered to be free from breathing problems.

Furthermore, a group of seven retropugs was included in the study to analyse the impact of brachycephaly on physical condition. This crossbreed with slightly longer muzzle has not yet become prevalent so we were not able to find more participants. All of the seven retropugs passed the test and showed a significant reduction in respiratory rate after recovery compared to pugs. This indicates that they were better able to compensate for the lack of oxygen resulting from exercise within the recovery time. However, the findings may not be transferable to all retropugs because of the small sample size, therefore further research is needed.

Animal welfare implications

The introduction of the stress test shows that breed standards for pugs have been reconsidered for the first time. It remains to be seen whether such a test alone will be sufficient to select healthier pugs. Fundamental rethinking of the pedigree breeding of show dogs, involving independent and professional quality controls, is essential because uncontrolled pedigree breeding has increasingly led to diseases that must be 'repaired' by the veterinary profession (Oechtering 2013).

The FCI standard of the pug breed has changed since June 2009. The following specifications are now included:

> Nose: Black with fairly large well opened nostrils. Pinched nostrils and heavy over nose wrinkle is unacceptable and should be heavily penalised (FCI standard no 253)

The pugs examined in this study did not fulfil the requirements for nares (nostril index: 0.13 [± 0.01]). Even if they had obtained their breeding licenses before June 2009, according to the old standard, it should still be considered that they will pass on their appearance to their offspring. Furthermore, the following is stated in the FCI standard:

> Muzzle: Relatively short, blunt, square, not upfaced. Eyes or nose never adversely affected or obscured by over nose wrinkle' (FCI standard no 253)

However, nasal function is always adversely affected in a brachycephalic skull. Extremely squashed anatomical structures result in airway obstruction and stenoses, which can considerably impair nasal function (Harvey 1982; Aron & Crowe 1985; Wykes 1991; Koch *et al* 2003; Noeller *et al* 2006; Oechtering *et al* 2007; Riecks *et al* 2007). The standard for the pug breed should be revised in favour of less brachycephaly. The results obtained in the examined retropugs showed that a longer muzzle is an important contribution to a healthier dog. It would thus be logical to rephrase the FCI standard from 'Muzzle: relatively short' to 'Muzzle: short, but distinct'.

Conclusion

Pugs that exhibit an excessively brachycephalic appearance should be excluded from breeding to promote healthier offspring. This rule should apply both to current breeding dogs and future generations. It is humans' responsibility to breed offspring that are free of ailments. Considering the extreme brachycephalic appearance of pugs, it may be doubted whether the very next generations will be able to achieve an improved health status. Crossbreeding another breed with a well-formed muzzle may be a method for minimising the occurrence of BAS and its related disorders.

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