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Morphometric assessment and body condition scoring as predictors of brachycephalic obstructive airway syndrome in dogs

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Abstract
Brachycephalic obstructive airway syndrome (BOAS) results from extreme craniofacial conformation and obesity in brachycephalic dogs. This study assessed morphometrics and body condition in 60 dogs, including Pugs, Boxers, Shih Tzus, Lhasa Apsos, Bulldogs, and Pekingese. Measurements included Craniofacial Ratio (CFR), eye width ratio (EWR), skull index (SI), neck girth ratio (NGR), and neck length ratio (NLR), using soft tape and radiographs. The mean CFR and NGR indicated high BOAS risk, especially in Pugs, while skull indices confirmed brachycephalic conformation (SI: 0.937±0.01). Most dogs had elevated BCS (7-8), further increasing risk. Results highlight that craniofacial conformation and body condition are key predictors of BOAS, supporting targeted weight management and selective breeding to improve respiratory health.

Keywords: BOAS, Brachycephalic dogs, craniofacial ratio, skull index, neck girth ratio, body condition score and morphometrics

1. Introduction

Brachycephaly in dogs is characterized by a shortened skull and flattened facial features, primarily resulting from selective breeding for aesthetic traits. Extreme brachycephaly, often due to exaggerated breeding, creates a mismatch between skull size and internal head structures, leading to lifelong, sometimes life-threatening, health issues. High body condition scores further worsen these risks, increasing the severity of clinical signs (Chandler, 2016) [5]. Anatomical distortions affect the upper respiratory tract, dentition, middle ear, eyes, brain, and skeletal system, manifesting as brachycephalic obstructive airway syndrome (BOAS), which reduces quality of life and increases morbidity (Liu *et al.*, 2017) [8]. Studies on skull indices have shown that craniofacial conformation directly relates to the severity of airway obstruction and associated comorbidities (Koch *et al.*, 2014; Liu *et al.*, 2017) [7, 8]. Morphometric analysis and body condition scoring are reliable measures to assess BOAS severity, enabling objective evaluation of conformational risk factors and early identification of high-risk dogs (Packer *et al.*, 2015) [9]. By quantitatively assessing craniofacial dimensions and body condition, correlations between physical conformation, obesity, and respiratory compromise can be established. This study aims to evaluate morphometrics and body condition scores as diagnostic and prognostic tools for BOAS, providing insights for veterinary interventions, breeding strategies, and welfare improvements in brachycephalic breeds.

2. Materials and Methods

A total of 60 brachycephalic dogs were included in the study. All measurements were performed on conscious, unrestrained animals. Dogs were selected based on breed and clinical presentation, with body condition and craniofacial conformation evaluated using standardized methods.

2.1 Morphometric Measurements
Nine conformational features related to brachycephaly were measured using bony landmarks wherever applicable, and all measurements were recorded to the nearest millimeter using a soft measuring tape, following the methodology described by Liu *et al.* (2017) [8].

2.1.1 Craniofacial Ratio (CFR): CFR was calculated as the ratio of snout length (SnL) to cranial length (CL). Snout length was measured along the surface of the head at the skull midline from the stop to the rostral end of the nasal planum, while cranial length was measured along the surface of the head at the skull midline from the external occipital protuberance to the midpoint between the medial canthi of the eyes (Figure 1 & 2).

Fig 1: Measurement of snout length (SnL)

Fig 2: Measurement of cranial length (CL)

2.1.2 Eye Width Ratio (EWR)
EWR was determined as the ratio of Eye Width (EW) to Skull Width (SW). Eye width was defined as the linear distance between the medial canthi of both eyes, and skull width was measured as the widest linear distance between the external zygomatic arches (Figure 2).

2.1.3 Skull Width Ratio (SWR)
SWR was calculated as the ratio of skull width to Skull Length (SL), where skull width was the distance between the left and right external zygomatic arches, and skull length was the sum of cranial length and snout length.

2.1.4 Neck Girth Ratio (NGR)
NGR was defined as the ratio of Neck Girth (NG) to Chest Girth (CG). Neck girth was measured at the midpoint between the external occipital protuberance and the cranial angles of the scapulae, while chest girth was measured at the deepest part of the thoracic cavity (Figure 5 & 6).

Fig 3: Measurement of eye width (EW)

Fig 4: Measurement of skull width (SW)

Fig 5: Measurement of neck girth (NG)

Fig 6: Measurement of chest girth (CG)

Fig 7: Measurement of neck length (NL)

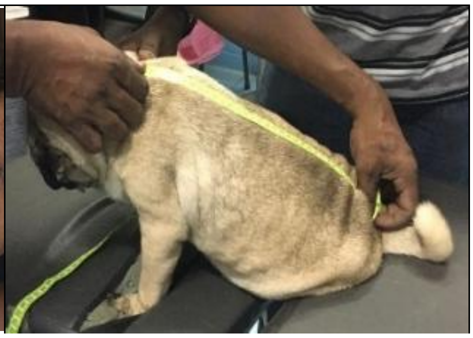


Fig 8: Measurement of body length (BL)

2.1.5 Neck Length Ratio (NLR)

NLR was calculated as the ratio of neck length (NL) to body length (BL). Neck length was measured along the dorsal midline from the external occipital protuberance to the cranial angles of the scapulae, and body length was measured along the dorsal midline from the scapular cranial angles to the root of the tail (Figure 7 & 8).

2.1.6 Skull Index: Radiographs were obtained to calculate the skull index as described by Caccamo *et al*. (2014) [1]. Skull length was measured from the prosthion (between the roots of the upper central incisors) to the external occipital protuberance, and skull width was measured as the distance between the most lateral points of the zygomatic arches (Fig. 9 & 10). Skull index was calculated using the formula:

$$\text{Skull Index} = \frac{\text{Maximum Zygomatic Width} \times 100}{\text{Skull length}}$$

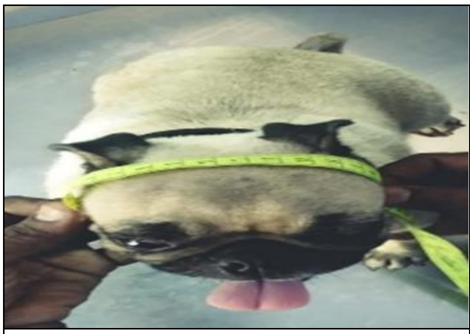
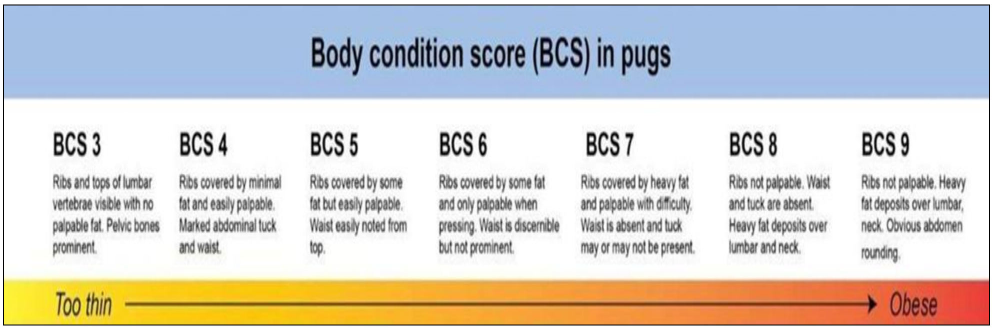


Fig 9: Measurement of skull length from the prosthion (between the roots of the upper central incisors) to the external occipital protuberance.

Fig 10: Measurement of skull width as the distance between the most lateral points of the zygomatic arches.

2.1.7 Body Condition Scoring (BCS)

Body condition was assessed using a 1-9 point scale following Liu *et al*. (2017) [8] and the University of Cambridge BOAS Research Group (2016) (Figure 11). Dogs with scores of 7, 8, or 9 were considered high-risk for breathing difficulties. The scoring criteria were as follows: BCS 3-ribs and tops of lumbar vertebrae visible; pelvic bones prominent; BCS 4-ribs covered by minimal fat, easily palpable; marked abdominal tuck and waist; BCS 5-ribs covered by some fat, easily palpable; waist easily noted from above; BCS 6-ribs covered by some fat, palpable only with pressure; waist discernible but not prominent; BCS 7-ribs covered by heavy fat, difficult to palpate; waist absent, tuck may not be present; BCS 8-ribs not palpable; waist and tuck absent; heavy fat deposits over lumbar region and neck; BCS 9-ribs not palpable; heavy fat deposits over lumbar region and neck; obvious abdominal rounding. Morphometric and BCS assessments were used to correlate craniofacial conformation and body condition with the severity of Brachycephalic Obstructive Airway Syndrome (BOAS) in the study population.



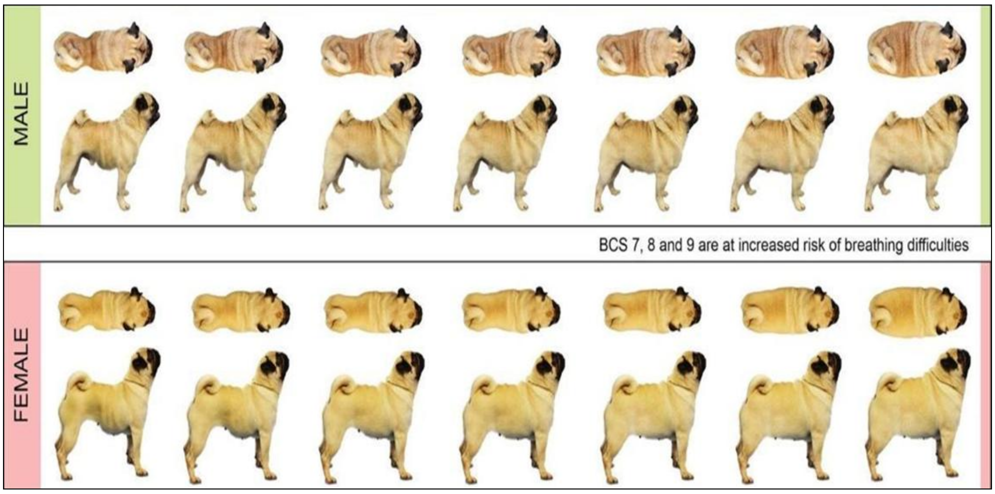


Fig 11: Body condition scoring (BCS) of brachycephalic dogs using a 3-9 point scale, with higher scores (7-9) indicating increased risk for breathing difficulties (University of Cambridge BOAS Research Group, 2016; Liu *et al*., 2017) [8]

3. Results

Morphometric Analysis

Morphometric measurements were performed in a total of 60 brachycephalic dogs. The mean snout length was 1.735±0.11 cm, and the mean cranial length was 11.17±0.176 cm, resulting in a mean craniofacial ratio (CFR) of 0.17±0.018. Eye width and skull width were measured as 4.65±0.00 cm and 17.55±0.24 cm, respectively, giving a mean eye width ratio (EWR) of 0.26±0.00. Neck length and neck girth were 12.75±0.22 cm and 38.3±0.78 cm, respectively, resulting in a mean neck girth ratio (NGR) of 0.70±0.009. The ratio of neck length to body length (NLR) was 0.33±0.00, with a mean body length of 38.05±1.17 cm.

Breed-specific morphometric comparisons indicated that Pugs had relatively higher CFR and NGR values, whereas Boxers and Lhasa Apsos showed higher NLR. Shih Tzus exhibited the highest NGR, while Bulldogs had comparatively lower CFR and NGR values. These measurements indicate significant variation in craniofacial and body conformation across different brachycephalic breeds (Table 1).

Table 1: Morphometric Parameters of Brachycephalic Dogs (N=60)

Breed	CFR (Mean ± SE)	EWR (Mean ± SE)	Skull Index (SI) (Mean ± SE)	NGR (Mean ± SE)	NLR (Mean ± SE)
Pug	0.172±0.013	0.26±0.017	1.35±0.02	0.72±0.03	0.34±0.005
Boxer	0.3243±0.026	0.2200±0.031	1.253±0.146	0.5943±0.091	0.4343±0.022
Shih Tzu	0.2033±0.025	0.2383±0.027	1.391±0.126	0.8633±0.105	0.4150±0.039
Lhasa Apso	0.2600±0.025	0.2150±0.027	1.100±0.126	0.7950±0.105	0.4500±0.039
Bulldog	0.1883±0.019	0.2117±0.004	1.210±0.034	0.6050±0.005	0.3283±0.048
Pekingese	0.1800±0.017	0.2533±0.045	1.370±0.200	0.8233±0.134	0.430±0.036

Skull index was calculated by both soft tape morphometric measurements and radiographic analysis. Using soft tape, the mean skull length was 130.2±0.28 mm and skull width was 175.5±0.24 mm, resulting in a mean skull index of 136±0.22. Radiographic measurements yielded a mean zygomatic width of 89.979±1.011 mm and skull length of 95.716±0.954 mm, resulting in a mean skull index of 0.937±0.010. These results demonstrate consistency between direct measurement and radiographic evaluation of skull conformation (Table 2).

Table 2: Skull Index Measured by Morphometrics and Radiography (N=60)

S. No	Parameter	Radiography SI (Mean ± SE)	Soft Tape SI (Mean ± SE)
1	Skull Width (mm)	89.979±1.011	130.2±0.28
2	Skull Length (mm)	95.716±0.954	175.5±0.24
3	Skull Index (SI)	0.937±0.010	136±0.22

Body Condition Scoring (BCS)

Body condition was assessed using a 9-point scale according to the Cambridge BOAS Research Group (2017) for pugs and the WSAVA Global Nutrition Committee (2020) [10] for other breeds. Among the 60 dogs evaluated, the majority had a BCS of 8 (33%, N=20), with Pugs comprising 75% of this group. BCS 7 was observed in 19 dogs (31.6%), primarily Pugs (52%) and equal proportions of Boxers and Shih Tzus (21% each). BCS 6 was recorded in 13 dogs (21.6%), mainly Pugs (53.8%) and Shih Tzus (30.7%). The least frequent score was BCS 9, observed in 8 dogs (13%), predominantly Pugs (62.5%) and Bulldogs (37.5%). These data indicate a high prevalence of overweight and obese dogs among brachycephalic breeds, particularly Pugs, which may exacerbate the risk of BOAS (Table 3).

Table 3: Body Condition Scoring (BCS) of Brachycephalic Dogs (N=60)

Breed	BCS 6	BCS 7	BCS 8	BCS 9	Total
Pug	-	10 (27%)	15 (40.5%)	5 (13.5%)	37
Boxer	-	4 (16.6%)	2 (33.3%)	-	6
Shih Tzu	4 (50%)	4 (50%)	-	-	8
Lhasa Apso	2 (100%)	-	-	-	2
Bulldog	-	-	3 (50%)	3 (50%)	6
Pekingese	-	1 (100%)	-	-	1
Total	13 (21.6%)	19 (31.6%)	20 (33.3%)	8 (13.3%)	60

Overall, the study revealed that Pugs exhibited the highest prevalence of conformational risk factors, including elevated craniofacial ratios, neck girth ratios, and body condition scores, indicating a greater predisposition to BOAS. Shih Tzus and Lhasa Apsos demonstrated higher neck girth or neck length ratios, whereas Bulldogs and Boxers showed comparatively lower craniofacial ratios. The majority of the study population was overweight or obese (BCS 7-8), emphasizing the role of body condition in exacerbating respiratory compromise in brachycephalic breeds. Morphometric and radiographic skull indices were consistent, confirming reliable assessment of craniofacial conformation. These results collectively underscore the combined influence of anatomical conformation and body condition in determining the severity of brachycephalic obstructive airway syndrome.

4. Discussion

In this study, morphometric analysis was conducted on 60 brachycephalic dogs to evaluate craniofacial conformation and its association with Brachycephalic Obstructive Airway Syndrome (BOAS). The mean craniofacial ratio (CFR) observed across breeds indicated a high predisposition to respiratory compromise, supporting previous findings by Packer *et al.* (2015) [9], who reported that CFR values below 0.5 are associated with increased BOAS risk. The relationship between CFR and neck girth ratio (NGR) further highlighted the importance of neck conformation as a predictor of airway obstruction, corroborating observations by Liu *et al.* (2017) [8]. Radiographic assessment confirmed the brachycephalic nature of the study population, with a mean skull index (SI) of 0.937±0.01, in agreement with Koch *et al.* (2014) [7], who considered skull indices below 1.25 characteristic of brachycephalic breeds. The consistency between morphometric and radiographic measurements underscores the reliability of both methods for evaluating craniofacial structure and identifying dogs at high risk for BOAS.

Breed-specific analysis revealed significant variation in morphometric parameters. Pugs exhibited the highest CFR and NGR, reflecting their greater susceptibility to airway obstruction, consistent with Liu *et al.* (2017) [8] and the Cambridge BOAS Research Group (2017). Shih Tzus and Lhasa Apsos had elevated NGR and Neck Length Ratio (NLR), suggesting that neck conformation may contribute to airway compromise. Bulldogs and Boxers had lower CFR, reflecting differences in skull morphology that influence BOAS severity.

Body condition scoring revealed that most dogs had elevated BCS (7-9), indicating overweight or obese status, which exacerbates respiratory compromise. These findings align with Chandler (2016) [5] and the Cambridge BOAS Research Group (2017), emphasizing the negative impact of obesity on airway function.

Overall, both craniofacial conformation and body condition are critical determinants of BOAS risk. Morphometric indices (CFR, NGR, SI) combined with BCS provide a comprehensive assessment of risk factors. These findings highlight the importance of weight management, breed-specific monitoring, and selective breeding to reduce BOAS incidence and improve respiratory health and quality of life in brachycephalic dogs.

5. Conclusion

Morphometric assessment and body condition scoring in 60 brachycephalic dogs revealed that extreme craniofacial conformation and elevated body condition are major risk factors for BOAS. Pugs exhibited the highest craniofacial ratios and prevalence of overweight status, highlighting their increased susceptibility. Skull indices confirmed the brachycephalic nature of all breeds studied. Elevated BCS (7-9) was common across breeds, indicating that obesity exacerbates respiratory compromise. Morphometric and BCS evaluations together provide a reliable method for identifying dogs at high risk of BOAS. These findings emphasize the importance of breed-specific monitoring, weight management, and selective breeding to improve health and quality of life in brachycephalic dogs.

Conflict of Interest
Not available

Financial Support
Not available

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