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Department of Animal Breeding and Genetics

Phenotypic variation for BOAS within four brachycephalic dog breeds – Can good welfare be obtained?

Fenotypisk variation for BOAS för fyra brakycefala hundraser – Kan god djurvälfärd uppnås?

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Abstract

Brachycephalic obstructive airway syndrome (BOAS) is an upper airway obstruction that was considered the most severe disorder identified according to the Generic Illness Severity Index for Dogs. The aim of this master thesis was to investigate the phenotypic variance correlated to BOAS in the Swedish population of four brachycephalic breeds; English Bulldog, French Bulldog, Pug and Boston Terrier and discuss their welfare implications. The project consisted of two parts; one inventory and one survey. The inventory consists of conformational description of the four brachycephalic breeds and the survey was to investigate the BOAS related problems in the same breeds and their owner's perspective of health and welfare. The conformational risk factors correlated to BOAS found in this study were snout length and craniofacial ratio for French Bulldogs, snout length, chest girth, neck length, sternum length and craniofacial ratio for English Bulldogs and none for either Pugs or Boston Terriers. According to the survey noisy breathing and heat intolerance were the most common BOAS-related problems for all the four breeds in this study. The conclusion of the study was that there was enough phenotypic variance to improve the BOAS problem for both French Bulldogs and English Bulldogs. For Boston Terriers the BOAS problem was not severe enough in this study to get a result and for the Pugs the phenotypic variance is too small. For the welfare aspect this study showed that BOAS is a welfare problem and that there was a normalization for some of the problems connected to BOAS for English Bulldogs, French Bulldogs and Pugs.

Keywords: BOAS, French Bulldog, English Bulldog, Pug, Boston Terrier, Conformation, welfare, phenotypic variation, respiration, brachycephaly, dog

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1 Introduction

The dog species is a very diverse species and there are over 300 breeds recognized by Fédération Cynologique Internationale (FCI). These breeds are defined by different breed standards which states different phenotypes such as size, shape or color of the dog. Brachycephalic features are desired in a lot of the recognized dog breeds, signified by shortened skull and muzzle. According to Koch *et al.* (2003) the following breeds can be considered brachycephalic; English Bulldog, King Charles Spaniel, Pug, Boston Terrier, Maltese, Pekingese, Miniature Pinscher, Shih Tzu, Yorkshire Terrier, Boxer and Chihuahua. The brachycephalic features have been shown to cause respiratory problems called Brachycephalic obstructive airway syndrome (BOAS), which is a chronic obstruction of the upper airway (Liu *et al.*, 2017; Packer *et al.*, 2015).

Aim of the study

The aim of this master thesis was to investigate the phenotypic variance correlated to BOAS in the Swedish population of four brachycephalic breeds; English Bulldog, French Bulldog, Pug and Boston Terrier and discuss their welfare implications.

1.1 Brachycephalic obstructive airway syndrome

Brachycephalic obstructive airway syndrome (BOAS) or Brachycephalic airway syndrome (BAS) is an upper airway obstruction, earliest mentioned in literature in 1979 (Knecht, 1979). It is a progressive disease, where it is most common to become severe at the age of 12 months and increases with age (ibid.). BOAS is considered as the most severe disorder identified according to the Generic Illness Severity Index for Dogs (Packer *et al.*, 2012).

The syndrome causes physical abnormalities in the upper airways which is primarily stenotic nares and elongated soft palate (Koch *et al.*, 2003). The decrease of space for the normal amount of tissue in the nose of the dogs pushes the tissues back into the throat of the brachycephalic dogs. This increases the resistance during the inspiration and causes a higher negative pressure in the body of the dog. This negative pressure causes the soft tissue in the respiratory tract to narrow the passage and become hyperplastic, which means that the growth of the tissues increases. This causes secondary changes such as enlarged tonsils, everted lateral saccules of larynx, narrowed rima glottidis and if the negative pressure is too high, collapse of the larynx and trachea might occur. These tissues are shown in figure 1. Dogs suffering from BOAS may have problems with sleeping because the respiratory tract narrows when relaxed during sleep (ibid.). Roedler *et al.* (2013) found that brachycephalic dogs develop strategies to avoid the obstruction during sleep by adopting different body positions (sitting up or resting head in elevated position) or by having their mouth open and breathing through their mouth. The respiratory tract also narrows because of relaxation during sedation or anesthesia but during this procedure the diaphragm still produces the negative pressure and therefore can cause the upper airway tissue to collapse (Koch *et al.*, 2003).

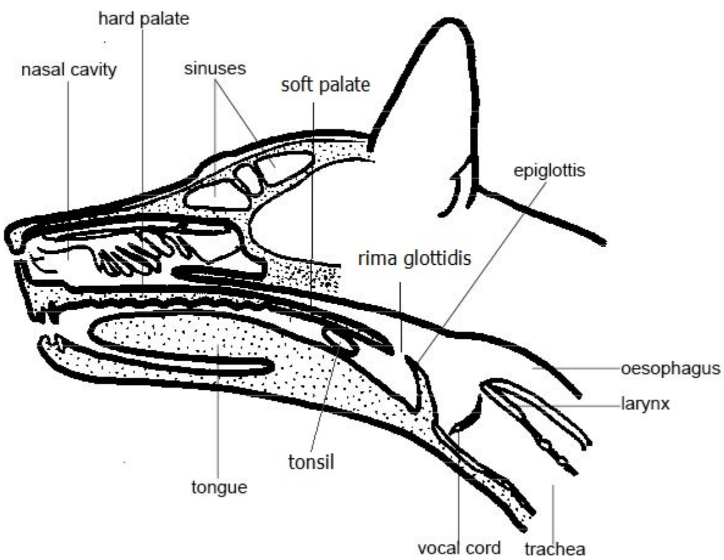

Figure 1. The anatomy of the head and respiratory tract of the dog. (CC by 3.0 Adjusted)

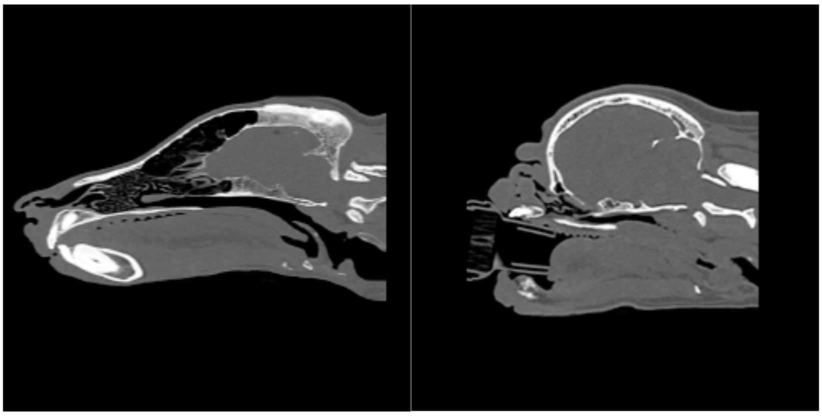

Figure 2. CT image of a German Shepherd (left) and a Pug (right) (University of Cambridge, 2015a) showing how the structures in the skull of the Pug are altered by the shortness of the skull and muzzle. Note that the Pug in this CT image is intubated.

The negative pressure by the altered respiration in the brachycephalic breeds affect more than just the upper respiratory tract, it has been shown to affect the esophagus, auditory canals, central nervous system and the lower respiratory tract. The effects can be enlargement of the tongue, difficulties to swallow, hiatal hernia, gastric bloating, inflammation in the ears, neurologic signs and bronchiectasis (Koch *et al.*, 2003).

Breathlessness have three different qualities recognized by the medical literature. The three qualities are respiratory effort, air hunger and chest tightness (Beausoleil & Mellor, 2015). Respiratory effort is defined as the conscious awareness of the force required by the respiratory muscle to achieve the necessary or desired respiration. Respiratory effort can arise when an increase of depth and frequency of breathing is needed. The unpleasantness by respiratory effort is very individual. Though if the respiratory effort does not match with the amount needed and therefore a mismatch of air volume occurs then air hunger arises. Air hunger is described as the sensation experienced as needing more air, increased urged to breath or as suffocating. Air hunger is always reported as unpleasant and even moderate air hunger is more unpleasant than maximal respiratory effort. Chest tightness is related to bronchoconstriction and occurs in respiratory diseases such as asthma. These qualities may occur in combinations which can increase the unpleasantness of the sensation in the animal. BOAS is a condition which illustrates how impaired respiration can lead to unpleasant respiratory effort and air hunger (Beausoleil & Mellor, 2015).

Thermoregulation is another mechanism affected by the restricted airflow of the brachycephalic dog (Koch *et al.*, 2003). Dogs pant to reduce surplus heat, but with a lower airflow this ability is reduced (ibid.). The thermoregulation mechanism is extremely limited in brachycephalic dogs because of the smaller surface area of the nasal mucosa where the evaporation can occur which therefore can result in both exercise- and heat intolerance (Roedler *et al.*, 2013). Also, Beausoleil & Mellor (2015) writes that brachycephalic dogs have a problem with exercise intolerance because of their dramatic increase in respiratory effort. Dogs that are severely affected can even faint and have cyanosis after mild exercise (ibid.).

Brachycephalic breeds are also predisposed to hydrocephalus, facial nerve paralysis, skinfold dermatitis, eye bulb prolapse and false positioning of the teeth because of the foreshortening of the skull (Koch *et al.*, 2003). Hydrocephalus is a neurological condition that results in abnormal accumulation of cerebrospinal fluid in the skull and therefore results in higher pressure on the brain (Hydrocephalus Association, 2019).

1.1.1 Risk factors for BOAS

A previous study from the Great Britain studied 189 Pugs, 214 French Bulldogs and 201 English Bulldogs that were either referred for BOAS consultation at a veterinarian, pet dogs volunteered by their owners or show dogs (Liu *et al.*, 2017). In this study they graded BOAS in four categories; 0 (BOAS free), I (mild BOAS), II (moderate BOAS) and III (severe BOAS) (ibid.). According to this study, the proportion of dogs affected by BOAS (having BOAS functional score II or III) were 64.6% for the pugs, 58.9% of French Bulldogs and 51.2% of the English Bulldogs (ibid.). However, Liu *et al.* (2017) did not find any significant differences between the breeds when analyzing the distribution of the BOAS functional grades. In the study by Packer *et al.* (2015) they studied 700 dogs from 97 different breeds in Great Brittan (of which 32 Pugs, 13 French Bulldogs, 16 English Bulldogs and 6 Boston Terriers) (ibid.). The dogs were either referred for BOAS consultation at a veterinarian, breeders, first opinion veterinary practice or rescue centers (ibid.). In the study they had 88-91% BOAS affected Pugs, 70-75% affected French Bulldogs, 33-63% affected English Bulldogs and 50-83% Boston Terriers (ibid.). Packer et al. (2015) found that the three breeds with the highest risk of BOAS were Pug, French Bulldog and English Bulldog. Roedler *et al.* (2013) conducted a survey study in Germany with answers from 100 brachycephalic dog breed owners. According to the study by Roedler *et al.* (2013) were they studied Pugs and French Bulldogs, 66% of the dogs had frequent stridor, which is noisy breathing caused by obstructed airways (Wikipedia, 2019), and 36% of the dogs had collapsed because of dyspnea, which is labored breathing (Karolinska Institutet, 2019), at least once in their life. 88% of the dogs had exercise intolerance according to their owners, with 70% of the dogs with exercise intolerance having the main problems during the summer (ibid.). 46% of the dogs in the same study had eating disorders and 56% had problems sleeping. When asked which problem restricted the dogs most, exercise intolerance stood for 15%, breathing problems 13%, heat intolerance 10%, sleeping problems 9% and eating problems 9% (ibid.).

Craniofacial ratio is a ratio between snout length and cranial length (figure 5) and Packer *et al.* (2012) found that the mean craniofacial ratio for Pugs were 0.08, for French Bulldogs 0.19, for English Bulldogs 0.22 and for Boston Terriers 0.15. Packer *et al*. (2012) also found that the mean craniofacial ratio for the BOAS affected dog were 0.15 whilst the unaffected dogs had a mean craniofacial ratio of 0.56. During the same study they found that 68% of the affected dogs had noisy breathing, but less than 2% had noisy breathing in the unaffected group of dogs.

According to Packer *et al.* (2015) the conformational risk factors related to BOAS were craniofacial ratio and neck girth across several breeds. The median for craniofacial ratio was 0.08 or 0.12 for Pugs, 0.18 or 0.19 for French Bulldogs, 0.22 or 0.25 for English Bulldogs and 0.14 or 0.23 for Boston Terriers, depending on which part of the study is regarded. The median for neck girth found in their study was 31.8 or 32.2 cm for Pugs, 33 or 35.3 cm for French Bulldogs, 42.2 or 43.8 cm for English Bulldogs and 28.2 or 30.2 cm for Boston Terriers. Packer *et al.* (2015) also found that the proportion of dogs affected dropped steeply when relative muzzle length increased. 80% of the dogs affected by BOAS was found to have craniofacial ratio <0.1. Packer *et al.* (2015) also found that dogs with craniofacial ratio >0.5 were not affected by BOAS at all. Neck girths was also a measurement significantly associated with a higher risk of BOAS. Packer *et al.* (2015) found in their study that the dog with the lowest craniofacial ratio (0.03) was a Pug and had a predicted 95% risk of procuring BOAS, but if the craniofacial ratio was 0.21 then the risk would only be half (48%). The overall BOAS risk was calculated as 48-97% for Pugs, 30-89% for French Bulldogs, 26-88% for English Bulldogs and 21-72% for Boston Terriers. They demonstrated that a 5 cm decrease in the neck girth for a Pug decreased the risk of BOAS from 93% (32 cm neck girth) to 89% (Packer *et al.,* 2015).

In the study by Liu *et al.* (2017) they found that the conformational risk factors are breed specific because of the conformational variances between Pugs, French Bulldogs and English Bulldogs, though all the breeds had a significant correlation between stenotic nostrils and higher risk of having more severe BOAS. Liu et al. (2017) found that French Bulldogs affected by BOAS had significantly shorter snout lengths, greater neck girths, longer backs, lower craniofacial ratio, lower neck length ratio and higher neck girth ratio. Neck length ratio is a ratio between neck length and back length and neck girth ratio is a ratio between neck girth and chest girth (figure 5). A decrease of 0.01 of craniofacial ratio or increase of 0.01 neck length ratio was found to have 1.07 times greater risk of procuring BOAS for French Bulldogs. An increase of 0.01 of neck girth ratio was found to have 1.12 times greater risk of procuring BOAS for French Bulldogs. Liu *et al.* (2017) also found that

English Bulldogs affected by BOAS had significantly greater neck girths and higher neck girth ratio. For an increase of 0.01 of neck girth ratio was found to have 1.29 times greater odds for English Bulldogs (Liu *et al.,* 2017).

Other variables that were found to have significant importance of procuring BOAS functional grade II or III according to Liu *et al.* (2017) were stenotic nostrils for both Pugs and French Bulldogs. Liu *et al.* (2017) also found that French Bulldogs had the largest proportion of dogs with moderately to severely stenotic nostrils with 75.4%, while Pugs had a 65.3% prevalence and English Bulldogs 44.2%. Pugs with moderately to severely stenotic nostrils were shown to have 4.58 greater odds of being BOAS affected than Pugs with open or mildly stenotic nostrils (ibid.). For French Bulldogs the odds were 5.65 times greater (ibid.).

1.2 Welfare

Animal welfare is a concept that is both science-based and value-based, which complicates the science of the concept (Fraser, 2008). Broom (1996) states that welfare for an individual is the state regards to the attempts to cope with the environment, while Webster (2005) states that welfare is the capacity of a sentient animal to avoid suffering and sustain fitness.

According to Fraser (2008) there are three perspectives for the observation of animal welfare; first perspective that focuses on the affective state of the animal, second perspective that focuses on the animals ability to live a natural life and the third perspective where the animals basic health and functioning is in focus. These perspectives are neither completely separated or completely dependent of each other (ibid.). Fraser's (2008) perspectives can be correlated to the Five Freedoms.

The Five Freedoms are a well-known and accepted international standard for animal welfare is from 1965 by the Farm Animal Welfare Council (2009):

1. **Freedom from Hunger and Thirst** - by ready access to fresh water and a diet to maintain full health and vigor.
2. **Freedom from Discomfort** - by providing an appropriate environment including shelter and a comfortable resting area.
3. **Freedom from Pain, Injury or Disease** - by prevention or rapid diagnosis and treatment.
4. **Freedom to Express Normal Behavior** - by providing sufficient space, proper facilities and company of the animal's own kind.
5. **Freedom from Fear and Distress** - by ensuring conditions and treatment which avoid mental suffering.

The first of Frasers' (2008) perspectives correlates to the fifth freedom, the second correlates to the fourth freedom and the third perspective correlates to the first, second and third freedom. If the animal welfare is improved according to one perspective the welfare according to the others are not automatically improved, even though these perspectives overlap each other (ibid.).

In humans the affective state of breathlessness consists of both immediate unpleasant feelings and subsequent emotions connected to the unpleasant feelings. According to Beausoleil & Mellor (2015) animals could suffer from the same unpleasant feelings and this can compromise the animals' welfare even though the animals' experiences cannot be measured. These unpleasant feelings usually conclude into specific behaviors to avoid the life-threatening situation of breathlessness such as withdrawal, escape attempts and struggling. The three different qualities for breathlessness vary in unpleasantness and how these are combined is important for the implication of the welfare of the animal affected. Also, breathing is usually a mechanism that one is not aware of, but when respiration is stimulated, challenged, obstructed or attended to it becomes into awareness, and can be perceived as very stressful (Beausoleil & Mellor, 2015).

According to Roedler *et al.,* (2013) respiratory distress due to upper airway obstruction and overheating due to limited thermoregulation are one of the most life-threatening circumstances, which therefore deteriorates the quality of life for the animal. They also state that sleeping, eating and physical activity are basic needs which are affected by brachycephaly and can also decrease the quality of life for the animal (Roedler *et al.,* 2013). According to Jensen (2009) social-, forage-, feeding- and sleeping behaviors are natural for domesticated dogs. Social behaviors such as communication and playing behaviors are important for the hierarchy in a pack. A neotenized appearance, reduction of olfactory sensors and reduction of ability to vocalize can reduce the ability to communicate (Jensen, 2009). Also, according to Jensen (2009) dogs normally sleeps 1.5 hours (average) several times a day. Dogs are also, natural hunters (Jensen, 2009), which means that they naturally run and hunt prey for food.

Packer *et al.,* (2012) found that for certain breeds the breathing noise or difficulties breathing during either sleep or exercise were considered normal and therefore the improvement of welfare will be constrained for the clinically affected animals. Some owners may not seek veterinary help for the disorders if they are considered normal, but also because if the disorders are considered normal than there may not be any requirement for changing it. Packer *et al.* (2012) also found that 58% of the owners of affected dogs did not perceive their dogs to have breathing difficulties.

1.3 General information about the breeds

1.3.1 History

English Bulldog and French Bulldog originate from the same molossian type of dog from the Epirus and Roman empire (Federation Cynologique Internationale, 2015). The first classification of the Bulldog was made in 1630s but has been mentioned before as bandogs (Federation Cynologique Internationale, 2011a). Bulldogs original purpose was bull baiting but has also been used as fighting dogs (ibid.). After 1835 the English Bulldog started to evolve into the shorter faced and squatter version as the English Bulldog is more known for today (ibid.). The first time the English Bulldog entered the show ring was during the 1860 and this subsequently led to a personality change in the breed (ibid.). English Bulldog is known as the national dog of Great Britain (ibid.). The French Bulldog is a product of different crossings of Bulldog done by breeders in Paris during 1880s (Federation Cynologique Internationale, 2015). The French Bulldog originally belonged to market porters, butchers and coachmen, but then became more connected to the higher society and artistic world because of the breeds' appearance and character (ibid.). The first breed club for the French Bulldog was founded in 1880 in Paris and the first registrations of the breed dates from 1885 (ibid.). The first time a French Bulldog entered the show ring was during 1887 (ibid.).

Figure 3. Bulldogs in the four different sizes in 1900 (Lane, 1900). Large Bulldog in the upper left corner, toy Bulldog in the upper right corner, small Bulldog in the lower left corner and medium Bulldog in the lower right corner. (Public domain)

The Boston Terrier originates from the United States of America. Dog fighting was popular even in the States and many searched for a dog with the best qualities for this use, therefore many people went to Great Britain to find this. This concluded in a cross between the English Bulldog and some hot-tempered terrier breeds. The first and most famous Boston Terrier is a dog called Hope, which was a cross between the English Bulldog and a Bullterrier. The Bullterrier was a cross between the English Bulldog and an old English terrier. These crosses gave the Boston Terrier the characteristic black and white coloration. The breeding of the Boston Terrier originated during the 1870 to 1890 (Svenska Bostonterrierklubben, 2011).

Figure 4. Boston Terrier in 1900 (Lane, 1900). (Public domain)

The Pug originates from a short haired, flat-faced small dog with a curled tail over the back in East Asia called Happa-dog (MopsOrden & SDHK, 2015). The Happa-dog/Pug has been admired in Europe as early as 1500s' and found its' way to Europe with traders of the Dutch East India Company (Federation Cynologique Internationale, 2011b). The Pug has long been a symbol for the royal patriots and the Pug arrived in England 1689 (ibid.). The fawn was the only color seen until 1877 when a black pair was introduced from the Orient (ibid.).

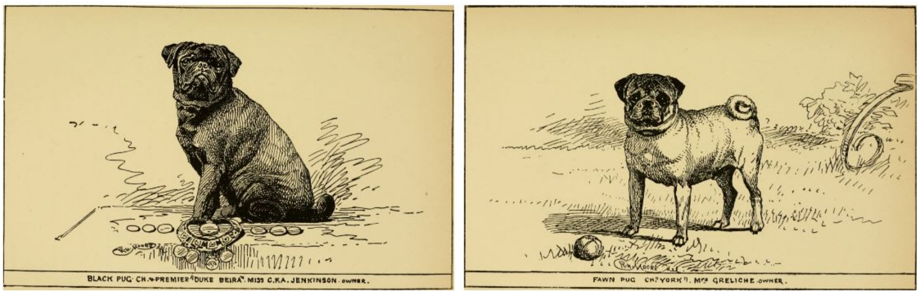

Figure 5. Both black and fawn Pugs in 1900 (Lane, 1900). (Public domain)

1.3.2 Breed standards and Breed Specific Instructions

The breeding standards from FCI mention regulations about both the muzzle and nose, these texts are shown in table 1.

Table 1. *Breed standards for the four breeds describing conformation related to BOAS*

Breed	Muzzle	Nose
English Bulldog	Muzzle short, broad, turned upwards and deep from corner of eye to corner of mouth. Over nose wrinkle, if present, whole or broken, must never adversely affect or obscure eyes or nose. Pinched nostrils and heavy over nose wrinkle are unacceptable and should be heavily penalized.[1]	Nose and nostrils large, broad and black. Nostrils large, wide and open, with well-defined vertical straight line between.[1]
French Bulldog	Very short, broad, with concentric symmetrical folds. The length of muzzle is about 1/6 of the total length of the head.[2]	Black, broad, snubbed, with symmetrical and well opened nostrils, slanting towards the rear. The slope of the nostrils as well as the upturned nose must, however, allow normal nasal breathing.[2]
Boston Terrier	Short, square, wide and deep and in proportion to the skull. It is free from wrinkles, shorter in length than in width or depth; not exceeding in length approximately one-third of the length of the skull. The muzzle from stop to end of the nose is parallel to the top of the skull.[3]	Black and wide, with a well-defined line between the nostrils. Well opened nostrils.[3]
Pug	Relatively short, blunt, square, not up faced. Eyes or nose never adversely affected or obscured by over nose wrinkle.[4]	Black with fairly large well opened nostrils. Pinched nostrils and heavy over nose wrinkle are unacceptable and should be heavily penalized.[4]

1. FCI-Standard Nº 149 (2011). 2. FCI-Standard Nº 101 (2015). 3. FCI-Standard Nº 140 (2014).

4. FCI-Standard Nº 253 (2011).

Breed specific instructions (BSI) are an aid for the show ring judges regarding exaggerations in pedigree dogs (The Nordic Kennel Clubs, 2018). Basic exaggerations for all dogs that can acquire a disqualification of the dog states “All dogs should be able to breathe normally, also when moving” (ibid.). In these instructions they state three levels of breathing distress and how they should be assessed:

> 1. Non-significant/temporary signs of affected breathing, but without causing any difficulty to the dog: This should be noted, but not necessarily affect the quality grading. This should, however, be considered at the competition assessment.

2. Milder affection of the ability to breath (milder respiratory problems), as well as anatomical conditions that potentially affect the ability to breathe (pinched nostrils, too short nose, overly small head and/or very short proportions, underdeveloped ribcage and so on). This should influence the quality grading.
3. Obvious signs of respiratory problems should motivate disqualification. Those signs of breathing distress are at hand if the dog already while standing still and without any "provoking external factors" (like hot temperature, exciting stimuli and so on) shows labored respiration such as:

- Mouth breathing with obvious retraction of the mouth angle, and/or very protruding tongue
- Pronounced breathing sounds (snoring); inspiratory and/or expiratory
- Retractions in the fore chest area and/or behind the ribcage synchronous with the respiration
- Nodding movements of the head and neck synchronous with the respiration

(The Nordic Kennel Clubs, 2018)

The breathing should always be evaluated during and after the movement (ibid.).

English Bulldog, French Bulldog, pug and Boston Terrier are all included in the BSI as breeds with specific exaggerations (ibid.).

The French Bulldog, Boston Terrier and the Pug are all according to the BSI a brachycephalic and small mollosoid breed, which includes a conformation with a shortened skull, overly short bridge of nose and an underdeveloped tail (ibid.). The French Bulldog risk areas stated in the BSI:

Breathing problems: Forced breathing, with pronounced snoring sounds due to short muzzle, pinched nostrils and/or narrow respiratory channels (insufficient room in pharyngeal cavities and airways) and/or ribcage.
Face and eyes: Too short muzzle and protruding eyes, which increase the risk of eye injuries.
Proportions and construction: Overly short proportions in neck and back.
(The Nordic Kennel Clubs, 2018)

The Boston Terrier risk areas stated in the BSI:

Breathing problems: Forced breathing, with pronounced snoring sounds due to a short muzzle, pinched nostrils and narrow respiratory channels (insufficient room in pharyngeal cavities and airways) and/or ribcage.
General construction: Overly short body, roach back, diminutive tail, and too short and flat in muzzle. Heavy and coarse head.
(The Nordic Kennel Clubs, 2018)

For Pugs the risk areas in the BSI are:

> **Breathing problems:** Forced breathing with pronounced snoring sounds due to short muzzle, pinched nostrils, narrow respiratory channels (insufficient room in pharyngeal cavities and airways) and/or short and open ribcage with short ribs and sternal bone. Obesity/overweight.
> **Face:** Overly short muzzle with improper dentition, excessive loose skin, and hair on a nose wrinkle disturbing the function of the eyes as well as the nose. The standard does in fact not ask for a nose wrinkle – neither unbroken nor broken.
> (The Nordic Kennel Clubs, 2018)

The English Bulldog is also a brachycephalic breed according to the BSI, though it is also considered a molossoid type and not a small molossiod type of breed as the others (ibid.). English Bulldogs risk areas stated in the BSI:

> **Breathing:** Forced breathing, with pronounced snoring sounds due to short muzzle, pinched nostrils and/or narrow respiratory channels (insufficient room in pharyngeal cavities and airways).
> **Face and eyes:** Excessively short bridge of muzzle, excessively loose facial skin and loose eyelids can cause injury and inflammation of the eyes. Overhanging nose roll can cause inflammations.
> (The Nordic Kennel Clubs, 2018)

1.4 Laws and regulations

In Sweden there are several legislations, conventions and regulations, to protect animals that can be connected to the BOAS problem, that is obligated to follow; European Convention for the Protection of Pet Animals (ETS No.125, 1987), the Swedish Animal Welfare Act (SFS 2018:1192), the Swedish Animal Welfare Ordinance (SFS 2019:66), regulations from the Swedish Board of Agriculture (SJVFS 2008:5) and the Swedish Kennel Club's regulations (Svenska Kennelklubben, 2019). The Swedish Kennel Club's regulations are only obliged to follow for breeders registered to the Swedish Kennel Club. Though in this study both the old Swedish Animal Welfare Act (SFS 1988:534) and the old Swedish Animal Welfare Ordinance (SFS 1988:539) will be discussed because of their effect on the breeding up until recently.

1.4.1 Protection of Pet animals

In the Protection of Pet Animals (ETS No.125, 1987) there are three articles that are relevant for this study; article 3 about the basic principles for animal welfare, article 4 about keeping of animals and article 5 about breeding.

Article 3: Nobody shall cause a pet animal unnecessary pain, suffering or distress.
Article 4: Any person who keeps a pet animal or who has agreed to look after it, shall be responsible for its health and welfare.
Article 5: Any person who selects a pet animal for breeding shall be responsible for having regard to the anatomical, physiological and behavioral characteristics which are likely to put at risk the health and welfare of either the offspring or the female parent. (ETS No.125, 1987)

1.4.2 Swedish Animal Welfare Act

In the Swedish Animal Welfare Act (SFS 2018:1192) there are four paragraphs that are relevant. Three paragraphs under section two about basic provisions concerning animal management and treatment (ibid.):

1 § Animals shall be treated well and shall be protected from unnecessary suffering and disease.
2 § Animals shall be accommodated and handled in a good environment that is appropriate for animals and in such a way as to:

1. promote their welfare
2. they can perform behavior that are highly motivated and important for the animal's wellbeing (natural behavior), and
3. behavioral disorders are prevented.

11 § It is prohibited to carry out breeding in such a way that it can cause suffering to the parent or the offspring. The Government or the authority that the Government decides, may notify […] regulations on conditions for or prohibition of breeding that may affect the animal's natural behavior, normal bodily functions or the ability to naturally breed its offspring.

One paragraph under section four surgical procedures etc. (ibid.):

1 § If an animal is sick, injured or in other ways, through its behavior, shows signs of illness, the animal shall be given the necessary care without delay, if necessary, by veterinarian, or other measures shall be taken, unless the illness or injury is so severe that the animal must be killed immediately […].

According to section 10 paragraph 1 in the Swedish Animal Welfare Act (ibid.) the only relevant paragraph that is penalized is section 2 paragraph 11 and section 4 paragraph 1. These paragraphs were not penalized in the old Swedish Animal Welfare Act from 1988 (SFS 1988:534) but was a change in the new Swedish Animal Welfare Act (SFS 2018:1192).

1.4.3 Swedish Animal Welfare Ordinance

In the Swedish Animal Welfare Ordinance (SFS 2019:66), section two paragraph 21 mentions regulations about breeding:

> **21§** the Swedish Board of Agriculture may issue regulations about […] 2. laying down conditions for or prohibiting breeding, the object of which is such that it may affect the animal's natural behavior, normal bodily functions or the ability to naturally breed its offspring.

There were no changes from the old Swedish Animal Welfare Ordinance (SFS 1988:539), though the prohibition against certain breeding were transferred from the Swedish Animal Welfare Ordinance (ibid.) to the Swedish Animal Welfare Act (SFS 2018:1192).

1.4.4 Regulations from the Swedish Board of Agriculture

The regulations from Swedish Board of Agriculture and general advice about caring for dogs and cats (SJVFS 2008:5 Saknr L102) has one paragraph under the first section that states:

> **24§** Animals may not be bred if
>
> p 1. they have diseases or disabilities that can be inherited.
>
> p 4. breeding combination from available information increases the risk of disease or disability in the offspring.
>
> p 6. they lack the ability to reproduce naturally.

1.4.5 Swedish Kennel Club's regulations

The Swedish Kennel Club also has regulations (Svenska Kennelklubben, 2019) for their members and one paragraph mentions breeding:

> **2:2** For breeding only use dogs that do not have severe diseases/disabilities, and which have a good and breed specific mentality.

2 Materials & methods

This project consists of two parts; one inventory and one survey. The inventory consists of conformational description of four brachycephalic breeds; Boston Terrier, English Bulldog, French Bulldog and Pug. The survey was to investigate the BOAS-related problems in the same breeds and brachycephalic dog owner's perspective of health and welfare for these breeds.

Inventory

The dogs included in the inventory were selected by the owners volunteering to evaluate their dog at the Swedish Kennel Clubs' headquarters in Stockholm, Sweden, or in either Gothenburg, Sweden or Klippan, Sweden. During the inventory the owner filled out a form about the dog, a veterinary examination was done by one of two veterinarians, exterior description was done by two show judges and photographing of the dog was executed.

During the inventory information about breed, age, if the dog was registered in the Swedish Kennel club, which country the dog was born, gender, if the dog had been operated in the skull, oral cavity, throat and/or respiratory system. Also, body condition was scored with a scoring from 1 to 9, where score 1 is underweight and score 9 is obese (Laflamme, 1997).

Nine conformational measurements were taken during the inventory and are shown in figure 5. Snout length (mm) was measured from the tip of the nose to between the eyes where the inside of the corners of the eyes meet. Cranial length (mm) was measured from just between the eyes, between the ears, to the back of the head where the bony process projects out. Neck length (cm) was measured from the bony process projects out on the back of the head to the top of the shoulders. Back length (cm) was measured from the top of the shoulders to the set of the tail. Chest length (cm) was measured from the point of the sternum between the shoulders to the last rib. Neck girth (cm) was measured around the lower part of the neck. Chest girth (cm) was measured around the largest part of the chest. Sternum length (cm) was measured from the point of the chest, between the front legs and to the end of the chest bone. Snout width (cm) measured the width of the lower jaw. All the measurements except for snout width were measured with a soft measuring tape. Snout width were measured with a small measuring stick. Three ratios were then calculated from these measurements; craniofacial ratio, neck girth ratio and neck length ratio because these were studied in previous studies connected to BOAS (Liu et al., 2017). Craniofacial ratio was calculated by dividing snout length with cranial length. Neck girth ratio was calculated by dividing neck girth with chest girth and neck length ratio was calculated by dividing neck length with back length.

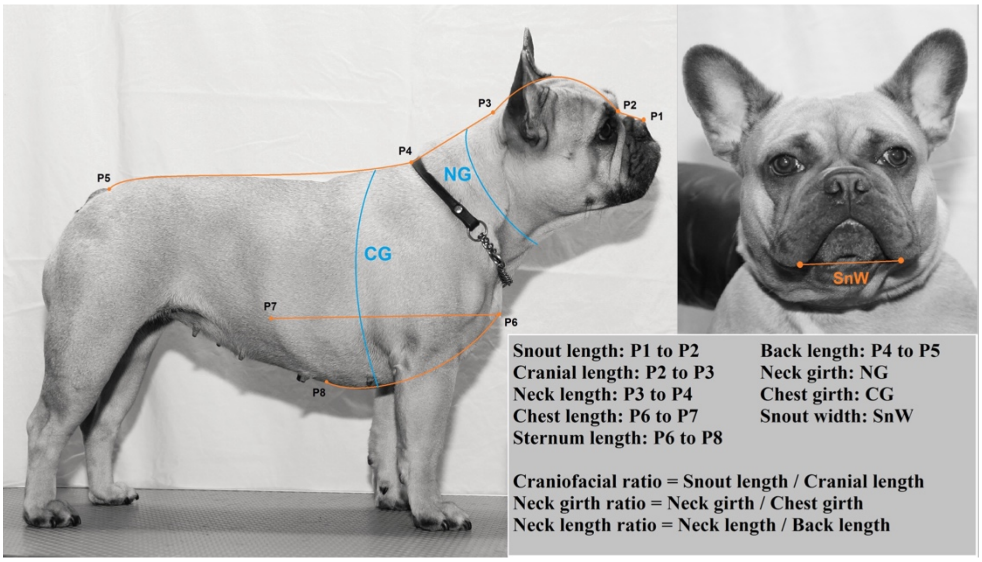

Figure 6. The phenotypic measurements and ratios used in this study. The photos are from dogs in the study. Photo: Elin Johansson & Ida Bertilsson

The nostrils were graded according to a four graded scale from open nostrils to severe stenosis (Liu et al., 2017) by a veterinarian. The author for this study then converted the results into numbers, were open nostrils had score 1, mild stenosis had score 2, moderate stenosis had score 3 and severe stenosis had score 4. For the nose fold the show judges described it on the form and the author then converted the description together with the pictures of the dogs into a three graded scale; score 0 for no nose fold, score 1 for a small or parted nose fold and score 2 for a whole nose fold or a nose fold over the nose.

The BOAS scoring was based on description and grading from the veterinary examination but scored by the author of this project. BOAS scoring was based from the functional grading of BOAS from the University of Cambridge (University of

Cambridge, 2015b). For the BOAS scoring, the score 0 was dogs with no respiratory sounds, score 1 were dogs with respiratory sounds but only noticeable with a stethoscope, score 2 had respiratory sounds noticeable without stethoscope and score 3 had both respiratory sounds without stethoscope and dyspnea. The dogs were then categorized as BOAS affected or non-affected according to the University of Cambridge (2015b) scoring of clinically affected and not affected with BOAS. BOAS affected dogs were the dogs with BOAS score 2 or 3 and the non-affected dogs were the dogs with BOAS score 0 or 1 (University of Cambridge, 2015b).

2.1 Survey

Owners and breed organizations of the different dog breeds: Pug, French Bulldog, English Bulldog and Boston Terrier were sent an online survey from Netigate through mail and social media. The survey included questions about breed, age, if the owner perceived the dog to be healthy, if they had any of the problems related to BOAS (University of Cambridge, 2015b); sleeping disorder, snoring or otherwise loud breathing, intolerance for heat, intolerance for exercise, syncope or collapse, troubles eating and if the owner perceived that the dog had good welfare according to the problems stated before. Sleeping disorders were described as examples if the dog cannot get air when they fall asleep, so they wake up or if they have trouble sleeping on flat floors, if they sleep on their backs, sitting up or lying with their head on a pillow or on the armrest. Heat intolerance were described as easily being overheated. Exercise intolerance were described as if the dog needs to have breaks during their walks or if they need long recuperation after exercise. Syncope was described as dog collapsing and becoming unconscious during a small period of time but recuperating fast after. Eating disorders were described as if the dog has problems with regurgitations or vomiting. See appendix 1 for the correct formulations of the questions in Swedish.

The survey was sent to the breed organizations by email and distributed through Facebook and was open for 8 weeks. The survey was also sent by email to all the owners according to the Swedish Board of Agriculture's owner register for these breeds and was open for them for 4 weeks.

2.2 Statistical analysis

Data was analyzed using the statistical program SAS 9.4. First the variables from the inventory were tested for normal distribution by the univariate procedure. The significant differences between the mean values were than analyzed with a t-test by the means procedure, if the variables were normally distributed. Otherwise a chi square test was performed by the npar1way procedure. For the analyses of the variables from the survey, frequency procedure with a chi square test was performed. If the frequencies were too low for the chi square test to be valid, a Fischer exact test was performed with the frequency procedure. These procedures were done to evaluate if the frequencies were significantly different from the expected and therefore could show a connection between the categorical variables analyzed. The significance level in this study was $\alpha=0.05$. Because of the amount of analyses performed in this study, a false discovery rate test was performed for every p-value to eliminate significant results that were significant by chance. This test was performed with the multitest procedure. The false discovery rate was set at a 0.05 level in this study. The p-values shown in this study is therefore the adjusted p-values.

3 Results

3.1 Inventory

3.1.1 Demographics

119 dogs were assessed during the inventory; 15 Boston Terriers, 32 Pugs, 18 English Bulldogs and 54 French Bulldogs. 110 of the dogs were registered in the Swedish kennel club and 96 of the dogs were born in Sweden. The dogs not born in Sweden were born in Norway, Poland, Hungary, Russia, England, Italy, Estonia, Lithuania, Czechs Republic, Denmark and some had unknown origin. The study population consisted of 52 males, 66 females and 19% of the dogs were neutered. Six dogs had operated skull, oral cavity, throat and/or respiratory system and only four dogs out of the total study population were perceived as unhealthy because of respiratory problems. The mean age of the dogs at the time of the inventory was 50 months, which was 4.17 years (range, 9 months to 12 years and 5 months) and the mean body condition score was 6.03 ± 1.18 (mean ± standard deviation, SD). In the study population 15 of the dogs had normal nares, 46 of the dogs had mild stenosis, 36 had moderate stenosis and 19 had severe stenosis. Eight of the dogs in the study population had no nose fold, 59 had a small or parted nose fold and 52 dogs had whole nose fold or an over-nose fold. For the BOAS scoring 80 dogs had score 0, 9 dogs had score 1, 13 dogs had score 2 and 17 dogs had score 3.

3.1.2 Phenotypic variance

There was shown to be some variance, mean values and median values for all of the measurements and ratios for the four breeds in this study as shown in table 2.

Table 2. *Phenotypic variance, mean and median of the measurements and ratios for the four breeds*

		Boston Terrier	Pug	English Bulldog	French Bulldog
Snout length (mm)	Variance	20-30	11-25	15-46	19-38
	Mean	23.5	17	32.8	29.3
	Median	23	17	33	30
Snout width (cm)	Variance	6-8	5-9	9-12.5	6-10.5
	Mean	6.6	6.8	10.2	7.8
	Median	6.5	6.8	10	8
Cranial length (mm)	Variance	80-125	90-150	125-185	95-170
	Mean	105.7	111.5	150.1	121.3
	Median	105	110	150	120
Neck length (cm)	Variance	9-15	8-13	10-19	9-14.5
	Mean	11.8	10.1	15.3	11.4
	Median	11	10	14.8	11
Neck girth (cm)	Variance	25-35	27-65	45-56	30-45.5
	Mean	31.1	36.1	50.3	38.7
	Median	32	34	50	38
Chest length (cm)	Variance	20-42	16-29	28-39	16-36
	Mean	26.2	24.6	33.2	29.5
	Median	26	25.5	33	30
Sternum length (cm)	Variance	16-22	12-27	19-29	14-29
	Mean	19.1	16.9	23.7	19.4
	Median	19	16	22.3	19
Chest girth (cm)	Variance	41-55	42-56	63-80	50-65
	Mean	48.9	49.5	72.1	57.2
	Median	49	50	71.5	57
Back length (cm)	Variance	24-37	15-36	33-47	26-38
	Mean	30.8	27.2	39.9	31.2
	Median	30	28	40	31
Craniofacial ratio	Variance	0.16-0.31	0.09-0.22	0.12-0.32	0.15-0.39
	Mean	0.23	0.16	0.22	0.24
	Median	0.22	0.15	0.21	0.24
Neck girth ratio	Variance	0.55-0.68	0.61-1.27	0.63-0.79	0.59-0.76
	Mean	0.64	0.73	0.70	0.68
	Median	0.64	0.71	0.70	0.68
Neck length ratio	Variance	0.32-0.44	0.29-0.57	0.28-0.53	0.28-0.45
	Mean	0.38	0.37	0.38	0.37
	Median	0.38	0.37	0.39	0.36

For the Boston Terriers the variance distribution is shown in figure 6 for all of the measurements. Snout length was normally distributed but skewed towards the lower values with one extreme value of 30 mm. Chest length also had an extreme value of 42 cm, but the distribution of the chest length was not normal. Snout width was also not normally distributed. Even though the neck length was shown to be bimodal, the normality test showed that the neck length was normally distributed. Craniofacial ratio, neck girth ratio and neck length ratio were all normally distributed. Though all the other measurements were normally distributed with a slight skewness towards the higher values.

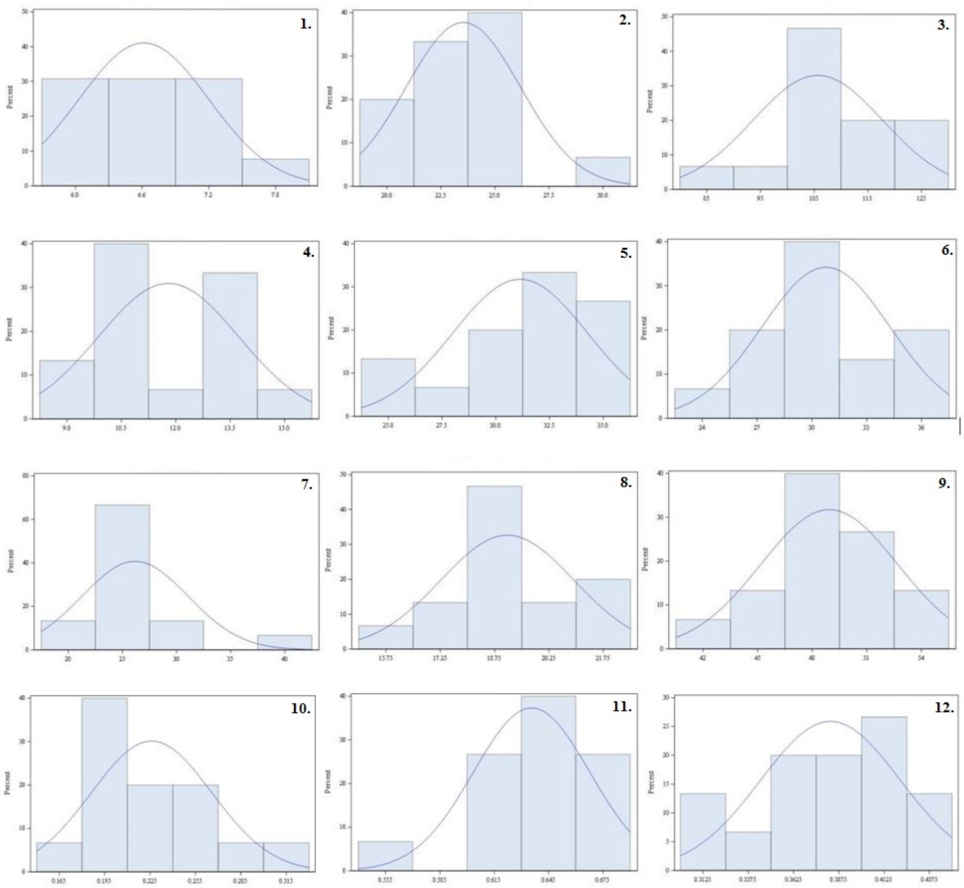

Figure 7. Distribution of the phenotypic variances for Boston Terrier. 1. Snout width (cm) 2. Snout length (mm) 3. Cranial length (mm) 4. Neck length (cm) 5. Neck girth (cm) 6. Back length (cm) 7. Chest length (cm) 8. Sternum length (cm) 9. Chest girth (cm) 10. Craniofacial ratio 11. Neck girth ratio 12. Neck length ratio

For the English Bulldogs the variance distribution is shown in figure 7 for all of the measurements. Snout length, neck length and chest girth were normally distributed, but had a slight skewedness towards the higher values. For the cranial length and neck girth the variance were also normally distributed, though they were skewed to the lower values. The variances for snout width, chest length, back length and craniofacial ratio were not normally distributed even though chest length, back length and craniofacial ratio are bimodal in the figure 7. The variance of neck girth ratio and neck length ratio was normally distributed with a slight skewedness towards the lower values, though neck length ratio had an extreme value of 0.53. Only sternum length was not normally distributed.

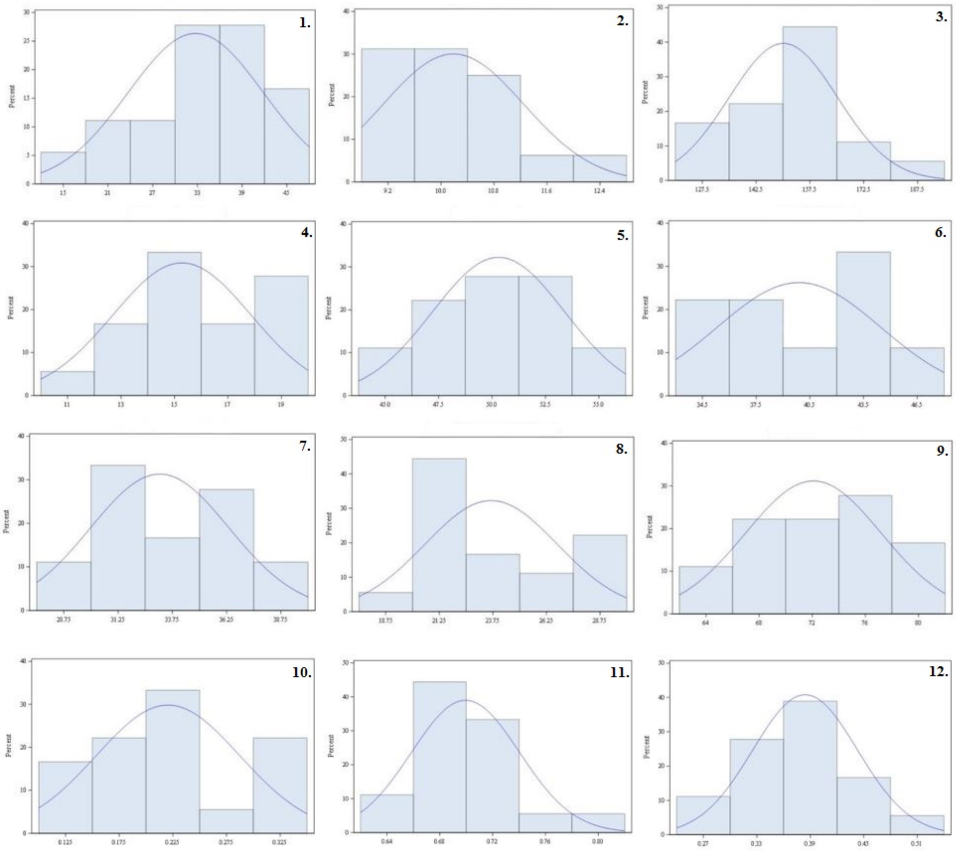

Figure 8. Distribution of the phenotypic variances for English Bulldog. 1. Snout length (mm) 2. Snout width (cm) 3. Cranial length (mm) 4. Neck length (cm) 5. Neck girth (cm) 6. Back length (cm) 7. Chest length (cm) 8. Sternum length (cm) 9. Chest girth (cm) 10. Craniofacial ratio 11. Neck girth ratio 12. Neck length ratio

For the French Bulldogs the variance distribution is shown in figure 8 for all of the measurements. Three of the measurements had extreme values; cranial length had one French Bulldog with 170 mm, chest length had one French Bulldog with 16 cm and sternum length had one French Bulldog with 29 cm. For all variances except for snout length, snout width neck length, chest length and sternum length were all normally distributed and neck length, neck girth, sternum length and chest girth were a little skewed to the higher values. The variance of craniofacial ratio, neck girth ratio and neck length ratio were all normally distributed, but craniofacial ratio and neck length ratio had a slight skewedness towards the lower values and neck girth ratio towards the higher values.

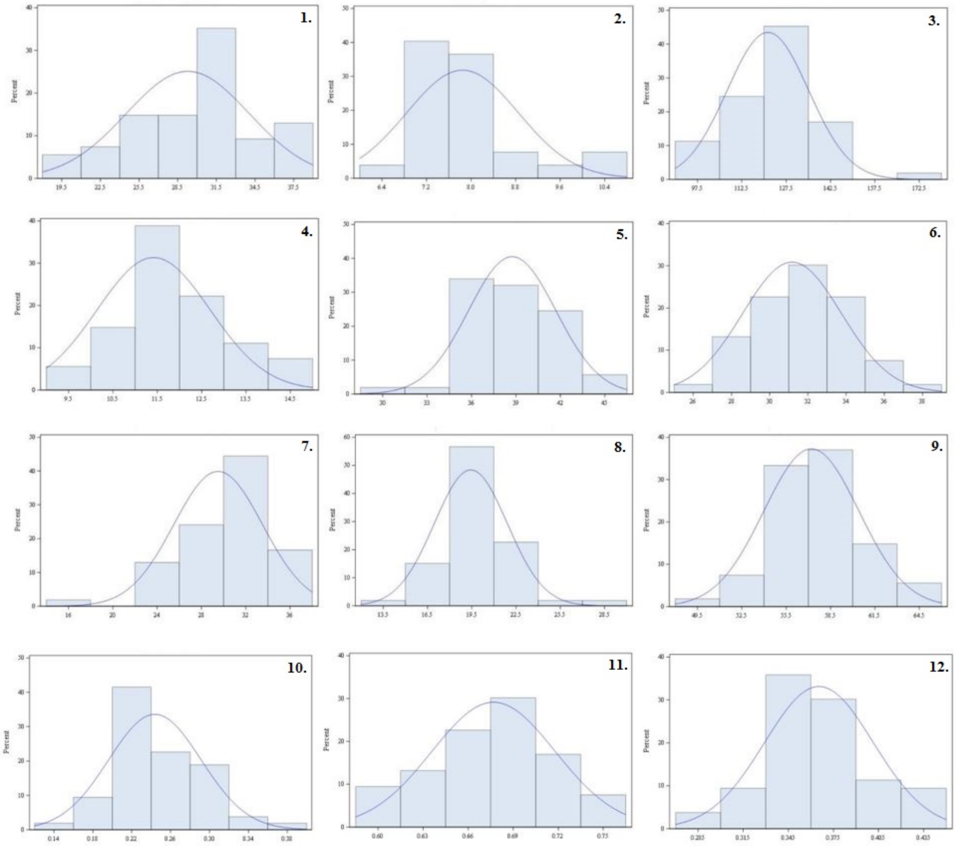

Figure 9. Distribution of the phenotypic variances for French Bulldog. 1. Snout length (mm) 2. Snout width (cm) 3. Cranial length (mm) 4. Neck length (cm) 5. Neck girth (cm) 6. Back length (cm) 7. Chest length (cm) 8. Sternum length (cm) 9. Chest girth (cm) 10. Craniofacial ratio 11. Neck girth ratio 12. Neck length ratio

For the Pugs the variance distribution is shown in figure 9 for all of the measurements. All the measurements except for snout length, chest girth, craniofacial ratio and neck length ratio were not normally distributed. The variance for cranial length and neck length were skewed to the lower values and the variance for chest length and chest girth were skewed to the higher values. There were also three measurements with extreme values; neck girth had one Pug with 65 cm, sternum length had one Pug with 27 cm and back length had one Pug with 15 cm. The variance of craniofacial ratio and neck length ratio had a skewedness to the lower values and the neck length ratio had an extreme value of 0.57. The neck girth ratio had an extreme value of 1.27.

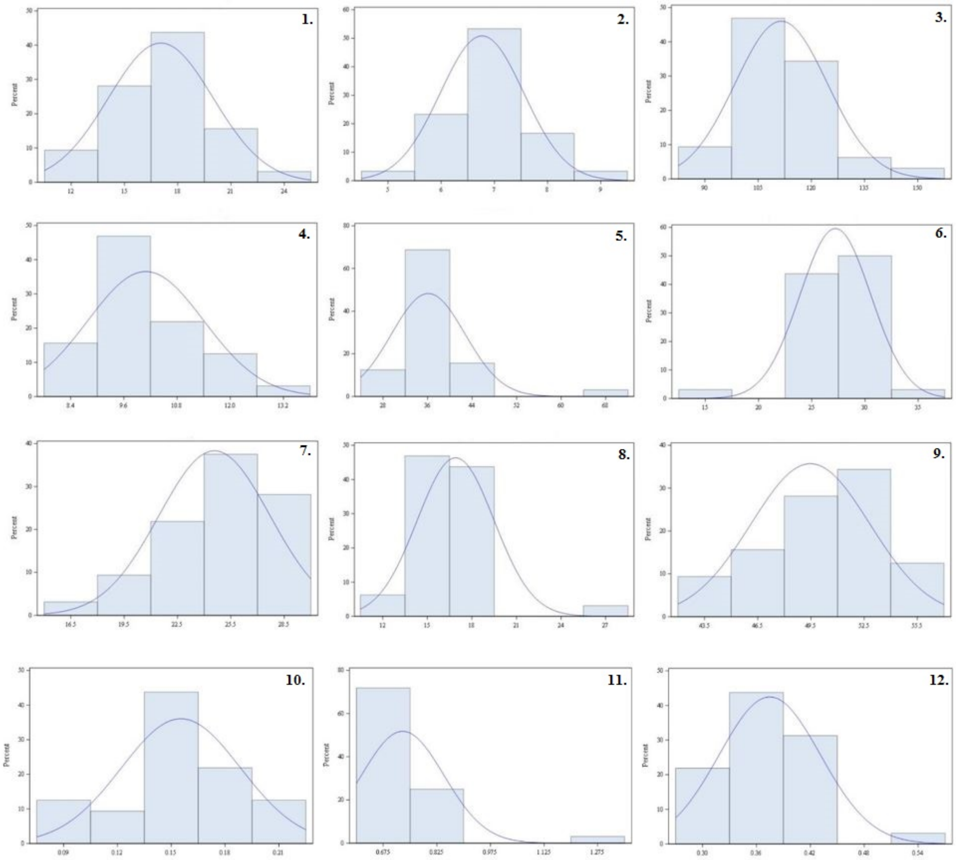

Figure 10. Distribution of the phenotypic variances for Pug. 1. Snout length (mm) 2. Snout width (cm) 3. Cranial length (mm) 4. Neck length (cm) 5. Neck girth (cm) 6. Back length (cm) 7. Chest length (cm) 8. Sternum length (cm) 9. Chest girth (cm) 10. Craniofacial ratio 11. Neck girth ratio 12. Neck length ratio

As can be seen in figure 10, the distribution of the different nostril phenotypes was different for the breeds. In studied Boston Terrier population two dogs had normal nostrils, 10 dogs had mild stenosis, three dogs had moderate stenosis, but none had severe stenosis. For the English Bulldog population there were 7 dogs with normal nostrils, six dogs with mild stenosis, two dogs with moderate stenosis and three dogs with severe stenosis. For the French Bulldog population there were five dogs with normal nostrils, 16 dogs with mild stenosis, 18 dogs with moderate stenosis and 13 dogs with severe stenosis. For the Pug population there were one dog with normal nostrils, 14 dogs with mild stenosis, 13 dogs with moderate stenosis and three dogs with severe stenosis. There were three dogs in the study that did not have a scoring of the nostrils, one Pug and two French Bulldogs. All the breeds distribution of stenotic nostrils was shown to non-normal, as shown in figure 10, although the range for the English Bulldog was the same as for the Pugs and French Bulldogs. Only Boston Terriers did not have any individuals with severe nostrils. For the median values Boston Terrier and English Bulldogs had a score of 2 (mild stenosis) and Pugs and French Bulldogs had a median of score 3 (moderate stenosis).

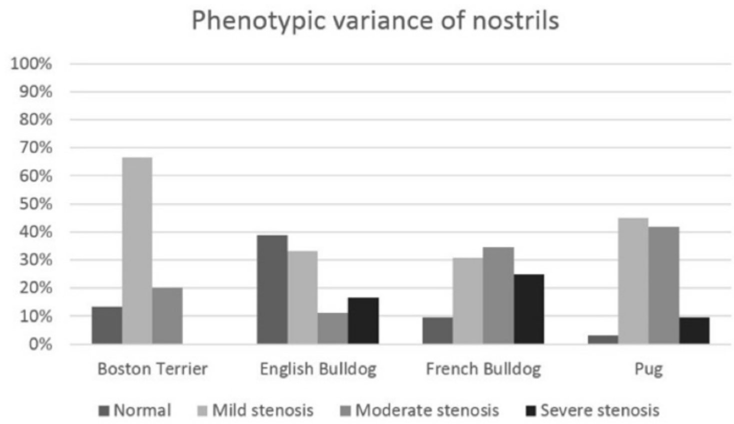

Figure 11. The distribution of nostril phenotypes for the four brachycephalic breeds.

The distribution of dogs with the different categories of nose folds are shown in figure 11. In the studied Boston Terrier population, 8 dogs had no nose folds at all, seven dogs with small or parted nose folds and none with whole nose folds or with a nose fold over the nose. In the English Bulldog population, none had no nose fold, but four dogs had small or parted nose folds and 14 dogs had whole nose folds or a nose fold over the nose. In the French Bulldog population, none had no nose fold, but 48 dogs had small or parted nose folds and six dogs had whole nose folds or a nose fold over the nose. In the Pug population, all 32 dogs had whole nose folds or a nose fold over the nose. The median nose fold for Boston Terrier was no nose fold, for French Bulldog a small or parted nose fold and for both English Bulldog and Pug a whole nose fold or a nose fold over the nose. None of the breeds distribution of nose folds were normally distributed.

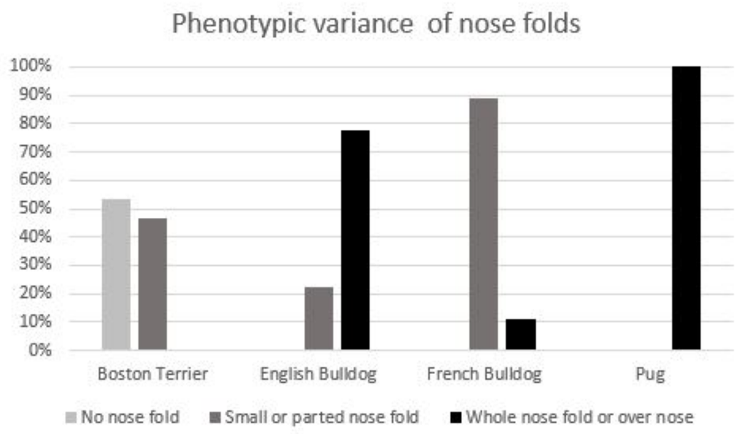

Figure 12. The distribution of nose fold phenotypes for the four brachycephalic breeds.

The distribution of dogs, within each breed, with the different categories of BOAS scoring are shown in figure 12. For the Boston Terrier population, 12 dogs had BOAS score 0, two dogs had BOAS score 1, one dog had BOAS score 2 and none had BOAS score 3. For the English Bulldog population, 13 dogs had BOAS score 0, one dog had BOAS score 1, two dogs had BOAS score 2 and two dogs had BOAS score 3. For the French Bulldog population, 37 dogs had BOAS score 0, three dogs had BOAS score 1, four dogs had BOAS score 2 and 10 dogs had BOAS score 3. For the Pug population, 18 dogs had BOAS score 0, three dogs had BOAS score 1, six dogs had BOAS score 2 and five dogs had BOAS score 3.

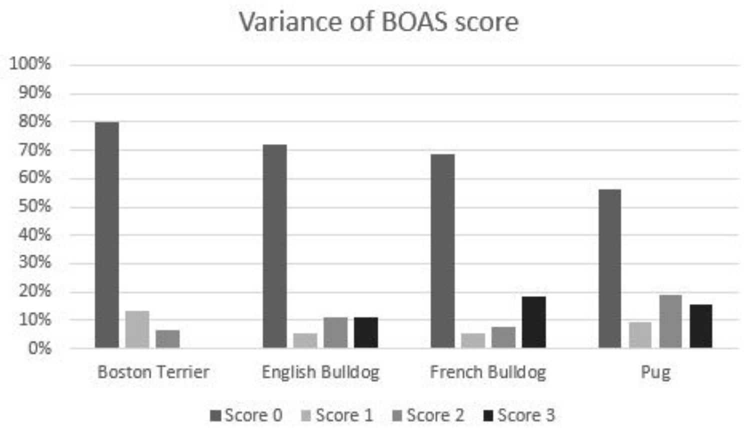

Figure 13. Distribution of BOAS scoring for the four brachycephalic breeds.

3.1.3 Phenotypic differences between Swedish born dogs and foreign

For the total study population, no significant differences were found regarding the phenotypic parameters. There were 12 Swedish Boston Terriers, three foreign-born Boston Terriers, 13 Swedish English Bulldogs, four foreign-born English Bulldogs, 44 Swedish French Bulldogs, nine foreign-born French Bulldogs, 27 Swedish Pugs and five foreign-born Pugs. None of the breeds had any significant differences between the Swedish and foreign-born dogs when analyzing the phenotypic parameters in this study.

3.1.4 Phenotypic differences depending on BOAS

Differences between BOAS scores

For the total study population, there were no significant phenotypic differences between dogs with BOAS score 0 and BOAS score 1. Regarding dogs with BOAS score 0 and BOAS score 2, the significant differences were that the dogs with BOAS score 0 had higher craniofacial ratio (t=4.07, p=0.0042) than the dogs with BOAS score 2. Between the dogs with BOAS score 0 and BOAS score 3 the significant differences were longer snouts (x^2=6.3779, p=0.0406), higher craniofacial ratio (t=2.69, p=0.0086), higher neck girth ratio (x^2=8.2093, p=0.0294) and more severe stenosis (x^2=16.2185, p=0.0014) for the dogs with BOAS score 0.

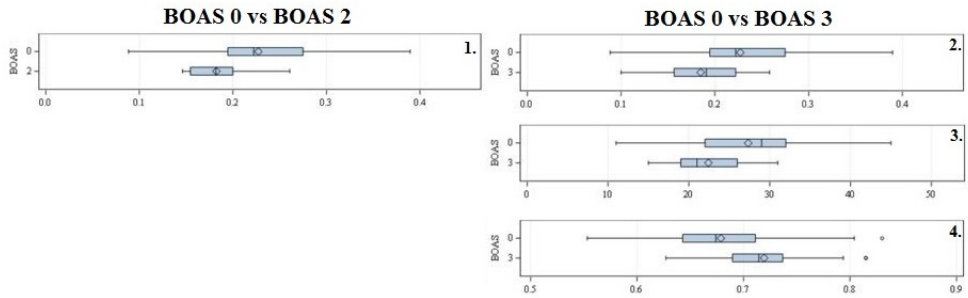

Figure 14. Phenotypical differences in variance between BOAS score 0 and the other BOAS scores. 1. & 2. Craniofacial ratio 3. Snout length (mm) 4. Neck girth ratio. The "box" represents the middle 50% of the scores, the line in the "box" marks the median and the square shape marks the mean. The whiskers outside the box represents the 25% extreme values.

Differences between BOAS affected and non-affected dogs

For the total study population 89 dogs were categorized as non-affected by BOAS and 30 (25%) dogs were affected. The affected dogs were significantly shorter for snout length (x^2=10.0943, p=0.007) and lower craniofacial ratio (t=-4.16, p=0.0014), shown in figure 14. There were no significant differences in the proportion of BOAS affected dogs depending on their nose fold. There was a significant higher risk of being BOAS affected with severe stenosis than with open nostrils, mildly stenotic nostrils or moderately stenotic nostrils (x^2=10.4573, p=0.007).

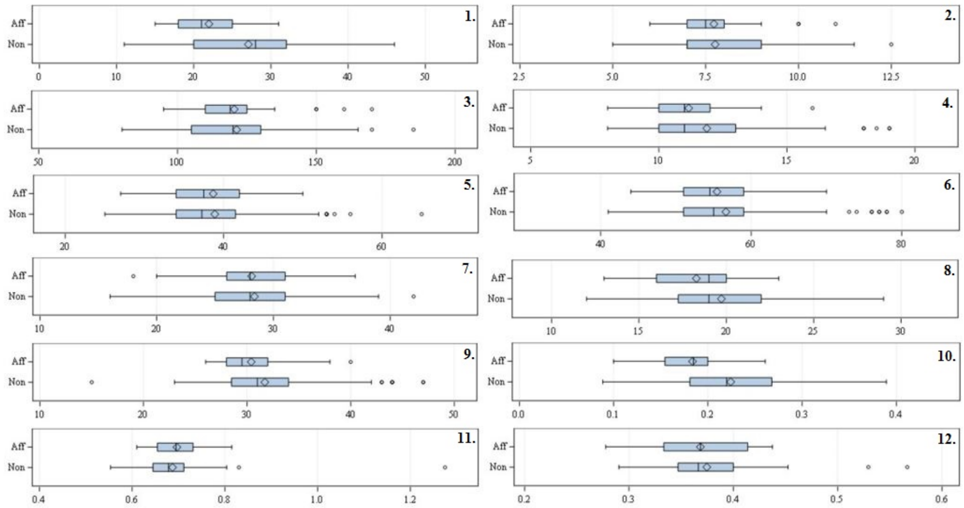

Figure 15. Phenotypic variance between BOAS affected and non-affected dogs across all four breeds. 1. Snout length (mm) 2. Snout width (cm) 3. Cranial length (mm) 4. Neck length (cm) 5. Neck girth (cm) 6. Chest girth (cm) 7. Chest length (cm) 8. Sternum length (cm) 9. Back length (cm) 10. Craniofacial ratio 11. Neck girth ratio 12. Neck length ratio The "box" represents the middle 50% of the scores, the line in the "box" marks the median and the square shape marks the mean. The whiskers outside the box represents the 25% extreme values.

For the English Bulldog population in the study there were 14 non-affected dogs and 4 affected dogs (22.2%). For this population the affected dogs had a significantly shorter snouts (t=-3.05, p=0.0378), lower chest girths (t=-2.9, p=0.0378), shorter sternums (x^2=6.1048, p=0.0378) and lower craniofacial ratio (t=-2.88, p=0.0378), shown in figure 15. There were no significant differences in the proportion of BOAS affected English Bulldogs depending on their nose fold. For the stenosis of the nostrils, English Bulldogs had significantly higher risk of being classified as BOAS affected if they had moderate stenosis compared to mild stenosis or open nostrils (x^2=7.824, p=0.0378).

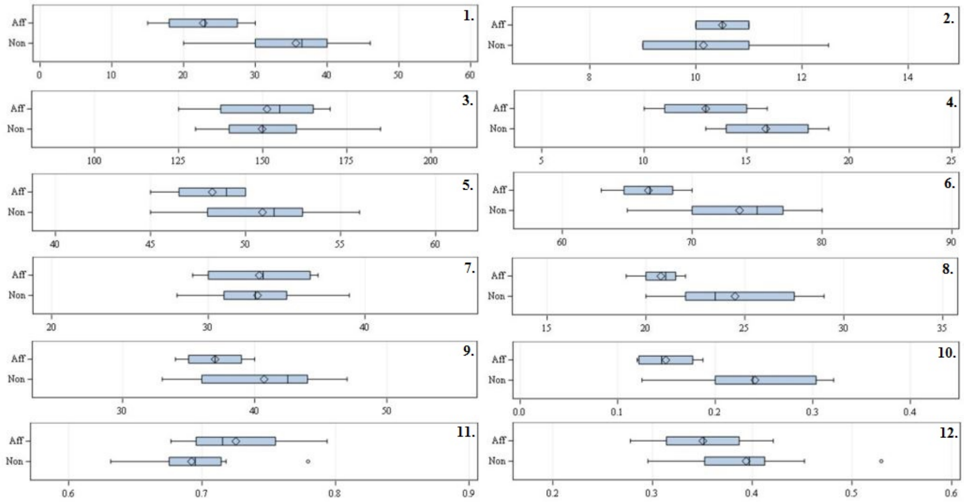

Figure 16. Phenotypic variance between BOAS affected and non-affected English Bulldogs. 1. Snout length (mm) 2. Snout width (cm) 3. Cranial length (mm) 4. Neck length (cm) 5. Neck girth (cm) 6. Chest girth (cm) 7. Chest length (cm) 8. Sternum length (cm) 9. Back length (cm) 10. Cranio-facial ratio 11. Neck girth ratio 12. Neck length ratio The "box" represents the middle 50% of the scores, the line in the "box" marks the median and the square shape marks the mean. The whiskers outside the box represents the 25% extreme values.

In the French Bulldog population in the study there were 40 non-affected dogs and 14 BOAS affected dogs (25.9%). The affected French Bulldogs had significantly shorter snout (x^2=12.3014, p=0.007) and lower craniofacial ratio (t=-3.33, p=0.0112) shown in figure 16. There were no significant differences in the proportion of BOAS affected French Bulldogs depending on their nose fold or stenosis of the nostrils.

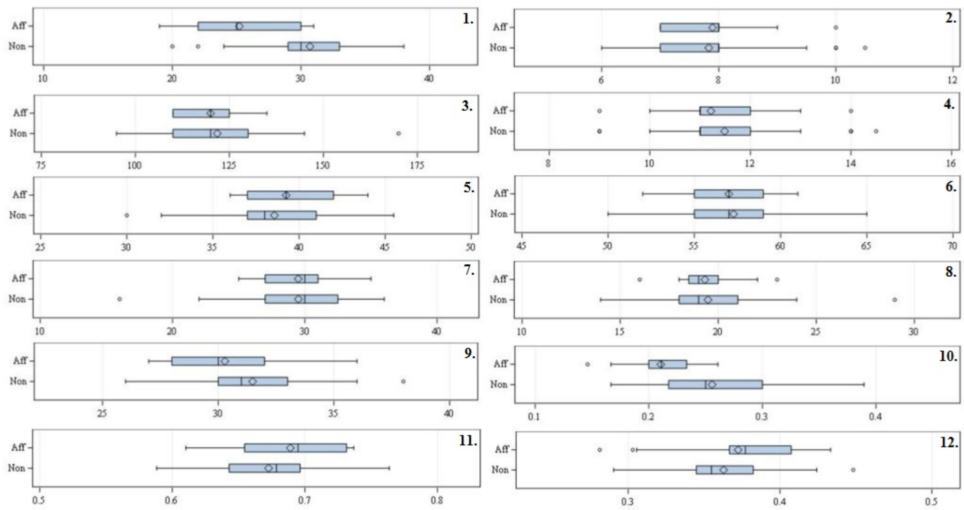

Figure 17. Phenotypic variance between BOAS affected and non-affected French Bulldogs. 1. Snout length (mm) 2. Snout width (cm) 3. Cranial length (mm) 4. Neck length (cm) 5. Neck girth

(cm) 6. Chest girth (cm) 7. Chest length (cm) 8. Sternum length (cm) 9. Back length (cm) 10. Cranio-facial ratio 11. Neck girth ratio 12. Neck length ratio The "box" represents the middle 50% of the scores, the line in the "box" marks the median and the square shape marks the mean. The whiskers outside the box represents the 25% extreme values.

There were 21 non-affected dogs and 11 BOAS affected dog (34.4%) in the Pug study population. In this population none of the mean values were significantly different between the categories. There were no significant differences in the proportion of BOAS affected Pugs depending on their nose fold or stenosis of the nostrils.

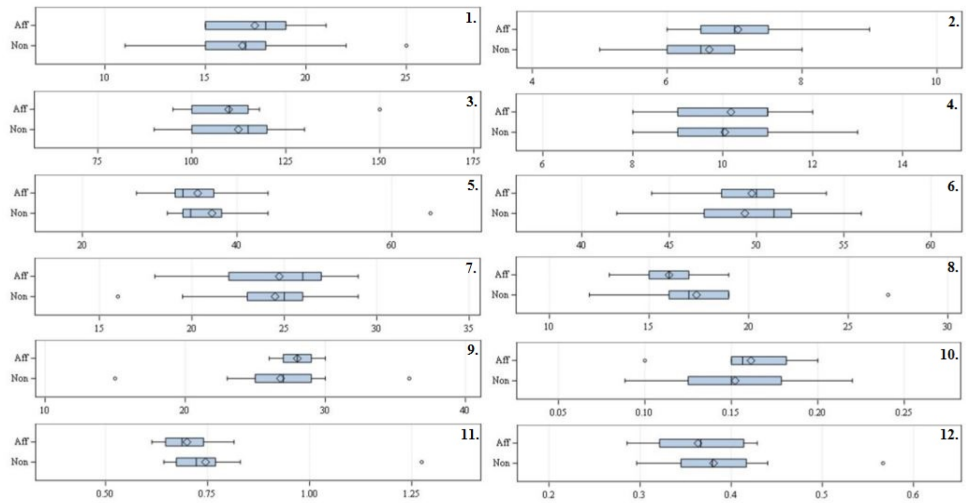

Figure 18. Phenotypic variance between BOAS affected and non-affected Pugs. 1. Snout length (mm) 2. Snout width (cm) 3. Cranial length (mm) 4. Neck length (cm) 5. Neck girth (cm) 6. Chest girth (cm) 7. Chest length (cm) 8. Sternum length (cm) 9. Back length (cm) 10. Cranio-facial ratio 11. Neck girth ratio 12. Neck length ratio The "box" represents the middle 50% of the scores, the line in the "box" marks the median and the square shape marks the mean. The whiskers outside the box represents the 25% extreme values.

For the Boston Terrier population in the study there were no results when comparing the BOAS affected and non-affected dogs because only one Boston Terrier were categorized as BOAS affected (6.7%).

3.2 Survey

3.2.1 All breeds

Dog owners for 2013 dogs participated and completed the survey; 228 Boston Terriers, 215 English Bulldogs, 1083 French Bulldogs and 487 Pugs. In the survey 865 dogs were younger than two years old, 1030 dogs were between three and eight years old and 118 dogs were older than nine years old. This study showed that the proportion of dogs being perceived as healthy or with good welfare was significantly lower with the older age categories (see test statistics in appendix 2 table 3). The study also showed that significantly more dogs with BOAS-related problems where older except for eating disorders (see test statistics in appendix 2 table 3).

The survey showed that the most common BOAS-related problem was noisy breathing (53.7%) and then heat intolerance (31.4%) across the breeds. Eating disorders occurred in the study population with 7.4%, exercise intolerance with 6.9%, sleeping disorders with 6.2% and syncope with 1.4% as the least occurred problem. All of the problems had a significant correlation with each other (see test statistics in appendix 2 table 4), which means that dogs with one BOAS-related problem had a higher risk of also having the other BOAS-related problems. Across all four breeds in the study 37.5% had none of the BOAS-related problems, 52.2% had one or two of the problems, 9,2% had three or four of the problems and 1.1% had five or six of the problems.

87.6% (1764 dogs) were perceived by their owners to have good health and 92.1% (1853 dogs) were perceived to have good welfare. All of the BOAS-related problems were significantly correlated to poor health or poor welfare across all four breeds (see test statistics in appendix 2 table 5 & 6). 75 dogs (3.7%) were perceived by their owners to have poor health and poor welfare. 1712 dogs (85%) were instead perceived to have good health and good welfare, even though 986 of these dogs (57.5%) had at least one BOAS-related problems. All BOAS-related problems were perceived to lead to poor health and poor welfare for the dogs according to the owners (see test statistics in appendix 2 table 7). However, dogs with up to two of the problems had a significantly higher chance of being perceived with good health and good welfare, but the dogs with more than two problems were at a significantly higher risk of being perceived with poor health and poor welfare (x^2=521.7914, p<.0001).

3.2.2 Boston Terrier

Of the 228 Boston Terriers in the survey 102 dogs were younger than two years old, 107 dogs were between three and eight years old and 19 dogs were older than nine years old. This study showed that the proportion of dogs being perceived as healthy or with good welfare was not significant depending on the age categories for Boston Terriers. The study showed that significantly more Boston Terriers had heat intolerance (x^2=18.0583, p=0.0034) when older, but all the other BOAS-related problems were nonsignificant depending on age (see test statistics in appendix 2 table 8).

For Boston Terriers the most common BOAS-related problem was noisy breathing (42.1%) and then heat intolerance (14.9%). Eating disorders occurred in the studied Boston Terrier population with 5.7%, sleeping disorders with 4.4%, exercise intolerance with 2.6% as the least occurred problem. None of the Boston Terriers had syncope in this study. A correlation was found between noisy breathing, heat intolerance, sleeping- and eating disorders for the Boston Terrier population, though sleeping disorders were not correlated with heat intolerance (see test statistics in appendix 2 table 9). Heat intolerance were instead correlated to exercise intolerance (see test statistics in appendix 2 table 9). For the studied Boston Terrier population, 53.5% had none of the BOAS-related problems, 40.8% had one or two of the problems, 5.7% had three or four of the problems and none had five of six of the problems.

90.4% of the Boston Terriers were perceived by their owners to have good health and 93.4% were perceived to have good welfare. For the studied Boston Terrier population, sleeping disorders, noisy breathing and heat intolerance were all significantly correlated to poor health, but only noisy breathing, eating- and sleeping disorders were correlated to poor welfare (see test statistics in appendix 2 table 10 & 11). Exercise intolerance was significantly correlated to poor health, but to good welfare for Boston Terriers in this survey (see test statistics in appendix 2 table 10 & 11). Eating disorders were only significantly correlated to poor welfare (see test statistics in appendix 2 table 10 & 11) for Boston Terriers. Five Boston Terriers (2.2%) were perceived by their owners to have poor health and poor welfare. 202 Boston Terriers (88.6%) were instead perceived to have good health and good welfare, even though 84 of these dogs (41.6%) had at least one of the BOAS-related problems. The Boston Terriers with noisy breathing or sleeping disorders had significantly higher risk to be perceived with poor health and poor welfare than with good health and good welfare (see test statistics in appendix 2 table 12). Only the Boston Terriers with none of the problems had a higher chance of being perceived healthy and with good welfare (x^2=11.4421, p=0.0078).

3.2.3 English Bulldog

Of the 215 English Bulldogs in the survey 70 dogs were younger than two years old, 134 dogs were between three and eight years old and 11 dogs were older than nine years old. This study showed that the proportion of English Bulldogs being perceived as healthy was significantly lower with the older age categories (see test statistics in appendix 2 table 13). Though the proportion of English Bulldogs being perceived with good welfare was not significant depending on the age categories. The study showed that none of the BOAS-related problems were significant depending on age for the English Bulldogs.

For English Bulldogs the most common BOAS-related problem was noisy breathing (47.9%) and then heat intolerance (26.1%). Eating disorders occurred in the studied English Bulldog population with 3.7%, exercise intolerance with 7.9%, sleeping disorders with 4.2% and syncope with 0.9% as the least occurred problem. A correlation was found between noisy breathing, sleeping disorders, heat- and exercise intolerance for the English Bulldog population (see test statistics in appendix 2 table 14). Only exercise intolerance was found to have a correlation to eating disorders (x2=20.2528, p=0.0106). Syncope was not significantly correlated to any of the BOAS-related problems for English Bulldogs (see test statistics in appendix 2 table 14). For the studied English Bulldog population, 44.2% had none of the BOAS-related problems, 48.3% had one or two of the problems, 7% had three or four of the problems and 0.5% had five of six of the problems.

87.4% of the English Bulldogs were perceived by their owners to have good health and 94% were perceived to have good welfare. All the BOAS-related problems were significantly correlated to poor health or poor welfare (see test statistics in appendix 2 table 15 & 16), except for syncope for the English Bulldog population in this study. Nine English Bulldogs (4.2%) were perceived by their owners to have poor health and poor welfare. 184 English Bulldogs (85.6%) were instead perceived to have good health and good welfare, even though 94 of these dogs (51.1%) had at least one of the BOAS-related problems. The English Bulldogs with any of the BOAS-related problems like noisy breathing, heat intolerance, sleeping disorders, exercise intolerance or eating disorders had significantly higher risk to be perceived with poor health and poor welfare compared to English Bulldogs with no BOAS-related problem (see test statistics in appendix 2 table 20).

Another analysis showed that English Bulldogs with up to two of the problems had a higher chance of being perceived healthy and with good welfare compared to the English Bulldogs with three or four of the BOAS-related problems (x^2=91.7462, p<.0001). There were no results relevant concerning English Bulldogs with five or six of the problems because there was only one English Bulldog reported with either good health and good welfare or with poor health and poor welfare.

3.2.4 French Bulldog

Of the 1083 French Bulldogs in the survey 525 dogs were younger than two years old, 517 dogs were between three and eight years old and 41 dogs were older than nine years old. This study showed that the proportion of French Bulldogs being perceived as healthy or with good welfare was significantly lower with the older age categories (see test statistics in appendix 2 table 18). The study also showed that significantly more dogs had BOAS-related problems when older (see test statistics in appendix 2 table 18) except for eating disorders and noisy breathing.

For French Bulldogs the most common BOAS-related problem was noisy breathing (53.9%) and then heat intolerance (32.5%). Eating disorders occurred in the studied French Bulldog population with 9.9%, exercise intolerance with 7.7%, sleeping disorders with 6.4% and syncope with 1.2% as the least occurred problem. For French Bulldogs all of the BOAS-related problems had a significant correlation with each other (see test statistics in appendix 2 table 19), which means that the French Bulldogs with one of the BOAS-related problems had a higher chance of also having the other problems. For the studied French Bulldog population, 36.4% had none of the BOAS-related problems, 55.2% had one or two of the problems, 9.7% had three or four of the problems and 1.7% had five of six of the problems.

86.3% of the French Bulldogs were perceived by their owners to have good health and 91.5% were perceived to have good welfare. All the BOAS-related problems were significantly correlated to poor health or poor welfare (see test statistics in appendix 2 table 20 & 21). 45 French Bulldogs (4.2%) were perceived by their owners to have poor health and poor welfare. 905 French Bulldogs (83.6%) were instead perceived to have good health and good welfare, even though 525 of these dogs (58%) had at least one of the BOAS-related problems. The French Bulldogs with noisy breathing, heat intolerance, sleeping disorders, exercise intolerance, eating disorders or syncope had significantly higher risk to be perceived with poor health and poor welfare than with good health and good welfare compared to French Bulldogs with no BOAS-related problem (see test statistics in appendix 2 table 26).

Another analysis showed that French Bulldogs with up to two of the problems had a higher chance of being perceived healthy and with good welfare compared to the French Bulldogs with over two of the BOAS-related problems (x^2=354.6553, p<.0001).

3.2.5 Pug

Of the 487 Pugs in the survey 168 dogs were younger than two years old, 272 dogs were between three and eight years old and 47 dogs were older than nine years old. This study showed that the proportion of Pugs being perceived as healthy or with good welfare was significantly lower with the older age categories (see test statistics in appendix 2 table 23). The study also showed that significantly more Pugs had BOAS-related problems when older (see test statistics in appendix 2 table 23) except for syncope.

For Pugs the most common BOAS-related problem was noisy breathing (61%) and then heat intolerance (39%). Sleeping disorders occurred in the studied Pug population with 7.4%, exercise intolerance with 6.8%, eating disorders with 4.1% and syncope with 2.9% as the least occurred problem. A significant correlation was found between noisy breathing, sleeping disorders, eating disorders, heat- and exercise intolerance for the Pug population (see test statistics in appendix 2 table 24). Exercise intolerance was also found to have a correlation to syncope (see test statistics in appendix 2 table 28). For the studied Pug population, 29.4% had none of the BOAS-related problems, 59.1% had one or two of the problems, 10.9% had three or four of the problems and 0.6% had five of six of the problems.

89.3% of the Pugs were perceived by their owners to have good health and 91.8% were perceived to have good welfare. All the BOAS-related problems were significantly correlated to poor welfare (see test statistics in appendix 2 table 26) for Pugs. Sleeping- and eating disorders and heat- and exercise intolerance were significantly correlated to poor health (see test statistics in appendix 2 table 25). Syncope and noisy breathing were not significantly correlated to health for the studied Pugs. 16 Pugs (3.3%) were perceived by their owners to have poor health and poor welfare. 421 Pugs (86.4%) were instead perceived to have good health and good welfare, even though 283 of these dogs (58.1%) had at least one of the BOAS-related problems. The Pugs with noisy breathing, heat intolerance, sleeping disorders, exercise intolerance or eating disorders had significantly higher risk to be perceived with poor health and poor welfare than with good health and good welfare compared to Pugs with no BOAS-related problem (see test statistics in appendix 2 table 32).

Another analysis showed that Pugs with up to two of the problems had a higher chance of being perceived as healthy and with good welfare compared to the Pugs with three or four of the BOAS-related problems (x^2=92.5701, p<.0001). No results were relevant concerning Pugs with five or six of the problems because there was only one Pug reported with either good health and good welfare or with poor health and poor welfare.

4 Discussion

4.1 All breeds

For all of the four breeds in the inventory of this study the percentage of BOAS affected dogs were much lower in the study population compared to the literature. This could be because the study population was not representative of the different breeds populations because the participation in the inventory was voluntary and dog owners to dogs with a lot of problems might not participate. It could also be that the Swedish populations have less problems with BOAS, though when comparing Swedish born dogs and foreign-born dogs the BOAS score was not higher for the foreign dogs in general. So therefore, it is more likely that the study population might not be representative of the BOAS problem in Sweden even though 25% of all the dogs were categorized as BOAS affected. It should also be known that the study population from the inventory was quite small, which could also affect the results.

Across all breeds there were no significant phenotypic differences between the dogs with BOAS score 0 and BOAS score 1, which confirms that the dogs with BOAS score 0 and 1 are not clinically affected by BOAS (University of Cambridge, 2015). The phenotypic risk factors found for being scored BOAS 2 or 3 were shorter snouts, lower craniofacial ratio, lower neck girth ratio, more narrow snouts and more stenosis of the nostrils. Craniofacial ratio has been shown before to have an effect on BOAS across breeds (Packer et al., 2015). It might therefor not be a stretch to conclude that snout length also has a true effect because it is a factor in the craniofacial ratio. The ratio is a better way to compare and select for because it is not affected by the size of the dog, but how the proportions of the phenotypes are related. None of the individuals in this study had craniofacial ratio >0.5 and only one individual was found to have <0.1, so therefore the results from Packer *et al.* (2015) about these thresholds and their effect on BOAS can neither be confirmed or denied by this study. Packer *et al.* (2015) also found neck girth to be a risk factor across breeds. This was not confirmed in this study, but neck girth ratio was, where neck girth is a factor. Snout width has not been investigated as a risk factor for BOAS before, but according to this study this measurement should be considered as a risk factor at least across the four brachycephalic dog breeds in this study. Another conformational risk factor that has been confirmed in previous studies are stenosis of the nostrils (Liu *et al.,* 2017), which was also confirmed across all breeds in this study. The nose fold, a conformational factor thought to affect the development of BOAS was in this study not a risk factor.

For the results in the survey the health and welfare perceived by the dog owners decreased and all the BOAS-related problems increased (except for eating disorders) with the dogs' age. This confirms that BOAS is a progressive disease. However, exercise intolerance can also increase naturally in elderly dogs. For eating disorders, the result can be explained by inclusion of other eating disorders in the survey that might not be connected to BOAS and therefore not correlated to age. All of the problems were correlated to each other, which means that if the dog had one of the problems it was a higher risk of developing any of the other problems as well.

About 63% of the study population in the survey had at least one of the BOAS related problems, where noisy breathing and heat intolerance were the most common and syncope the least common problem. The proportion of the brachycephalic dogs having the different BOAS-related problems in the study by Roedler *et al.* (2013) was all higher than confirmed in this study. The population that Roedler *et al.* (2013) selected to answer their survey were owners to dogs that were referred for surgical treatment for Brachycephalic syndrome. This could explain the higher proportion of the population that suffers from problems connected to BOAS in their study. What was concerning is that even though the population in this study was not selected from dogs under veterinary care, the proportion of dogs having problems with noisy breathing in this study (53.65%), was not much lower than the dogs suffering from stridor in Roedler *et al.* (2013) study (66%). The two most common problems, across all breeds, according to the survey were noisy breathing and heat intolerance. Their correlation is quite logical because of the anatomy of the dog's respiration, also stated by Koch *et al.* (2003). A dog who cannot ventilate properly will more likely have problems with heat- and exercise intolerance. It is of great concern that about half of the dogs had problems with noisy breathing, about 1/3 of the dogs had problems with heat intolerance and about 7% had exercise intolerance according to this study. Syncope was the least occurring BOAS-related problem and is also connected to respiration and reduction of airflow. This problem is very serious because it means that the individual becomes unconscious under a small period of time because of the severe restriction of air. Even though only 1.44% of the dogs in the study had this problem, this means that about 30 dogs have severe respiratory problems that were recognized by their owners. This is 30 dogs too many, because no one should pass out because of restricted airflow. As stated by Roedler *et al.,* (2013) respiratory distress due to upper airway obstruction and overheating due to limited thermoregulation are one of the most life-threatening circumstances. These life-threatening circumstances causes severe stress and anxeity in the dogs. These problems therefore decreases the welfare of the animals and also put the animals at risk of suffering, which is against the freedom from pain, injury and disease and the freedom from discomfort from the Five Freedoms (Farm Animal Welfare Council, 2009). This is also against article 3 in the Protection of Pet Animals (ETS No.125, 1987) and paragraph 1 in section 2 in the Swedish Animal Welfare Act (SFS 2018:1192) which states that animals should be protected against unnecessary pain, suffering or distress.

Six to seven out of 100 dogs had problems with eating disorders, exercise intolerance and/or sleeping disorders. The number of dogs with exercise intolerance in this study could be a lower number than the truth because exercise intolerance might be easily be interpreted as a calm and "philosophical" dog. According to Roedler *et al.,* (2013) and Jensen (2009) sleeping, eating and physical activity are basic needs. Not being able to run, play and "hunt" can severely decrease the quality of life for the animal by not being able to perform natural behaviors. Also, the social behaviors are important for dogs to be able to perform (Jensen, 2009). These can be restricted because of the compressed neck and muzzle of the brachycephalic dogs because of a possible reduction in olfactory sensors and vocalization abilities, which together with exercise intolerance can reduce the ability for the dogs to socialize and play with other dogs, but also the exercise intolerance can reduce the playing behavior. All these problems affect the natural behavior of the dogs which is a focus point in two of the three perspectives about animal welfare stated by Fraser (2008). These problems therefore go against the perspective that the animals should have an ability to live a natural life, but also the animal's basic health and functioning. About 87% of the dogs were perceived as healthy and 92% were perceived with good welfare by their owners. This concludes that the brachycephalic dog owners perceived their dogs as unhealthier then having bad welfare. An explanation could be that the four brachycephalic dog breeds are prone to more health problems, then just BOAS-related problem that are not lifted in this survey. All of the BOAS-related problems were correlated to poor health and poor welfare by the owners. Though 57% of the dogs that were perceived as healthy and with good welfare had at least one of the BOAS-related problems and the dogs with up to two of the BOAS-related problems had a higher chance of being perceived as healthy and with good welfare. This shows that some of the problems are normalized by these brachycephalic dog owners and not considered as a health or welfare problem. This normalization can lead to continued breeding with individuals with BOAS and BOAS-related problems, which will increase the frequency and severity of BOAS in the brachycephalic dog breeds. It could also affect, if the dog owners seek veterinarian aid for the BOAS-related problems, which will negatively affect the health and welfare of the individual directly. Not only will this normalization affect the dogs, but also new dog owners that might not have the knowledge to understand the health and welfare problems behind these normalized disorders and not realize suffering of the dog as well as the economic costs until it is too late. Therefore, neither BOAS nor any of the BOAS-related problems should be normalized in any dog breed. When problems are normalized, they will not be given full attention, and the work to change the phenotype will be limited. It is therefore important to raise awareness about BOAS as a problem for the dog and not something that is natural for the breed.

4.2 Boston Terrier

The studied Boston Terrier population did not have any of the most severe scoring for neither BOAS, nose folds or stenosis of the nostrils which is positive and something the breeders should strive to retain. However, the study population was quite small, so it might be that the most affected individuals were not volunteered to this inventory. Though for the stenosis there were more individuals with mild stenosis than Boston Terriers with open nostrils. This is quite alarming because the breed standard states that the nostrils should be well opened and, in the BSI, pinched nostrils are a risk factor that the show judges should consider when judging the breed. There should therefore be more emphasis on the conformation of the nostrils in the selection of breeding material so that the problem with BOAS does not increase in this breed.

Unfortunately, there were no results when comparing the BOAS affected and non-affected phenotypes for the Boston Terrier study population because only one Boston Terrier were categorized as BOAS affected. When compared to the general mean values across all breeds for the BOAS affected, then the Boston Terriers have a higher study breed mean value for snout length, sternum length and craniofacial ratio compared to the BOAS affected dogs. This was positive because these were the phenotypic risk factors found in this study across all breeds and a higher value was correlated to a lower risk of procuring BOAS. Though for snout length the Boston Terriers had a lower breed mean than for the general mean for dogs with BOAS score 0. An explanation can be that in the general mean value English Bulldog was included and therefore the mean value can increase because English Bulldogs are larger than the Boston Terriers. The short muzzle is a risk factor for forced breathing stated in the BSI for the show judges (The Nordic Kennel Clubs, 2018). The BSI also, states that the muzzle should not be too short (The Nordic Kennel Clubs, 2018), but does not define what “too short” is. If comparing to the general results for BOAS affected dogs then the limit should be at 22 mm, which should not be impossible according to the Boston Terrier population in this study. For craniofacial ratio the Boston Terriers had the same mean breed value as the dogs with BOAS score 0 and this is a very positive result. The Boston Terriers from this study also had a high median craniofacial ratio compared to previous studies (Packer *et al,* 2012, 2015). In the breed standard the muzzle should not be longer than 1/3 of the cranial length (FCI-Standard Nº 140, 2014), which implies that the craniofacial ratio should be lower than 0.33, which all Boston Terrier had in this study. Though this might be something to change in the future because of the significant effect craniofacial ratio has in developing BOAS, both confirmed in this study and previous studies (Packer *et al.,* 2012, 2015). From the general results snout width and neck girth ratio was also found as risk factors for developing BOAS score over 0 in this study. The snout width mean was lower for the Boston Terriers than for the dogs with BOAS score 0, but this can have the same explanation as the snout length described above. The neck girth ratio was lower for the breed mean value than for dogs with BOAS score 0 and this can be explained by the proportion of the Boston Terriers compared to the other brachycephalic breeds in this study. The Boston Terrier has a more slender body conformation than the other more compact brachycephalic breeds. The neck girth was higher in this study than in previous studies (Packer *et al.* 2015), thicker necks can result in smaller airways and more resistance when breathing. None of the phenotypic parameters were different between the Swedish born- and foreign Boston Terriers. It is therefore unclear if increased breeding with foreign dogs can help with the phenotypic variance against BOAS. As a previous study has shown (Packer *et al.,* 2015) Boston Terriers still have a 21-71% risk of developing BOAS and therefore BOAS is an important aspect to involve in the breeding of Boston Terriers. All of the laws and regulations stated in this study states that breeding should not be done if the offspring has a higher risk of developing diseases or problems, and this study shows that BOAS is a problem that should be considered.

According to the survey the perceived health or welfare was not correlated to age in Boston Terriers and only heat intolerance was more frequent the older the Boston Terriers were. This could mean that heat intolerance was more pronounced progressive problem in this breed. Even if the owners of Boston Terriers did not consider heat- and exercise intolerance to affect the health or welfare when comparing age. Noisy breathing, heat intolerance, sleeping disorders and eating disorders were correlated to each other and the correlation between noisy breathing, heat intolerance and sleeping disorder can be explained because all of these problems are depending on respiration and if the respiration is decreased then the risk of procuring any or all of these problems are increased. There was a correlation between eating disorders and heat intolerance and noisy breathing, but no correlation was found between eating disorders and sleeping disorders. This could be explained by that the eating disorders might not be BOAS-related but could be other disorders present at the same time. Sleeping disorders were also correlated to exercise intolerance and that might be explained because both problems have a respiratory cause, but exercise intolerance was not correlated to the other respiratory problems, noisy breathing, heat intolerance or syncope, which could be explained by a low frequency of dogs affected in the study because of misinterpretation of a calm and "philosophical" dog. About 90% of the Boston Terriers were perceived as healthy and about 93% with good welfare, which could imply that the owners of Boston Terriers perceive the breed as unhealthier than with poor welfare, or that some owners do not consider bad health or BOAS- related problems as a welfare problem. It could also imply that the health problems considered when answering the survey are not connected to BOAS and therefore did not affect the welfare answers.

In the study population of Boston Terriers about 50% of the dogs had at least one of the BOAS-related problems and about 46% of the Boston Terriers perceived as healthy and with good welfare had at least one problem which was quite alarming. A majority of the owners perceived heat- and exercise intolerance as health problems, but not welfare problems, which is interesting since heat- and exercise intolerance limits the dogs' natural behavior when it comes to playing and "hunting" as described by Jensen (2009). For the eating disorders the owners perceived the problem connected to welfare, but not to health, which could be because of the causes to the eating disorders or that the regurgitation is not perceived as affecting the dogs' health but welfare. A higher percentage of the owners to dogs with BOAS-related problems perceived their dog to be unhealthy with poor welfare than healthy and with good welfare which implies that there is an awareness of BOAS among the Boston Terrier owners.

4.3 English Bulldog

For English Bulldogs the nose folds did not have an effect on developing BOAS in this study, though about 80% of the English Bulldogs had whole nose fold or nose fold over the nose. According to the English Bulldogs breed standard a whole nose fold is accepted, but a nose fold over the nose is not accepted, it should never obscure the eyes and should be penalized (FCI-Standard Nº 149, 2011). It also, states in the BSI for English Bulldogs that an overhanging nose fold can cause inflammation and should be considered by the show judges (The Nordic Kennel Clubs, 2018). Therefore, the high frequency in this study was alarming. There was a higher risk of developing BOAS with moderate stenosis for the English Bulldogs. When comparing the English Bulldog variation, about 70% of the English Bulldogs in this study had less than moderate stenosis (figure 10), which is a good basis for decreasing BOAS by conformational changes. This proportion was higher than in previous studies (Liu *et al.,* 2017), which can be explained by the selection of the study population, since the frequency of stenosis did not differ between the English Bulldogs born in Sweden and foreign English Bulldogs. Still 60% of all the English Bulldogs in this study had some stenosis, which was still a large proportion especially since the English Bulldog breed standard states that the nostrils should be open and that pinched nostrils should be penalized (FCI-Standard Nº 149, 2011).

The risk factors found to be correlated to BOAS for English Bulldogs was snout length, neck length, chest girth, sternum length and craniofacial ratio. The breed mean for the snout length in this study was higher than for the BOAS affected English Bulldogs. About 75% of the non-affected English Bulldogs had longer snouts than the affected English Bulldogs with the longest snout. This was promising, because the phenotypic variation of snout length should be enough to decrease BOAS. The breed standard states that the English Bulldog should have a short muzzle (FCI-Standard Nº 149, 2011), but no maximum value is stated and therefore an elongation of the muzzle should not be against the breeding standard. The BSI states that the shortness of muzzle should not cause forced breathing (The Nordic Kennel Clubs, 2018), which this study shows it does, by the correlation to developing BOAS. Craniofacial ratio was one ratio that was both confirmed to have an effect on BOAS in this study and in previous studies (Packer *et al.,* 2012, 2015). The mean craniofacial ratio for the BOAS affected English Bulldogs was lower than the mean breed value in this study. About 75% of the non-affected dogs had higher craniofacial ratio than the BOAS affected dogs with highest craniofacial ratio value, which was promising for the selection of this phenotypic trait against BOAS. Though the mean craniofacial ratio value of the breed was the same compared to the study by Packer *et al.* (2012), but the median from this study was lower than the median in the study by Packer *et al.* (2015). Neck confirmation was not confirmed to be correlated to BOAS in this study, though neck girth (Liu *et al.,* 2017; Packer *et al.,* 2015) and neck girth ratio (Liu *et al.,* 2017) were the neck conformations that were correlated to BOAS in previous studies. The median value of neck girth in this study was higher than in the previous study (Packer *et al.,* 2015), which is negative because Liu *et al.* (2017) found that larger neck girths was correlated to higher risk of developing BOAS in English Bulldogs. For the neck girth ratio, the mean breed value in this study for the English Bulldogs is 0.70 which was quite high for a ratio and according to Liu *et al.* (2017) an increase of 0.01 units in neck girth ratio increases the odds of developing BOAS with 1.29. So, the neck is definitely a conformation that should be considered in the selection of breeding individuals for English Bulldogs to decease the BOAS problem. Another factor that affects the neck girth ratio and was shown in this study to have an effect on BOAS was chest girth. In this study both chest girth and sternum lengths' breed mean value for English Bulldogs was higher than for the BOAS affected English Bulldogs and about 75% of the non-affected English Bulldogs had larger chest girths or longer sternums than the average BOAS affected English Bulldog. This is positive because this enables the dogs to have more lung capacity due to larger chest cavities. None of the phenotypic parameters were different between the Swedish born- and foreign English Bulldogs. It is therefore unclear if increased breeding with foreign dogs can help with the phenotypic variance against BOAS.

According to the survey, "perceived health" was the only factor correlated to age in English Bulldogs. This means that the older the dog gets the worse health the owner perceives them to have. All the problems directly connected to the respiration: noisy breathing, sleeping disorders, heat- and exercise intolerance were correlated to each other, but not syncope, probably because the frequency was too low for syncope. Eating disorders were connected to exercise intolerance, which was quite interesting, but cannot be explained. All BOAS-related problems were correlated to perceived poor health and poor welfare except for syncope. 88% of the English Bulldogs were perceived as healthy and 94% with good welfare, which could imply that the owners of English Bulldogs perceive the breed as unhealthier than with poor welfare, or that some owners do not consider bad health or BOAS-related problems as a welfare problem. It could also imply that the health problems considered when answering the survey are not connected to BOAS and therefore did not affect the welfare answers.

In the study population of English Bulldogs about 55% of the dogs had at least one of the BOAS-related problems and about 50% of the English Bulldogs that were perceived as healthy and with good welfare had at least one problem which was quite alarming. Many owners perceived that the dogs with up to two BOAS-related problems were healthy and with good welfare, which means that some of the BOAS-related problems were normalized. The problems are most likely to be noisy breathing and heat intolerance because they are the most common problems.

As a previous study has shown (Packer *et al.,* 2015) English Bulldogs have a 26-88% risk of developing BOAS and therefore is an important aspect to involve in the breeding of English Bulldogs. All of the laws and regulations stated in this study states that breeding should not be done if the offspring has a higher risk of developing diseases or problems, and this study shows that BOAS is a problem that should be considered.

4.4 French Bulldog

For French Bulldogs nose folds did not have an effect on BOAS, but stenosis of the nostrils had. The risk of developing BOAS was higher when having severe stenosis for French Bulldogs in this study and about 75% of the French Bulldog study population had less than that. This is promising for the selection against BOAS, but the negative was that only 10% of the French Bulldogs had open nostrils. According to the breed standard for the French Bulldog, they should have well opened nostrils to allow for normal breathing (FCI-Standard Nº 101, 2015) and the show judges should consider if the pinched nostrils are a cause for the forced breathing (The Nordic Kennel Clubs, 2018). Though the proportion of French Bulldogs in this study with moderate to severe stenosis were lower than in previous studies (Liu et al., 2017), which is positive. However, it is still a phenotypic trait that need to be considered for selection against BOAS.

The risk factors found to be correlated to BOAS for French Bulldogs were snout length and craniofacial ratio in this study. The mean breed snout length was higher than the mean for the BOAS affected French Bulldogs and more than 25% of the non-affected French Bulldogs had longer snouts than the BOAS affected dogs, which gives the opportunity for selection in this breed. Previous study from Liu *et al.* (2017) confirmed that snout length is a risk factor for French Bulldogs when developing BOAS. The BSI states that the shortness of muzzle should not cause forced breathing (The Nordic Kennel Clubs, 2018), which it is shown in this study that is does by the correlation to BOAS. BSI also states that too short muzzles can cause eye injuries (The Nordic Kennel Clubs, 2018). For the craniofacial ratio the breed mean was higher for the French Bulldogs in this study than the BOAS affected French Bulldogs. The breed mean value and median value for craniofacial ratio was also higher than in previous studies (Packer *et al.,* 2012, 2015). This is positive because Liu *et al.* (2017) found that lower craniofacial ratio is a higher risk for BOAS in French Bulldogs. According to Liu *et al.* (2017) a decrease of craniofacial ratio by 0.01 the risk of procuring BOAS was 1.07 times greater, so therefore the change probably does not have to be that drastic to make a difference for the BOAS outcome within the breed. According to the breed standard, the muzzle should be about 1/6 of the cranial length (FCI-Standard Nº 101, 2015), which almost all of the individuals in this study exceeded. The shortest snout for the French Bulldogs was around 1/6 of the cranial length. The snout length should absolutely not be shorter, and according to the results in this study it would be positive if the breed standard changed. Some risk factors that was not confirmed in this study but found in previous studies are neck girth (Packer *et al.,* 2015; Liu *et al.,* 2017), back length (Liu *et al.,* 2017), neck length ratio (ibid.) and neck girth ratio (ibid.). For the neck girth the breed mean in this study was higher than in previous study (Packer *et al.,* 2015), which is negative because Liu e*t al.* (2017) found that greater neck girths are connected to higher risk of BOAS. The breed mean value of neck girth ratio in this study was quite high (0.68) and according to Liu *et al.* (2017) higher neck girth ratio have an increased risk of BOAS. An increase of 0.01 units of neck girth ratio the risk of procuring BOAS was 1.12 times greater (Liu *et al.,* 2017). Therefore, this is a very important parameter to select when choosing breeding material in the breed and that it does not need drastic decrease of neck girth ratio to make a difference of the risk of developing BOAS in French Bulldogs. Included in the neck girth ratio parameter is the chest girth, which is considered a risk factor for BOAS in both this study and previous (Koch et al., 2003). According to the BSI the whole ribcage conformation is a risk that should be considered (FCI-Standard Nº 101, 2015). Another risk factor stated by the BSI was overly short necks, which is one component in neck length ratio. The breed mean of neck length ratio in this study was 0.37, which is quite high considering that the neck length is divided by the back length in this ratio. Both the back and neck length were stated in the BSI as risk factors for French Bulldogs by being overly short. Though according to Liu et al. (2017) longer backs and lower neck length ratio are connected to higher risk of developing BOAS. So, then the backs should not be longer in this breed, but the selection should be focused on longer neck to higher the neck length ratio in the dogs. It is also important not to select for shorter backs because of the risks stated in the BSI.

According to the survey the perceived health, welfare and BOAS-related problems, except for eating disorders and noisy breathing, were connected to age for French Bulldogs. This means that the older the dog gets the worse health and welfare the owner perceives them to have and the higher frequency of dogs with problems. The explanation of why the noisy breathing is not correlated to age could be the high frequency in the lower age categories and therefore the difference between the age categories were not large enough to become significant, which is quite alarming. The eating disorders might not be BOAS-related but be other eating disorders that are not progressive problems and therefore do not correlate to the age categories. Though all of the BOAS-related problems were correlated to each other, some of the eating disorders might be connected to BOAS. All BOAS-related problems were correlated to perceived poor health and poor welfare. 86% of the French Bulldogs were perceived as healthy and 92% with good welfare, which could imply that the owners of French Bulldogs perceive the breed as unhealthier than with poor welfare, or that some owners do not consider bad health or BOAS-related problems as a welfare problem. It could also imply that the health problems considered when answering the survey are not connected to BOAS and therefore did not affect the welfare answers.

In the study population of French Bulldogs about 64% of the dogs had at least one of the BOAS-related problems and about 58% of the French Bulldogs perceived as healthy and with good welfare had at least one problem which is quite alarming. Many owners perceived dogs with up to two of the BOAS-related problems as healthy and with good welfare, which implies that some of the BOAS-related problems are normalized. The problems are most likely to be noisy breathing and heat intolerance because they are the most common problems.

As a previous study has shown (Packer *et al.,* 2015) French Bulldogs have a 30-89% risk of developing BOAS and therefore is an important aspect to involve in the breeding of French Bulldogs. All of the laws and regulations stated in this study states that breeding should not be done if the offspring has a higher risk of developing diseases or problems, and this study shows that BOAS is a problem that should be considered.

4.5 Pug

The population of Pugs are very homogenous and none of the phenotypic parameters affecting BOAS analyzed in this study differed between the affected and non-affected dogs. There were neither a significant difference between the Swedish born and foreign Pugs for any of the phenotypic parameters in this study. Even if they have some small variation in the measurements and ratios, it is very alarming, and shows that breeding for healthy Pugs within current population will be very difficult. Without variation it's very difficult (or even impossible) to breed for more healthy Pugs with less BOAS-related problems. Regarding nose folds, there were no phenotypic variance at all. Even though nose fold was not shown to have an effect on BOAS in this study, it is still something quite negative for the breed, and is also stated in the breed standard (FCI-Standard Nº 101, 2015), that heavy nose folds should be heavily penalized and are unacceptable. For the stenosis, less than 5% of the Pugs in the study had open nostrils, which is stated in the breed standard that the Pugs should have (FCI-Standard Nº 101, 2015). This is a serious problem since pinched nostrils are an important risk factor for developing BOAS. Even the BSI states that pinched nostrils should not cause forced breathing (The Nordic Kennel Clubs, 2018).

In this study about 34.4% of the Pugs were BOAS affected which is very alarming. When compared to the general results, the Pugs breed means were lower for snout length, sternum length and craniofacial ratio than compared to the BOAS affected dogs across all the four breeds in this study. For the snout length and sternum length, the explanation is that the Pugs are the smallest of the breeds in this study. However, the craniofacial ratio is quite alarming because this is not affected by the size of the dog. Craniofacial ratio was also a risk factor found in previous studies (Packer *et al.,* 2012, 2015). What is positive is that the breed mean value and median value were higher than in the previous studies (Packer *et al.,* 2012, 2015), but still needs to improve by selecting longer snouts. Packer *et al.* (2015) also found that if the craniofacial ratio was 0.21, the BOAS risk would be 48% and less than 25% of the Pugs in this study had craniofacial ratio around 0.21.

According to the survey the perceived health, welfare and BOAS-related problems, except for syncope, were connected to age for Pugs in this study. This means that the older the dog gets the worse health and welfare the owner perceives them to have and the higher frequency of dogs with the problems. The explanation to why the syncope is not correlated to age could be the low frequency in all age categories and therefore the difference between the age categories were not large enough to become significant. Though when analyzing the correlation between all of the BOAS-related problems all of the problems were correlated to each other, except for syncope, which was only correlated to exercise intolerance. All BOAS-related problems were correlated to perceived poor health and poor welfare, except for syncope. 89% of the Pugs were perceived as healthy and 92% with good welfare, which could imply that the owners of Pugs perceive the breed as unhealthier than with poor welfare. Another explanation is that some owners do not consider health problems or BOAS-related problems as welfare problems. It could also imply that the health problems considered when answering the survey are not connected to BOAS and therefore did not affect the welfare answers. In the study population of Pugs about 70% of the dogs had at least one of the BOAS-related problems and about 58% of the Pugs perceived as healthy and with good welfare had at least one problem which is quite alarming. Though for the Pugs the owners perceived that the dogs with up to two of the problems were healthy and with good welfare, which means that some of the BOAS-related problems are normalized. The problems are most likely to be noisy breathing and heat intolerance because they are the most common problems.

As a previous study has shown (Packer *et al.,* 2015) Pugs have a 48-97% risk of developing BOAS and therefore it is an important aspect to involve in the breeding of Pugs. All of the laws and regulations stated in this study states that breeding should not be done if the offspring has a higher risk of developing diseases or problems, which this study shows that BOAS is a problem that should be considered.

4.6 Errors in study and further investigations

One error of this study was that the inventory had a very small study population. It would therefore be interesting to see if the results would be the same with a larger population. It would also be interesting to do the same analysis but with a different selection, to better represent the Swedish population. It would also be interesting to investigate how large the proportion of dogs that are operated for BOAS in Sweden and how this affects the welfare and health of the animals perceived by the owners. One improvement of the survey would be to include the question about if the dog has gone through BOAS-related surgery, since this can affect the results. It would also be interesting to investigate the other health problems that these dog breeds have, like problems with eyes, backs or extremities.

5 Conclusion

According to the results in this study a conclusion can be made that there is enough phenotypic variance to improve the BOAS problem for both French Bulldogs and English Bulldogs. For Boston Terriers the BOAS problem was not severe enough to get a result and the population was too small, so a further investigation would be needed. For the Pugs, the situation is quite alarming, the phenotypic variance is too small and there was no significant difference for the foreign Pugs as well, so there need to be a more drastic approach to improve the BOAS problem in this breed. They might have to consider opening the studbook to achieve more phenotypic variation. For the welfare aspect this study showed that BOAS is a welfare problem and that there is a normalization for some of the problems connected to BOAS for English Bulldogs, French Bulldogs and Pugs which needs to be addressed.

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Appendix 1 – Survey

Fråga 1. Vilken ras har du?

Boston Terrier
Fransk Bulldogg
Engelsk Bulldogg
Mops

Fråga 2. Hur gammal är hunden?

0–2 år
3–8 år
9+ år

Fråga 3. Anser du att din hund är frisk?

Ja
Nej
Vet inte

Fråga 4. Har din hund någon av nedanstående problem?

Sömnproblem (ex de får inte luft när de somnar så de vaknar igen, har svårt att sova på mage på platt golv utan sover tex ofta på rygg, sittandes eller liggandes med huvudet på en kudde eller ett armstöd)?

  Ja
  Nej
  Vet inte

Ljudlig andning och/eller snarkningar?

  Ja
  Nej
  Vet inte

Värmeintolerans (tex blir lätt överhettade)?

  Ja
  Nej
  Vet inte

Motionsintolerans (tex behöver pausa under promenad, behöver lång tid för återhämtning efter motion)?

  Ja
  Nej
  Vet inte

Syncopes (Kollapsar och blir medvetslös under en kort period men återhämtar sig sedan snabbt?

Ja

Nej

Vet inte

Svårigheter att äta och svälja (tex uppstötningar och kräkningar)?

Ja

Nej

Vet inte

Med avseende på fråga 4, anser du att din hund har god välfärd?

Ja

Nej

Vet inte

Appendix 2 – Survey statistics

General statistics

Table 3. *Variables analysed and compared to age*

	Chi square value	p-value	Adjusted p-value
Health	29.3241	<.0001	0.0001
Welfare	20.6653	0.0004	0.0004
Noisy breathing	10.8774	0.028	0.0286
Heat intolerance	105.8981	<.0001	0.0001
Sleeping disorders	20.1269	0.0005	0.0005
Exercise intolerance	55.7156	<.0001	0.0001
Eating disorders	5.6795	0.2244	0.2244
Syncope	24.0012	<.0001	0.0001

Table 4. *BOAS-related problems analysed and compared*

		Chi square value	p-value	Adjusted p-value
Noisy breathing	Heat intolerance	183.8654	<.0001	0.0001
Noisy breathing	Sleeping disorders	105.5626	<.0001	0.0001
Noisy breathing	Exercise intolerance	96.044	<.0001	0.0001
Noisy breathing	Eating disorders	70.7077	<.0001	0.0001
Noisy breathing	Syncope	19.6222	0.0006	0.0006
Heat intolerance	Sleeping disorders	113.7077	<.0001	0.0001
Heat intolerance	Exercise intolerance	202.1787	<.0001	0.0001
Heat intolerance	Eating disorders	60.1207	<.0001	0.0001
Heat intolerance	Syncope	13.7359	0.006	0.0063
Sleeping disorders	Exercise intolerance	236.3618	<.0001	0.0001
Sleeping disorders	Eating disorders	176.1621	<.0001	0.0001
Sleeping disorders	Syncope	43.8722	<.0001	0.0001
Exercise intolerance	Eating disorders	133.414	<.0001	0.0001
Exercise intolerance	Syncope	73.7945	<.0001	0.0001
Eating disorders	Syncope	64.0744	<.0001	0.0001

Table 5. *Variables analysed and compared to health answers*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	69.4131	<.0001	0.0001
Heat intolerance	158.5305	<.0001	0.0001
Sleeping disorders	176.7544	<.0001	0.0001
Exercise intolerance	199.0578	<.0001	0.0001
Eating disorders	112.0378	<.0001	0.0001
Syncope	46.4844	<.0001	0.0001

Table 6. *Variables analysed and compared to welfare answers*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	119.736	<.0001	0.0001
Heat intolerance	152.821	<.0001	0.0001
Sleeping disorders	410.9181	<.0001	0.0001
Exercise intolerance	280.3051	<.0001	0.0001
Eating disorders	288.9256	<.0001	0.0001
Syncope	68.8344	<.0001	0.0001

Table 7. *Variables analysed and compared to the combined health and welfare answers*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	67.3132	<.0001	0.0001
Heat intolerance	93.731	<.0001	0.0001
Sleeping disorders	352.8168	<.0001	0.0001
Exercise intolerance	305.4715	<.0001	0.0001
Eating disorders	213.5294	<.0001	0.0001
Syncope	99.8824	<.0001	0.0001

Boston Terrier statistics

Table 8. *Variables analysed and compared to age – Boston Terrier*

	Chi square value	p-value	Adjusted p-value
Health	2.5469	0.4359	0.5691
Welfare	6.6031	0.2221	0.3163
Noisy breathing	1.016	0.6016	0.725
Heat intolerance	18.0583	0.0011	0.0034
Sleeping disorders	1.1037	0.8027	0.8983
Exercise intolerance	14.7865	0.0301	0.0566
Eating disorders	3.0716	0.6533	0.7676
Syncope	1.2407	0.5307	0.6564

Table 9. *BOAS-related problems analysed and compared – Boston Terrier*

		Chi square value	p-value	Adjusted p-value
Noisy breathing	Heat intolerance	16.2736	0.0003	0.0011
Noisy breathing	Sleeping disorders	17.4167	<.0001	0.0005
Noisy breathing	Exercise intolerance	5.1192	0.0745	0.1251
Noisy breathing	Eating disorders	15.7833	<.0001	0.0005
Noisy breathing	Syncope	1.3811	0.4211	0.5655
Heat intolerance	Sleeping disorders	7.6194	0.0678	0.118
Heat intolerance	Exercise intolerance	23.822	0.0005	0.0017
Heat intolerance	Eating disorders	16.7345	0.0029	0.0076
Heat intolerance	Syncope	11.7181	0.0789	0.1279
Sleeping disorders	Exercise intolerance	2.4075	0.3908	0.5402
Sleeping disorders	Eating disorders	19.2553	0.0056	0.0139
Sleeping disorders	Syncope	0.0558	1	1
Exercise intolerance	Eating disorders	5.8179	0.1229	0.1863
Exercise intolerance	Syncope	0.0413	1	1
Eating disorders	Syncope	0.0657	1	s

Table 10. *Variables analysed and compared to health answers – Boston Terrier*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	11.8839	0.0015	0.0041
Heat intolerance	21.7421	0.0015	0.0041
Sleeping disorders	38.1974	0.0002	0.0008
Exercise intolerance	17.3734	0.0152	0.0325
Eating disorders	8.8959	0.0962	0.1507
Syncope	0.1073	1	1

Table 11. *Variables analysed and compared to welfare answers – Boston Terrier*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	22.0775	<.0001	0.0005
Heat intolerance	10.447	0.0282	0.0552
Sleeping disorders	80.8266	<.0001	0.0005
Exercise intolerance	16.451	0.0359	0.0649
Eating disorders	35.9855	<.0001	0.0005
Syncope	37.163	0.0263	0.0537

Table 12. *Variables analysed and compared to the combined health and welfare answers – Boston Terrier*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	7.9703	0.0085	0.019
Heat intolerance	0.7331	0.6723	0.7707
Sleeping disorders	59.3619	0.0002	0.0008
Exercise intolerance	0.1529	1	1
Eating disorders	3.6076	0.2011	0.2954
Syncope	-	-	-

English Bulldog statistics

Table 13. *Variables analysed and compared to age – English Bulldog*

	Chi square value	p-value	Adjusted p-value
Health	15.0639	0.0089	0.0186
Welfare	6.8027	0.1255	0.1673
Noisy breathing	0.6296	0.73	0.7617
Heat intolerance	9.9966	0.0624	0.0936
Sleeping disorders	2.3467	0.1947	0.2396
Exercise intolerance	2.2069	0.4914	0.5361
Eating disorders	0.7851	0.8159	0.8333
Syncope	10.7182	0.1064	0.1485

Table 14. *BOAS-related problems analysed and compared – English Bulldog*

		Chi square value	p-value	Adjusted p-value
Noisy breathing	Heat intolerance	17.7579	<.0001	0.0004
Noisy breathing	Sleeping disorders	10.214	0.0011	0.0031
Noisy breathing	Exercise intolerance	15.7972	0.0001	0.0004
Noisy breathing	Eating disorders	2.444	0.1567	0.2033
Noisy breathing	Syncope	3.3083	0.1083	0.1485
Heat intolerance	Sleeping disorders	8.1308	0.023	0.0381
Heat intolerance	Exercise intolerance	50.9031	<.0001	0.0004
Heat intolerance	Eating disorders	0.08292	0.6122	0.653
Heat intolerance	Syncope	3.7087	0.407	0.4651
Sleeping disorders	Exercise intolerance	15.3137	0.0044	0.0106
Sleeping disorders	Eating disorders	8.975	0.0384	0.0614
Sleeping disorders	Syncope	0.1329	1	1
Exercise intolerance	Eating disorders	20.2528	0.0042	0.0106
Exercise intolerance	Syncope	5.0154	0.255	0.2985
Eating disorders	Syncope	12.0994	0.108	0.1485

Table 15. *Variables analysed and compared to health answers – English Bulldog*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	1.6687	0.4364	0.4871
Heat intolerance	18.196	0.001	0.003
Sleeping disorders	27.7033	0.0002	0.0007
Exercise intolerance	30.9434	<.0001	0.0004
Eating disorders	11.9312	0.0109	0.0217
Syncope	122.3269	0.0003	0.001

Table 16. *Variables analysed and compared to welfare answers – English Bulldog*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	7.841	0.0137	0.0244
Heat intolerance	13.5157	0.0113	0.0217
Sleeping disorders	54.9131	<.0001	0.0004
Exercise intolerance	17.9682	0.0062	0.0142
Eating disorders	20.2678	0.0072	0.0157
Syncope	9.4256	0.1714	0.2165

Table 17. *Variables analysed and compared to the combined health and welfare answers – English Bulldog*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	6.43	0.0146	0.025
Heat intolerance	10.8272	0.0124	0.0229
Sleeping disorders	62.7969	<.0001	0.0004
Exercise intolerance	26.4189	0.001	0.003
Eating disorders	23.8334	0.0023	0.0061
Syncope	20.5509	0.0466	0.0722

French Bulldog statistics

Table 18. *Variables analysed and compared to age – French Bulldog*

	Chi square value	p-value	Adjusted p-value
Health	18.4409	0.0004	0.0005
Welfare	14.5982	0.0039	0.0045
Noisy breathing	2.913	0.5725	0.5725
Heat intolerance	50.7203	<.0001	0.0001
Sleeping disorders	11.4844	0.0097	0.0106
Exercise intolerance	39.8179	<.0001	0.0001
Eating disorders	5.7059	0.1337	0.1365
Syncope	11.9656	0.0086	0.0096

Table 19. *BOAS-related problems analysed and compared – French Bulldog*

		Chi square value	p-value	Adjusted p-value
Noisy breathing	Heat intolerance	94.9512	<.0001	0.0001
Noisy breathing	Sleeping disorders	60.0674	<.0001	0.0001
Noisy breathing	Exercise intolerance	50.2729	<.0001	0.0001
Noisy breathing	Eating disorders	48.1138	<.0001	0.0001
Noisy breathing	Syncope	9.2442	0.0344	0.0359
Heat intolerance	Sleeping disorders	70.229	<.0001	0.0001
Heat intolerance	Exercise intolerance	125.0812	<.0001	0.0001
Heat intolerance	Eating disorders	39.761	<.0001	0.0001
Heat intolerance	Syncope	12.7687	0.0099	0.0106
Sleeping disorders	Exercise intolerance	184.847	<.0001	0.0001
Sleeping disorders	Eating disorders	114.4596	<.0001	0.0001
Sleeping disorders	Syncope	57.5851	<.0001	0.0001
Exercise intolerance	Eating disorders	81.1493	<.0001	0.0001
Exercise intolerance	Syncope	71.7486	<.0001	0.0001
Eating disorders	Syncope	72.1588	<.0001	0.0001

Table 20. *Variables analysed and compared to health answers – French Bulldog*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	63.8627	<.0001	0.0001
Heat intolerance	90.2729	<.0001	0.0001
Sleeping disorders	100.5386	<.0001	0.0001
Exercise intolerance	143.1135	<.0001	0.0001
Eating disorders	77.0765	<.0001	0.0001
Syncope	45.1583	<.0001	0.0001

Table 21. *Variables analysed and compared to welfare answers – French Bulldog*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	67.2724	<.0001	0.0001
Heat intolerance	90.1952	<.0001	0.0001
Sleeping disorders	246.3444	<.0001	0.0001
Exercise intolerance	190.2743	<.0001	0.0001
Eating disorders	177.437	<.0001	0.0001
Syncope	77.1589	<.0001	0.0001

Table 22. *Variables analysed and compared to the combined health and welfare answers – French Bulldog*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	42.7549	<.0001	0.0001
Heat intolerance	57.8776	<.0001	0.0001
Sleeping disorders	216.6071	<.0001	0.0001
Exercise intolerance	215.7684	<.0001	0.0001
Eating disorders	147.7195	<.0001	0.0001
Syncope	127.0044	<.0001	0.0001

Pug statistics

Table 23. *Variables analysed and compared to age – Pug*

	Chi square value	p-value	Adjusted p-value
Health	15.2339	0.0018	0.0025
Welfare	21.1173	<.0001	0.0002
Noisy breathing	14.1682	0.0027	0.0036
Heat intolerance	36.698	<.0001	0.0002
Sleeping disorders	8.1845	0.0446	0.0549
Exercise intolerance	16.9145	0.0003	0.0005
Eating disorders	7.9068	0.0495	0.0594
Syncope	8.5176	0.1061	0.1213

Table 24. *BOAS-related problems analysed and compared – Pug*

		Chi square value	p-value	Adjusted p-value
Noisy breathing	Heat intolerance	45.7893	<.0001	0.0002
Noisy breathing	Sleeping disorders	18.7891	<.0001	0.0002
Noisy breathing	Exercise intolerance	24.1638	<.0001	0.0002
Noisy breathing	Eating disorders	9.4504	0.0285	0.036
Noisy breathing	Syncope	7.1577	0.0611	0.0715
Heat intolerance	Sleeping disorders	25.747	<.0001	0.0002
Heat intolerance	Exercise intolerance	35.2594	<.0001	0.0002
Heat intolerance	Eating disorders	14.2968	0.0017	0.0024
Heat intolerance	Syncope	2.4301	0.5561	0.5561
Sleeping disorders	Exercise intolerance	230.8647	<.0001	0.0002
Sleeping disorders	Eating disorders	46.513	<.0001	0.0002
Sleeping disorders	Syncope	4.4796	0.2462	0.2686
Exercise intolerance	Eating disorders	36.8131	<.0001	0.0002
Exercise intolerance	Syncope	24.1288	<.0001	0.0002
Eating disorders	Syncope	3.9962	0.2961	0.3158

Table 25. *Variables analysed and compared to health answers – Pug*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	4.3213	0.3144	0.3281
Heat intolerance	41.9108	<.0001	0.0002
Sleeping disorders	34.0895	<.0001	0.0002
Exercise intolerance	20.9581	<.0001	0.0002
Eating disorders	19.2829	<.0001	0.0002
Syncope	3.6209	0.2163	0.2415

Table 26. *Variables analysed and compared to welfare answers – Pug*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	24.6005	<.0001	0.0002
Heat intolerance	39.7009	<.0001	0.0002
Sleeping disorders	79.2118	<.0001	0.0002
Exercise intolerance	74.9932	<.0001	0.0002
Eating disorders	72.509	<.0001	0.0002
Syncope	16.7534	0.0241	0.0313

Table 27. *Variables analysed and compared to the combined health and welfare answers – Pug*

	Chi square value	p-value	Adjusted p-value
Noisy breathing	11.1993	0.0012	0.0017
Heat intolerance	25.7276	<.0001	0.0002
Sleeping disorders	36.6648	<.0001	0.0002
Exercise intolerance	68.8702	<.0001	0.0002
Eating disorders	30.8438	<.0001	0.0002
Syncope	1.2715	0.3885	0.3968

Appendix 3 – Popular scientific summary

Kan förändringar i trubbnosiga rasers utseende minska andningsproblematiken?

Att trubbnosiga hundraser har problem med andningen är vedertaget, men hur allvarliga är problemen i Sverige? Finns de tillräckligt med variation i utseendet hos dessa hundraser för att minska problematiken? Och hur är välfärden för dessa hundarna? Detta undersökte Ida Bertilsson i sitt examensarbete som Husdjursagronom på Sveriges Lantbruksuniversitet, SLU, i samarbete med Svenska Kennelklubben.

Andningsproblematiken BOAS, Brachycephalic obstructive airway syndrome, är ett syndrom där hunden på grund av den korta nosen får trångt i och runt luftvägarna och är speciellt vanligt hos trubbnosiga hundraser. Detta syndrom har undersökts i flera tidigare forskningsstudier, främst på Universitetet i Cambridge i England. I dessa studier har man kunnat koppla ihop utseendet hos hunden med andingsproblematiken samt konstaterat att BOAS är vanligast hos mops, engelsk bulldogg, fransk bulldogg och bostonterrier. Men hur är de egentligen med de svenska trubbnosiga raserna?

Genom en enkät utskickad till hundägare av dessa hundraser så ansågs ungefär hälften av hundarna ha problem med ljudlig andning och en tredjedel ha problem med värme. Andra problem som förekom var svårigheter att äta och svälja, problem med att somna och sova, behov utav pauser under promenader, behov av lång återhämtning efter motion och problem med att hundar svimmar av på grund utav syrebrist. Problematiken kan därför konstateras vara allvarlig även här i Sverige. Att detta är ett hälso- och välfärdsproblem för dessa hundar är självklart, vilket även hundägare till dessa raser visade i enkäten. Dock visade studien också en normalisering av några av problemen, främst problemen med ljudlig andning och värmeintolerans. Detta behöver åtgärdas om en förändring och minskning av andningsproblematiken ska kunna ske. Men vad kan man göra för att minska BOAS? Forskargrupperna från universitetet i Cambridge har kopplat BOAS-problematiken till hundars utseende. Men stämmer även detta på den svenska populationen?

I examensarbetet, i samarbete med SKK:s inventering, så kan man se att de finns vissa exteriöra faktorer som har en koppling till andningsproblematiken. Hur skallen, nosen och bröstkorgen är utformad har visats ha påverkan på hur stor risk hunden har för att utveckla BOAS. En längre nos, mer öppna näsborrar och större bröstkorg visar sig oftast bidra till mindre andningssvårigheter hos främst fransk- och engelsk bulldogg. För bostonterrier fanns de inte tillräckligt många individer med BOAS-problematik i studien för att kunna dra några slutsatser, dock betyder detta inte att bostonterrier som ras inte har problem med andningen, och en felaktig avel skulle kunna ge ökade problem. För mops så fanns de inga skillnader i utseendet mellan individer med andningsproblem och individer utan, vilket tyder på att mopsarna är för homogena och variationen för liten för att kunna basera aveln mot friskare hundar på utseendet. Eftersom situationen med BOAS är mycket allvarlig inom rasen bör kraftiga åtgärder vidtas.