



Thick-skinned or just a little chubby?

A clinical study of skinfold thickness measured with a caliper in different dog breeds

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Thick-skinned or just a little chubby? A clinical study of skinfold thickness measured with a caliper in different dog breeds.

Tjockhudad eller bara lite knubbig? En klinisk studie av tjocklek på hudveck mätt med skjutmått på olika hundraser.

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Abstract

In the clinical assessment of dogs, or in rehabilitation plans, the evaluation of body condition score (BCS) is a part of assessing the dog's health and nutritional status. However, BCS is not sufficient as a measuring tool as it is subjective. When creating a weight loss plan for fat loss or a rehabilitation plan for muscle gain, there is a need to establish the baseline and evaluate if the goals are met at follow-up appointments. There are several validated methods to assess fat mass/lean mass in dogs, however, most of these methods are not applicable for a clinical setting. Thus, there is a need for a reliable, repeatable and cost-effective method, that may help to assess the dog's fat mass. In the human field, skinfold calipers are being used for fat mass assessment. The aim of the study was to investigate if skinfold thickness measured with a caliper, can be a useful complementary evaluation method in the clinic, for nutritional assessments of dogs. The specific objectives of the study were to evaluate intra- and inter-observer reliability of caliper measurements and to investigate the correlation to BCS in alive and dead dogs. In addition, the study investigated the potential influence of breed on the skinfold thickness in normal weight to slightly overweight individuals.

This study investigated 20 dogs of four different breeds (border collie, cavalier king Charles spaniel, French bulldog and labrador retriever) in a clinical setting. Data from this clinical study were also compared with data from another cohort where 23 dead dogs of different breeds were measured. All dogs from both cohorts were measured by caliper measurements in triplicates at three locations (the neck, the axilla and the lumbar back) by two observers in a blinded procedure.

The intra- and inter-observer reliability presented as intraclass correlation coefficient (ICC) of the measurements differed for the different locations. For observer 1, intra-observer reliability was 0.965 for the neck, 0.848 at the axilla and 0.987 at the lumbar back. For observer 2, the corresponding ICC was 0.971, 0.880 and 0.972. The inter-observer reliability was analysed for the different locations and ICC at the neck was 0.899, at the axilla 0.816 and the lumbar back 0.774. The correlations of the measurements at the different locations to BCS were examined and were all significant (P-value for the neck was 0.028, for the axilla: 0.001 and for the lumbar back: 0.034). When analysing the measurements by breed, there were some differences. The border collie as a group showed significant differences in regards of thinner skinfold thickness, compared to all other breed groups in the location of the neck, as well as with the labrador group in the locations of the axilla and at the lumbar back. The cavalier group showed significant differences in the locations of the neck and lumbar back compared to the labrador group. Significant differences between breeds groups were noted in the location of the neck in 50% paired comparisons, as compared to only 17% at the axilla. In the French bulldog group, individuals measured thicker skin folds than individual border collies, which suggest that both the breed type and the size (weight and height) of the dog, may cause discrepancies.

The analyses indicated that the ICC was classified as good, however, both the dog and the examiner should be familiarised with the procedure. Measurements in triplicate would preferably be performed and used to calculate a mean value for the location. Caliper measurements may be used clinically when the dog acts as its own control, as in a follow up in a weight loss/weight gain program as the ICC was classified as good to be used within or between assessors. The analyses indicate a positive correlation between skinfold thickness and BCS in normal to slightly overweight dogs, however there is a need for further investigations regarding how breed may influence the results. Further studies containing extended sample sizes would be preferred, including also Dual Energy X-ray Absorptiometry (DEXA) comparisons. Studies on different breeds, such as brachycephalic dogs, can give an indication if skin conformity is a variable to consider when using the method in clinical practice. Further longitudinal studies should be

performed, to give more information about the usefulness of the method in detecting changes in the dog's fat and body composition over time.

Keywords: BCS, body composition, brachycephalic, DEXA, fat mass, intra- and inter-observer reliability, skinfold caliper, skinfold thickness, overweight

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Abbreviations

BCS	Body Condition Score
BIA	Bioelectrical impedance analysis
DEXA	Dual Energy X-ray Absorptiometry
BF%	Body fat percentage
ICC	Intraclass Correlation Coefficient
SD	Standard deviation
SEM	Standard error of mean
SLU	Swedish University of Agricultural Sciences

1. Introduction

Measurement of body weight and assessment of body condition score (BCS) are common methods in clinical settings in veterinary medicine as a part of assessing the overall health and nutritional status of dogs. Laflamme (1997) recommends not using body weight alone as a parameter for nutritional status, as the measurement cannot distinguish fat from lean mass. Burkholder (2000), Laflamme (1997) and de Souza Buzo et al. (2023) suggest that the BCS scoring is a reliable tool for clinical assessment of fat mass, although it is semi-subjective. However, de Souza Buzo et al. (2023) comments that there may be discrepancies between observers as differences in vision may be present. Laflamme (2006) proposed the use of the BCS system which Laflamme (1997) developed. This is a 9-point BCS scale, which today is the most commonly used BCS system in veterinary clinical practice (Santarossa et al. 2018), as in research studies. Evaluation of body fat and lean mass is a part of the assessment of the general health of a dog and recording of changes in these components are useful to ensure that a nutritional and/or rehabilitation plan is working appropriately (Laflamme 1997; Gille et al. 2023). This information is important to the veterinary staff for any adjustments in the treatment plan. For the owner, the information may keep them motivated to continue following a plan (Bockstahler et al. 2019). The most common nutritional treatment and/or rehabilitation goals are to reduce body fat in an obese patient, without losing lean tissue (Laflamme 2006) or to gain muscle mass in a patient going through rehabilitation (Millis & Ciuperca 2015). In either situation, the need of an objective and reliable tool for initial evaluation and for follow up is crucial, to be able to perform appropriate adjustments of the treatment. To increase owners' knowledge and provide positive reinforcement are keys in client communication (Maddison et al. 2021). This is enabled by using an objective measurement tool (Bockstahler et al. 2019; Brookes et al. 2024), increasing the likelihood of compliance with a certain treatment regime.

Different objective measurement tools have been investigated to assess fat and/or lean muscle mass in dogs, such as radiography, ultrasound, dual x-ray absorptiometry (DEXA), bioelectrical impedance analysis (BIA) and measuring tape (de Souza Buzo et al. 2023; Rae et al. 2024; Söder et al. 2024). Using DEXA to establish body composition (distribution between fat and lean mass) has been validated in dogs (German et al. 2010; Jeusette et al. 2010; Laflamme 1997). It has been shown that DEXA is reliable, repeatable and shows good correlation to BCS as to analysis made on dead dogs (Case et al. 2011; Eskol Svenningsen & Baltzer Larsen 2025; Laflamme 1997). The DEXA method is therefore considered the gold standard technique for assessment of total body fat and lean mass content (Case et al. 2011; Eskol Svenningsen & Baltzer Larsen 2025; Laflamme 1997). However, radiography, ultrasound and DEXA are not easily used in clinical

settings, as the methods require sedation of the dog, skilled personnel and are costly (Case et al. 2011). Rae et al. (2024) showed that BIA could be used in a clinical setting, however, it is expensive to purchase the equipment and some dogs requires clipping and/or sedation for the procedure. Ugras (2020) and Yaguiyan-Colliard et al. (2015) mentions that BIA is a useful tool in healthy animals, however, Coppini et al. (2005), found BIA limiting when it comes to patients that are not healthy, for example dehydrated, malnourished or with tumours. Yaguiyan-Colliard et al. (2015) also mentions that the method is not yet evaluated for different breeds, which may influence the outcome and the interpretation of the results. The goal would be to find an uncomplicated, low-cost method for assessment of body composition that correlates to golden standard DEXA, and in addition, displays high both intra- and inter-observer reliability that can be used in veterinary clinics. Assessing the fat mass and associate this to BCS and enhance the body composition assessment, may give the clinician a valuable tool to apprise a feasible treatment/rehabilitation plan for the dog.

One device that may be used for measurement of nutritional status, is a skinfold caliper. A caliper consists of a pair of measurements “jaws”, in between which the object that is measured is placed. When the jaws are closed, the distance between the jaws is measured. The device can have an analogue or a digital display (Esparza-Ros et al. 2022). A skinfold caliper is used to measure the compressed skinfold thickness of the subcutaneous adipose tissue, including the double layer of skin (Cintra-Andrade et al. 2023; Zanna et al. 2012). According to Cintra-Andrade et al. (2023), the method has shown to be reliable in humans when using the equipment correctly and when the maintenance of the caliper is up to date. The difference in pressure may be ≤ 2.0 g/mm² between upward and downward pressure, but are considered trivial and have been generalised as tolerable to any type of skinfold caliper. Studies performed in humans show variances between different calipers and it is therefore recommended to perform all repeated measurements with the same type of device (Esparza-Ros et al. 2022; Lewandowski et al. 2022). One previous study in dogs has shown that BCS correlated with measurements of skinfold thickness (de Souza Buzo et al. 2023). According to Cintra-Andrade et al. (2023), the Harpenden® skinfold caliper is providing a determined static and dynamic calibration by the pressure of the jaws and is thus recommended for accurate measurements. If the calibration is made, the difference in pressure should not differ more than mentioned above and a calibration is recommended to be done annually (Cintra-Andrade et al. 2023; Kirk 2024). The Harpenden® skinfold caliper has to the author’s knowledge, not been used previously in dogs.

The skin is a complex structure and it consists of three layers (from internal to the external layer); the hypodermis, the dermis, and the epidermis. The hypodermis (the subcutaneous tissue) segment primarily consists of lipids

(Pavletic 1991; Souci & Denesvre 2021). The hypodermis contains adipose tissue and contributes to the measured mass in the skinfold (*Physical and Clinical Assessment of Nutrition Status* 2014; Zwick et al. 2018). Souci & Denesvre (2021) explains the skin structure as following: “The thickness of the skin is mostly formed by the dermis which is connected to the epidermis by a basal membrane”. The morphological aspect and thickness of the skin varies between species, breed, and even genders, age, and body location (Diana et al. 2008; Hobi et al. 2023). The epidermis differs between humans and dogs, for example in thickness and in layering; dogs have less intercellular matrix than other species, resulting in a thin epidermis with dense epidermal layers (Theerawatanasirikul et al. 2012). According to Souci and Denesvre (2021), the overall skin structure is well represented across different mammalian species and body sites, although in the interfollicular epidermis, the number of stacked cells in a layer can vary depending on the species. For dogs, the stratum spinosum has one or two cell layers in the haired-skin regions and up to four in humans (Souci & Denesvre 2021).

Zwick et al (2018) suggests that there are some differences between humans and other mammals, regarding the deposits of fat in the hypodermis. There are also some notable differences in dermis/epidermis, between humans and dogs (Pavletic 1991; Theerawatanasirikul et al. 2012), and this may lead to a need for evaluation of the caliper-method accuracy in dogs. So far, only one study (de Souza Buzo et al. 2023) has used a skinfold caliper (other than Harpenden®) for measurements of skinfold thickness at the lumbar area of dogs of 21 different breeds. The study found a positive correlation between the skinfold thickness and the BCS of the included dogs. Further evaluation of the skinfold caliper in veterinary setting is suggested by de Souza Buzo et al. (2023) to assess if it a useful tool in nutritional assessment of dogs.

In many medical fields (including veterinary medicine), decisions regarding treatment are based on observations and examinations performed by the health professional (Vanbelle et al. 2024). The concepts of reliability, repeatability, reproducibility and predictability, are of importance in these cases (Harvey 2024; Laflamme 1997; Vanbelle et al. 2024). Reliability can be divided in intra- and inter-observer reliability. Harvey (2024) and Vanbelle (2024) explain that intra-observer reliability describes the consistency of the measurements/observations, made by the same observer on the same patient, in a short time frame. Inter-observer reliability on the other hand, describes the consistency in measurements/observations between two (or more) different observers, in an identical situation on the same patient.

The use of less expensive and less personal demanding equipment may result in that fat mass could be more frequently evaluated in clinical settings, but the assessment method used still needs to be objective and reliable. The method

should preferably complement BCS and enhance the prediction of bodyfat percentage, as BCS may be less objective and might not acknowledge smaller changes in body composition. The skinfold caliper is a simple equipment that is used in human medicine and in human athlete and sport training (Cintra-Andrade et al. 2023; Tornero-Aguilera et al. 2022), to evaluate fat mass and the caliper could be a useful tool also for dogs. As skin conformity differs between humans and dogs, and some dog breeds differs from each other, the method needs to be evaluated for reliability in a clinical setting and compared to assess fat mass as in the form of BCS, in dogs of different breeds.

The hypothesis is that there will be differences in skin fold thickness, between different normal weight dogs of different breeds of different sizes (under/over 14 kg). The hypothesis is also that French bulldogs will have thicker skin folds, compared to other breeds within the same size and BCS.

1.1 Aim

The overall aim of the study was to investigate if the skinfold thickness measured with a caliper in a veterinary clinical setting can be a useful complementary evaluation method in nutritional assessments of dogs. The specific objectives of the study were to evaluate intra-and inter-observer reliability of caliper measurements and to investigate the correlation to BCS in alive and dead dogs. In addition, the study investigated the potential influence of breed on the skinfold thickness in normal weight to slightly overweight individuals.

1.2 Research questions

- How is the intra-observer reliability between measurements in triplicate with a skinfold caliper in alive compared to in dead dogs?
- How is the inter-observer reliability of measurements of skinfold thickness with a caliper in alive compared to in dead dogs?
- How do measurements with a skinfold caliper correlate with assessed BCS in alive and dead dogs, divided normal weight and overweight?
- How does the specific breed of dog relate to the thickness of the skinfold as measured by a skinfold caliper in normal weight to slightly overweight, alive dogs of four different breeds?

2. Material and method

2.1 General study design

This study compared two different cohort of dogs. One cohort consisted of data from a previous study performed at a veterinary hospital in Denmark by the veterinary students Eskol Svenningsen & Baltzer Larsen (2025).

The other dog cohort consisted of dogs measured in the current clinical study, which is an independent project in Veterinary nursing. The clinical study was performed at a small animal veterinary clinic in Sweden.

Both cohorts held animal ethic permission. The Danish permission was issued by “The Local Ethical and Administrative Committee” of the Department of Veterinary Clinical Sciences, Dyrhavevej 16, DK-1870 Frederiksberg C: 2024-24. The permission of the clinical was issued by “SLU:s djuretiska tillstånd” with SLU-ID: Dnr 5.8.18-12184/202.

2.2 Study population and recruitment

2.2.1 The Danish cohort

In the Danish study, the measurements were executed in dead dogs and the cohort consisted of 23 dogs of 14 different breeds, and the BCS range was from 2-9 (Eskol Svenningsen & Baltzer Larsen 2025). The dogs were euthanised for different reasons unrelated to the study and were donated to the study by their owners. The owners signed a written consent form for the euthanised dog being used in research and for educational purposes.

2.2.2 The clinical cohort

In the clinical study, the measurements were executed in a clinical setting, on alive, awake dogs. In this clinical study, there were four different breeds represented, with an aimed BCS of 4-5, i.e. normal weight. The recruitment took place at the clinic. Owners of dogs that were considered suitable, were asked to join the study, either when they were at the clinic or were contacted by the observer by phone. They were getting written (in Swedish) and oral information about the study and were requested to sign an owner consent form. The owner was able to choose to retract the consent and thus the dog from the study at any time. An appropriate time for performing the measurements was assigned, within one to two weeks of being approached.

The four breeds included in the study were selected to represent different conformation and sizes of dogs.

The specific breeds chosen were also selected due to convenience as these show a high representation at the chosen clinic.

2.3 Inclusion and exclusion criteria

2.3.1 The Danish cohort

The dogs needed to be above one year of age and could be of any breed. The dog was excluded if it had a tumour ≥ 5 cm in diameter or a tumour located at a measurement location, were severely dehydrated or had fluid accumulation in the body or suffered from traumatic injury.

2.3.2 The clinical cohort

The dog needed to be adult (above one year of age) to avoid bias related to not being fully grown. The dog needed be healthy (as stated by the owner). The dog would preferably be scored a 4-5 on the BCS as these scores are considered ideal weight (Freeman et al. 2019). The dog needed to be comfortable with standing on an examination table and comfortable with being handled by the observers.

If the dog needed more than two breaks to be at ease, it was to be removed from the study. If the dog could not tolerate being handled without being stressed (stated by the owner or the observer) it was also to be removed from the study. If the dog had any skin condition, endocrine disease or was taking any medication that might affect the skin it was excluded. Dogs considered underweight or obese (BCS of 1-3 or 8-9) were excluded.

2.4 Caliper measurements

The caliper measured the skin in a double layer (skinfold), including the adipose tissue within the hypodermis. The measurements were performed with a Harpenden® skinfold caliper (Baty International Ltd, West Sussex, UK) (figure 1), which was calibrated according to the manufacturer's instructions. Measurements were executed at three locations; the dorsal neck (half the distance from the crista nuchae to the cranio-proximal crest of the scapula), at the cranial thorax at the axilla (at the 4th-5th rib, halfway between the spinal processes of the vertebrae and the sternum) and at the lumbar back (right in between the most cranial part of the wings of ilia). The measurements were performed in triplicates and by two blinded observers, thus doing a total of nine measurements per dog per observer.

The skin was lifted 2-5 cm and the skinfold caliper was placed horizontally for the axilla, and vertically for the dorsal neck and the lumbar back. The height of the skinfold was noted in centimetres with a standard ruler. The lift was made as high as possible without causing stress on the dog. The sequent skinfold measurements were obtained by taking a new grip with the same, subjective height as in the first objective measurement trying to ensure the same

measurement location. The observer performing the measurements did not read the display of the caliper. This was done by the other observer, who also wrote down the measurement in the work sheet.



Figure 1. The equipment used for the measurements: Caliper, measure tape and a ruler.

2.4.1 The Danish cohort

The dogs were placed in ventral recumbency with front limbs pulled cranially and hind limbs caudally, immediately following euthanasia. Within 31 minutes post-euthanasia, the measurements were executed. Only one side of the thorax was evaluated for the axilla, which was randomized.

2.4.2 The clinical cohort

The dog was put on an examination table in the appropriate height for the observer to perform the acquired measurements. The owner stood in front of the dog, to make sure the dog stood still and to enable correct measurements. If the owner or the observers felt the need to use a muzzle, this was to be put on before commencing the measurements. The owner had the opportunity to express if they felt the dog needed a break during measurements. The work sheet where the measurements were noted, also included information about the dog (e.g. breed, age, sex, body weight, neutering status, BCS) and any additional notes regarding the dog (e.g. breaks needed, skin condition or if the dog was moving). The fur was measured at the withers with a standard ruler as well as the height of the skinfold.

The placement of the caliper measurement locations was standardised by the use of a standardised measuring tape from ScandiOrtopedic.

Observer 1 was righthanded and observer 2 was lefthanded but all measurements were performed on and from the left side. The first observer (the student) was instructed by the supervisor in the correct use of the caliper when the instrument was delivered, and the second observer (the co-worker) was instructed by the first observer. The observers did one practice round with one dog when the equipment arrived, to get to know how to handle them. These measurements were not recorded.

2.5 Body condition score assessment and weight

The BCS was assessed according to the 9-point BCS scale developed by Laflamme (1997). Ribs were palpated and the abdominal line was assessed visually from the side and the waistline visually from above. Fat deposits were evaluated at the neck and base of tale, if present.

2.5.1 The Danish cohort

The BCS evaluation was performed primarily by palpating the ribs and the waist was assessed visually from above. For the assessment of the waist, the dog was elevated from the ground by lifting the pelvis and sternum from the ventral side to not disturb the waistline. The lifting was performed either by both observers at once, or by one of the observers, depending on the weight of the dog. The BCS was assessed by the two observers individually and afterwards an agreement was reached on a final score, which was the score recorded as data. Dogs were weighted by the veterinarian performing the euthanasia.

2.5.2 The clinical cohort

Both observers did their own BCS assessment independently and blinded from each other, which was recorded in the work sheet as data. The BCS was made as a single assessment when the dog had arrived at the clinic. The dogs in the clinical study were weighed on the same, calibrated scale when arriving to the clinic.

2.6 Dog size

The Swedish kennel club lists both the cavalier king Charles spaniel and French bulldog as breeds under 35 cm in withers and French bulldogs up to 14 kg (Kennelklubben 2025). Therefore, the cut-off of 14 kg was chosen as a limit for small dog in this study. None of the dogs in either cohort weighed near the cut-

off threshold of 14 kg and this will reduce the risk of the data in the analyses would not be skewed in either direction.

2.7 General data handling and statistical analyses

Microsoft Excel, GraphPad Prism 5.0 (GraphPad Prism Software, Inc., San Diego, CA, United States) RStudio (2023.12.0 + 369 Posit Software, PBC, Boston, United States) were used for data processing and statistical analyses. D'Agostino and Pearson's omnibus normality tests were used to evaluate the normal distribution of the caliper data. All caliper data in both cohorts and at each location, were normally distributed using all dogs from the two different cohorts, respectively. The caliper data compared between the different breeds was not normally distributed and was compared with Kruskal-Wallis test followed by Dunn's Multiple Comparison Test. The results are presented as mean value $\pm$ standard deviation (SD), except when expressing the precision of measurements, where standard error of mean (SEM) from the triplicates is used. The means of the triplicate were used to compare the results between the cohorts and between breeds in the clinical cohort, to investigate differences between the observers as well as between the measurements made with the caliper for each observer. The means of the calculated SEMs were used to compare the precision between observers. In both cohorts, the Pearson's correlation coefficient was used for the analyses of correlation to BCS at each location separately. BCS data was inserted in Excel. The data was categorized within the breed groups for the clinical cohort. In the Danish cohort, the BCS data was sorted in BCS groups 4-5 and 6-7

The analysis of intra- and inter-observer reliability (Intra-class correlation coefficient-ICC) of caliper measurements was performed in R. The libraries "tidyverse" and "ICC" in RStudio were used to calculate the intraclass correlation coefficients (ICCs) with the 95% confidence interval (CI) for measurements performed with the caliper. The reliability within the observer (intra-observer reliability) was calculated from the individual triplicates (1, 2, and 3) for each observer at each anatomical location. The reliability between observers (inter-observer reliability) was calculated based on the means of the triplicates from both observers 1 and 2 at each anatomical location. The threshold for statistical significance was set at a p-value of < 0.05 for all analyses.

2.7.1 Data handling in the clinical cohort

The measurements and data were transferred manually from the handwritten worksheets to Microsoft Excel 365 by the student. Analyses were made in Excel to calculate mean of the triplicates for each observer. The dogs were categorised by breed but also by BCS, to calculate means for the measurements of each location within the breed but also for BCS groups 4-5 and 6-7. The mean standard

deviation (SD) for the different cohorts, for the different breed groups and for the different BCS groups were calculated in Excel, as well as standard error of the mean (SEM) for the difference in precision between the observers for all dogs. The SEM indicates the standard deviation for a sample mean (Ejlertsson 2003).

3. Results

3.1 Dog characteristics

Both cohorts consisted of approximately 20 dogs. The dogs in the Danish cohort had been euthanised at the time when the caliper measurements were performed and in the clinical cohort, the dogs were standing and awake. The Danish cohort included several breeds including mixed breeds, which were categorised in this result section as under 14 kg or over 14 kg. The clinical cohort included four breeds: border collies, cavalier king Charles spaniels, French bulldogs and labrador retrievers of gun type. The dogs in the clinical cohort did not have any skin conditions. None of the dogs in the clinical cohort needed to be muzzled or take any breaks during the measurements. Listed in table 1 are the dog characteristics of each cohort.

Table. 1 Dog characteristics

	Danish cohort	Clinical cohort
Dogs total	23	20
Breeds total	14	4
BCS range	2-9	4-7
No of BCS 4-5	13	11
No of BCS 6-7	6	9
Weight range kg (mean)	2-52 (17.8)	8-33 (16.7)
Under 14 kg	11	10
Over 14 kg	12	10
Age range years (mean)	1-15 (6.2)	1-12 (4.7)
Females (neutered)	10 (1)	11 (3)
Males (neutered)	13 (3)	9 (3)
Short fur (<2 cm)	8	8
Long fur (>2 cm)	15	12

3.2 Descriptive statistics of caliper measurements

The mean value of the triplicate for each location and for each cohort is presented in table 2, including means for the triplicates when sectioning for BCS 4-5 and 6-7. Both cohorts showed numerically higher skinfold thickness in overweight dogs (BCS 6-7) compared to in normal weight dogs (BCS 4-5). The Danish cohort showed overall a higher variation in the calliper measurements, as shown by the numerically higher SD compared to the clinical cohort.

Table 2. Mean values of measurements of skinfold thickness in triplicate (mm) including SD, on the three different locations for both dog cohorts.

Mean $\pm$ SD	Danish cohort all dogs	Clinical cohort all dogs	Danish cohort BCS 4-5	Clinical cohort BCS 4-5	Danish cohort BCS 6-7	Clinical cohort BCS 6-7
Neck	8.1 $\pm$ 4.1	7.6 $\pm$ 2.6	6.9 $\pm$ 2.2	6.6 $\pm$ 2.1	11.5 $\pm$ 5.0	8.7 $\pm$ 2.7
Axilla	6.6 $\pm$ 3.5	7.4 $\pm$ 1.6	5.7 $\pm$ 2.0	6.3 $\pm$ 1.0	9.9 $\pm$ 4.9	8.7 $\pm$ 1.3
Lumbar	8.1 $\pm$ 3.5	9.3 $\pm$ 2.4	6.9 $\pm$ 2.3	7.4 $\pm$ 1.8	10.1 $\pm$ 4.7	9.4 $\pm$ 1.9

3.2.1 The Danish cohort

All dogs except for two were measured by two observers. The total number of measurements was 387, whereas 72 of these were performed on dogs with normal weight (BCS 4-5).

3.2.2 The clinical cohort

All dogs were measured by two observers. The total number of measurements where 360 and 66 of these were performed on dogs with normal weight (BCS 4-5). The difference in assessed BCS was largest in the French bulldog group that ranged from 4 to 7, compared to the Border collie group that did not include any dog above BCS 5. The variation (SD) was numerically higher in the French bulldog and in the labrador groups compared to the other breed groups. French bulldogs presented high mean measurement numbers overall, even above the values presented for normal weight labradors (table 3). The data indicates a numerical increase of 1-4 mm increase in skinfold thickness comparing BCS 4-5 and BCS 6-7 in the cavalier and the labrador group. The French bulldog group presented a decrease at both the neck location with 1.7 mm and at the lumbar location with 1.5 mm in comparison between their BCS-groups.

Table 3. Mean values of skinfold thickness divided by breeds the clinical cohort. Mean $\pm$ SD in mm.

	Border collies	Cavalier King Charles	French bulldog	Labrador retriever
All dogs: Neck	5.3 $\pm$ 1.6	6.2 $\pm$ 1.1	8.4 $\pm$ 1.7	10.0 $\pm$ 3.0
All dogs: Axilla	6.2 $\pm$ 0.7	7.1 $\pm$ 1.7	7.4 $\pm$ 1.4	9.0 $\pm$ 1.5
All dogs: Lumbar	7.4 $\pm$ 1.2	6.8 $\pm$ 1.5	8.7 $\pm$ 1.8	10.2 $\pm$ 2.2
BCS 4-5: Neck	5.3 $\pm$ 1.6	5.8 $\pm$ 1.1	9.4 $\pm$ 2.2	7.8 $\pm$ 0.5
BCS 4-5: Axilla	6.2 $\pm$ 0.7	6.0 $\pm$ 1.3	6.6 $\pm$ 1.2	6.9 $\pm$ 0.7
BCS 4-5: Lumbar	7.4 $\pm$ 1.2	6.0 $\pm$ 0.6	9.6 $\pm$ 2.6	7.0 $\pm$ 0.5
BCS 6-7: Neck	-	6.8 $\pm$ 1.0	7.7 $\pm$ 0.8	10.5 $\pm$ 3.5
BCS 6-7: Axilla	-	8.6 $\pm$ 0.6	7.8 $\pm$ 1.4	9.4 $\pm$ 1.2
BCS 6-7: Lumbar	-	8.2 $\pm$ 1.2	8.1 $\pm$ 0.8	11.0 $\pm$ 1.5

3.3 Correlations of caliper measurements and body condition score

Analyses on correlations of skinfold thickness and body condition score (BCS) were performed on each localisation for each cohort. The correlations were all significant but the strength of the correlations varied for different locations between the cohorts (table 4). In the Danish cohort, the neck measurements showed the most significant correlation to BCS, whereas in the clinical cohort, the measurements performed at the axilla showed the most significant correlation to BCS.

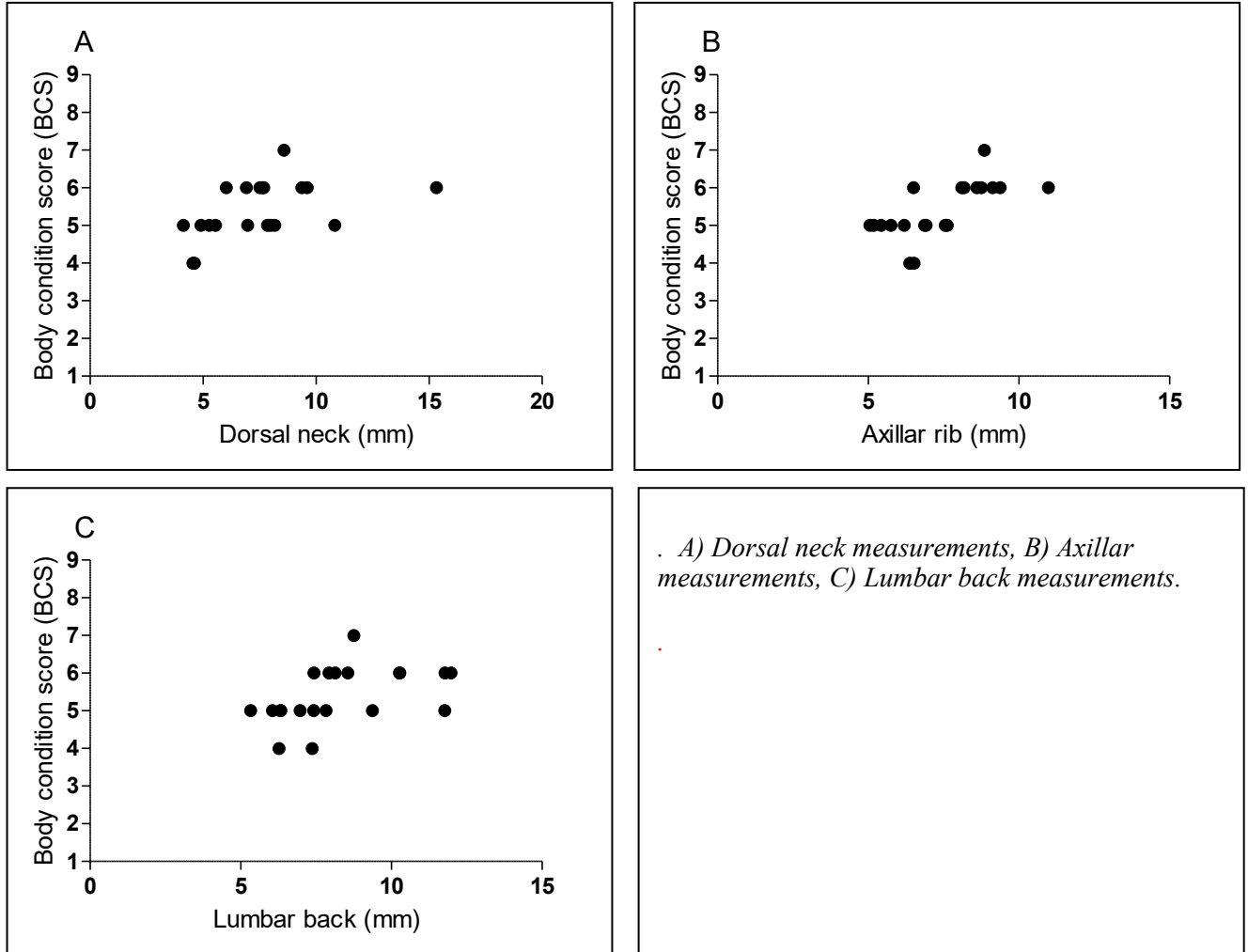
Table 4. Correlation analyses of skinfold thickness and BCS.

	Danish cohort, Neck, 23 dogs	Clinical cohort, Neck, 20 dogs	Danish cohort, Axilla, 23 dogs	Clinical cohort, Axilla, 20 dogs	Danish cohort, Back, 23 dogs	Clinical cohort, Back, 20 dogs
Pearson r	0.59	0.49	0.45	0.67	0.51	0.48
95% confidence interval	0.24 to 0.81	0.06 to 0.77	0.044 to 0.73	0.32 to 0.86	0.13 to 0.76	0.043 to 0.76
P value two-tailed	0.003	0.028	0.032	0.001	0.012	0.034
R square	0.35	0.24	0.20	0.45	0.26	0.23

3.3.1 Visualisation of linear relationships in the clinical cohort

In the clinical cohort consisting of four different breeds, the regression coefficient suggested that the axilla was the location with the highest correlation between skinfold thickness and BCS (table 4). The linear relationships for the correlations of caliper measurements and BCS in the clinical cohort, are plotted in figure 2.

Figure 2. Correlations between skinfold thickness and BCS in the clinical cohort for the different locations (the dorsal neck, the axilla and the lumbar back). Each dot represents one dog and the mean of the triplicates (x-axis) and the mean BCS (y-axis) for that individual



3.4 Comparisons between breeds in the clinical cohort

Due to the small number of dogs within the breed-groups, and that data was not normally distributed, the analyses between breeds were performed with Kruskal-Wallis test (table 5). The most significant P-value in the comparison of all breeds was the location of the neck. Comparing the different locations between breeds, all results were significant, and therefore additional analyses were performed with a Dunn's multiple comparison test (table 6).

Table 5. Comparisons between breeds in the clinical cohort with Kruskal-Wallis test analyses.

	Comparison of all 4 breeds at the neck	Comparison of all 4 breeds at the axilla	Comparison of all 4 breeds at the back
P-value	< 0.0001	0.0038	0.0019
P-value summary	***	**	**
Number of groups	4	4	4
Kruskal-Wallis statistics	22.50	13.42	14.89

The border collie group showed significant differences in having thinner skinfolds compared to all other breed groups in the location of the neck, as well as with the labrador group in the locations of the axilla and at the lumbar back (table 6). The cavalier group showed significant differences in the locations of the neck and lumbar back compared to the labrador group. Significant differences between breeds groups were noted in the location of the neck in 50% paired comparisons, as compared to only 17% at the axilla.

Table 6. The significant paired comparisons of caliper measurements between breeds conducted with Dunn's multiple comparison test.

Dunn's Multiple Comparison Test	Difference in rank sum	Significant? Yes/No Cut off value P < 0.05	Summary
Neck B vs Neck F	-16.85	Yes	**
Neck B vs Neck L	-22.05	Yes	***
Neck C vs Neck L	-16.55	Yes	**
Axilla B vs Axilla L	-18.95	Yes	**
Back B vs Back L	-13.80	Yes	*
Back C vs Back L	-18.70	No	**

Comparisons between the different locations, neck, axilla and lumbar back (back) between the breed groups (B=Border collie, C= Cavalier king Charles, F= French bulldog, L= Labrador Retriever).

3.5 Intra -and inter-observer reliability

The intra-and inter -observer reliability was calculated for the two cohorts using ICC (table 7). There were some differences present between the two cohorts regarding the reliability. Both the intra- and the inter-observer reliability were numerically higher in the Danish cohort than in the clinical cohort. In the Danish cohort, the location with the lowest ICC was the axilla, which differs from the clinical cohort, where the lowest ICC was shown for the lumbar back (table 7).

Table 7. Intra- and inter-observer reliability of skinfold thickness measured with a caliper, both cohorts included.

Location	Intra				Inter	Inter
	ICC (95% CI)				ICC (95% CI)	ICC (95% CI)
	Observer 1 Danish cohort	Observer 2 Danish cohort	Observer 1 Clinical cohort	Observer 2 Clinical cohort	Danish cohort	Clinical cohort
Neck	0.992 (0.984- 0.997)	0.992 (0.983- 0.996)	0.965 (0.928- 0.985)	0.971 (0.941- 0.987)	0.977 (0.945- 0.990)	0.899 (0.767- 0.959)
Axilla	0.991 (0.981- 0.996)	0.992 (0.984- 0.996)	0.848 (0.714- 0.931)	0.880 (0.770- 0.946)	0.937 (0.856 - 0.973)	0.816 (0.598- 0.922)
Lumbar	0.993 (0.985- 0.997)	0.993 (0.986- 0.9 97)	0.987 (0.973- 0.994)	0.972 (0.943- 0.988)	0.956 (0.899- 0.981)	0.774 (0.520- 0.903)

ICC -intraclass correlation coefficient, relates to the reliability index as when test-retest, intra-rater (observer), and inter-rater (observer) reliability analyses are performed.

As the reliability between observers in the clinical cohort showed a larger difference than between observers in the Danish cohort (table 7), the standard error of mean (SEM) for the different locations were calculated for the individual observers in the clinical cohort. These values of precision (mean SEM) suggest that observer 1 showed a numerically lower mean standard error compared to observer 2 (table 8). The location that differed the most between observers in the clinical cohort according to ICC (table 7), was the lumbar back. The values from the measurement in this location differed more than mean 1 mm between observers (table 8), and both the inter-observer reliability (table 7) and the mean SEM (table 8) showed the numerically highest difference between observers at this location. The SEM between observers 1 and 2 differed between 0,1-0,5 mm.

Table 8. Mean value of the measurement location and mean SEM-mean for observer 1 and 2 in the clinical cohort.

Location	Observer 1 mean value in mm	Observer 2 mean value in mm	Observer 1 SEM-mean value in mm	Observer 2 SEM- mean value in mm
Dorsal neck	7.36	7.59	0.22	0.25
Axillar rib	7.23	7.56	0.28	0.29
Lumbar back	8.72	7.88	0.12	0.17

SEM-standard error of mean, was calculated from the mean of the mean of the triplicate for each observer for each location (all dogs, not divided by breed). The analyse shows the difference in standard error of mean for each observer.

4. Discussion

The overall aim of this study was to investigate if measurements performed with a skinfold caliper, could serve as a useful tool in a clinical setting for objective assessment of nutritional status of dogs. To be a useful tool, it would have to be easy to use, give repeatable and reliable measurements, without creating too much stress for the individual dog. The specific objectives were to evaluate the intra- and inter observer reliability of the caliper measurements and to investigate a possible correlation to BCS, and if there were differences between the thickness of the skinfolds of different breeds. The results would then give an implication about if skinfold caliper measurements is a useful tool and if so, what aspects to consider in a clinical setting. As there were several breeds in the cohorts, the results would give a suggestion if there are aspect to consider regarding different breeds.

4.1 The two different cohorts

The Danish study performed the caliper measurements on dead dogs, and the intra- and inter-observer reliability of the measurements were high according to previously established limits for reliability (Koo & Li 2016). In the clinical study, alive, awake dogs were used, and the intra- and inter-observer reliability was slightly lower compared to the Danish cohort of dead dogs, which was expected. The particular study design of the clinical cohort was selected as standing, awake dogs would be the preferred way of evaluation of skinfold thickness with a caliper in a veterinary clinical setting.

To the author's knowledge, there is no consensus in how to classify the sizes of dog breeds. The Swedish kennel club lists both the cavalier king Charles spaniel and French bulldog as breeds under 35 cm in withers and French bulldogs up to 14 kg (Kennelklubben 2025). Therefore, the cut-off of 14 kg was chosen as a limit for small dog in this study. The means of caliper measurements for the Danish cohort had an overall numerically higher SD compared to the clinical cohort, also in the groups divided by BCS. This could be due to the larger span in dog size (kg) and in body condition (BCS) and an increased breed variety in the Danish cohort compared to the clinical cohort.

4.2 The performance of the observers and the intra- and inter-observer reliability

To avoid bias and to enhance the accuracy when comparing cohorts, it is recommended to have the observers in both cohorts blinded (Mathieu 2020). In both cohorts, the observers were blinded, thus they did not read their own caliper measurements. When comparing intra- and inter-observer reliability, Koo & Li (2016) suggest that a rule of thumb is to obtain at least 30 heterogeneous samples and involve at least three observers. It was not the case in this study, as there were two observers in each cohort and the cohorts were not exactly identical. Koo & Li (2016) also states that ICC estimate is a complex coefficient to interpret and is an anticipated value of the true ICC, as to why it is important to discuss any deviations in the data further. An ICC between 75-90% is considered to be a good reliability and above 95%, is considered excellent (Koo & Li 2016; Smith et al. 2013). All locations in both cohorts showed good to excellent ICC values according to these cut-off values. However, there are no general cut-off points to ICC, and it is up to each researcher to apply a suitable cut-off according to the research and conditions at hand (Taherzadeh Chenani & Madadzadeh 2021). As the Danish study was performed in dead dogs, the triplicate measurements were done without letting go of the pinch-grip of the skinfold. This however, was not possible in the clinical study, as not all of the alive dogs were able to stand exactly still. To make the measurements as equal as possible in the clinical cohort, the observer released and made re-grip after each measurement, aiming at a skinfold with the same height in all triplicate. This specific adjustment in the procedure in the clinical cohort, compared to the Danish cohort, lead to the expectation that not all measurements would be as meticulous in the clinical cohort as in the Danish cohort.

Regarding the intra- and inter-observer reliability, the inter-observer reliability in the clinical cohort, were not as high as in the Danish cohort. There may be several factors contributing to these differences. In the clinical cohort, the dogs were generally more mobile during the measurements made by observer 1. This could possibly be caused by the new situation and that the dog was more accustomed to the procedure when observer 2 started measuring. To avoid this bias, the starting order of the two observers should have been randomized. These results may indicate that the dog needs some time to habituate to the situation before measuring is commenced. This could either be achieved by adding a number of measurements and then exclude the measurements during which the dog was more mobile or performing some dummy measurements on beforehand, that will not be registered. The fact that one observer in the clinical cohort was left-handed, that all measurements were made from the left side, and both observers used the right hand when holding the caliper, which is something that

could have affected the precision for the lefthanded observer and may have caused some variation between observers. In the Danish cohort the side for measurements were randomised, which excludes this potential error, even if the observers would have had different dominant hands.

The ICC:s, the mean values of the measurement locations and the mean standard errors (SEM) of the triplicate in the clinical cohort, indicated slightly different performance of the observers. The ICC includes not only a correlation analysis but also a comparison of that the values from the observers are similar. The results thus indicated a slightly higher performance regarding precision of observer 1, and that the measurements may have been made in a slightly different locations on the lumbar back. As all measurements locations were located with a ruler and measuring tape, the location itself should be the same. However, the height skinfold lift differed numerically in height between the observers (observer 1; mean skin lift height 3,3 cm and observer 2; mean skin lift height 3,6 cm), and this may have caused the differences in the mean value of measurements between the observers. This could have been avoided if there was a predetermined lift height.

The magnitude on the measurement error was not calculated, as there is only one measurement session per person per dog and there is no intervention made. However, between the breeds, the difference between the measurements is several mm and the measurement errors between observers were 0,5 mm at the most. The magnitude of measurement error in correlation to difference between breeds, is probably not a significant error in these circumstances.

4.3 Body condition score (BCS) assessment and size

The aim of the clinical study, was to use dogs with BCS of 4-5, however, due to lack of study material, it was not possible within the time frame. When recruiting dogs, the owners stated that the dog was a BCS 5 but when the dog was admitted to the study, the observers graded the dog differently. This phenomenon is what could be called “weight blindness” and according to Gille et al. (2024) is this misestimation of body condition common among dog owners (Laflamme 1997; Gille et al. 2023). The clinical cohort was originally supposed to consist of BCS 4-5, however, due to the weight blindness, some of the recruited dogs were scored higher and there was not enough time to find further dogs with normal weight.

The sample size was not sufficient with only dogs with BCS 4-5, and therefore there are nine dogs scoring BCS 6-7 included in the clinical cohort. A BCS above 5 seemed to be present among both small and bigger dogs. In the clinical cohort there were both small dogs (cavalier king Charles and French bulldogs) and bigger dogs (labradors) that were above BCS 5 and in the Danish cohort the BCS

above 5 were spread relatively even in both small dogs (under 14 kg) and the bigger dogs (above 14 kg). However, an overweight big dog, would presumably have thicker skinfolds compared to an overweight small dog, in regards of millimetres. If measurements are done in dogs that are close to the weight cut-off point, there might be risk that the analysis are flawed, if an under- or overweight dog is categorised only by weight. The use of BCS will limit the problem, as a BCS is assessed also with regards of the size (height and length) of the dog. To further avoid such errors, a wither cut-off could be included.

According to Laflamme (1997), fat deposits develop in different locations in different BCS (measured in 255 dogs of different breeds). In BCS 6, there is a slight excess covering the ribs. Noticeable fat deposits around lumbar area and base of the tail develops at BCS 7 and fat deposits at the neck may be present at BCS 9. A BCS assessment is a good way to measure the nutritional health status on the dog, as it is repeatable, reproducible and predictable (Laflamme 1997) however, there may be some inter-observer variation (Case et al. 2011). In certain breeds, it may be more difficult than in other to distinguish the “correct” BCS-score. For example, in some breeds with extra skinfolds and extremely short legs, such as in a basset hound, it may be more difficult to distinguish the features stated in the BCS-scale. Jeusette et al. (2010) also suggests that different breeds might have different fat mass content in the body in general (thus not only at the neck, axilla and back, and that BCS scales adapted for different breeds and/or breed groups, should be developed. The BCS score might also be influenced in its appearance due to hormone disruptions or by medications (Bennaim et al. 2019). Both Laflamme (2006) and Gille et al. (2023) suggests that by educating owners in the correct way of performing BCS assessment, the accuracy on BCS assessment from owners will increase.

As mentioned above, there are elements that may complicate the BCS assessment. In the Danish cohort, the dogs lacked muscle tone due to being euthanised and this might affect the scoring of BCS, as the dog needed to be lifted up to make assessments. In the clinical study the observers scored the dogs independently, using a printed BCS chart as a guide. Observer 1 in the clinical cohort has previous formal training in BCS-scoring and observer 2 was taught by observer 1. The scoring was identical except in one dog where a half grade differed, resulting in the same score when analysing the data, as no half grades were used.

Laflamme (1997) showed in her study, that there was a significant correlation between BCS and total body fat evaluated by DEXA scans. Buzo et al. (2023) found a positive correlation between skinfold thickness measured by a caliper at the lumbar back, and BCS. Söder et al. (2025), found that the skinfold thickness of the dorsal neck showed a trend for linearity to total body fat, and that the sum of two skinfold showed a significant, nonlinear relationship to total body fat,

evaluated by DEXA. These previous findings suggests that this is an interesting field to investigate further. The results presented in this study, also suggests that there is a positive correlation between skinfold thickness and BCS, however, further investigation regarding the influence of breeds and measuring locations could be proposed.

4.4 Correlations of caliper measurements and BCS

A Pearson r value between 0,4-0,5 would be considered a fair correlation, which both cohort achieved, however, there are no set cut offs for interpretation (Akoglu 2018). For a clinical perspective, the findings should be valued in combination with other data (Ejlertsson 2003).

There were significant correlations between the skinfold thickness and the BCS, however, the significance varied between locations in the two cohorts. The Danish cohort presented the neck as the most significant location compared to BCS, which differs from the clinical cohort, that presented the axilla as the most significant location. It may be of importance in further studies, as it may indicate that combining different locations may be of interest when performing caliper measurements. There are some main differences between the two cohort in this study, that may explain the variations in the results. The dogs in the Danish cohort had a greater span in sizes, 2-52 kg compared to the clinical cohort, 8-33 kg. The BCS range did also differ; in the Danish cohort the range was 2-9 and in the clinical cohort the range was 4-7. The presence of obese dogs (BCS 8-9) in the Danish cohort, may explain the strong relationship of the neck and BCS, as according to Laflamme (1997) dogs need to be obese before developing clear fat deposits at this location. This could have been further investigated by comparing a subsample from the Danish cohort with the clinical cohort.

The size of the dog will have an impact on the relationships between skinfold thickness and BCS. According to my clinical experience when evaluating a dog for BCS, one will consider the size and/or breed of the dog. Caliper measurements will not acknowledge if the dog is a small dog or a big dog (height/weight), as it only measures the skinfold thickness. By this reasoning, there will probably be a need of considering the size differences in dogs, when performing comparisons of predicted total body fat according to the value of the skinfolds (Söder et al. 2025). The results show a linear relationship between skinfold thickness and BCS at all locations measured. Future studies should further investigate the relationship of skinfold thickness and total body fat evaluated by gold standard DEXA. The study by Söder et al. (2025) indicated that by accounting for the body weight of dogs, the relationship between skinfold thickness and total body fat became stronger.

The fact that the dogs in the Danish cohort were dead, and dogs thereby were completely still when the measurements were performed, may also contribute to

the variety. The dogs in the clinical cohort generally stood still, but there were some movements which may have caused alterations in the skin lift, and thus the exact measuring locations. The dogs in the Danish cohort were placed in ventral recumbency with front limbs pulled cranially, which may cause the skin at the axilla to tighten and/or be misplaced compared to the skin in an awake, standing dog. These arguments may be reasons for the differences in significance of the correlations for the measurement locations in the different cohorts.

Considering the differences between breeds, the difference between the measurements were significant in three pairwise comparisons of the neck, one at the axilla and two at the back. In all the locations, the border collie and the labrador breeds showed significant differences to each other. Between these two breeds, there was a significant difference at the axilla measurements, and none of the other breeds showed difference in this location. These groups differed also in BCS as border collies were two BCS 4 and two BCS 5 and labradors only had one BCS 5 and three BCS 6. For the neck measurements, the border collie compared to French bulldog and cavalier compared to labrador, showed significant differences. This result may indicate that some of the differences in skinfold thickness do not relate to the size of the dog. In the case where cavalier king Charles showed differences to the labradors, the size of the dogs could probably be the differing factor. However, border collies are considered to be a bigger breed than French bulldogs, and here the size factor should not be applicable. The main difference between border collies and French bulldogs, are their conformation i.e. the classification of breed, as the French bulldog is a severely brachycephalic breed (O'Neill et al. 2022). In the clinical study, two brachycephalic breeds were included; cavalier king Charles and French bulldog. The data suggests that there is not a clear positive relationship between the size (height and weight) of the dog and the thickness of the skinfolds in dogs with BCS 4-7. In the clinical cohort, there were measurements on French bulldogs that showed thicker skinfold at the neck and back in a normal weight dog, compared to a normal weight labrador retriever. This might be explained by the excessive skinfolds that are presented in brachycephalic dogs, especially in bulldogs (Hobi et al. 2023), but this needs to be explored further. This might suggest that in brachycephalic dog breeds, the skinfolds thickness of the neck and back, might not correlate in the same way to BCS as in other breeds. This could also be an explanation to why the measurements in the Danish cohort differed from the clinical cohort regarding the neck measurements. In the Danish cohort, there were only three brachycephalic dogs included, none of them French bulldog or cavalier king Charles spaniel. The brachycephalic dogs in the Danish cohort, were all dogs over 20 kg and were not the breeds that are mentioned as dogs with the most excessive skinfolds (Hobi et al. 2023).

4.5 Measurement locations

There is a difference in skinfold thickness depending on which location of the human body the measurement is taken (Nösslinger et al. 2022), and this fact is also something that Diana et al. (2004) mentions for dogs. This can also be seen in the present study, and it might be important to present a protocol for which locations to use in a clinical setting to avoid errors due to different measuring locations. However, if the same location is repeatedly evaluated and compared within an individual dog, this should not create bias in the result interpretation. Using the same locations in an individual dog in repeated measurement occasions (such as for example in a weight loss program), would be a possible routine as the dog with that set up is its own reference.

4.6 Skin and coat

In domestic mammals, the haired skin is thickest over the dorsal surface of the body (in dogs the sacrum) compared to the lateral surface, where it is thinner (mostly in the axilla in dogs) (Diana et al. 2008; Theerawatanasirikul et al. 2012; Souci & Denesvre 2021), which was also observed in the cohorts of this study. Pavletic (1991) describes that there also are differences in the skin of an individual animal in the dermis; most pliable skin regions (axilla, flank, dorsal neck) have smaller and more loosely woven collagen bundles. Areas where the skin is least mobile (tail, ear, digital pads) have wider, more closely packed collagen bundles, with few elastic fibres (Pavletic 1991). These differences in skin pliability, can be of importance when choosing where to perform skin fold measurements, as the areas where the skin is tighter, might be more uncomfortable for the dog. The thickness of the skin is directly related to the thickness of the dermal layer in the dog, which varies according to the body area, sex and breed (Pavletic 1991) and the thickness is also depending on the fluid content in the skin (Diana et al. 2008). The thickness of the skinfold, would be affected both by the thickness of the skin and by the amount of adipose tissue as mentioned previously. As suggested by Jeusette et al. (2010), the hypodermal fat may not be distributed equally in all breeds and that may need to be of consideration when implementing measuring techniques in a clinical setting. Thick skin is defined as dermis greater than 1 mm in thickness, whereas thin skin is defined as a dermal thickness less than 1 mm (Pavletic 1991). Diana et al. (2004) found that there were differences in skin thickness related to the hydration state of the dog, when measurements of skin thickness were performed with ultrasound. This may be taken into consideration if the technique is being used in a clinical setting, as the observer should aiming at taking repeated measurements

around the same time of day and take notes if the owner states that the dog has not been eating and drinking normally and/or have had vomiting/diarrhoea.

One other feature that may be considered to influence the thickness of skin, is fur. Theerawatanasirikul et al. (2012) however, did not find any difference between the thickness of skin in short- respectively longhaired dogs. However, they found in their study, that pugs and labrador retrievers (which were considered to have short- and medium length fur) had thicker epidermis, while golden retriever and shih-tzu (long hair) had the thinnest epidermis in their study. This information also suggests that breed, in addition to size, may be a factor to consider when measuring and evaluating skinfold thickness.

In both the clinical and the Danish cohort, the length of the fur was noted, however, no specific analyses were made with these parameters. As suggested above, the fur length may have an impact, and especially in mixed breeds, this may be something to take in to consideration in further studies.

4.7 The procedure

The measurement procedure in the study, took about 15 min total, including explaining the study to the owner. In a clinical setting, the time for measurements would be less, as there would only be one person performing the measurements and the explanations would be part of the routine information that would be done in an appointment. The dogs in the clinical study accepted the procedure well, although there were some shaking and movement. None of the dogs needed to be muzzled and none of the owners asked for a break. The impression was that the nervousness from the dogs did not arise from the measurements, but from standing on an examination table in a clinical environment. The procedure is easy to perform with basic training. There are some limitations when performing the measurements; if the dog moves too much or is uncomfortable with being on a table. Pain around the measuring localisations might influence measurements as well.

4.8 Clinical implications

The results indicate that a skinfold caliper, as a method to indirectly measure bodyfat in dogs, is a useful complement to BCS, which is a semiobjective method, as it may give objective and detailed information about the progress in changes in bodyfat percentage. The numbers from the measurements can give information in millimetres, which may be challenging to estimate in BCS assessment. Presenting changes in numbers may motivate owners to continue with a treatment plan

and/or do behavioural changes that will be beneficial to the dog's nutritional status and overall health.

Some parameters need considered in a clinical setting: The caliper measurements should be performed in at least triplicate, and possibly with a training round before, to get the dog accustomed to the procedure. A mean should be calculated from the triplicate and recorded as data. The preferred measurement locations would presumably be the axilla and the neck which showed significant correlations to BCS, but this needs to be further verified. As indicated in this study, these locations can be used to measure smaller changes in fat deposition and thus be a complement to the BCS, that might not pick up the subtle changes between measuring appointments. The examiner should be familiar with the procedure and always perform the measurements in the exact same locations. The measurement location and the height of the skinfold should be noted in the patient chart, to make it possible to replicate the procedure at a later appointment, preferably by the same examiner.

The ease of the procedure and relatively stress free, would make the skinfold caliper measurements a feasible option in the clinic, to get an objective measurement of the dog's body fat mass to complement the BCS assessment, in a normal clinical routine check-up. It is possible to use the skinfold caliper without a BCS score, however, the measurement results, would not be of great value if there is not a follow up session. This is due to the results indicating that the weight/height of the dog, is not the only indicator of the thickness of the skinfold would be in a normal weight dog.

4.9 Limitations of the study and further studies

The small numbers of dogs in the cohorts are a limitation of this study and also the fact that the dogs were not the same BCS. To further investigate if French bulldog and/or other types of brachycephalic breeds differ from non-brachycephalic breeds, an increased number of brachycephalic dogs could be investigated.

The different sizes of breeds are limited in this study and as the number of dogs in each breed group is limited, analysis to rule out size as a factor, is limited.

The procedure may benefit from randomising observer measuring succession and also adding observers.

The study is comparing to BCS, which is a semi-objective tool, however, comparing measurements to DEXA measurements, would be ideal in future studies.

5. Conclusion

The hypothesis was that there will be differences in skin fold thickness, between different normal weight dogs of different breeds of different sizes (under/over 14 kg). The hypothesis was also that French bulldogs will have thicker skin folds, compared to other breeds within the same size and BCS.

The results indicate that there are differences between different breeds and sizes of dogs. The results also indicates that despite French bulldogs being a smaller breed, they may have thicker skinfolds compared to bigger dogs such as labradors, regardless of assessed the same BCS.

The results indicate that the intra- and inter- observer reliability was high.

For comparison between different breeds, this study is limited, but the results indicate that besides the BCS and size of dogs, the breed type may also be of importance for measurements of skinfold thickness with a caliper. As DEXA is the gold standard, one limitation of this study is that it does not compare the caliper measurements to DEXA but to BCS, which is not as objective. Further studies containing extended sample sizes would be preferable, including DEXA comparisons. Studies on different breeds, such as brachycephalic dogs, can give an indication if skin conformity and fat distribution is a variable to consider when using the method in clinical practice. Further studies should preferably include at least three observers performing the same measurements, in longitudinal study designs, to give more information about reliability in clinical situations and the usefulness of the method in detecting changes in the dog's body composition over time.

The caliper measurements may be used clinically as a complement to BCS, it is a useful tool if the dog acts as its own control, as in a follow up in a weight loss/weight gain program.

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Popular science summary

Inom djursjukvården används vikt och hullbedömning på hundar, som en del i bedömningen av hundens hälsostatus. Hullbedömning sker ofta med hjälp av en nio-gradig skala, där 1 innebär att hunden är utmärglad och 9 betyder att hunden har grav övervikt. En hund som bedöms 4–5 har idealisk kroppsvikt. Detta kallas då att hunden har en BCS (body condition score) på 4–5. När en hullbedömningsskala (BCS-score) används, så tar den hänsyn till hull i förhållande till hundens kroppsform, men säger inte så mycket om hur mycket fettmassa som hunden har. För att få fram ett mer objektivt mått på hur mycket kroppsfett en hund har, så har olika metoder använts; t.ex. ultraljud eller måttband för att bedöma underhudsfett på olika områden på hunden eller helkroppsscanning med DEXA (dual energy X-ray absorptiometry) som är en slags specialröntgen. Av dessa olika mätmetoder är DEXA den som i dagsläget har visat sig stämma bäst överens med fördelningen mellan hundens fett- och muskelmassa och är därmed det som andra mått jämförs med, så kallat ”gold standard”. Problemet med DEXA är att det är en dyr metod och hunden måste ges lugnande eller sövas vid undersökningen. För att hitta en metod som är enklare att använda i den dagliga verksamheten, undersökte den här studien om mått av hudveck på hunden, mätta med ett skjutmått, kan vara en bra metod att använda som ett komplement till BCS ute på kliniker. Hudveckan mättes med ett speciellt skjutmått (Harpenden®), med manuell display. För att en metod ska vara användbar på klinik, är det önskvärt att metoden kan användas vid olika tillfällen och helst även av olika personer, och ändå ge tillförlitliga mått.

I studien deltog 20 hundar av fyra olika raser; border collie, cavalier king charles spaniel, fransk bulldogg och labrador retriever. Hundraserna valdes ut för att få spridning på storlek och för att få med minst en trubbnosig ras. Trubbnosiga hundar kan ha överdrivna hudveck och/eller förtjockad hud, vilket gjorde det intressant att ha med dem i denna studie där hudveck mättes. Hundarna som deltog var vuxna hundar, både hanar och tikar. Alla hundar hullbedömdes och hade ett hull mellan BCS 4 och 7. Alla hundar var friska från hudproblem.

Studien gick till så att hundägare på en mindre klinik i Sverige, blev tillfrågade om de ville delta i studien. Vid besöket fick hunden stå på ett undersökningsbord, med matte eller husse stående vid nosen, medan de två observatörerna utförde mätningar. Mätningarna gjordes vid nacke, vid armhålan samt vid rygglutet. Huden lyftes upp ca 3–4 cm och sedan mättes med skjutmättet. Varje observatör gjorde tre mätningar på varje ställe medan den andra observatören läste av skjutmättets display och antecknade måttet. Alla mått matades in i datahanteringsprogram och sedan gjordes uträkningar på hur lika resultat observatörerna fått, hur stor skillnad det var på hudveck mellan olika raser och om det spelade roll vilken hullbedömning hunden hade fått. Dessa mätningar

jämfördes också med 23 andra hundar som deltagit i en dansk studie, där likadana mätningar gjorts på donerade hundar som avlivats, av andra orsaker än själva studien.

Resultatet visade att hundarnas fett i hudvecket i nacken och armhålan, hade ett samband med hundens hull, d.v.s. BCS. Detta mått mätt med skjutmått kan således troligen användas om en hund ska gå upp eller ner i vikt och vi vill följa det med ett objektivt mått.

Mätningarna visade att det finns skillnader mellan olika raser, t.ex. hade franska bulldoggar generellt tjockare hudveck än exempelvis border collie. För att ta reda på mer om hur olika raser skiljer sig i huduppbyggnad i förhållande till hull så behövs det göras fler studier med fler hundar som deltar.

Resultaten i den här studien, pekar på att hudveck mätta med ett skjutmått, kan vara en bra kompletterande metod till att skatta hullet med BCS, för att bedöma en hunds kropps fett och för att följa upp hundens eventuella upp- eller nedgång, exempelvis vid bantning eller ett muskelbyggande rehabiliteringsprogram. Skjutmåttsmätningar ger ett objektivt mått som kan ge information även för mindre förändringar (mm) i hudveckstjocklek. Det är några punkter som behöver tas i beaktande för att metoden ska vara användbar; personen som utför mätningen bör ha fått träning i hur skjutmättet används, ett antal mätningar bör utföras vid samma tillfälle, på samma mätpunkt och ett medelvärde av dessa bör räknas ut. Det kan vara lämpligt att låta hunden genomgå en "testomgång" innan mätvärdena noteras, för att den ska vänja sig vid proceduren. Anteckningar om den exakta mätpunkten och höjden på hudvecket som lyfts upp, bör noteras i journalen för att underlätta vid nästkommande mätning.

Den här studien kan ses som en pilotstudie och ytterligare studier bör utföras, där större populationer av hundar, samt jämförelser med DEXA-analyser, ingår. Studier där olika raser, kan ge mer information om ifall hudkomposition är något som behöver övervägas i samband med att hudvecksmätning ska användas på kliniker. Ytterligare studier bör även göras över en längre tid, för att utvärdera om metoden är användbar när det gäller att följa upp eventuella förändringar i hundens kropps fettsammansättning över tid.

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