Swedish University of Agricultural Sciences
Faculty of Veterinary Medicine and Animal Science
Department of Anatomy, Physiology and Biochemistry

Evaluation of four methods for the assessment of joint swelling in dogs

Stina Bergfors

Uppsala

2012

Master degree thesis for the Veterinary program

ISSN 1652-8697
Master degree thesis 2011:57

SLU
Swedish University of Agricultural Sciences

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Stina Bergfors

Supervisor: Anna Bergh, Department of Anatomy, Physiology and Biochemistry
Examiner: Clarence Kvart, Department of Anatomy, Physiology and Biochemistry

Master degree thesis for the Veterinary program, Uppsala 2012
Faculty for Veterinary medicine and Animal science
Department of Anatomy, Physiology and Biochemistry
Course code: EX0329, Level: X, 30 hp

Key words: joint swelling, dogs, tape measure, slide caliper, tonometry, rehabilitation, outcome assessment tools

Online publication of this work: http://epsilon.slu.se
ISSN 1652-8697
Master degree thesis 2011:57

CONTENT

SUMMARY

Evaluation of joint swelling is an important part of the orthopedic examination and can be used to follow a patient's progress during rehabilitation and therapy. Usually a swelling is assessed by palpating the joint but a more objective, but still easy to use, method would be preferable.

This study seeks to increase the knowledge in veterinary rehabilitation by validating four different measurement tools (three recognized and one novel) for the assessment of elbow joint swelling: palpation, tape measure (circumference and figure eight measurement), slide caliper (craniocaudal and mediolateral positioning) and tonometer. This was achieved by calculating the inter- and intra-rater reliability and correlating the results from the different measurements with each other.

The methods with best inter- and intra-rater reliability as well as good correlation among themselves were shown to be slide caliper with craniocaudal positioning, circumference and figure eight. Additional studies, with a larger and more diverse material, ought to investigate these methods further.

Key words: joint swelling, dogs, tape measure, slide caliper, tonometry, rehabilitation, outcome assessment tools

SAMMANFATTNING

Utvärdering av ledsvullnad är en viktig del av den ortopediska undersökningen och kan användas för att följa en patients utveckling under rehabilitering och behandling. Vanligen bedöms en svullnad genom palpation av leden men en mer objektiv, fast ändå lätthanterlig, metod vore att föredra.

Denna studie söker att öka kunskapen inom veterinär rehabilitering genom att validera fyra olika mätinstrument (tre erkända och en ny) för bedömning av armbågsledssvullnad: palpation, måttband (mätningar av omkrets och i form av en åtta), skjutmått (kraniokaudal och mediolateral positionering) samt tonometer. Detta åstadkoms genom att beräkna inter- och intratestreliabilitet samt korrelera resultaten från olika mätningar med varandra.

De metoder med bäst inter- och intratestreliabilitet så väl som god korrelation sinsemellan visade sig vara skjutmått med kraniokaudal positionering, omkrets samt mätning i form av en åtta. Ytterligare studier, med ett större och mer varierande material, borde undersöka dessa metoder närmare.

Nyckelord: ledsvullnad, hundar, måttband, skjutmått, tonometri, rehabilitering, verktyg för utfallsbedömning

INTRODUCTION

The assessment of joint function and swelling is an important part of the orthopedic examination (Arthurs, 2011). A swollen joint could indicate an inflammatory process in response to trauma, infection or such (Jacobson, *et al*., 1998). The degree of swelling can be used to assess a prognosis, help choose therapy and rehabilitation and to evaluate treatment (Hesbach Lamoreaux, 2007; Lindley & Watson, 2010).

Swelling can be assessed subjectively by palpating the joint (Millis, 2004). Sometimes a more objective evaluation is preferable since it is important that the outcome is the same whatever method is used and that different clinicians achieve the same result, in order to compare patients and follow progression (Bellamy, 2005). When assessing joints with small effusions imaging diagnostics, like magnetic resonance (MR) and ultrasonography, are important instruments (Jacobson, *et al*., 1998) and have both been studied in the dog (Lamb and Wong, 2005; Baeumlin *et al*., 2010). These devices are however not always available or practical in the everyday clinical situation, furthermore they are relatively expensive techniques. In everyday practice joint effusion is most often assessed by palpation. Palpation is a fast, ready at hand and economic option but not an objective one. The result of the method might differ between clinicians and for the inexperienced it might be difficult to make a correct assessment.

A rise in rehabilitation of animals increases the use of alternative measuring tools, previously used in human medicine but not yet validated for animals. For example is the use of a tape measure (used for measuring joint swelling in humans (Estersson, 1979)) or a slide caliper (used in rodent models for rheumatoid arthritis to measure joint width (Bendele, 2001)) more objective alternatives, without using the advanced techniques previously mentioned. The use of these tools on dogs is examined in this study since validated outcome assessments tools are vital to objectively evaluate rehabilitation.

In ophthalmology, a tonometer is used to measure intraocular pressure (Hessemer, Rössler, & Jacobi, 1989) and it might be possible that this technique could be used to estimate a joint swelling caused by excess fluid in the joint. Since the tonometer is a rather expensive instrument a broader use would be valuable to fully exploit its potential, wherefore this is investigated in this study. Furthermore it would be a fast and simple technique to detect an effusion if it works.

The elbow is a common cause of pain and front leg lameness in dogs (Canapp *et al*., 2009). Elbow dysplasia and osteoarthritis are frequent causes of lameness localized to the joint of the elbow (Scott & Witte, 2011), both conditions that can go unnoticed for a long period of time (Innes, 2009). According to an experienced animal physiotherapist there is a high frequency of police dogs with joint swelling localized to the elbows (personal communication: Pettersson, 2010). This is the

reason why the study used this particular patient group and joint since a parallel study[1] wanted to collect normal values for police dogs walking on a pressure mat.

OBJECTIVE

This study seeks to increase the knowledge in veterinary rehabilitation by validating four different measurement tools (three recognized and one novel) to assess elbow joint swelling: palpation, tape measure (circumference and figure eight measurement), slide caliper (craniocaudal and mediolateral positioning) and tonometer. This was achieved by calculating the inter- and intra-rater reliability and correlating the results from the different measurements techniques with each other. To the best of the author's knowledge this comparison has not been made before. The hypothesis of the study is that there is a difference in reliability and correlation between the different assessment tools, wherefore one method will be more preferable than the others. From the experiences made in the study recommendations for the methods' practical application can be given.

[1] Master degree thesis for the Veterinary program by veterinary student Regina Lindberg

LITERATURE REVIEW

CLINICAL SIGNIFICANCE

In the clinical situation it is important to be able to measure the progress of a disease and the outcome of treatments. Furthermore measurements can be used in clinical research, in epidemiological studies and to standardize treatment policies. The method for measuring must have validity; determine the factor of interest, as well as reliability; yield the same result with repeated assessments, and responsiveness; detect changes. The assessor is a source of error but training in the method of measurement can maximize their reliability (Bellamy, 2005).

The elbow joint – anatomical overview relevant to joint swelling

The fibrous joint capsule of the canine elbow joint only covers the cranial part of the elbow. The capsule ends laterally and medially where the corresponding collateral ligaments begin (see Figure I). The ligaments are regarded as a thickening of the joint capsule. The fibrous joint capsule, along with the olecranon fossa, is aligned with the synovial membrane, which form communicating pouches (see Figure I). One pouch in fossa radialis protrudes medially under the attachments of the biceps brachii muscle as well as under the attachments of the extensor carpi radialis and common digital extensor muscles. One pouch lies in the olecranon fossa and protrudes under the medial epicondyle of humerus (Constantinescu & Constantinescu, 2009).

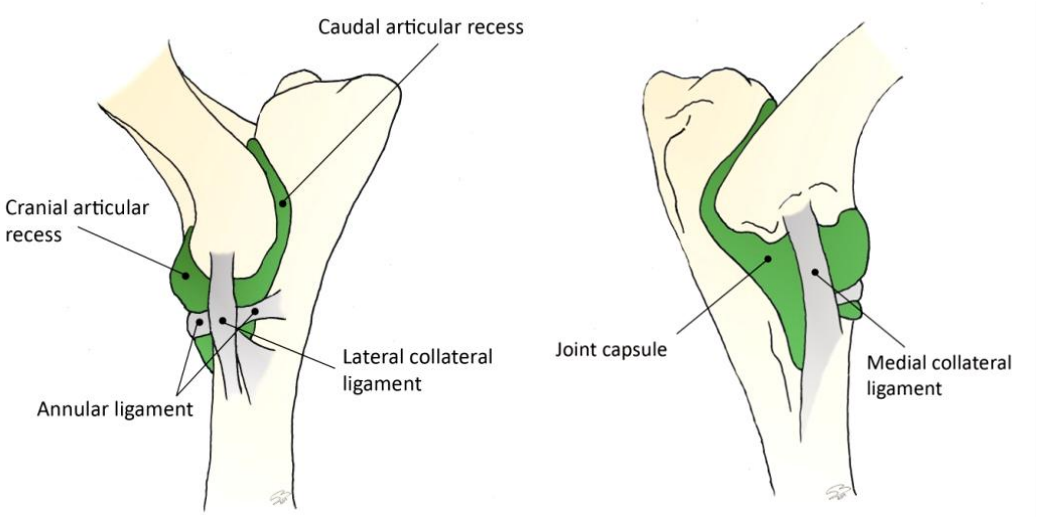

Figure I: *Left elbow – lateral and medial view respectively. The left elbow joint is shown with the extension of the joint capsule as well as the attachment of the lateral and medial collateral ligaments.*

Joint swelling – pathogenesis

Joint swelling is caused either by joint effusion (intracapsular) or by edema in the tissue around the joint (extracapsular) (Estersson, 1979). An increased amount of synovial fluid is produced during exercise but excessive joint fluid can also be seen in an inflammatory or degenerative joint disease. The cause of an inflammation varies from infectious or immune mediated to traumatic or stress produced, all resulting in an unspecific joint swelling in the acute state (Rao,

2010). Degenerative joint diseases include a range of conditions where the joint cartilage is injured leading to a degenerative cellular response resulting in an increased production of proteolytic enzymes, with more damage to the cartilage as an effect (Salter, 2002). One cause of degeneration is osteochondrosis, a common development disorder of the growth cartilage in dogs (Ytrehus, Carlson, & Ekman, 2007) and a part of elbow dysplasia (Innes, 2009).

EXAMINATION OF JOINT SWELLING

When examining a patient's joints and limbs a comparison should always be made with the contralateral extremity, to find both variations and resemblances (Arthurs, 2011). When investigating lameness radiography is often used, this readily shows bone lesions but will not always reveal soft tissue damage. An alternative that visualizes soft tissue is ultrasonography, which has been studied for the use in dogs (Lamb & Wong, 2005). Magnetic resonance imaging diagnosis has also been studied in canines (Baeumlin *et al*., 2010). Goniometry, the measurement of angles, is used to evaluate joint function by measuring the range of motion. This is a well documented method in human medicine and has to some extent been validated for the use on dogs (Jaegger, Marcellin-Little, & Levine, 2002).

Palpation

Joint effusion is most easily palpated in the standing dog, with full weight bearing limbs (Millis, 2004). An effusion in the elbow joint can most readily be palpated caudally to the lateral humeral condyle (see Figure I), where it is felt like a soft swelling (Arthurs, 2011). Based on the anatomy of the elbow joint the synovial recesses can be palpated both cranially and caudally to the lateral collateral ligament of the elbow joint (Constantinescu & Constantinescu, 2009).

Tape measure

In human medicine joint swelling is sometimes measured with tape measure to receive a more objective assessment of the swelling rather than just making a subjective observation (Estersson, 1979). The use of tape measure has been studied in assessing muscle mass as an indication of limb use in dogs (Millis, 2004) but to the best of the author's knowledge there is no validation for its use in assessing joint swelling, though the use has been suggested because of its accuracy in human patients (Hesbach Lamoreaux, 2007).

Circumference

Human studies show that measuring the circumference of a joint gives reproducible assessments of the joint swelling in certain joints when measured at specific anatomical landmarks (Nicholas *et al*., 1976).

Figure eight

In human medicine joint swelling is sometimes measured using a tape measure placed in the shape of a figure eight. This method is chosen in situation when a measurement of the circumference would not include the affected part of the joint. The measurement can be reproduced since easily recognizable anatomical landmarks are established (Estersson, 1979).

Slide caliper

Joint width can be measured with a caliper and is used in rat models of rheumatoid arthritis (Bendele, 2001). A slide caliper (Figure II) can be used to determine the thickness of small objects. The instrument has one fixed point and one flexible, enabling a correct adjustment to the space between one side of the measured object to the other. The thickness can then be read on an analog scale or a digital display, depending on the model.

Figure II: *Digital slide caliper.*

Tonometer

A tonometer is used in ophthalmology to measure intraocular pressure (IOP). There are different kinds of tonometers, some which are penlike, handheld and battery-driven, making them easy to manipulate. There are tonometers that have to be in direct contact with the cornea to measure the IOP whilst others measure the pressure through the eyelid (transpalpebral). The tonometer used in this study (se Figure III) was a transpalpebral tonometer and the following description concerns this model. When measuring the IOP a small rod is pressed against the eyelid and depending on the elasticity of the eye the rod will be pushed back at different speed. The tonometer uses the velocity at which the rod is pushed back to calculate the IOP, which is then shown on a digital display (Lösch *et al*., 2005; BiCOM, 2011).

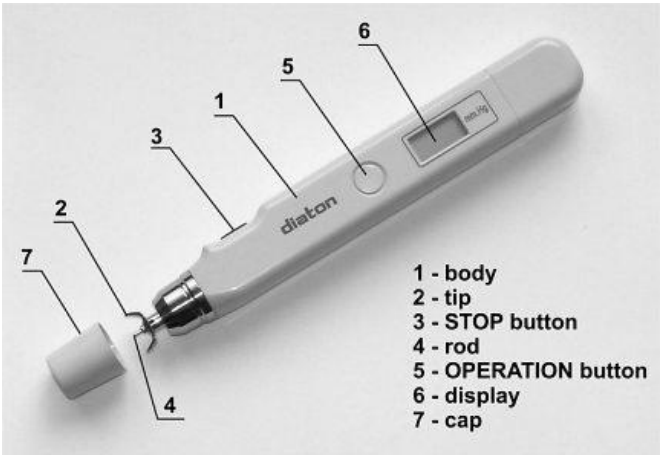

Figure III: *A Diaton tonometer, by courtesy of InnZ medical (BiCOM, 2011).*

MATERIAL AND METHODS

STUDY DESIGN

The study consisted of two parts including different measurements of joint swelling on euthanized dogs as well as living, here on referred to as the "in vitro" and "in vivo" study respectively. Ethical permission was given by the Ethical Committee on Animal Experiments in Uppsala, Sweden. The measuring methods and protocols were almost the same for both groups of dogs; exceptions are presented in the explanation of each study. Prior to the study instructions were given on how to perform the measurements (both in writing and orally). Except for palpation and tonometry the assessors where blinded to the result of their measurements since a separate person performed the reading.

MATERIAL

In vitro study

Three canine carcasses, belonging to the Swedish University of Agricultural Sciences, were used prior to their use in the veterinary education. The dogs were of different breeds: two German Shepherds and one Drever (ages unknown). Both elbow joints of each dog were injected with multiple standardized amounts of sodium chloride solution (see Appendix I) to simulate joint swelling. After injection measurements of the joints were made by assessors blinded to the specific amount of sodium chloride solution. The assessors were two veterinary students in their final year. Two of the dogs were injected twice to repeat the measurement. During measurements a semi standing position was attained by holding the dogs upright, two of the dogs by using a box between the front and back legs and one dog by elevating the body with harness and ropes tied to it.

In vivo study

The dog unit of the Stockholm police force made their dogs available for the study during two days when their ordinary training took place. During those days interested handlers had the opportunity to join the study with their police dogs. Before entering the handlers filled in an owner's agreement of participation (see Appendix II) and a questionnaire (see Appendix III). There were three different assessors, all experienced veterinarians. Each dog was measured by two different assessors (see Appendix VI for exact distribution).

A total of 12 dogs participated in the in vivo study, nine males and three females. The dogs were of different breeds: German Shepherd (6 dogs), Malinois (4 dogs) and Dutch Shepherd dog (2 dogs). The ages varied between one to nine years (mean value 3.8 years, standard deviation 2.1). A number of the dogs had been in service for some years whilst others were being tested if they could be used in the police force. For summary and further information on the dogs see Table I.

Table I: *Police dogs participating in the study. The duration of duty refers to how long the dog has been working in the police force. Where the duration of duty is "test" the dog has not yet been approved but is being tested as a police dog*

	Sex	Neutered	Breed	Year of birth	Duration of duty
1	Female	No	Malinois	2002	2 years[2]
2	Female	No	German Shepherd	2010	Test
3	Male	No	German Shepherd	2009	Test
4	Male	No	Dutch Shepherd dog	2007	Test
5	Male	No	Malinois	2006	3 years
6	Male	No	German Shepherd	2009	Test
7	Male	No	German Shepherd	2008	9 months
8	Male	No	German Shepherd	2009	Test
9	Male	No	German Shepherd	2007	Unknown
10	Male	No	Dutch Shepherd dog	2006	3 years
11	Female	No	Malinois	2006	3 years
12	Male	Yes	Malinois	2007	Unknown

Exclusion criteria

To take part in the study the dogs could not, at that time, stand on treatment with anti-inflammatory or analgesic medicine (like non steroidal anti-inflammatory drugs or corticosteroids).[3]

METHODS

A clinical examination was performed by experienced veterinarians, familiar with the dogs, before measurements began (the two examining veterinarians inspected ten and two dogs respectively).The different methods for measuring joint swelling were performed in the same predetermined order in all dogs, both in the in vivo and the in vitro study; palpation, slide caliper, circumference, figure eight and tonometer (for measuring protocol and measurement instructions see Appendix IV and V). The tonometer was not used in the in vitro study (since there was no tonometer available to borrow at the time). In addition the placement of the slide caliper was adjusted after the in vitro study, resulting in two different measuring positions during the in vivo study, instead of one. All measurements, besides the palpation and tonometry were made in triplicate. All measurements took place with the dog in a standing position except for the tonometry[4], where the dog laid on the opposite side from where the measuring took place. When standing the dog's limbs had to be fully weight bearing.

[2] Previously four to five years of work with watchmen

[3] This exclusion criterion was established since the dogs were to be tested on a pressure mat later on in another study taking place parallel to this one. One dog happened to enter the study though he was on medication and was allowed to continue in the evaluation of assessments tools since this had no importance for the measurements

[4] The tonometer used in the study demanded a vertical positioning for measurements wherefore the dogs had to lie down during these.

Palpation

The synovial recesses where palpated caudally and cranially to the lateral collateral ligament of the elbow joint. The joint was assessed as "without remark" (Swedish: "utan anmärkning": u.a.) or an effusion was estimated as "mild" (Swedish: "lindrig"), "moderate" (Swedish: "måttlig") or "severe" (Swedish: "kraftig"). One measurement on each elbow joint was made and the assessor noted the result themselves.

Tape measure

A tape measure with a dynamometer (ReDog of Sweden™) (see Figure IV) was used to assure that different assessors used the same force when measuring. Each measurement was performed three times on each elbow joint. The assessor adjusted the dynamometer to a marking, representing the standardized applied force, while a separate person did the reading.

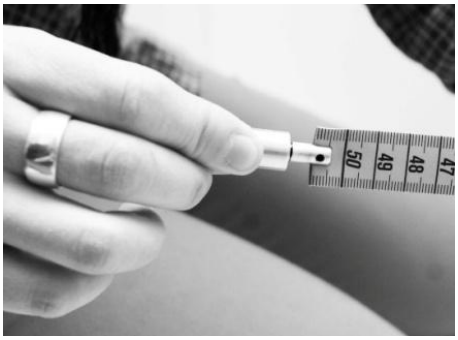

Figure IV: *A dynamometer at the end of the tape measure to ensure that the same force is used in each measurement.*

Circumference

The circumference of the elbow joint was measured by placing the tape measure horizontally over the lateral collateral ligament, in level with the joint space (see Figure V).

Figure eight

The tape measure was placed in the shape of a figure eight around the elbow joint, starting from the lateral collateral ligament. The tape measure was then placed passing just proximally to olecranon and approximately two centimeters distally (see Figure V).

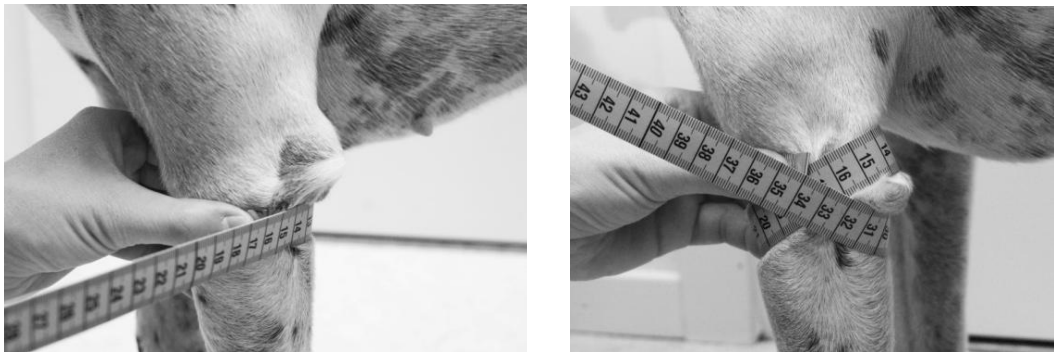

Figure V: *Measurement with tape measure; circumference and figure 8 respectively.*

Slide caliper

The slide caliper (ReDog of Sweden™) was placed in two different positions for the measurement, referred to as cranial/caudal and medial/lateral (for protocol see Appendix IV). A dynamometer on the flexible part of the slide caliper (see Figure II) ensured that a standardized pressure was applied in each measuring. When the assessor estimated a correct positioning a separate person read the result on the slide caliper's digital display.

Medial/Lateral

The disks of the slide caliper were placed medially and laterally over the elbow, centering over the collateral ligaments, in level with the joint space (see Figure VI).

Cranial/Caudal

The disks of the slide caliper were placed cranially and caudally over the elbow, right below tuber olecranii (see Figure VI).

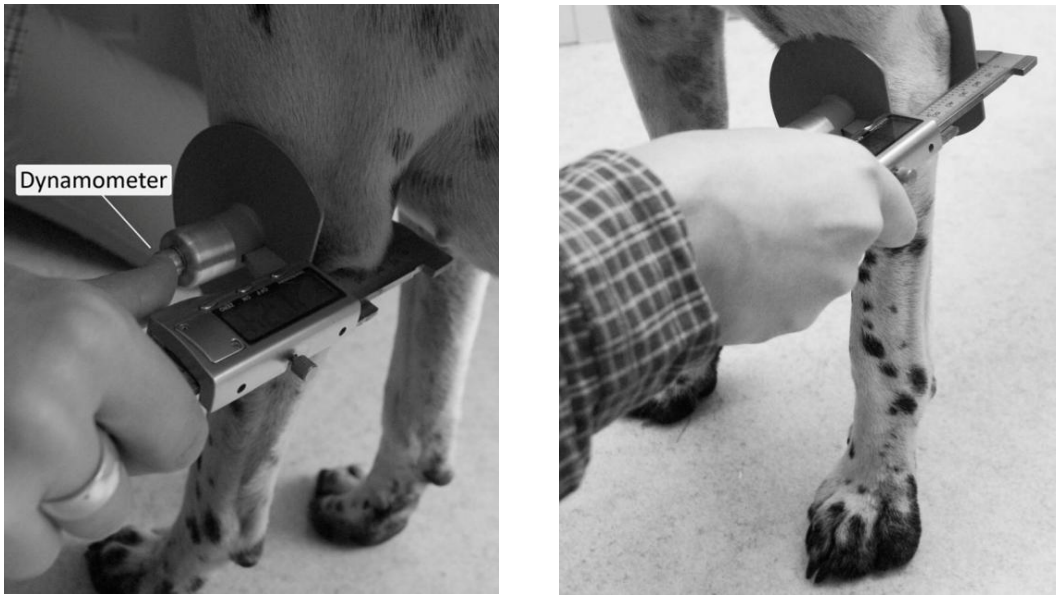

Figure VI: *Measurement with slide caliper; medial/lateral and cranial/caudal placement respectively.*

Tonometer

Before using the tonometer (BiCOM.inc Diaton tonometer) a small area over the craniolateral synovial recess of the elbow joint was shaved. The tonometer needs six registrations of the pressure to calculate a mean value, which was used as a result in this measuring method. The assessors noted the result themselves and one mean value was attained for each elbow.

DATA ANALYSIS

Statistical analysis of the data from the in vivo study was performed by an experienced statistician[5] (the data from the in vitro study was not analyzed, see result for more information). The following description of the analysis is an adapted translation of the information given to the author by the statistician.

Modified linear models where created for each of the numerical response variables (slide caliper C/C and M/L, circumference, figure 8 and tonometer) with regard to assessor, dog and left or right side as descriptive variables. Ten values where considered as faulty measurements because of distinct deviation (so called: "outliners") and where not included (se Appendix VI for exact values). Tables for analysis of variance were used to distribute the variance according to the different factors.

Intra class correlation (ICC)[6] was calculated to render values for inter- and intra-rater reliability[7]. Inter-rater reliability could not be attained for the tonometer because of too little data. ICC can be interpreted as follows:

- 0-0.2 indicates poor agreement
- 0.3-0.4 indicates fair agreement
- 0.5-0.6 indicates moderate agreement
- 0.7-0.8 indicates strong agreement
- >0.8 indicates almost perfect agreement.

The models were also used to estimate the respective value for each dog and body side, whereupon the correlation between the numerical variables was calculated.

The categorical variable, palpation, could not be analyzed due to lack of enough material, especially dogs with different degrees of joint swelling[8].

[5] Statistician Mikael Andersson at the Swedish University of Agriculture.
[6] ICC is the intraclass correlation, which describes how strong the resemblance is between units in the same group, for example how distinct the inter-rater-reliability is.
[7] The inter-rater reliability describes how even the result of different assessors' measurements are, while the intra-rater reliability shows how even the result is when the same assessor repeats a measurement.
[8] Totally three dogs were considered, by one of the assessor, to perhaps have a mild swelling (see appendix VI).

RESULT

IN VITRO STUDY

The experimental situation could not satisfactory imitate a living dog, standing on weight bearing limbs. Therefore the in vitro study served more as an opportunity to practice the different measuring methods; to be able to make adjustments for the in vivo study and to minimize sources of error. No analysis was made on the data collected in the in vitro study (for additional information contact the author).

IN VIVO STUDY

The following result is an adapted translation of the information given to the author by the statistician. Note that in contradiction to the instructions, 25 % of the dogs (see Appendix VI) where cut for tonometrical measurements before the second assessor had performed the other measurements.

Variance for numerical variables

Total variance for the five models of the numerical response variables (slide caliper C/C and M/L, circumference, figure 8 and tonometer), with regard to assessor, dog and left or right side, is described in Figure VII along with the variance of accidental errors[9].

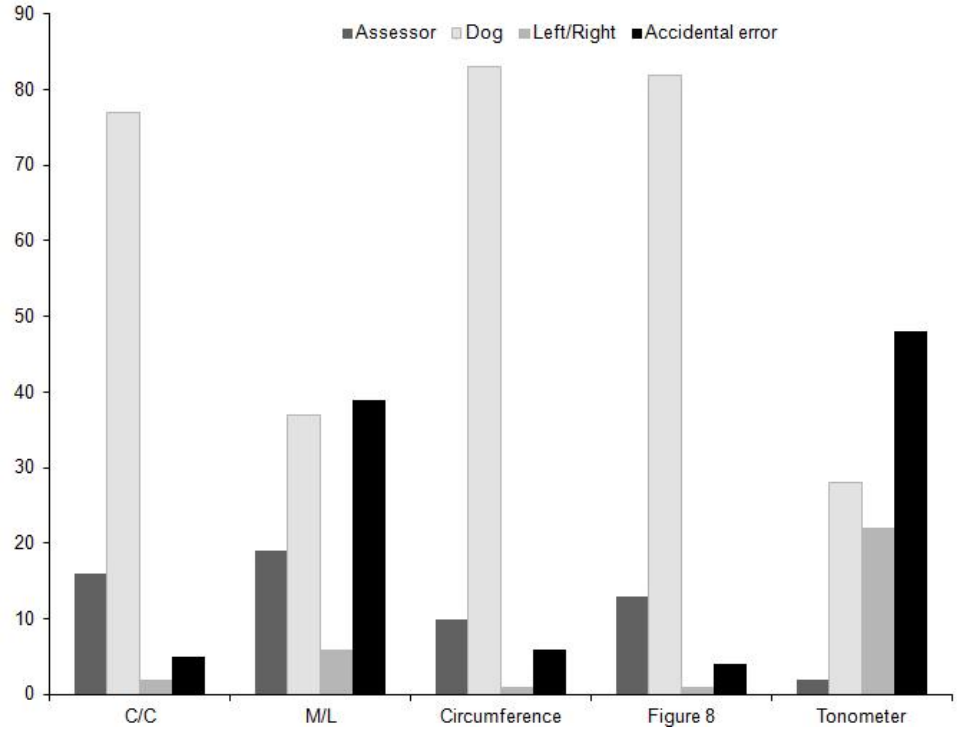

Figure VII: *Total variance (in percent) with regard to assessor, dog and left or right side is shown for the five models along with the variance of accidental errors. C/C and M/L refers to the different measurements with the slide caliper.*

[9] An accidental error is caused by misdistribution of the samples: Repeated measurements, rendering more values often reduce the accidental error (Andersson, 1984). Small variance in accidental error indicates good precision (George).

Inter-rater reliability

Interclass correlation (ICC) between the assessors (i.e. inter-rater reliability) is described in Table II for the slide caliper and tape measure. No value was attained for the tonometer.

Table II: *ICC for assessors. C/C and M/L refers to the different measurements with the slide caliper*

	C/C	M/L	Circumference	Figure 8	Tonometer
ICC	0.59	0.33	0.49	0.36	-

Intra-rater reliability

Interclass correlation (ICC) between measurements made by the same assessor (i.e. intra-rater reliability) is described in Table III for the slide caliper, tape measure and tonometer.

Table III: *ICC between measurements. C/C and M/L refers to the different measurements with the slide caliper*

	C/C	M/L	Circumference	Figure 8	Tonometer
ICC	0.95	0.61	0.94	0.96	0.52

Correlation between measuring models

Correlation between the different measuring models is described in Table IV to give a notion of the relationship between the variables. Significant correlations (three models are significantly correlated) are depicted in shaded, bold, italic figures.

Table IV: *Correlation between the five measuring models. C/C and M/L refers to the different measurements with the slide caliper. Shaded, bold, italic figures are significant correlations.*

	C/C	M/L	Circumference	Figure 8	Tonometer
C/C		0.34	***0.95***	***0.95***	-0.15
M/L	0.34		0.37	0.32	-0.29
Circumference	***0.95***	0.37		***0.98***	-0.18
Figure 8	***0.95***	0.32	***0.98***		-0.12
Tonometer	-0.15	-0.29	-0.18	-0.12	

DISCUSSION

The study has evaluated four different measurement tools for assessing joint swelling; the subjective palpation and the objective slide caliper, tape measure and tonometer. Unfortunately the study material was too small to draw any conclusion about the palpation but analysis of the data could determine inter- and intra-rater reliability as well as correlation between the different methods for the other instruments.

To optimize the study a comparison should also have been made with ultrasound, a validated method for detecting joint swelling. When comparing the use of ultrasonography with the clinical examination (including inspection, palpation and range of motion) of human elbows, the examination can in most cases find a swelling corresponding to joint effusion found with ultrasound, though ultrasonography is more reliable (Luukkainen *et al*., 2005). To be able to quantify a joint swelling more objectively and in a way that is practical in the everyday clinical work is of great value in the striving to use evidence based methods in veterinary medicine.

SOURCES OF ERROR

In the assessment of muscle mass an investigation establishes the importance of limb position and points out the value of practice in the method and standardized techniques to obtain reproducible results. The study also states the significance of a dynamometer attached to the tape measure to ensure that a standardized tension is applied in each measure (Millis, 2004).

Both tape measure and slide caliper were equipped with a dynamometer to ensure the same tension was applied in each measure. All measurements took place in the standing dog (except for tonometry) so that the measurements would be performed with the same weight bearing on each leg.

To further minimize sources of error, strict instructions were given to the assessors on how to perform the measuring. Sources of error that were not excluded in the study were difference in hair coat and callosities in the skin (though this was said to be noted if thought to interfere with the measurement). According to the instructions the dogs' hair would not be cut for the tonometry measurements before all the other instruments had been used. These instructions were not followed; 25 % of the dogs were cut before the second assessor had performed the other measurements (see Appendix VI). This should however not have had much influence on the result since the area in question is small (maximum one square centimeter) and a majority of the dogs were uncut before measurements. In case the cutting did interfere with the measurements it would have had the same influence on both the left and right elbow (thus not rendering a difference).

If the study is repeated non-sequential measuring should be considered. This was done in a study comparing different instruments to measure limb circumference to ensure that every new measure really was a new measurement (Baker *et al*., 2010).

The assessment methods used in this study cannot differentiate between extra- and intracapsular swelling. Preferable would have been to compare the measuring result with an ultrasonographic evaluation of each dog's elbow joints. The ultrasound might also been able to detect small swellings, not noticed with the other instruments. If the study is repeated an ultrasound can be used as a control method (having the "correct answer") that other instruments are compared with.

VARIANCE AND CORRELATION

There was a marked variance for the slide caliper, tape measure and tonometer with regard to assessor and dog. The variance concerning the left or right body side was much less except for the tonometer. Moderate to good inter-rater reliability (see Table II) and very good intra-rater reliability (see Table III) was attained for the instruments. The results, showing better intra- than inter- rater reliability, are generally supported by human studies (Cleland, 2005).

Assessor variance and Inter-rater reliability

Despite strict instruction preceding the measurements there was quite a variance between different assessors regarding the slide caliper, tape measure and tonometer (see Figure VII) A reason for this might be that thought thorough instructions were given, personal experience might have taken over, resulting in inaccurate measurements. The observers noted, during the measurements, that the assessor sometimes did not follow instructions as strictly as was hoped. If a similar study is performed it is essential to even more strongly explain the importance of a standardized technique. Despite the variance, the inter-rater reliability was moderate to good for both slide caliper C/C and circumference. The inter-rater reliability was only slightly lower for figure 8 and slide caliper M/P (see Table II).

Variance between dogs and body sides

The marked variance between different dogs (see Figure VII) is expected due to their difference in size. Variance between right and left elbow is small for both the slide caliper techniques and the tape measure methods but not for tonometry (see Figure VII). This is as it ought to be since there should not be a distinct difference between the legs if the dog is not swollen in one of its elbows. That the tonometer displays a large variance indicates that the instrument might not be suited for these kinds of measurements. Another possible explanation might be that the tonometer is very sensitive for external factors; that exact positioning of the joint and small differences in skin thickness etc. might interfere with the measurement.

Intra-rater reliability

The intra-rater reliability was very good for slide caliper C/C, circumference and figure 8. For the tonometer and slide caliper M/P the intra-rater reliability was only slightly lower (see Table III). If the study is repeated, non-sequential measurements with the same instruments ought to be considered, to ensure that each measurement is made anew, guaranteeing no false high intra-rater reliability. Non-sequential measuring was for example used in a study comparing different ways of measuring limb circumference (Baker *et al.*, 2010).

Accidental error

The accidental error is high for the slide caliper M/L and the tonometer (see Figure VI). For the slide caliper this might be due to different positioning of the instrument (the craniocaudal placement is more exact and easier to repeat than the mediolateral). For the tonometer the explanation might be the heterogeneity of the tissue, rendering very different circumstances for which the measurement takes place (compared to when measuring intraocular pressure on homogenous eyelids).

Correlation between the methods

There is a significant correlation between the measurements circumference and slide caliper C/C, circumference and figure 8 along with figure 8 and slide caliper C/C, showing that these methods give roughly the same result.

TAPE MEASURE

The circumferential measurements gave the least variance with regard to the person performing the measuring. It also correlates significantly to the techniques using a figure 8 and the craniocaudal approach with the slide caliper.

Considering that circumferential measurements, of for instance the thigh, often is used, by both veterinarian orthopedic surgeons and physical therapist, for evaluation of limb use and function (Baker *et al*., 2010) the method seems valuable. The use on human joints (Nicholas *et al*., 1979) indicates that it ought to be able to practice this on animals too. Further studies with a larger material and greater variety in joint swelling might give a better picture of how the tape measure can be used in veterinary medicine for joint evaluation. Perhaps a tape measure designed for circumferential measurements ought to be used though a study comparing different instruments for measuring limb circumference does not find these to be better than usual tape measures (Baker *et al*., 2010).

In view of the successful use of the figure 8 measure on for example human ankle joints (Estersson, 1979) further studies ought to examine the use in canine patients. The anatomical difficulties measuring a swelling in a human ankle resemble the anatomy of the canine elbow joint (see Figure I).

SLIDE CALIPER

An issue when using the slide caliper is that there is a risk for variable results due to prominent bone structures in the measuring area, interfering with the measurement. This means that for a swollen joint to contribute to an increased result it has to be swollen beyond the bone structures. This might be put right by having a caliper with smaller tips (i.e. it can be placed so that it bypasses the bone structures) but would also need other anatomical landmarks (e.g. measure cranially or caudally to the collateral ligaments). When comparing the two different positionings of the slide caliper, the craniocaudal had small variance (see correlation between the methods and comparison of assessor variance, Table IV and Figure VII).

With the particular slide caliper used in this study something to be observant about is that a built in calculator gives the difference between two measurements

if the instrument is not zeroed in between. In this study no deviating results where noted, in concerned cases the incorrect result was directly observed and corrected.

The use of slide calipers to measure joints in rats (Bendele, 2001) suggests that it would be possible to use in other animals as well. It might be that a slide caliper works best when measuring smaller areas, for example phalangeal joints, whatsoever the instrument ought to be investigated further for the use in joint measurements.

TONOMETER

The results of this study demonstrate the difficulties in using the tonometer to assess joint effusion in dogs. One reason is the difficulty in having the dog lying on the side, non-weight bearing. It is possible that a tonometer that could be used in a standing dog would work differently. Also the participating dogs had in most cases no detectable joint swelling (see Appendix VI), making it hard for the tonometer to measure an increased pressure.

CONCLUSION

This pilot study demonstrates a moderate to good inter-rater reliability and very good intra-rater reliability for especially slide caliper C/C, circumference and figure 8 in normal police dogs. Further studies, focused on these methods, are needed to confirm present results. The result should also be compared with measurements on dogs with different degrees of joint swelling in order to secure the reliability and validity of the measurement tools in a clinical setting. A larger study material would also make it possible to determine the range of error for each method.

ACKNOWLEDGMENT

The author would like to thank the Stockholm police's dog unit for participating with dogs and handlers in the study. Also thanks to ReDog for lending their slide caliper and tape measure for use in the study and to InnZ medical for lending their Diaton tonometer and pictures for use in the study. Thanks to Josefin Bergh Eklöf, Sören Johansson and Ellinor Åberg who helped during the days of measurements as well as the veterinarians from Bagarmossen.

Further the author would like to thank her fellow student; Regina Lindberg for introducing her to this degree project and for discussing ideas and giving constructive criticism all the way from brainstorming to finished paper. A special thanks to Ila (Regina's pointer) for standing model for the photographs of measurements.

Of course a great thanks to this study's supervisor; Anna Bergh, whom by giving hints, suggesting articles and serving constructive criticism has managed to herd the author in the right direction. In addition the statistician, Mikael Andersson, deserves thanks for producing a result from the mess of data that was given to him.

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Figures and Tables

The tonometer depicted in Figure III and on the front page is used by courtesy of InnZ medical (BiCOM, 2011). All other photographs, illustrations, diagrams and tables are the author's own property.

VOLUMES INJECTED SALINE SOLUTION

Saline solution of standardized volumes was injected in the elbow joints bilaterally to simulate joint swelling in the in vitro study. After a first injection measuring took place after which a second injection was performed to increase the measuring material.

	First Injection (ml)		Second Injection (ml)	
	Right	**Left**	**Right**	**Left**
Drever	0	+2	0	+4
Black German Sheppard	+4	0	+5	+2
Brown German Sheppard	+2	0	+2	0

INFORMATION INFÖR DELTAGANDE I STUDIE AVSEENDE UTVÄRDERING AV OLIKA MÄTMETODER OCH EVENTUELLT SAMBAND MELLAN LEDSVULLNAD I ARMBÅGSLED OCH BELASTNING

SYFTE MED STUDIEN

Syftet med studien är att utvärdera fyra olika mätmetoder för ledsvullnad i armbågsled samt undersöka eventuellt samband mellan en sådan svullnad och belastningsgrad mätt på en tryckmätningsmatta. Tjänstehundar ska klara mycket i både arbete och träning, varför det är viktigt att i ett tidigt skede kunna upptäcka eventuell ledpåverkan för att kunna sätta in förebyggande träning/åtgärder. Tjänstehundar är tuffa och stoiska hundar som ofta dröjer med att visa tecken på smärta. Det kan därför vara av vikt att på ett relativt snabbt och enkelt sätt bedöma ledernas status. Det är även av värde att kunna jämföra hur resultat från olika mätmetoder överensstämmer.

BESKRIVNING AV STUDIEN

Försöket tar ca 45-60 min/hund. Ni kommer att passera fyra stationer:

1. ***Information:*** Ifyllande av djurägarintyg och ett frågeformulär rörande hunden
2. ***Veterinärundersökning:*** En kortare klinisk undersökning
3. ***Registrering av ev ledsvullnad i armbåge***: Hundens armbågsleder kommer att bedömas avseende ledsvullnad med hjälp av fyra olika mätmetoder; skänkelmätare, palpation, mätning med måttband samt Tonometer (en apparat som mäter tryck, används oftast för att mäta trycket i ögat). Inför mätningen med Tonometer kommer ett litet område (ca 2x2 cm) att rakas över armbågslederna.
4. ***Registrering med tryckmätningsmatta samt rörelsesensorer:*** En mjuk sele med rörelsesensorer sätts på hunden som därefter får vänja sig vid sele och att gå över mattan (cirka 5 minuter) . Efter uppvärmningen får hunden skritta och trava över en tryckmätningsmatta som mäter hur hunden belastar sina tassar. Hunden kommer att filmas när den går över mattan. När mätning erhållits från tryckmätningsmattan är studien avslutad för er och hundens del.

Studien förväntas inte medföra några komplikationer, orsaka smärta eller på annat sätt påverka de deltagande hundarna i negativ bemärkelse. Inga medicinska preparat eller andra substanser kommer att tillföras hundarna under studiens gång. Studien är godkänd av etisk nämnd, nummer C 62/11.

SAMTYCKE

Jag har muntligen informerats om studien och tagit del av och förstått ovanstående skriftliga information. Jag är medveten om att deltagande i studien är frivilligt och att jag när som helst kan avbryta deltagandet.

HUNDENS NAMN:

DATUM:

UNDERSKRIFT AV HUNDFÖRARE: **NAMNFÖRTYDLIGANDE:**

KONTAKTPERSON

Leg. Veterinär Anna Bergh, anna.bergh@slu.se
Institutionen för anatomi, fysiologi och biokemi
BOX 7011, 750 07 UPPSALA
MOBIL 070 3035997

FRÅGEFORMULÄR

För att få lite bakgrundsinformation ber vi dig fylla i detta frågeformulär. Om det är någon fråga du inte kan svara på, skriv ”Vet ej”.

1. Hundens kön	Tik	☐	Hane	☐
2. Kastrerad	Ja	☐	Nej	☐

3. Ras	
4. Ålder (födelsedata)	
5. Tid i tjänst	
6. Hundens huvudsakliga arbetsuppgifter (exempelvis: skydd, spår etc.)	

7. Resultat av eventuell armbågsleds-röntgen (AD-röntgen)	**HÖGER**	**VÄNSTER**

8. Står hunden på smärtlindrande eller antiinflammatorisk medicin, i så fall vilken/vilka? (exempelvis: Rimadyl, Metacam, Prednisolon m.m.)	
9. Är hunden under det senaste året behandlad för hälta, i så fall vilket/vilka ben/tassar?	

Vi tackar så mycket för er medverkan!

MEASURING PROTOCOL

The following measuring protocol was used in the in vivo study. It was modified from the protocol used in the in vitro study since the tonometer was not applied in that part and neither were the different positions of the slide caliper. In the protocol C and M stands for the different positions of the slide caliper (cranial/caudal and medial/lateral respectively), explained in the material and methods section.

Mätperson: **Hundnamn:**

REGISTRERING		1		2		3	
		Höger	**Vänster**	**Höger**	**Vänster**	**Höger**	**Vänster**
Palpation							
Skänkelmätare (mm)	**C**						
	M						
Måttband horisontell (cm)							
Måttband 8:a (cm)							
Tonometer (pa)							

Kommentarer:[10]

[10] If the dog for example had a callosity in the skin, showed pain during clinical examination etc.

MEASURING INSTRUCTIONS

The following measuring instructions where give to the assessors before the in vivo study. Note that the cranial/caudal measuring with the slide caliper is not mentioned, instructions regarding this was instead given orally. The instructions for the tonometer were also slightly changed in accordance to the requirements for the specific model that was used.

Beskrivning av mätningars utförande

Vid mätningarna hjälps två personer åt; en är ”mätperson” och den andre är ”avläsare”. Vid den subjektiva mätningen (palpation) kommer mätpersonen själv att notera sitt resultat. Vid övriga mätningar ska mätpersonen endast lägga an instrumentet korrekt och bedöma när det är redo att avläsas, därefter noterar avläsaren resultatet. De objektiva mätningarna utförs totalt tre gånger vardera på varje led. Alla mätningar utförs på belastat hund.

Palpation – Subjektivt mätning

Armbågsledens ledfickor palperas cranialt och caudalt om laterala kollateralligamentet. Leden bedöms som ”u.a.” (utan anmärkning) alternativt bedöms en ledsvullnad som ”lindrig”, ”måttlig” eller ”kraftig”.

Måttband: Omkrets

Laterala kollateralligamentet palperas ut och måttbandet läggs an horisontellt över ligamentet, i nivå med ledspringan. Kontrollera att måttbandet ligger i våg runt om leden. Drag i momentnyckeln till markeringen och låt avläsaren notera resultatet. Upprepa mätningen ytterligare två gånger (totalt tre mätningar).

Måttband: 8:a

Måttbandet ska läggas an i form av en åtta runt armbågsleden. Lämplig utgångspunkt är armbågens laterala kollateralligament, därefter läggs måttbandet an så att det passerar precis proximalt om armbågsspetsen och ca 2 cm distalt om densamma. Drag i momentnyckeln till markeringen och låt avläsaren notera resultatet. Upprepa mätningen ytterligare två gånger (totalt tre mätningar).

Skänkelmätare

Skänkelmätarens plattor läggs an medialt och lateralt över armbågen. Centrera plattorna över armbågens kollateralligament, i nivå med ledspringan. Kontrollera att även den mediala plattan ligger dikt an mot armbågen (håll gärna fast den där med en hand under mätningen men iakttag försiktighet så att inget tryck påverkar leden). Mätpersonen bedömer när båda plattorna på skänkelmätaren ligger dikt an mot armbågsleden och avläsaren noterar resultatet på den digitala monitorn. Upprepa mätningen ytterligare två gånger (totalt tre mätningar).

Tonometer (Tonopen™)

Inför mätningen med tonometer kommer ett område över armbågen att rakas. Vid mätningen läggs instrumentet an så att den utskjutande delen träffar i det rakade området, över ledfickan. Tonometern talar själv om när den har uppmätt ett användbart värde, vilket avläsaren noterar. Upprepa mätningen ytterligare två gånger (totalt tre mätningar).

SUMMARY OF ALL COLLETED DATA

C/C and M/L refers to the different measurements with the slide caliper. Some values are missing and denoted with a hyphen ("-"). Outliners (mentioned in "data analysis") are depicted in bold text. Note that most dogs are measured by veterinarian A and B but some are measured by veterinarian C instead of B. "ua" stands for Swedish "utan anmärkning – without remark. Dogs marked with "¤" where clipped for tonometrical measurements before veterinarian A performed the other measurements.

	VETERINARIAN A						VETERINARIAN B					
	Right elbow			Left elbow			Right elbow			Left elbow		
DOG 1												
Palpation	ua			ua			ua			ua		
C/C (mm)	44,7	45,7	44,9	44,6	44,7	45,1	44,4	44,4	44,4	42,8	44,5	44,8
M/L (mm)	59,0	58,4	54,3	63,9	61,0	62,1	61,6	61,3	61,0	57,7	55,4	56,5
Circumference	17,6	17,6	17,6	18,1	18,0	17,9	16,9	16,8	17,1	16,9	17,6	17,4
Figure 8	37,8	37,7	37,4	38.5	38,3	38,3	38,8	39,2	39,0	40,6	39,0	38,5
Tonometer	77,0			72,0			65,0			67,0		
DOG 2¤												
Palpation	ua-mild			ua			Tender			ua		
C/C (mm)	49,9	50,5	48,9	48,1	48,3	48,0	50,2	50,4	51,8	48,9	48,9	48,4
M/L (mm)	60,9	60,8	61,6	69,8	71,2	69,6	61,3	66,8	68,2	62,0	64,4	64,6
Circumference	19,0	19,3	19,1	20,0	20,3	19,3	20,0	19,8	20,5	19,5	19,8	20,0
Figure 8	40,5	40,6	40,7	42,3	41,3	42,2	**52,0**	43,5	42,5	41,0	41,5	41,5
Tonometer	65,0			58,0			80,0			51,0		
DOG 3												
Palpation	ua			ua			ua			ua		
C/C (mm)	49,4	49,9	49,9	49,9	50,8	50,6	**60,0**	50,8	50,4	50,6	51,2	49,7
M/L (mm)	68,6	69,1	69,1	67,2	68,5	67,4	64,0	64,7	61,1	62,1	60,0	59,1
Circumference	20,1	19,8	19,8	20,3	20,2	20,3	20,0	19,5	19,5	19,2	19,8	20,0
Figure 8	42,6	43,2	42,5	43,5	43,5	43,5	43,0	44,0	44,0	43,8	43,0	43,0

Appendix VI Values from the measurements

Tonometer	67,0			56,0			85,0			77,0		
	VETERINARIAN A						**VETERINARIAN B**					
	Right elbow			**Left elbow**			**Right elbow**			**Left elbow**		
DOG 4												
Palpation	ua			ua-mild			ua			ua		
C/C (mm)	46,3	46,7	48,4	49,5	51,5	48,4	51,4	**58,2**	51,6	48,7	52,6	52,1
M/L (mm)	62,8	60,5	59,4	58,7	58,1	59,5	62,4	61,9	62,0	64,8	62,1	63,1
Circumference	19,8	19,6	19,5	19,8	19,8	19,5	18,5	18,5	18,5	19,0	19,5	19,4
Figure 8	41,0	40,7	40,5	42,0	42,0	42,3	43,5	43,5	42,5	42,5	40,5	42,0
Tonometer	8?						-			83,0		
DOG 5												
Palpation	ua			ua			ua			ua		
C/C (mm)	43,2	43,7	43,5	42,6	42,6	42,6	42,3	42,3	41,3	42,8	42,7	42,9
M/L (mm)	55,2	56,2	56,6	60,2	62,8	62,4	50,3	49,7	50,5	52,2	49,0	44,5
Circumference	16,8	16,8	16,8	17,2	17,2	17,0	15,7	15,6	16,0	16,5	16,2	16,8
Figure 8	34,6	34,7	34,6	36,5	35,3	35,2	36,0	36,1	35,5	35,5	34,5	35,0
Tonometer	72,0			81,0			43,0			69,0		
DOG 6¤												
Palpation	ua			ua			ua			ua		
C/C (mm)	53,4	56,8	55,1	52,5	53,4	53,2	54,1	56,8	56,5	53,5	54,7	53,2
M/L (mm)	68,7	71,1	71,7	69,3	68,2	71,7	69,4	69,2	69,8	67,1	65,8	65,2
Circumference	21,0	21,1	21,6	21,5	21,3	21,6	21,0	20,5	20,5	21,0	21,3	21,5
Figure 8	44,6	45,2	44,5	44,4	45,0	44,5	45,0	46,5	46,0	44,5	44,5	45,0
Tonometer	-			-			69,0			60,0		
DOG 7												
Palpation	ua			ua			ua			ua		
C/C (mm)	45,6	45,2	44,2	46,5	47,2	45,4	45,3	45,5	46,2	46,8	46,9	46,2

Appendix VI Values from the measurements

M/L (mm)	75,5	75,8	72,6	62,1	58,7	59,5	69,7	70,3	57,5	56,9	57,9	57,5
Circumference	19,5	19,6	19,3	19,5	19,1	19,5	19,0	18,7	18,5	18,7	18,0	18,5
Figure 8	39,4	39,4	39,1	40,2	39,6	39,7	41,0	42,0	42,5	43,0	42,5	42,5
Tonometer	73,0			74,0			81,0			67,0		
	VETERINARIAN A						**VETERINARIAN B**					
	Right elbow			**Left elbow**			**Right elbow**			**Left elbow**		
DOG 8												
Palpation	ua			ua			ua			ua		
C/C (mm)	50,0	50,4	51,3	50,6	51,0	52,4	**15,5**	**14,9**	**15,5**	**15,0**	**15,7**	**15,0**
M/L (mm)	61,8	64,2	63,5	69,9	65,9	67,4	33,0	32,5	33,1	27,2	26,8	28,1
Circumference	20,6	21,6	21,0	21,0	21,2	21,0	20,0	19,5	19,7	20,0	20,0	20,0
Figure 8	42,7	42,8	43,8	43,5	43,0	43,2	44,5	45,0	45,0	45,0	45,0	45,3
Tonometer	72,0			71,0			72,0			91,0		
DOG 9												
Palpation	ua			ua-mild			ua			ua		
C/C (mm)	54,1	54,7	54,5	50,3	50,4	50,9	52,9	52,5	51,8	52,1	52,1	52,3
M/L (mm)	69,1	73,0	67,7	**20,5**	65,3	64,0	41,2	41,5	55,4	59,7	62,5	61,2
Circumference	21,7	21,8	22,4	21,8	22,5	22,3	20,5	20,0	20,5	19,5	19,5	20,0
Figure 8	46,1	46,0	45,1	44,5	44,4	44,6	46,0	45,5	46,0	45,5	46,0	46,5
Tonometer	-						-			-		
DOG 10[¤]												
Palpation	ua			ua			ua			ua		
C/C (mm)	47,2	48,4	48,9	48,6	46,8	46,8	47,3	48,4	48,0	47,2	48,8	47,9
M/L (mm)	63,4	64,8	65,2	66,4	65,7	62,2	47,2	47,8	48,1	56,1	56,3	57,7
Circumference	19,8	19,7	19,5	20,0	19,9	19,8	18,5	18,3	18,0	19,2	19,0	18,7
Figure 8	42,0	41,9	41,5	40,7	41,0	41,0	43,5	43,0	42,0	41,5	41,0	43,0
Tonometer	78,0			69,0			63,0			68,0		

Appendix VI Values from the measurements

	VETERINARIAN A						VETERINARIAN C					
	Right elbow			Left elbow			Right elbow			Right elbow		
DOG 11												
Palpation	ua			ua			ua			ua		
C/C (mm)	42,1	42,5	43,9	43,0	42,8	42,3	41,2	42,3	41,8	40,7	41,2	41,7
M/L (mm)	58,7	63,3	66,3	60,8	63,1	56,0	52,5	52,0	50,7	56,0	48,5	51,5
Circumference	17,0	17,2	17,1	17,3	17,3	17,1	17,4	17,3	17,0	16,9	17,0	16,5
Figure 8	36,6	36,5	36,2	36,2	36,1	36,1	39,0	36,0	36,3	37,0	37,0	37,3
Tonometer	78,0			73,0			90,0			94,0		
DOG 12												
Palpation	ua			ua			ua			ua		
C/C (mm)	46,7	48,9	47,8	46,1	46,1	46,2	44,1	44,4	44,4	44,5	44,6	44,4
M/L (mm)	60,2	59,8	59,0	61,9	60,6	61,3	58,1	58,0	58,0	63,7	64,1	62,8
Circumference	19,0	19,0	18,8	19,0	18,9	19,0	19,0	19,0	18,5	18,0	18,0	18,3
Figure 8	39,7	39,8	40,2	40,0	40,1	39,8	41,0	39,5	39,3	39,5	39,3	39,0
Tonometer	77,0			78,0			50,0			68,0		