

Radiographic morphometric characteristics of stifle joint in orthopaedically healthy dogs

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This study presents a morphometric analysis of the stifle joint in orthopaedically healthy dogs, with an emphasis on variations associated with body weight and breed size. A total of 37 dogs were included and categorised into distinct weight groups and breed size classifications. Key morphometric parameters including patellar length, patellar ligament length, cortical thickness, and muscle thickness, were measured and systematically analysed. The results revealed significant variations in morphometric measurements across different weight categories and breed sizes. Dogs of similar breed and body weight exhibited comparable morphometric values, whereas overall measurements increased with breed size, irrespective of body weight. These findings highlight the influence of breed size as a primary determinant of stifle joint morphology. The study underscores the importance of establishing standardised morphometric reference values in dogs. Such standardisation can aid in the accurate assessment of orthopaedic conditions, improve the evaluation of surgical outcomes, and facilitate the identification of abnormalities related to bone morphology.

Keywords: Canine stifle, Dog, Radiographic morphometry

The stifle joint is among the joints most susceptible to orthopaedic disorders in dogs. Several conditions have been reported to influence its morphometric characteristics, including cranial cruciate ligament injury (Mostafa *et al.*, 2008) and patellar luxation (Žilincík *et al.*, 2018). Additionally, distal third femoral fractures and osteoarthritis are commonly encountered pathologies affecting this joint. The primary objective in the management of stifle joint disorders is to preserve the normal range of motion (Drum, 2010) and restore functional mobility as close to physiological conditions as possible. Even a reduction of 10° or more in extension or flexion has been associated with clinically significant lameness (Jandi and Schulman, 2007). Therefore, maintaining normal joint morphology, including its contours and angular relationships, is critical for achieving favourable clinical outcomes.

Morphometric parameters of the canine stifle joint show considerable variation influenced by factors such as age, body weight, and breed size. However,

standardized reference values for normal stifle joint morphology, particularly in relation to these variables, remain inadequately established. The availability of such baseline data is crucial for accurate clinical assessment, comparative evaluation, and postoperative monitoring.

Accordingly, the present study was undertaken to perform a detailed morphometric analysis of the canine stifle joint with respect to body weight and breed size. The data generated are intended to serve as reference values for comparison with affected limbs, thereby facilitating the evaluation of clinical and surgical outcomes. It is hypothesized that dogs of similar age and breed size will exhibit comparable morphometric characteristics. The parameters assessed in this study include patellar length, patellar ligament length, cortical bone thickness, and the thickness of the hamstring and quadriceps muscle groups.

Materials and Methods

A total of 37 orthopaedically healthy dogs with no prior history of musculoskeletal disorders were included in the study. All animals weighed less than 20 kg. The dogs were categorized based on body weight and breed size. Weight-based grouping was defined as follows: group I (0–5 kg), group II (5–10 kg), group III (10–15 kg), and group IV (15–20 kg). Breed-based classification comprised three categories: small breeds, including Pomeranian (n=8) and Shih Tzu (n=1); medium breeds, including Beagle (n=8), American Bully (n=3), and Mongrel (n=3); and large breeds, including Labrador Retriever (n=5), Husky (n=4), Greyhound (n=4), and Chow Chow (n=1).

Morphometric measurements of the stifle joint were recorded, including patellar length (PL), patellar ligament length (PLL), cortical thickness (CT), hamstring width (HW), and quadriceps width (QW). Patellar length was measured from the proximal to the distal extremity of the patella. Patellar ligament length was measured from the distal pole of the patella to its insertion at the tibial tuberosity. Cortical thickness and muscle thickness were measured at the mid-diaphyseal level of the femur along a line

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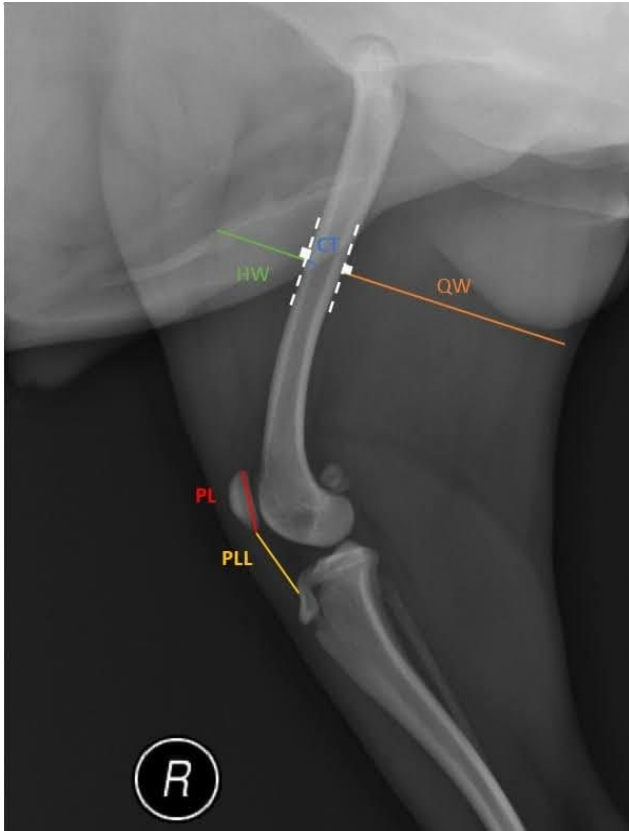


Fig. 1: Normal morphometric measurements: PL- Patellar length, PLL- Patellar ligament length, QW- Quadriceps width, HW- Hamstring width, CT- Cortical thickness.

perpendicular to the longitudinal axis of the bone. Quadriceps muscle thickness was measured from the cranial surface of the femur to the cranial margin of the muscle belly, whereas hamstring thickness was measured from the caudal surface of the femur to the caudal extent of the muscle belly (Sabanci and Ocal, 2016), as illustrated in figure 1.

Statistical analysis was performed using IBM SPSS Statistics version 29.0. One-way analysis of variance (ANOVA) followed by Tukey's honestly significant difference (HSD) post hoc test was applied to compare group means. A P-value of less than 0.05 was considered statistically significant.

Results and Discussion

Morphometry based on weight of dogs

Weight-wise morphometric measurements are presented in table 1. In dogs weighing up to 5 kg (group I), the mean age was 2.28 ± 0.18 months. This group predominantly comprised small breeds ($n=3$; Pomeranian and Shih Tzu) and medium breeds ($n=2$; mongrels), with the inclusion of two large-breed dogs (Husky) aged less than 4 months. The mean body weight of dogs in this group was 3.31 ± 0.42 kg. The mean patellar length was 11.07 ± 1.29 mm, while the mean patellar ligament length was 15.02 ± 1.54 mm. The longest patella and corresponding patellar ligament

were observed in a 4-month-old Husky. The mean cortical thickness was 1.62 ± 0.14 mm, with the lowest value recorded in the youngest dog and the highest in the oldest within the group. The mean hamstring and quadriceps muscle thicknesses were 33.74 ± 2.44 mm and 21.34 ± 1.79 mm, respectively. Large-breed dogs exhibited the greatest muscle thickness, followed by medium breeds, while small breeds showed the lowest values (29.71 ± 3.66 mm for hamstrings and 17.91 ± 0.17 mm for quadriceps). It was observed that despite comparable body weights (3.31 ± 0.42 kg), medium- and large-breed dogs demonstrated higher morphometric values than small-breed dogs.

In group II, a total of seven dogs weighing 5-10 kg were included. The mean body weight was 7.80 ± 0.60 kg. The majority of dogs in this group belonged to small and medium breeds ($n=6$), with only one large-breed dog (Labrador Retriever). The mean age of the dogs was 14.85 ± 4.56 months, with all individuals being older than 5 months. The mean patellar length was 13.94 ± 0.70 mm, which was greater than that observed in group I, likely reflecting the higher mean age of dogs in this group. A corresponding increase in patellar ligament length was also noted, with a mean value of 20.50 ± 1.01 mm, associated with increased patellar size. Despite the inclusion of dogs from different breed sizes, minimal variation was observed in patellar length, patellar ligament length, and cortical thickness within the group. The mean cortical thickness was 2.05 ± 0.10 mm. The mean hamstring muscle thickness was 50.12 ± 3.11 mm, with the highest value recorded in a Beagle weighing 8.4 kg. The mean quadriceps thickness was 25.90 ± 2.34 mm, with the maximum value observed in the Labrador Retriever. Although the Labrador Retriever did not exhibit the greatest hamstring thickness, it demonstrated the highest quadriceps muscle thickness within the group.

In group III (dogs weighing 10-15 kg), the mean age was 24.80 ± 5.61 months, with an average body weight of 12.56 ± 0.34 kg. This group included three small-breed dogs, four medium-breed dogs (all Beagles), and three large-breed dogs. The mean patellar length was 15.38 ± 0.92 mm. Patellar length was relatively consistent across most dogs, with the exception of one Labrador Retriever, which exhibited the greatest value (20.14 mm). The mean patellar ligament length was 20.54 ± 1.39 mm, showing a trend similar to that of patellar length. Cortical thickness demonstrated minimal variation within the group, with a mean value of 2.10 ± 0.04 mm. The mean hamstring muscle thickness was 62.48 ± 4.13 mm, with the highest value observed in a Labrador Retriever. The average quadriceps muscle thickness was 34.43 ± 3.17 mm. Notably, despite having a body weight comparable to other dogs in the group (approximately 14 kg), the Labrador Retriever exhibited the highest morphometric values, including the greatest hamstring thickness (89.20 mm), quadriceps thickness (46.20 mm), patellar length (20.14 mm), and patellar ligament

Table 1: Morphometric measurements of healthy dogs with respect to weight category.

Weight category	Group 1 (0-5 kg)	Group 2 (5-10 kg)	Group 3 (10-15 kg)	Group 4 (15-20 kg)
Weight (kg)	3.31 ± 0.42 ^a	7.80 ± 0.60 ^b	12.56 ± 0.34 ^c	17.23 ± 0.28 ^d
Age (months)	2.28 ± 0.18 ^a	14.85 ± 4.5 ^b	24.80 ± 5.61 ^c	8.84 ± 0.66 ^d
Cortical thickness (mm)	1.62 ± 0.14 ^a	2.05 ± 0.10 ^b	2.10 ± 0.04 ^{bc}	2.70 ± 0.08 ^d
PL (mm)	15.02 ± 1.54 ^a	18.63 ± 0.92 ^{ab}	20.54 ± 1.39 ^{abc}	27.02 ± 0.80 ^d
PLL (mm)	16.20 ± 1.40 ^a	20.50 ± 1.01 ^{ab}	21.10 ± 0.40 ^{abc}	31.72 ± 2.06 ^d
Hamstring width (mm)	33.74 ± 2.44 ^a	50.12 ± 3.11 ^{ab}	62.48 ± 4.13 ^{bc}	88.41 ± 5.54 ^d
Quadriceps width (mm)	21.34 ± 1.79 ^a	25.90 ± 2.34 ^{ab}	34.43 ± 3.17 ^{bc}	43.75 ± 2.23 ^c

Different alphabets in superscript represent significant difference (5% level) between the groups.

length (25.80 mm).

Group IV (dogs weighing 15-20 kg) had the highest number of animals (n=13). The majority were large-breed dogs (n=9), while only four were of medium-sized breeds. The mean age of dogs in this group was 8.84±0.66 yr, and the mean body weight was 17.23±0.28 kg. The relatively lower mean age compared to other groups may be attributed to the predominance of large breeds, as only younger individuals of these breeds typically weigh less than 20 kg. The mean patellar length and patellar ligament length were 22.27±1.48 mm and 31.72±2.06 mm, respectively. Cortical thickness showed minimal variation within the group (2.70±0.08 mm) but was significantly higher compared to the previous group. The mean hamstring and quadriceps muscle thicknesses were 88.41±5.55 mm and 43.75±2.24 mm, respectively. The greatest muscle thickness was observed in Greyhounds, likely due to their racing lineage and selective breeding for enhanced musculature. This was followed by bully breeds, which are also characterized by a robust and muscular conformation. In similarly aged Greyhounds, cortical thickness and patellar length were comparable. Among medium-sized dogs, bully breeds exhibited the greatest patellar ligament length, likely due to their relatively larger patellar size. In two dogs, the patellar ligament length was 1.8 times the length of the patella, while in one dog it was 2.25 times. According to Mostafa *et al.* (2008), a patellar ligament-to-patella ratio of approximately 2.06 may predispose dogs to patellar luxation. However, orthopaedic examination of these dogs revealed no abnormalities in gait.

A statistically significant difference (P<0.05) was observed in the mean body weight and age across all groups. Although variation in cortical thickness within each group was minimal, significant differences were identified among groups I, II, and IV. Similarly, for patellar length and corresponding patellar ligament length, significant differences (P<0.05) were noted between groups I and III, as well as between groups III and IV. In terms of hamstring muscle thickness, significant differences were observed between groups I and III and between

groups III and IV. However, for quadriceps muscle thickness, no statistically significant difference was found between groups III and IV.

Morphometry based on breed size of dogs

Breed-wise morphometric measurements were performed across three groups based on body size: small (n=9), medium (n=14), and large breeds (n=14). A total of 37 dogs were included in the study, all weighing less than 20 kg (Table 2).

In small breed dogs, the mean age was 16.22±4.81 months (range: 2-36 months), with most dogs (n=7) being 18 months of age or younger. The mean body weight was 7.54±1.52 kg (range: 1.8-13.2 kg). The average patellar length measured 12.41±1.25 mm (range: 8.2-16.12 mm), while the patellar ligament length was 15.77±0.99 mm (range: 12-18.8 mm). Patellar ligament length was observed to increase proportionally with patellar size. The mean cortical bone thickness was 1.82±0.10 mm (range: 1.4-2.12 mm). Within the weight range of 1.8-13.3 kg (mean: 7.54±1.52 kg), cortical thickness showed minimal variation; however, older dogs (>12 months) exhibited relatively thicker cortical bone compared to younger dogs, likely reflecting skeletal maturation and full bone development. The mean hamstring muscle thickness was 45.26±4.73 mm (range: 23.63-65.58 mm), while the mean quadriceps thickness was 21.47±1.95 mm (range: 14.97-28.78 mm). The wide variation in muscle thickness may be attributed to the broad age range of dogs included in the study, from 2-month-old puppies to 36-month-old adults. Even among dogs of similar age and breed, notable differences in muscle dimensions were observed, which may be influenced by genetic factors as well as variations in exercise levels and nutritional status affecting muscle development and strength.

In medium breed dogs, the mean age was 19.85±4.17 months (range: 2-48 months), and the mean body weight was 10.89±1.11 kg (range: 5.2-16.5 kg). The average patellar length was 14.00±0.45 mm (range: 11.5-18.2 mm), while the mean patellar ligament length was 20.52±1.50 mm (range: 17.2-32.7 mm). Both patellar length and patellar ligament length were greater than those observed in small breed dogs,

Table 2: Morphometric measurements based on the breed size of dogs.

Size of breed	Small breed dogs	Medium breed dogs	Large breed dogs
Weight (kg)	7.54 ± 1.52 ^a	10.89 ± 1.11 ^b	14.29 ± 1.20 ^{bc}
Age (months)	16.22 ± 4.81 ^a	19.86 ± 4.17 ^{ab}	6.53 ± 0.48 ^c
Cortical thickness (mm)	1.82 ± 0.11 ^a	2.10 ± 0.04 ^{ab}	2.49 ± 0.12 ^c
PL (mm)	12.41 ± 1.25 ^a	14.00 ± 0.45 ^{ab}	21.07 ± 1.51 ^c
PLL (mm)	15.77 ± 0.99 ^a	20.52 ± 1.50 ^{ab}	28.83 ± 2.06 ^c
Hamstring thickness (mm)	45.26 ± 4.73 ^a	55.10 ± 3.98 ^{ab}	80.96 ± 6.40 ^c
Quadriceps thickness (mm)	21.47 ± 1.95 ^a	32.49 ± 2.09 ^b	41.28 ± 2.69 ^c

Different alphabets in superscript represent significant difference (5% level) between the groups.

which is consistent with increased body size. A direct relationship was observed between patellar size and patellar ligament length, indicating that an increase in patellar dimensions is associated with a proportional increase in ligament length. The mean cortical thickness (2.10±0.04 mm; range: 1.6–2.4 mm) was also higher than that recorded in small breed dogs, suggesting relatively stronger bone structure in medium-sized breeds. The mean hamstring muscle thickness was 55.10±3.98 mm (range: 32.92–89.20 mm), while the mean quadriceps thickness was 32.49±2.09 mm (range: 22.08–46.40 mm). Among medium-sized breeds, bully-type dogs exhibited the greatest muscle thickness due to their inherently muscular conformation. These dogs also showed the highest patellar ligament lengths, corresponding to their larger patellar size. In two bully dogs, the patellar ligament length was approximately 1.8 times the patellar length, while in one dog it was 2.25 times. According to Mostafa *et al.* (2008), a patellar ligament-to-patella ratio of 2.06 or higher may predispose dogs to patellar luxation; however, orthopaedic examination at presentation revealed no abnormalities in gait. The lowest cortical thickness and muscle mass were observed in the youngest mongrel dog, likely due to incomplete skeletal and muscular development. Cortical thickness showed minimal variation among adult dogs, ranging from 2.1 to 2.4 mm. Overall, morphometric measurements were relatively consistent in dogs of similar age and weight categories, particularly among Beagles, which may be attributed to their uniform breed characteristics and comparable physiological development.

In large breed dogs, the mean body weight was 14.29±1.20 kg (range: 4–19 kg), and the mean age was 6.53±0.48 months (range: 3–10 months). The average patellar length was 21.07±1.51 mm (range: 9.2–29.7 mm), while the mean patellar ligament length was 28.83±2.06 mm (range: 14.11–33.2 mm). A similar trend was observed in this group, with patellar ligament length increasing proportionally with patellar size. The mean cortical bone thickness was 2.49±0.12 mm (range: 1.6–3.1 mm), which was the highest among all groups. The mean hamstring muscle thickness was 80.93±6.40 mm (range: 31.50–110.9 mm), while the

mean quadriceps thickness was 41.28±2.69 mm (range: 17.02–55.76 mm). Overall, muscle thickness was greatest in this group, likely due to larger body size as well as the inclusion of Greyhounds (n=4), which are genetically predisposed to well-developed hindlimb musculature. Among individual observations, the smallest patellar length (17.20 mm) was recorded in a young Husky (3 months old), reflecting its early developmental stage. The greatest hamstring (98.69±5.25 mm) and quadriceps (44.90±2.61 mm) muscle thicknesses were observed in Greyhounds, consistent with their athletic and racing lineage, which favours enhanced muscular development. Cortical thickness and patellar length were also comparable among similarly aged Greyhounds. The maximum cortical thickness (3.2 mm) was recorded in an 8-month-old Labrador. Overall, the lower mean age in this group compared to others is attributable to the inclusion of predominantly younger animals.

The mean body weight of small and medium breed dogs showed a statistically significant difference between the respective groups, whereas the mean age differed significantly between medium and large breed dogs. A statistically significant difference (P<0.05) in cortical thickness was observed between medium and large breed dogs. Similarly, patellar length, patellar ligament length, and hamstring muscle thickness differed significantly between medium and large breed dogs. In contrast, quadriceps muscle thickness showed significant differences across all three groups (small, medium, and large breeds).

It was concluded that most morphometric parameters increased with an increase in body weight. Within-group measurements were relatively comparable; however, overall values tended to increase with breed size, irrespective of individual body weight variations. Additionally, the length of the patellar ligament was found to increase proportionally with patellar size.

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OBITUARY

Dr. Oruganti Ramakrishna, affectionately known as ORK, was a distinguished veterinary surgeon, teacher, researcher, and academic administrator, born on November 29, 1936. His remarkable academic journey spanned several prestigious institutions in India and abroad. He earned his BVSc and MVSc in Veterinary Surgery and Radiology from Madras Veterinary College, completed his PhD at Punjab Agricultural University, Ludhiana, received the FRVAC from Denmark, and was conferred an honorary MD (Medicina Alternativa) by Colombo University.

During his illustrious career, Dr. ORK served as Professor and Head of the Department of Surgery and Radiology and later as Principal of the College of Veterinary Science, Tirupati. A dedicated mentor and inspiring teacher, he guided 38 MVSc and 8 PhD scholars. His pioneering contributions in cardiothoracic surgery, anaesthesia, soft tissue surgery, and embryo transfer technology in cattle significantly advanced veterinary research and education in India. He successfully led four ICAR-funded research projects and made notable contributions to the Indo-American Embryo Transfer Project.

Dr. ORK was a founding and highly active member of the Indian Society for Veterinary Surgery (ISVS). He organized two ISVS National Conferences at Tirupati as Organizing Secretary, later served as President of the Society, and remained an integral part of the ISVS fraternity even after retirement. He mentored young professionals, inspired generations of researchers, and guided office bearers with wisdom, warmth, and humility. In recognition of his enduring contributions, the Society instituted the prestigious "Dr. O. Ramakrishna Oration Award" in his honour. His presence at ISVS symposia was always vibrant and inspiring, marked by enthusiasm, kindness, and unwavering dedication to the profession.

Dr. ORK was admired for his integrity, humility, visionary leadership, and lifelong commitment to veterinary science. Through his exemplary service and scholarly contributions, he left an indelible mark on the field and in the hearts of countless students, colleagues, and admirers.

The entire ISVS fraternity deeply mourns his passing and extends heartfelt condolences to his bereaved family.



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