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Research Article

Radiogrametric Analysis of the Metapodial Bones in English Setters

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Abstract: Radiography is one of the most preferred imaging methods when it comes to obtaining bone-related data by veterinarians on subjects such as clinical cases and education. This study was carried out to discover the sex differences on the metacarpal and metatarsal bones of English Setter hunting dogs. It aims to reveal the relationship between each bone forming the metapodiums and differences between male and female individuals. Twenty-eight English Setter dogs (16 females, 12 males) were included in the study. Actively hunting dogs were selected for the study, aged between 1 and 8. The average weight of the dogs were 18.79±4.12 kilograms. X-ray images were obtained from dogs positioning fore limb in dorso-palmar and hind limb in dorso-plantar position. For metacarpus measurements, males had higher values than females. In contrast to the metacarpal bones, females had higher measurements than males at some values (MT3: BP; MT4: SD; MT5: SD, BD) for metatarsal bones. The most distinguishing bone between males and females for the metacarpus was MC3 with the $P<0.05$ value at all measurements taken from the bone, and MT3 for the metatarsus ($P<0.05$ for three out of five measured values). In conclusion, metapodiums had statistically significant differences in terms of gender.

Keywords: *Dog, Metacarpus, Metatarsus, Radiogrametric analysis, X-ray*

İngiliz Setterlerde Metapodial Kemiklerin Radyogrametrik Analizi

Öz: Klinik vakalar ve eğitim gibi konular göz önünde bulundurulduğunda, veteriner hekimler tarafından kemikle ilgili verilerin elde edilmesi söz konusu olduğunda radyografi en çok tercih edilen görüntüleme yöntemlerinden birisidir. Bu çalışma, İngiliz Setter ırkı av köpeklerinin metacarpal ve metatarsal kemiklerindeki cinsiyet farklılıklarını ortaya koymak amacıyla yapılmıştır. Bunun yanında metapodyumları oluşturan her bir kemik arasındaki ilişki değerlendirilmiş ve farklılıklar araştırılmıştır. Çalışmaya 28 adet İngiliz Setter ırkı köpek (16 dişi, 12 erkek) dahil edilmiştir. Çalışma için yaşları 1 ile 8 arasında değişen ve aktif olarak avlanan av köpekleri seçilmiştir. Köpeklerin ortalama ağırlığı 18.79±4.12 kilogramdır. Köpeklerin ön bacakları dorso-palmar ve arka bacakları dorso-plantar pozisyonda konumlandırılarak röntgen görüntüleri elde edildi. Metacarpus ölçümlerinde erkeklerin dişilerden daha yüksek değerlere sahip olduğu görüldü. Metacarpal kemiklerin aksine, metatarsale kemiklerde dişilerin bazı değerlerinin (MT3: BP; MT4: SD; MT5: SD, BD) erkeklerden daha yüksek ölçümlere sahip olduğu görüldü. Erkekler ve dişiler arasında metacarpus için en ayırt edici kemiğin MC3 (ölçülen tüm değerlerde $P<0.05$) ve metatarsus için MT3 (ölçülen beş değerden üçü için $P<0.05$) olduğu tespit edilmiştir. Sonuç olarak, metapodyumlar cinsiyet açısından istatistiksel olarak anlamlı farklılıklar göstermiştir.

Anahtar sözcükler: *Köpek, Metacarpus, Metatarsus, Radyogrametrik analiz, X-ray*

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Introduction

Radiogrametric analysis and measurements are the most practical and budget-friendly method for obtaining bone-related data from live animals. Veterinarians frequently use x-ray imaging techniques for clinical cases [1-4]. In addition to two-dimensional radiological imaging techniques, three-dimensional imaging techniques are also among the imaging techniques that are increasing in use today [5,6]. Although radiologic imaging techniques are not only used for treatment and/or diagnosis in veterinary medicine, but also used as educational materials as well [7,8].

Metapodial bones consists metacarpal and metatarsal bones. Dogs have 5 metacarpal and 5 metatarsal bones. Metacarpal bones are named as os metacarpale 1, os metacarpale 2, os metacarpale 3, os metacarpale 4 and os metacarpale 5 from medial to lateral. Os metacarpale 1 is the shortest and thinnest besides os metacarpale 5 is the thickest of the metacarpal bones [9]. In metatarsal bones, however, the os metatarsale 1 is very small and does not have a phalanx at its tip [10]. Metapodial bones have attracted the attention of scientists in many different scientific fields and many studies are done on them. These studies include obtaining morphometric data specific to animal breeds [11], evaluation of bones obtained in archaeological excavations [12-14] and metapodial fractures [15].

For dogs, metapodial bones are often important for orthopedic diseases and fractures. Orthopedically, fractures in the metacarpal and metatarsal bones are usually encountered due to road accidents, falling objects, falling from a height, fighting, crush injury and track injury, and fractures may include one or more metapodial bones [16]. English Setter breed dogs, which are preferred as hunting dogs, also have the possibility of encountering some orthopedic cases mentioned above. In order to increase the condition of life of these dogs, which are in our lives as companion animals or working animals, and to provide them with better recovery opportunities, the studies on metapodiums are of great importance as our study focuses on the relationship between each bone forming the metapodiums, differences between male and female individuals.

Material and Methods

Ethical Statement

This study was approved by the Istanbul University-Cerrahpaşa, Faculty of Veterinary Medicine Animal Experiments Local Ethics Committee (Approval no: 2022/22).

Animals

Twenty-eight clinically sound English Setter dogs (16 females, 12 males) actively hunting were included in the study. The dogs' ages ranged from 1 to 8. They had an average weight of 18.79±4.12 kg. Weights were taken just before the X-ray image by using a digital scale. Standard physical, orthopedic and neurological examinations were performed before conducting the experiment.

Radiographic Images

X-rays were taken via "Gierth TR 90/30" portable x-ray

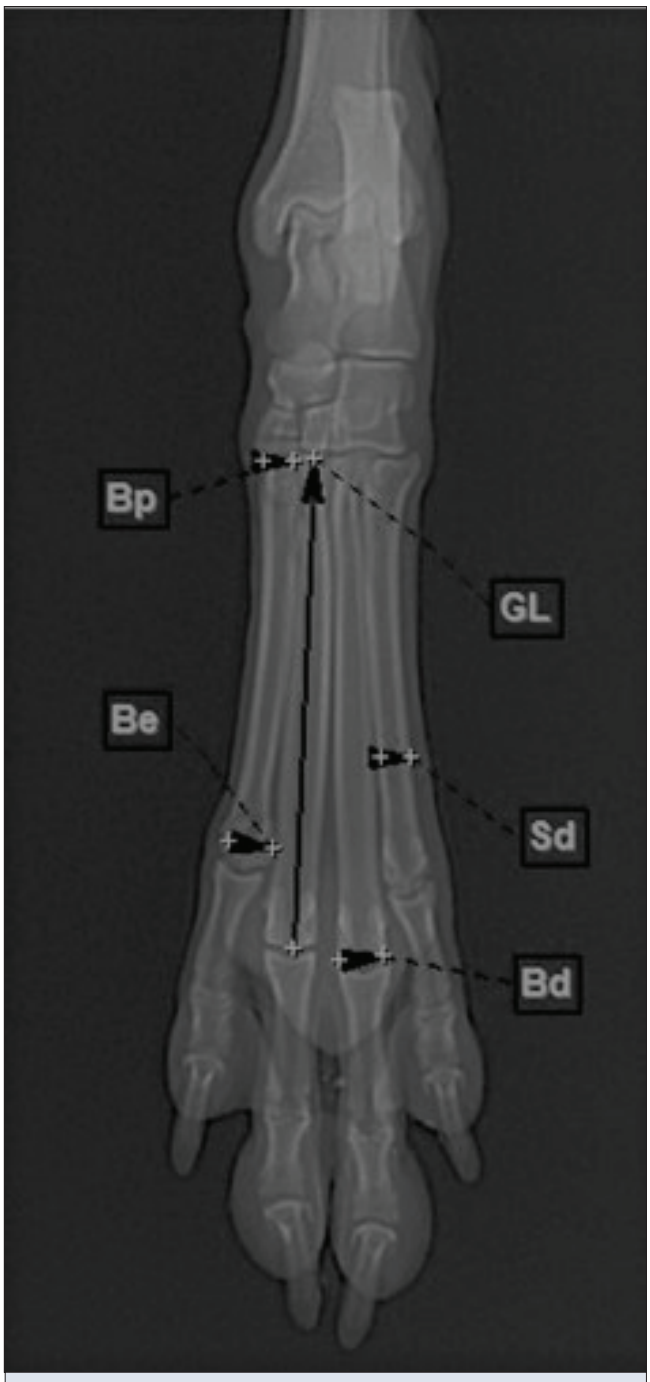

Fig 1. Radiogrametric measurements of metapodial bones (metatarsus). Bp: Width of proximal end; Sd: Smallest width of diaphysis; Bd: Width of distal end; GL: Greatest length; Be: Greatest width of metaphysis

device with 85 kW, 1.5 mAs settings from 1 meter distance to cassette. Radiographs are taken in dorso-palmar position for the fore limbs and dorso-plantar for the hind limbs. Attention was paid to make sure that all metacarpus and metatarsus were clearly visible while the images were taken. X-ray images of the dogs were also examined in terms of deformities in the metapoidiums and joint areas, fractures or cracks, and orthopedically healthy dogs were included in the study. Sedative or anesthetic agents were not used on dogs in the study.

Radiogrametric Measurements

Some measurements that are frequently used in publications [17-19] related to metapodium radiogrametric measurements *(Fig. 1)* are listed below with their explanations:

Width of proximal end (BP): Length of the widest point at the proximal end of the bone.

Smallest width of diaphysis (SD): Length of the narrowest part on diaphysis.

Width of distal end (BD): Length of the widest point at the distal end of the bone.

Greatest length (GL): The maximum length between proximal and distal end of the bone.

Greatest width of metaphysis (BE): Length of the widest point on metaphysis.

Radiogrametric measurements were obtained via "RadiAnt DICOM Viewer" using the digital ruler in the software program.

Statistical Analysis

Statistical analysis were performed using "IBM SPSS Statistics V21.0". Mean, STD (standard deviation) and P values are obtained and "One-way ANOVA" (Analysis of Variance) was performed to statistically determine the difference between gender groups via statistical program mentioned above. Independent t-test was used to analyze relationship between radiogrametric measurements of metacarpus and metatarsus regardless of sex discrimination. The effects of age and weight on radiogrametric measurements were also analyzed with bivariate correlation test via "IBM SPSS Statistics V21.0"

Results

Radiogrametric measurements of metapodial bones for male and female are given in *Table 1* and *Table 2*. BP value and gender discrimination in all metacarpal bones were statistically different. In general, considering the genders, it was observed that there were statistically significant differences in GL values of metapodiums. Except for MC5 (P: 0.08), the P values were 0.01 for the MC2, MC3 and MC4. For the MC5, the biggest difference was in BP. The most distinguishing bone between female and male was MC3. The difference between male and female for MC3 was statistically different in all measurements taken. In addition, the longest bone for both female and male individuals was MC3 (GL; male: 69.37±4.01 mm, female: 66.14±2.18 mm)

The results of metatarsus measurements for males and females are given in *Table 2*. It was observed that the metatarsal bones were not as deterministic as the metacarpus in terms of gender. Most of the metatarsal bone measurements were high in male. In contrast to the metacarpal bones, females had higher measurements than males at some values (MT3: BP; MT4: SD; MT5: SD, BD). In terms of gender, the greatest difference for metatarsus

Table 1. *Results of radiogrametric measurements of metacarpal bones in Setter dogs*

Measurement	Sex	MC2			MC3			MC4			MC5		
		Mean	STD	P	Mean	STD	P	Mean	STD	P	Mean	STD	P
BP (mm)	Male	5.83	0.84	0.02	5.44	0.73	0.03	5.92	0.93	0.01	9.89	0.93	0.01
	Female	5.34	0.72		4.98	0.81		5.34	0.73		8.62	1.06	
SD (mm)	Male	5.30	0.75	0.03	6.10	0.59	0.01	5.49	0.63	0.04	5.44	0.74	0.11
	Female	4.88	0.63		5.39	0.71		5.14	0.58		5.11	0.78	
BD (mm)	Male	7.25	0.76	0.02	7.39	0.88	0.02	7.24	0.74	0.06	7.30	0.72	0.01
	Female	6.76	0.80		6.84	0.88		6.86	0.74		6.75	0.84	
GL (mm)	Male	58.86	3.26	0.01	69.37	4.01	0.01	68.53	4.08	0.01	55.58	2.81	0.08
	Female	55.85	1.94		66.14	2.18		65.20	2.40		53.97	3.63	
BE (mm)	Male	9.08	1.17	0.06	8.93	0.88	0.01	8.77	1.19	0.12	9.26	1.07	0.01
	Female	8.52	1.06		8.55	0.79		8.38	0.67		8.53	0.84	

BP: Width of proximal end; SD: Smallest width of diaphysis; BD: Width of distal end; GL: Greatest length; BE: Greatest width of metaphysis; MC2: Metacarpus 2; MC3: Metacarpus 3; MC4: Metacarpus 4; MC5: Metacarpus 5; STD: Standard deviation

Table 2. *Results of radiogrametric measurements of metatarsal bones in Setter dogs*

Measurement	Sex	MT2			MT3			MT4			MT5		
		Mean	STD	P	Mean	STD	P	Mean	STD	P	Mean	STD	P
BP (mm)	Male	5.28	0.71	0.05	4.76	0.60	0.95	5.56	1.02	0.34	9.10	1.17	0.01
	Female	4.87	0.78		4.78	1.14		5.34	0.69		8.34	0.89	
SD (mm)	Male	4.60	0.76	0.02	5.91	0.87	0.44	4.80	0.71	0.72	4.24	0.69	0.66
	Female	4.18	0.60		5.76	0.66		4.87	0.76		4.36	1.19	
BD (mm)	Male	6.63	0.97	0.11	7.49	0.94	0.01	7.06	1.03	0.47	5.92	0.97	0.91
	Female	6.24	0.85		6.85	0.79		6.89	0.73		5.94	0.50	
GL (mm)	Male	63.36	5.44	0.16	74.90	6.48	0.05	76.92	7.33	0.08	66.22	6.95	0.16
	Female	61.54	4.19		72.04	4.15		73.83	5.70		63.91	5.05	
BE (mm)	Male	8.22	0.94	0.14	9.06	1.00	0.05	8.57	1.00	0.25	7.74	1.00	0.81
	Female	7.87	0.80		8.61	0.68		8.29	0.77		7.68	0.70	

BP: Width of proximal end; SD: Smallest width of diaphysis; BD: Width of distal end; GL: Greatest length; BE: Greatest width of metaphysis; MT2: Metatarsus 2; MT3: Metatarsus 3; MT4: Metatarsus 4; MT5: Metatarsus 5; STD: Standard deviation

Table 3. *Radiogrametric measurements of metacarpal bones, gender disregarded (independent t test)*

Measurement	MC2	MC3	MC4	MC5
BP (mm)	5.55[a]	5.18[b]	5.59[a]	9.17[c]
SD (mm)	5.06[a]	5.69[b]	5.29[a]	5.25[a]
BD (mm)	6.97[a]	7.08[a]	7.02[a]	6.99[a]
GL (mm)	57.14[a]	67.53[b]	66.63[b]	54.66[d]
BE (mm)	8.76[a]	8.72[a]	8.55[a]	8.84[a]

BP: Width of proximal end; SD: Smallest width of diaphysis; BD: Width of distal end; GL: Greatest length; BE: Greatest width of metaphysis; MC2: Metacarpus 2; MC3: Metacarpus 3; MC4: Metacarpus 4; MC5: Metacarpus 5
[a,b,c,d] *Values within a line with different superscripts are significantly different (P<0.05)*

was in the BD measurement of MT3 (P<0.01). For female and male, the longest bone in the metacarpus was MC3, but for the metatarsus, the longest bone was MT4 (GL; male: 76.92±7.33 mm, female: 73.83±5.70 mm). No radiogrametric measurements of MT4 were enough for sex-determination.

Statistical analysis of metacarpus and metatarsus bones without gender discrimination are given in *Table 3* and *Table 4*. The longest bone for the metacarpus was MC3 (67.53 mm). In terms of length (GL), MC3 and MC4 were not statistically different. However, GL results and MC2 and MC5 were statistically different from each other as well as from MC3 and MC4. The shortest bone was MC5 (GL: 54.66 mm). The greatest difference for metacarpus measurements was in BP value. BP values of MC5 were considerably higher than other metacarpus bones (9.17 mm). And this difference was statistically significant. BE values were close to each other in all metacarpus bones. There was no statistical difference for BE value between bones.

The longest bone for the metatarsus was MT4 (GL: 75.15 mm). However, as with metacarpus values, there was no statistical difference between MT4 and MC3 values. The highest difference was seen in the BP value among the metatarsus bones. BP values of MT5 were higher than other metatarsus bones, and this difference was statistically significant *(Table 4)*.

The correlation results of measurement values with age and weight are given in *Table 5*. It was observed that the weight showed a positive correlation on all radiogrametric values. The highest correlation was seen between weight and BE measurement (correlation value: 0.353). For age, only the correlation with BE value was statistically significant (correlation value: 0.195). When the measurement values were evaluated within themselves, the highest correlation was seen between BE and BD (correlation value: 0.634).

Discussion

The study is carried out on the metapodium of English Setter dogs, and the measured radiogrametric values were evaluated both between sexes and bones. Radiogrametric data obtained from X-ray images is of great value in terms of obtaining morphological data and determining the ways to be followed in the treatment process of orthopedic

Table 4. *Radiogrametric measurements of metatarsal bones, gender disregarded (independent t test)*

Measurement	MT2	MT3	MT4	MT5
BP (mm)	5.05[a]	4.77[a]	5.44[c]	8.67[d]
SD (mm)	4.36[a]	5.8[b]	4.84[c]	4.31[a]
BD (mm)	6.40[a]	7.13[b]	6.96[b]	5.93[d]
GL (mm)	62.32[a]	73.27[b]	75.15[b]	64.90[d]
BE (mm)	8.02[a]	8.81[b]	8.41[c]	7.71[a]

BP: Width of proximal end; SD: Smallest width of diaphysis; BD: Width of distal end; GL: Greatest length; BE: Greatest width of metaphysis; MT2: Metatarsus 2; MT3: Metatarsus 3; MT4: Metatarsus 4; MT5: Metatarsus 5
[a,b,c,d] *Values within a line with different superscripts are significantly different (P<0.05)*

Table 5. *Correlation results between radiogrametric measurements, age and weight*

Measurements	SD	BD	GL	BE	Age	Weight
BP	-.057	-.061	-.312**	.057	.023	.173**
SD		.404**	.184**	.397**	-.002	.208**
BD			.238**	.634**	.069	.240**
GL				.116*	-.020	.176**
BE					.195**	.353**
Age						.233**

**P<0.05, **P<0.01*

cases. Considering the differences between the sexes, as known, the bone structures of male individuals are expected to be larger than female individuals, and the metacarpus measurements in our study supported this thesis. Metatarsal data were found to have higher values in males than females in general, but this situation changed in some measurements (MT3: BP; MT:4 SD; MT5: SD, GL). Although the values of female individuals were measured to be higher than male individuals in the above-mentioned values, it was observed that the difference between the sexes was statistically insignificant (P>0.05). It is thought that the reason why the significant size differences seen in metacarpus are not evident in metatarsus is related to the weight on the forelimb being more than the weight on the hindlimb. Considering that males under the same conditions are heavier than females, it is thought that the weight difference on the forelimb may be greater than the weight difference on the hindlimb.

Dursun [9] and Bahadır and Yıldız [10] stated that MC3 and MC4 are the longest bones for carnivores that information is consistent with our study. However, both authors mentioned carnivores in general and no specific breed was stated as in our study. Hence, the breed-specific values and results in our study are important in terms of determining the differences in carnivores. In a study on marten, which is a carnivore, the longest metacarpus was reported to be MC3 [20] as in English Setter dogs. In addition, in cats [6] it is stated that MC3 is the longest bone followed by MC4, when the metacarpus' are evaluated. Although the aforementioned cat is a domestic cat, lynx [21], a wild cat, had also similar features to the dogs used in our study. For metatarsus of lynxes [21], it is seen that MT3 and MT4 were the longest, but the longer one between them was unclear. Similar results are also found in a metatarsus study on badger [22], an omnivore, states that MT3 and MT4 had nearly same length. It is seen that similar length measurements between the two bones are also suitable for marten [23] a carnivore. Results of our study shows that the longest bone is MT4 and MT3 comes right after it for the English Setter dogs. As in the studies given above, the longest metatarsus was found to be one of MT3 and MT4. When it comes to the longest bone, although there are differences in the fore and hind limb, the difference between MC3 - MC4 and MT3 - MT4 was statistically insignificant. Considering the metapodiums, it is seen that the bones that carry the weight are the bones numbered 3 and 4, as in other animals, and these bones are more developed than the others (MC1, MT1, MC2, MT2, and MC5, MT5). Cracks, fractures, etc., which occur as a result of trauma in these bones, that carry the majority of the weight, is more likely to occur than other metapodiums [15] also supports the results of our study. When the gender

factor was ignored, the difference in BP values between each metapodium was found to be statistically significant. This suggests that the effects of body weight on each metapodium are a biomechanically related consequence.

The correlation of measurements with weight is positive and statistically significant, indicating the effect of body weight on metapodial bones. In addition, the positive correlation between BE value and age show that the epiphyseal region thickens with age. The positive correlation between BE and BD also supports the thesis above, in conclusion our study shows that the distal part of the metapodial bones shows parallel increase with age.

The study, which was carried out on English Setter dogs on x-ray images, the differences between the sexes of metapodiums and the relations between the bones themselves were examined radiogrametrically. One of the difficulties encountered during the study was to be able to take x-rays in right position while the animals did not receive any anesthetic or sedative substances. This is an appropriate approach when considering ethics and animal welfare, but we would like to point out that animals should have calm characters to maintain the right image. In addition, many of the X-rays are taken more than once to obtain the appropriate image during the study. Classical osteometric studies are usually done with bones of dead animals [20-23]. However, thanks to the radiological imaging techniques, data of bone morphometry of the animals that are still alive can be obtained [1-4]. In general, both metacarpus and metatarsus mean values for males were higher than females, but when the difference between the sexes was statistically evaluated, it was significant for metacarpus in many measurements, but this was not the case for metatarsus. It was observed that the longest bone among the metacarpus was MC3, and MT4 among the metatarsus. Although the number is increasing, studies on animals belonging to a certain breed are insufficient. For future scientific studies, it is recommended to study race-specific morphological data, if possible. It is hoped that the basic data obtained with our study results will be useful in many fields such as education, archeology, anatomy and especially for veterinary clinical practice, such as veterinary orthopedists, that our results can be the basis for further surgical, therapeutic applications and research.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author (D. Aydın Kaya) on reasonable request.

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There is no funding support.

Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Ethical Statement

This study was approved by the Istanbul University-Cerrahpaşa, Faculty of Veterinary Medicine Animal Experiments Local Ethics Committee (Approval no: 2022/22).

Authors Contributions

Z.M. and M.K.: Conceived and supervised this study; Y.A., D.O.E. and D.A.K.: Collection of the data; E.Ö. and E.G.: Statistical analysis. All authors contributed to the critical revision of the manuscript and have read and approved the final version.

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