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MORPHOMETRIC MEASUREMENTS OF DIGITAL BONES IN JUVENILE MALE CAMELS (*Camelus dromedarius*)

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ABSTRACT

The objective of this study was to analyse the morphometric measurements of the bones forming the distal limb of 9-12 months old, male dromedarian camels. Limbs (distal to carpal and tarsal bones) of 14 camels were collected from a local slaughter house. Limbs were identified as right or left forelimb or hindlimb. Different morphometric measurements were obtained for the metapodials, first, second and third phalanges. In the morphometric analysis of the metapodials, there were no statistically significant differences between the right and left metacarpals or metatarsals in any measured parameter. However, the metacarpal bone was significantly ($P<0.05$) larger than the metatarsal bone in its width and diameter. The medial and lateral P1 of the forelimbs were significantly larger than the medial and lateral P1 of the hindlimbs. The second phalanx of the forelimbs was significantly longer than P2 of the hindlimbs. While digital bones of camels at this age are dynamic and these measurements are likely to change in advanced ages, information gained from this study can help veterinarians, camel practitioners, and zooarcheologists who are interested in camel medical disorders, camel history and domestication in studying this group of camel population all over the world.

Keywords: Digital bone, juvenile camels, morphometric measurements

Camels are hardy animals that have developed several physiological and anatomical adaptation mechanisms that allow them to survive in dry environments. There is a special interest in development and evolution of the camel limbs and foot among the scientific community. Most of the studies that could be cited in the literature are concentrated in studying the normal anatomy including blood and nerve supply and muscles and tendons of the limbs of camels (Jain *et al,* 1996; Jain *et al,* 1997; Wang *et al,* 2000).

However, there is lack of information regarding morphometric measurements of bones in adults as well as in juvenile camels in the recent literature. In Jordan, according to the regulations, only juvenile male camels aged up to 12 months are allowed to be slaughtered for meat production. While camels at this age are rapidly growing, and their bones are dynamic, information gained by studying the morphometric characteristics of these bones are helpful in diagnosing problems affecting camels of this particular age group. In addition, morphometric measurements of the digital bones are also helpful for zooarcheologists to pinpoint the origin of certain group of camels, their history of domestication, use, nutrition and housing, their sex and to distinguish between wild and domestic camel bones recovered from archaeological sites (Driesch, 1976). This study was designed to describe the morphometric characteristics of digital bones of normal, juvenile male dromedarian camels originated in the Jordanian desert.

Materials and Methods

Distal limbs of 14, 9-12 months old, male, one-humped apparently healthy camels were obtained from a local abattoir. Before slaughtering, animals were examined for the presence of musculoskeletal abnormalities. Immediately after slaughter, the fore and hind limbs were disarticulated at the radiocarpal and tibiotarsal joints, respectively. Each limb was then identified as fore or hind limb, right or left and transported to the Veterinary Health Centre at Jordan University of Science and Technology. Each limb was cleaned carefully using a stream of tap water to remove masses of dirt, and the distal limb was further inspected closely for abnormalities. Limbs with gross abnormalities were excluded from the study.

The bones forming the camel's distal limb skeleton (metapodials, first, second, third phalanges

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and proximal sesamoid bones) were obtained (14 forelimbs and 14 hindlimbs). To extract and preserve the bones, we used a method that was developed in our clinic. Briefly, the method included removing of the skin, subcutaneous tissue, fat, tendons and ligaments as much as possible using dissecting tools, with much care to prevent damage to the bone surface. The bones were then soaked in a plastic pot filled with water for about 2 weeks. This time was sufficient to degrade the remaining tissues. Fat adhered to the bone was removed by soaking the bones in 5 litres of benzene for a few days (2-3 days). To make the bones whiter, bleach was used on the bones for about 2 days (2 litres bleach/gallon of water). The bones were immediately rinsed with tap water for about 15 minutes to remove residual chlorine in order to prevent further degradation of the bone surface.

Different parameters of each bone that were measured included the greatest length (GL), the breadth of the proximal border (Bp), the breadth of the distal border (Bd), and the smallest diaphyseal breadth in the lateromedial (SD L/M) and dorsopalmer (SD D/P) projections. All measurements were taken according to Driesch (1976) using osteometric calibre (Fig 1 and 2).

Statistical Analysis

Data was expressed in mean±SD. One way analysis of variance was used to compare between the different parameters of the left and right metapodials of the fore and hindlimbs. Similar comparisons were made between different parameters of P1 and P2. When results of the ANOVA indicated that there were no statistical difference between right and left sides, data from left and right sides were pooled for duplication of the value number in calculation.

Results

The morphometric analysis of various parameters of the metapodials revealed that there were no statistically significant differences between left and right sides in all measurements (left metacarpal vs. right metacarpal) or (left metatarsal vs. right metatarsal). When comparison was undertaken between parameters of the bone in the forelimb and hindlimb, no statistically significant differences were found between metacarpals and metatarsals, except for the proximal width, distal width and lateromedial diameter. These 3 measurements were significantly ($P<0.05$) larger in the metacarpals (Table 1).

Regarding the morphometric measurements of P1, results indicated no statistically significant differences between lateral and medial P1 of the same limb in all measurements. There were no statistically significant differences between the laterals P1 of the forelimbs and between the laterals P1 of the hindlimbs. The same results were obtained when comparing medial P1 of both left and right sides. However, a statistically significant difference was observed between lateral P1 of the forelimb and lateral P1 of the hindlimb. The same results were found between medial P1 of the forelimb and medial P1 of the hindlimb. All measurements regarding lateral and medial P1 in the forelimb are significantly larger ($P<0.05$) than that of the hindlimb, except extension of the articular groove, and depth and width of palmar

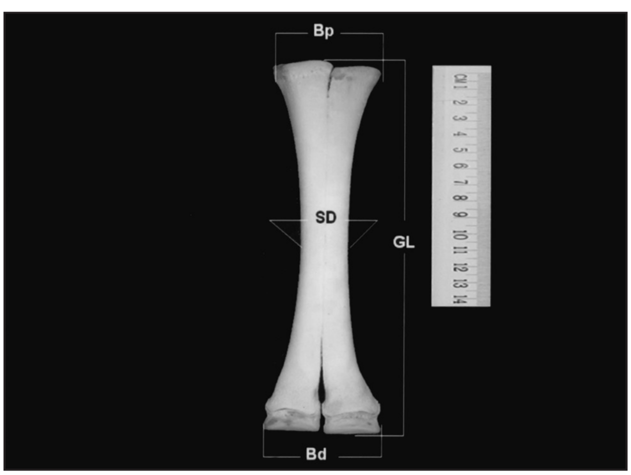

Fig 1. A photograph showing the morphometric measurements of metapodial bones (dorsal surface). Greatest length (GL), breadth of the proximal border (Bp), breadth of the distal border (Bd), smallest diaphyseal breadth in lateromedial direction (SD L/M).

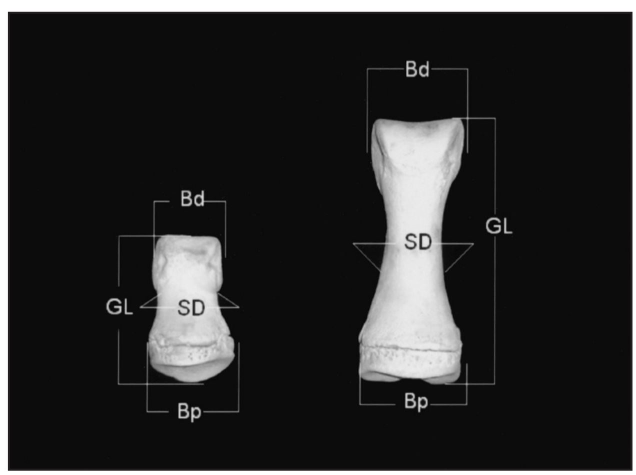

Fig 2. A photograph showing the morphometric measurements of the first (right) and second (left) phalanges (A, B) (dorsal view). Greatest length (GL), breadth of the proximal border (Bp), breadth of the distal border (Bd), and smallest diaphyseal breadth in lateromedial direction (SD L/M).

Table 1. Means±SD of various parameters of metapodial bones in millimetres (no=28).*

Parameters	Forelimb		Hindlimb	
	Right	Left	Right	Left
GL	318.5±19	319.4±21	320.8±17	321.5±17
Bp	64±3^{a}	65±1$^{a'}$	54.3±1^{a}	54.5±2$^{a'}$
Bd	73.9±10^{b}	74.1±10$^{b'}$	61.2±9^{b}	62.4±7$^{b'}$
SD D/P	27.2±4	27±4	25.7±4	25.8±4
SD L /M	30.5±3^{c}	30.5±3$^{c'}$	26±2^{c}	26±1$^{c'}$

*Means in a row with same non-significant letters are statistically significant (P<0.05)

articular groove, they were approximately equal in the fore and hindlimbs (Table 2).

Measurements of P2 revealed no statistically significant differences between left and right sides in all measurements. In addition, there were no statistically significant differences between lateral and medial P2 in the same limb. By comparing different P2 measurements in the forelimb and hindlimb, there were no statistically significant differences except for the greatest length; it was longer (P<0.05) in the forelimb than that in the hindlimb (Table 3).

Discussion

Camelids represent the extent sister group to ruminants (Janis, 2002). Camelids are unique among artiodactyls in their digitigrade foot posture and by their mode of locomotion (Janis, 2002). Studying camel's distal limb is needed to help in the proper diagnosis and treatment of many camel's distal limb problems as well as to seek their origins and to display light on their domestication history. Few studies can be cited in the current literature regarding the morphometry of digital bones in domestic animals (Janis, 2002; Ocal *et al,* 2004; Paral *et al,* 2004).

Because of the small population of adult camels in Jordan, slaughtering adult animals is not permitted; we limited our study to male, juvenile animals. From

Table 2. Means±SD of various parameters of P1 in millimetres (No=56).*

Parameters	Forelimb		Hindlimb	
	Lateral	Medial	Lateral	Medial
GL	88.0±13^{a}	81.2±12$^{a'}$	75.2±5^{a}	73.9±5$^{a'}$
Bp	34.7±1^{b}	33.4±4$^{b'}$	29.4±2^{b}	29.8±3$^{b'}$
Bd	30.1±4^{C}	29.1±4$^{c'}$	25.5±3^{C}	25.4±2$^{c'}$
SD D/P	18±2^{d}	17±2$^{d'}$	15.2±1^{d}	15.5±1$^{d'}$
SD L/M	18.8±2^{e}	18.4±1$^{e'}$	16±1^{E}	16±2$^{e'}$

*Means in a row with same superscript letters are statistically significant (P<0.05)

Table 3. Means±SD of various parameters of P2 in millimetres (no=56).*

Parameters	Forelimb		Hindlimb	
	Lateral	Medial	Lateral	Medial
GL	47.6±5^{a}	44.7±4$^{b'}$	46.8±5^{a}	43.8±4$^{b'}$
Bp	26±5	26±3	23.5±2	23.7±3
Bd	19.9±4	21±8	18.4±2	19±2
SD D/P	14.8±2	14.6±1	13.7±1	13.4±1
SD L/M	20.8±5	20.5±4	18.5±3	18.8±3

*Means in a row with same superscript letters are statistically significant (P<0.05)

the zooarcheologist point of view, measurements of juvenile bones are only helpful in studying specific groups of animals because of the dynamic nature of growing bones.

The gathered data regarding the camel's metapodials dimensions revealed no statistically significant differences between left and right sides in both fore and hindlimbs. However, a significant difference was found between metacarpals and metatarsals (Table 1). Metacarpal bones were found to be larger than the metatarsals in the GL, Bp and Bd measurements. This difference in metacarpal measurements could signify the difference in the proportion of weight bearing between the forelimb and the hindilmb. It appears that the forelimbs in camels of this age bear significantly more weight than the hindlimbs.

There was no significant difference between metapodials length in both fore and hindlimbs. No morphometric studies regarding camel metapodials could be found. Dyce *et al* (1987) reported that the metapodials of adult cattle are flatter in the forelimbs than the metapodials of the hindlimbs. Sisson *et al (*1975) also reported that the metatarsal bone in cattle is longer by 17 than the metacarpal bone.

There were no statistically significant differences between left and right sides in all measurements regarding P1 and P2 of young camels. In adult cattle, Ocal *et al (*2004) reported that the digital bones are almost the same in both limbs with respect to forelimb and hindlimb; also he reported no statistically significant differences between left and right sides in all measurements. There were no statistically significant differences between lateral and medial P1 of the same limb in all measurements.

In this study, P1 was longer and broader in the forelimb than P1 of the hindlimb. In adult cattle, P1 was found to be shorter and broader in the forelimb as compared to the hindlimb (Ocal *et al,* 2004). On the other hand, Nickel *et al (*1987) reported that P1 of cattle is somewhat shorter in the hindlimb than that of the forelimb. No statistically significant differences were found between P2 of the left and right sides and between lateral and medial P2 of the same digit. However, P2 appears significantly longer in the forelimb than that of the hindlimb. In adult cattle, P2 was significantly shorter and broader in the forelimb than that of the hindlimb except the lateral P2 of the forelimb it was longer than that of the hindlimb (Greenough and Weaver, 1997). Nickel *et al (*1987) advocated that P2 in cattle is shorter in the hindlimb than that of the forelimb.

No measurements were taken of P3 in camels in this study because it is too small and considered as a rudimentary bone embedded within the digital cushion of the foot pad.

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