Some Morphological and Radiological Studies on The Pelvic Limb Skeleton of Lumholtz Tree-Kangaroo (*Dendrolagus lumholtzii*)

A.S. Saber and Basma, M.K.
Department of Anatomy and Embryology,
Faculty of Veterinary Medicine, University of Sadat City, Sadat City, EGYPT.

With 9 figures **Received February, accepted for publication March 2019**

Abstract
One pelvic limb skeleton of the Lumholtz Tree-Kangaroo (*Dendrolagus lumholtzii*) was used in this study. Bones were prepared from the cadaver, morphologically described and the dimensions of each bone were measured. Moreover, plane X-ray images were done for the Os coxae, femur, tibia and fibula and the femur was chosen to estimate the cortical thickness index (CTI) and canal flare index (CFT). The results cleared the presence of the epipubic bones, seven tarsal bones and absence of the patella. Between the tibia and fibula there are two interosseous spaces and that the digits II, III are the smallest, while the digit IV is the largest.

Keywords: Tree-Kangaroo (*Dendrolagus lumholtzii*), pelvic limb, morphology, radiology.

Introduction
Tree-kangaroos(Fig.1) are marsupials of the genus *Dendrolagus*, adapted for arboreal locomotion. They inhabit the tropical rainforests of New Guinea, far north-eastern Queensland, and some of the islands in the region. Most tree-kangaroos are considered threatened due to hunting and habitat destruction. They are the only true arboreal macropods (Procter-Gray and Gansiosser, ,1987). This unusual kangaroo varies in colour from pale creamy brown to grey or rusty-brown. The ears are very small and rounded and the tail is long and thick but not prehensile. It has shorter limbs than the ground-dwelling kangaroos with stout muscular forelimbs armed with strong sharp curved claws to help it climb. The toes on the hind feet are all about the same length with uniformly granular sole for extra grip and strong curved claws. A double claw on the second and third fused toes is used for grooming (Cronin, 2008).

There are about 18 species from tree Kangaroo. Lumholtz Tree-kangaroo is named after the Norwegian explo rer Carl Sofus Lumholtz (1851–1922), 2006, who dis-covered the first specimen in 1883. Dendrolagus has been divided into a long-footed group, comprisisng both Australian species (*D. bennettianus, D. lumholtzi*) plus *D. inustus*, and a short-footed group including the remaining New Guinea species (Groves, 1982).

Although there has been a large number of studies on wild animals (Atalar and Özdemir, 2002; Dine et al. 1999; Girgin at al., 1988; Gulitekin and Ucar, 1980; Karan, 2012; Özdemir and Karan, 2001; Özdemir and Atalar, 2012), there is no study on hind limb bones morphology of the tree Lumholtz kangaroo could be found in the available literature.

This study was carried out on one pelvic limb skeleton of a cadaver of a Lumholtz Tree-Kangaroo brought by a postgraduate student to the Department of Anatomy and Pathology. The aim is to shed light on the anatomy of the pelvic limb bones of this rare, climbing, arboreal marsupial found only in Australia (North Queensland) and New Guinea.

Material and Methods

The skeleton of one male juvenile Lumholtz Tree-kangaroo was used in this study. The skeleton was prepared after the method explained by Plain radiograph pictures were taken for some bones of the hind limb (Os coxae, femur, tibia and fibula) to study and to evaluate the cortical thickness index (CTI) and the canal flare index (CFI) of the femur. The methods of calculation of the CTI and CFI was that adopted by Nguyen, et al., (2018). (Fig.2).

Results and Discussion

I. The pelvic bone (Os Coxae) (Figs 3,4)

The measurements and main features of hip bone are shown in the figs (2,3)
The pelvic bone is situated vertically in the living animal. It consists of ilium, ischium and pubis.

The ilium

Is a flat bone which forms more than half of the pelvic bone. It has three borders; dorsal, lateral and medial and two surfaces; gluteal and sacropelvic.
The dorsal border is arciform, and thick in the middle and tapers at both ends (***iliac crest***). The angle of junction of the iliac crest with the caudal border is known as ***cranial dorsal iliac spine***. The ***tuber coxa*** is the other pointed end of the ***iliac crest*** which continues ventrally with the lateral border. The lateral border is concave and ends on the dorsal part of the acetabulum. The medial border is slightly convex, begins dorsally medial to the tuber coxae and ends distally at the iliopubic eminence. Caudal to the cranial dorsal iliac spine is the blunt ***caudal dorsal iliac spine***. The two spines and intervening bone make up the ***tuber sacrale***, which forms most of the dorsal border (4.3 cm long). The rest of the dorsal border forms the ***greater ischiatic notch*** (1.9 cm long) and also

helps to form the ischiatic spine, which is dorsal to the acetabulum.

The ischium

Consists of tuberosity, body, table, and ramus. The length of the ischium from the level of ilium to the ventral border of the table is about 4 cm. It forms the caudal part of the os coxae and inters the formation of the acetabulum, obturator foramen, and symphysis pelvis. The gluteal surface is oblong and the gluteal line is absent.

The pubis

Extends from the ilium and ischium laterally to the symphysis medially and consists of a body and two rami. It is about 2.7cm long. The ***pubis tubercle*** projects cranially from the pubis at the level of the acetabulum and continues with the iliopubic eminence. The pelvic symphysis is 1.6 cm long.

The acetabulum

The cavity that receives the head of the femur. It measures 2.3cm long and 1.5cm wide. It is semilunar in shape, and encloses completely the head of the femur.

The Epipubic bone (pouch bone)

Large, long, dorsoventrally flattened bone (4.1 cm long) attached to the cranial border of the pubis. The contact border of the prepubis is about 1.5 cm long which get thinner and tapers cranially to form a long bar (3.5 cm long and 3 mm wide) which is nearly parallel to the longitudinal axis of the ilium.

II. Femur (Figs 5,6)

Long bone (10.5 cm long). The head is rounded and the fovea capitis is shallow. The neck is well distinct. The trochanter major is about 6 mm higher than the level of the head in tree kangaroo. König and Liebich (2009) mentioned that it extends beyond the level of the head of the femur in large animals, as mentioned also by Atalar and Ozdemir (2002) in mole rat; Dyce *et al*., (2002) in domestic animals; Evans and Christensen (1979) in dogs; Getty (1975) in large animals; Gultekin and Ucar (1980) in fox and jackal; Karan (2012) in feral pig; Ozdemir and Atalar, (2003) in squirrels; Ozdemir and Karan (2001) in badger; Dinc *et al*., (1999) in otter. The trochanter major stays level in small animals and the pig (König and Liebich, 2009) and in Bobcat (Ozgel and Aykut, 2015).

Fossa trochanterica was very obvious and deep. Trochanter minor was in the form of a highly prominent ridge (1.6 mm long) in the medial caudodistal part of caput femoralis.

The third trochanter could not be observed in this study. The studies of Ozdemir and Yilmaz et al., (1999) in porcupine, Karan (2001) in badger, Çevik-Demirkan et. al., (2007) in chinchilla, Karan (2012) in feral pigs, Ozgel and Aykut (2015) in Bobcat and Onwuama (2017) in grasscutter, denied also the presence of trochanter tertius. Moreover, Onwuama et al., (2017) argued the absence of the third trochanter of the grasscutter may confess greater ability to leap (hop), climb and run, escaping predators and other dangers, thereby enhancing survival in the wild.

However, the third trochanter is present in rodents (de Araújo et al, 2013 and Brombini et al., 2018) and in hedgehogs (Girgiri et al., 2016 and Özkan, 2002).

The medial and lateral epicondyles are very low elevations proximal to the medial and lateral condyles respectively. The lateral condyle is slightly larger than the medial one.

The femoral trochlea consists of two ridges separated by a wide shallow groove. The lateral ridge is slightly larger than the medial one, controversy to the findings of König and Liebich (2009) in large animals. The small facets for articulation with the fabellae (the two sesamoid bones embedded in the gastrocnemius muscle) described by Getty (1975) and König and Liebich (2009) in some animals was not found in this study and also in that of Ozgel and Aykut (2015) in Bobcat.

From the X-ray image the calculated Cortical Thickness Index (CTI) was 0.417 and the Canal Flar Index (CFI) was 0.4. Femoral cortical index and canal flare index are indicators of poor bone quality specially in osteoporosis which is usually accompanied by severe hypovitaminosis D. So, these indexes are useful tools to evaluate bone fragility and to predict fracture risk even in the normal and osteopenic individuals as well (Foela et al, 2015 ad Nguyen et al., 2018).

A bony patella is not observed in the present specimen. Samuels et al, (2017) Mentioned that this mystery is striking, in particular, within Mammalia where most marsupials lack an ossified patella, as did numerous fossil stem-mammals, despite seeming to share common ecological niches and the associated locomotor requirements. This opinion is supported by Holladay et. al. (1990). In the red kangaroo and wallaby, the later authors added that in the place of patella is a fibrocartilage pad, located in the tendon of the quadriceps femoris muscle. This structure is visible grossly, is palpable, and has the form normally expected of a bony patella.

III. Tibia and Fibula (Fig 7)

Are two fully formed long bones. They are separated by lager proximal interosseous space (4.5 cm long) and smaller, distal interosseous one (1.5 cm long). The measurements and main features of tibia and fibula are shown in the figs (4,6)

The intercondylar eminence between the two condyles of the tibia consists of higher lateral and lower medial parts (on the contrary to that mentioned in large animals by König and Liebich, 2009). The lateral condyle exhibits an articular surface to articulate with the proximal end of fibula.

The tibial tuberosity is a large process (2 cm long) projecting from the cranial aspect of the tibial shaft. The distal extremity carries the cochlea which presents a shallow median groove, sagitally oriented, and two flanked grooves. Similar findings were reported by (Evans and Christensen, 1979 in dog; Getty, 1975 in large animals; Karan, 2012 in feral pig; Özdemir and Atalar, 2003 in squirrels). The cochlesr surface of the tibia was oblique as described by Dinc et al., (1999) in otter, Atlalar and Özdemir (2002) in mole-rat and Ozgel and Aykut (2015) in Bobcat.

The medial side of the cochlea represents the medial malleolus. The lateral malleolus is formed by the fusion of the fibula and tibia, as described by König and Liebich (2009) in horse. The same authors added that the fibula of pig and the carnivores has retained its whole length, but reduced in length and fusion. In ruminants the fibula is completely reduced. Its proximal extremity is fused with the tibia, and its distal part persists as an isolated bone (os maeolaris) which articulates with the distal end of tibia.The relatively longer tibia & fibulae compared to femur is also mentioned New Zealand white rabbit (Agayi et al.,2012) and Miocene sabretooth borhyaenoids (Argot, 2004). I grasscutter the femur is relatively longer than to tibia and fibula, which suggest limited strides (Omwuama et al., 2018).

IV. Tarsal Bones (Ossa Tarsi) (Fig 8)
There are seven tarsal bones arranged in three rows; a ***proximal row*** (calcaneum or fibular tarsal and talus or tibial tarsal), a ***middle row*** (central tarsal, formerly navicular) and a ***distal row*** “first tarsal, formerly ectocuneiform (Os cuneiforme mediale) & second tarsal formerly mesocuneiform (Os cuneiforme intermedium) & third tarsal, formerly entocuneiform (Os cuneiforme laterale) and fourth tarsal bones, formerly cuboid (Os cuboideum)”.

Calcaneum Hight is 2.9 cm while, Taluas width is 2.2 cm and height is 1.7 cm. Tuber calcaneal of the fibular tarsal bone is very broad and expanded medially. Sustentaculum tali is broad transversely. The tibial tarsal bone is very broad transversely. The trochlear crests are parallel, oblique and widely separated. The central tarsal bone articulates proximally with the tibial tarsal and laterally with the 4th tarsal and distally with the 3rd – 1sr tarsal bones.

Tarsal bones are described in detail by Prideaux and Warburton (2009) in *Bohra nullarbora* sp. nov.

Warburton and Prideaux (2010) mentioned that the talocalcaneal articu-lation is the main component lower ankle joint of macropods and that the calcaneal-cuboid is the major component of the transverse tarsal joint. They also confessed that the talus of Dendrolagus is much broader relative to its length than in terrestrial kangaroos and wallabies. This is also observed in the present study.

Articulations between tarsal elements have been modified to enhance the hinge action at the ankle while restricting rotational movements (Szalay, 1994).

Tree-kangaroos (*Dendrolagus spp.*) have developed unique musculoskeletal adaptation to cope with a discontinuous, uneven and three-dimensional arboreal substrate (Warburton et al., 2011).

V. Metatarsal bones (Fig 8)

There are four metatarsal bones, the second and third are the smallest, while the fourth is the largest and strongest. The fifth metatarsal Is curved laterally as in Bohra nullarbora (Prideaux and Warburton, 2009).

Mt II of the tree-Kangaroo of this study is 3.2 cm long and 2mm wide. Mt III is 3.3 cm long and 2 mm wide. Mt IV is the largest and strongest, It measures 4.2 cm long and 6 mm wide, Mt V is 3.4 cm long and 5 mm wide.

Sesamoid bones, two for each metatarsal, articulate with the proximal extremity of each metatarsal bone. Prideaux and Warburton (2009) called it plantar sesamoid. They do not point out to that of Metatarsal II, III.

VI. Digits (Figs 8,9)

The fourth digit is very long and strong, the fifth is moderately so, the second and third are slender and united by skin (agreed with Beedard,1958). The digits measurements are as follow:

Digit II (slender and short)

Proximal Phalanx: 1.7 cm long & 2 mm wide.
Middle phalanx: 8 mm long & 2 mm wide.
Distal phalanx: 1 cm long

Digit III (slender and short)

Proximal Phalanx: 1.5 cm long & 2 mm wide.
Middle phalanx: 1.7 mm long & 2 mm wide.
Distal phalanx: 1 cm long

Digit IV (the longest and strongest)

Proximal Phalanx: 2.1 cm long & 6 mm wide.
Middle phalanx: 1.5 mm long & 6 mm wide.
Distal phalanx: 1.9 cm long

There are two plantar sesamoid bones on the plantar aspect of the proximal phalanx.

Digit V

Proximal Phalanx: 1.7 cm long & 5 mm wide.
Middle phalanx: 1.1 mm long & 5 mm wide.
Distal phalanx: 1.6 cm long
There are two plantar sesamoid bones on the plantar aspect of the proximal phalanx.

A full description of the phalanges of digits II-V was given by Prideaux and Warburton (2009) in the *Bohra nullarbora* sp. nov.

The toes on the hind feet are all about the same length with uniformly granular soles for extra grip and strong, curved claws. A double claw on the second and third toes is used for grooming (Cronin, 2008) (Figs 8.9).

Warburton and Prideaux (2010) mentioned that the enhanced mobility of the pes for greater flexibility and balance in a three-dimensional environment in *Bohra and Dendrolagus* sp. depends on the marked expansion of the tuber calcanei, enlargement and confluence of the caudal facets for the calcaneal-talar articulation, expansion and smoothing of the facets of the calcaneal-cuboid articulation, broadening of the talus, deepening of the talar head, flattening of the cuboid, and subequal length and stoutness of metatarsals IV-V. Together, these facilitate an expanded range of inversion/eversion and abduction/adduction movements i.e. adaptation to move in an arboreal environment. A conclusion which we also support and agree.

Acknowledgment
The authors acknowledge the skills of Mrs. Kerry johns, the anatomy technician in the Discipline of Anatomy and Pathology, School of Veterinary and Biomedical Sciences, JCU, Australia, for preparing the kangaroo bones of this study and the radiology department in the Military Veterinary Clinic, Almaza, Cairo for the X-ray images.

References
Al-Hussaini, A., H. and Demian, E.S. (1964): Practical animal biology, Vol. II, Systematic zoology, ed. Dar Al-Maaref, Cairo, Egypt.

Ajayi, I.E.; Shawulu, J.C.; Zachariya, T.S. Ahmed, S. and Adah, B.M.J. (2012): Osteomorphometry of the bones of the thigh, crus and foot in the New Zealand white rabbit (*Oryctolagus cuniculus*). IJAE, Vol. 117, n. 3: 125-133, 2012

Argot C. (2004): Functional-adaptive features and palaeobiologic implications of the post cranial skeleton of the Miocene Sabretooth borhyaenoid *Thylacosmilus atrox* (Metatheria). Alcheringa 28: 229-266.

Atalar Ö. and Özdemir D. (2002): Macro-anatomical investigations on the skeletons of the marten (*Martes fonia*). II. Ossa membri pelvini. Firat Univ. J. Health Sci. 16: 233-236.

Beddard, F. (1958): Mammalia, Volume X in “The Cambridge Natural History” edited by S.F. Harmer and A.E. Shipley. Authorized reprint edition by Wheldon& Wesley Ltd. and H.R. Engelmann (J. Gramer).

Brombini, G.C., Rahal, S.C., Schimming, B.C., Santos, I.F.C., Tsunemi,

M.H., Mamprim, M.J., Alves, L.S., Filadelpho, A.L. and Teixeira, C.R. (2018): Radiological and osteological study bof the pelvic limbs in free-ranging capybaras (*Hydrocheorus hydrochaeris*). Anat. Histol. Embryol.:1-11.

"Carl Sofus Lumholtz - biography"(2006): *Biography*. Australian National Herbarium. 17 December 2009.Retrieved 3 November 2019. citing: J.W. Cribb, The Queensland Naturalist, Vol.44, Nos.1-3, 2006

Çevik-Demirkan A., Özdemir V., Türkmenoglu I., Demirkan I. (2007): Anatomy of the hind limb skeleton of the chinchilla (*Chinchilla lanigera*). Acta Vet. Brno 76: 501-507.

Cronin, L. (2008): Croning's key guide, Australian Mammals. Jacana Books, Allen & Unwin, NSW, Australia.

Dinc, G., Aydin, A. and Atalar, O., (1999): *Firat Univ. Vet. J. Hlth. Sci.,* **13:** 229-232.

Elizabeth Procter-Gray and Udo Ganslosser (1986): The Individual Behaviors of Lumholtz's Tree-Kangaroo: Repertoire and Taxonomic Implications
Journal of Mammalogy, Vol. 67, No. 2 (May, 1986), pp. 343-352.

Feola, M., Rao, C., Tempesta. V., Gasbarra, E., Tarantino, U. (2015): Femoral cortical index: an indicator of poor bone quality in patient with hip fracture. Aging Clin Exp Res. 2015 Oct;27 Suppl 1: S45-50

Girgin, A., Karadag, H., Bilgic, S. and Temizer, A.K., (1988):
J. Vet. Sci. Selcuk Univ., **4:** 169-182.

Groves, C.P. (1982): The systemics of tree kangaroo (*Dendrolagus*; Marsupialia, Macropodineae). Aust. Mammal. 5: 157-186.

Gultekin, M. and Ucar, Y., (1980):
J. Facult. Vet. Med. Ankara Univ., **27:** 201-214.

Holladay, S.D., Smith, B.J., Smallwood, J.E., Hudson, L.C. (1990): Absence of an osseous patella and other observations in Macropodidae stifle. Ant Rec. Jan; 226 (1): 112-4.

Karan, M., (2012): Macro-Anatomical Study of Ossa Membri Pelvini in the Feral Pigs (*Sus scrofa*). Firat Univ. Vet. J. Hlth. Sci., 26: 31-34.

König, H.E. and Liebich, H-G (2009): Veterinary anatomy of domestic mammals**.** Schattauer, Sttuttgart, Germany.

Nguyen, B.N.T., Hoshino, H., Togawa,D. and Matsuyama, Y. (2018): Cortical Thickness Index of the Proximal Femur: A Radiographic Parameter for Preliminary Assessment of Bone Mineral Density and Osteoporosis Status in the Age 50 Years and Over

Population. Clin Orthop Surg.; 10(2): 149–156.

Onwuama, K.T.; Ojo, S.A.; Hambolu, J.O.: Dzenda, T.: Zakari,F.O. and Salami,S.O. (2018): Macro-anatomocal and morphometric studies of the hind limb of grasscutter *Thryonomys swinderianus, Temminck-1827). Anat. Histol. Embryol.; 47: 21-27.

Özdemir D, Karan M. (2001): Macro-anatomical investigations on the skeletons of badger (*Meles meles*). II. Ossa membri pelvini. Fırat Üniv. J Health Sci **15**: 397-400

Özdemir, D., Atalar, Ö. (2003): Macro-anatomical investigations on the skeletons of squirrel (*Sciurus vulgaris*). II. Ossa Membri Pelvini. Fırat Üniv. J Health Sci **17**: 151-154

Özkan, Z.E. (2002a): Macro-anatomical investigations on the hind limb skeleton of mole-rat (*Spalax leucodon* Nordmann). Vet Arhiv **72**: 159-166

Özkan, Z.E. (2002b): Macro-anatomical investigations on the skeletons of hedgehog (*Erinaceus europaeus* L.). II. Ossa membri pelvini. Vet Arhiv **72**: 213-220

Prideaux, G.J. and Warburton, N. (2009): *Bohra nullarbura* sp. Nov., a second tree-kangaroo (Marsupialia: Macropodidae) from the Pleistocene of the Nullarbor Plain, Western Australia. Records of the Western Australian Museum 25: 165-179.

Procter-Gray, E. & Gansiosser, U. (1987): "The individual behaviors of Lumholtz's Tree-Kangaroo: Repertoire and taxonomic iTree-kangaroo smplications". Journal of Mammalogy. **67** (2) : 343–352. doi: 10.2307/ 1380888. Retrieved 25 October 2013.

Samuels, M.E., Regnault, S, Hutchinson, J.R. (2017): Evolution of the patellar sesamoid bone in mammals. Peer J. 2017 Mar 21;5: e3103. doi: 10.7717/peerj.3103. eCollection 2017.

Szalay, F.S. (1994): Evolutionary History of the Marsupials and Analysis of Osteological Characters. Cambridge University Press: New York.

Warburton, N.M. and Prideaux, G.J. (2010): Functional pedal morphology of the extinct tree-kangaroo Bohra (Diprotodontia: Macropodidae). In Coulson, G. and Eldridge, M., (eds.) Macropods: The Biology of Kangaroos, Wallabies and Rat-Kangaroos. Collingwood, Victoria, CSIRO Publshing, pp. 137-151.

Warburton, N.M.; Yakovleff, M. and Malric, A. (2012): Anatomical adaptations of the hind limb musculature of tree-kangaroos for arboreal locomotion (Marsupialia: Macropodinae). Australian Journal of Zoology 60(4): 246-258.

Windsorm, D.E. and Dagg, A.I. (1971): Gaits in the Macropodinae (Marsupialia). J. Zool. 163, 165–175.

Yilmaz S., Dýnç G., Aydin A. (1999): Macro-anatomical investigations on the skeletons of porcupine (*Hystrix cristata*) II. Ossa membri pelvini. Tr. J. Vet. Anim. Sci. 23: 297-300.

Corresponding author:
A.S. Saber
Email: saberashraf_2@yahoo.com

Fig (1): Tree kangaroo (left) and Matschies Tree Kangaroo Skeleton (right). Museum of Osteology, Oklahoma City, Oklahoma.
Source: https://www.sciencesource.com/archive/Matschies-Tree-Kangaroo-Skeleton-SS2873838.html

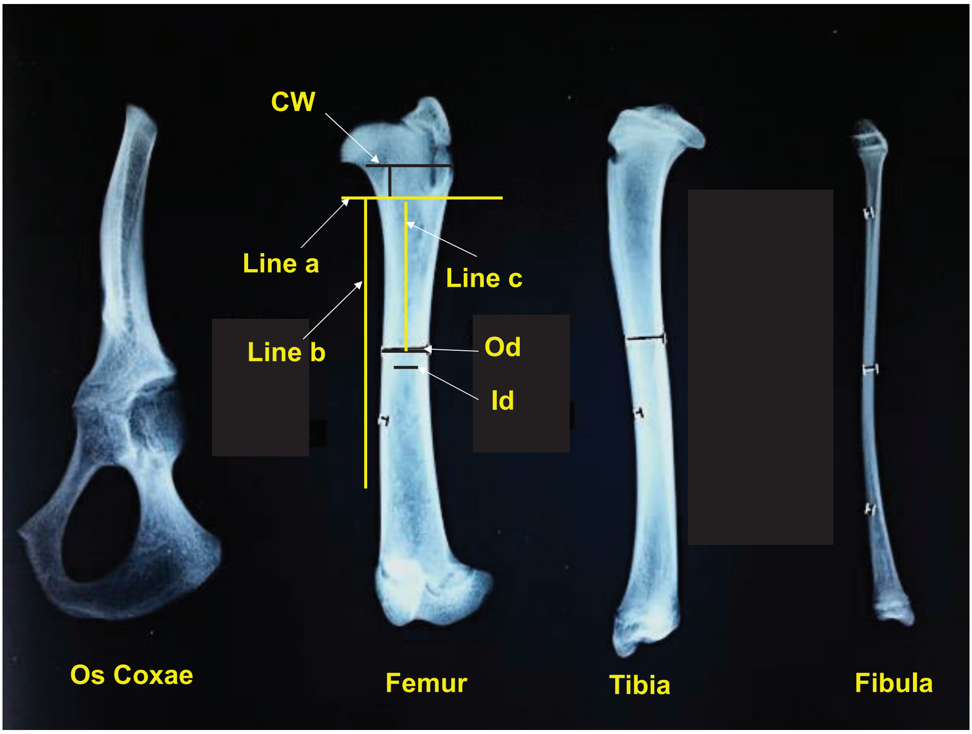

Fig (2): Measurements of cortical thickness index (CTI) and canal flare index (CFT) on an craniocaudal radiograph. Od: outer diameter of the femoral shaft at its middle, Id: Inner diameter of the femoral shaft at the middle of the shaft. CW: canal width (1 cm above Line a), Line a: a line drawn perpendicular to femoral shaft, Line b: a line drawn parallel to the shaft to be used as reference for drawing Line a, Line c: a 7-cm line drawn perpendicular to Line a, used to identify the shaft's inner and Od measurement levels. (after Nguyen, et al., 2018)

How to calculate: $\text{CTI} = \frac{Od - Id}{Od}$ $\text{CFI} = \frac{CW}{Id}$

$\text{CTI} = \frac{Od - Id}{Od}$ CTI = (12 -7)/12 = 0,417

$\text{CFI} = \frac{CW}{Id}$ CFI = 2.1/7 = 0,3

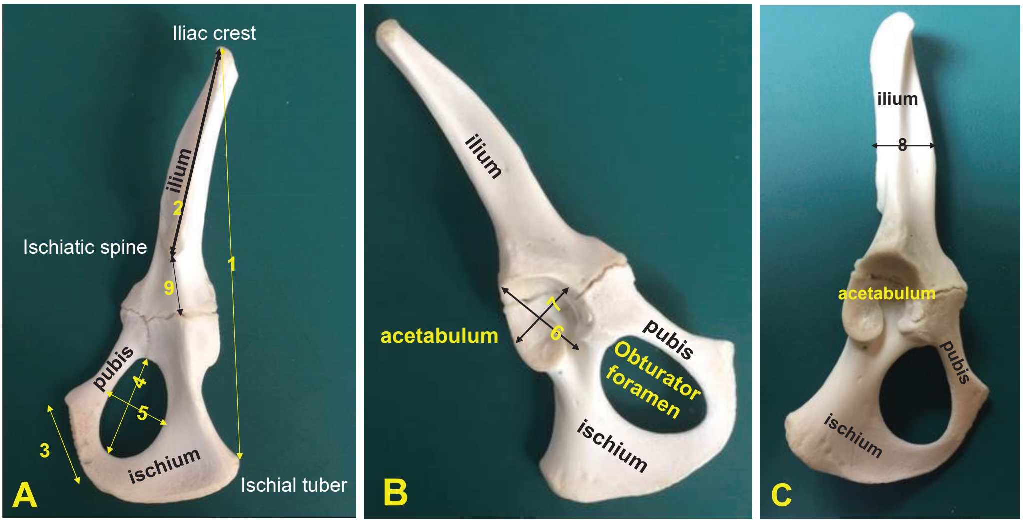

Fig (3): Measurements of the Os coxa (dimentions). A dorsal view, B ventro-medial view, C ventral view,

1 Total length of pelvis. (9.1 cm)
2 Distance from upper point of iliac crest to ischiatic spine. (4.3 cm)
3 Total length of pelvic symphysis. (1.6 cm)
4 Greatest length of obturator foramen. (2.3 cm)
5 Greatest width of obturator foramen. (1.5 cm)
6 Greatest length of acetabulum. (1.8 cm)
7 Greatest width of acetabulum. (1.5 cm)
8 Greatest width of ilium; measured from coxal tuber to sacral tuber. (1.9 cm)
9 Length of greater ischiatic notch; measured from dorsal to ventral at widest points. (1.1 cm)

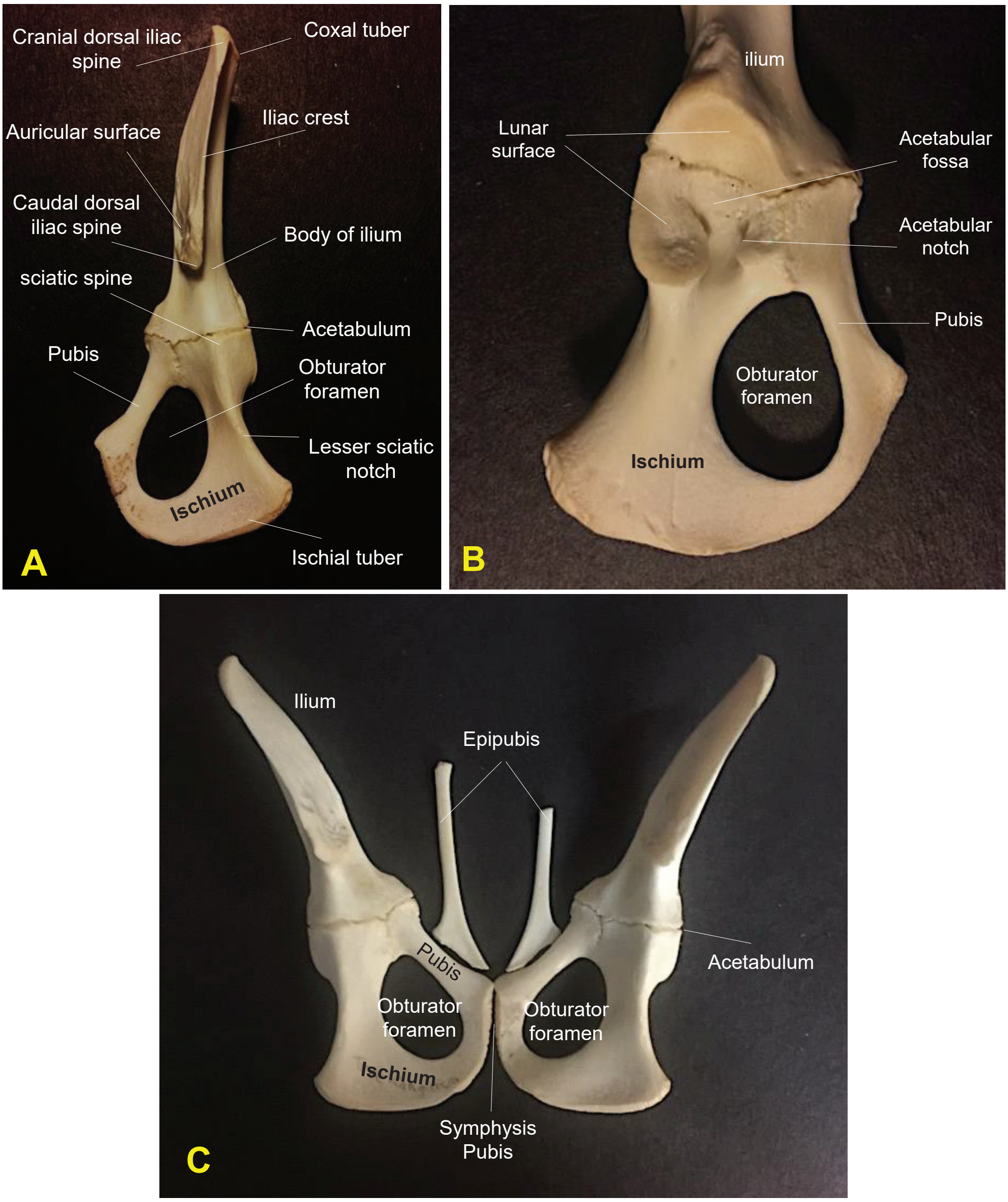

Fig (4): Right hip bone (Os coxae) of tree Kangaroo, dorsal view (A) and right acetabulum, ventral view (B), C Pelvic bone showing the epipubic, dorsal view (the right one with broken tip)

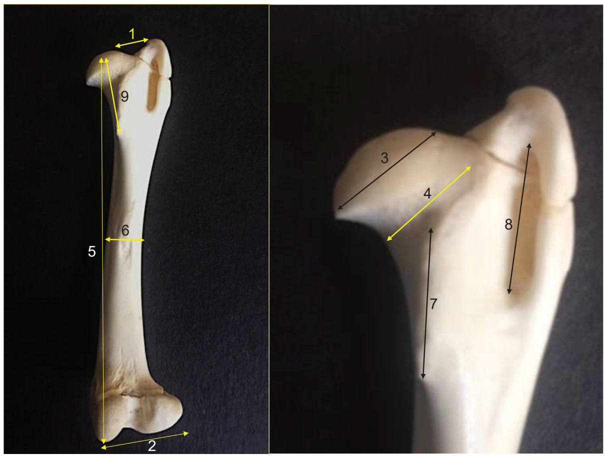

Fig (5): Measurements of the Femur (left) & Higher magnification of the proximal end of right femur (right).

F 1 Distance from head of femur to greater trochanter. (1.5 cm)

F 2 Distance from medial to lateral condyle. (2.4 cm)

F 3 Total width of head of femur. (1.4 cm)

F 4 Total width of neck of femur. (1 cm)

F 5 Total length of femur. (10.5 cm)

F 6 Width of femoral shaft measured at midshaft from medial to lateral.(1 cm)

F 7 Length of trochanter minor. (1.6 cm)

F 8 Length of trochter fossa. (1.6 cm)

F 9 Distance between head of femur and the distal point of trochanter minor. (1.7 cm)

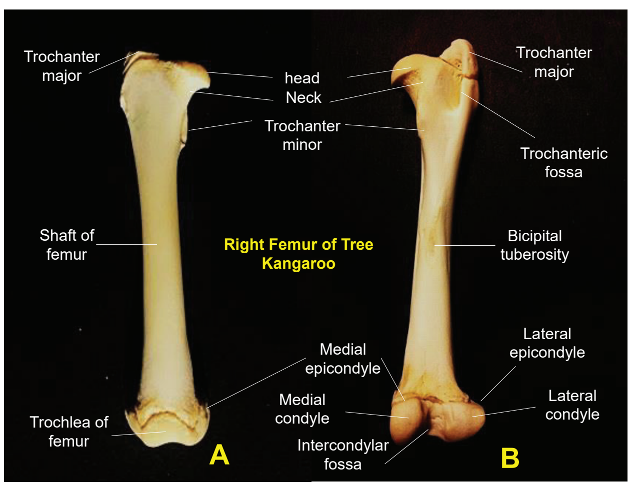

Fig (6): Right femur of tree Kangaroo. (A) cranial view and (B) caudal view

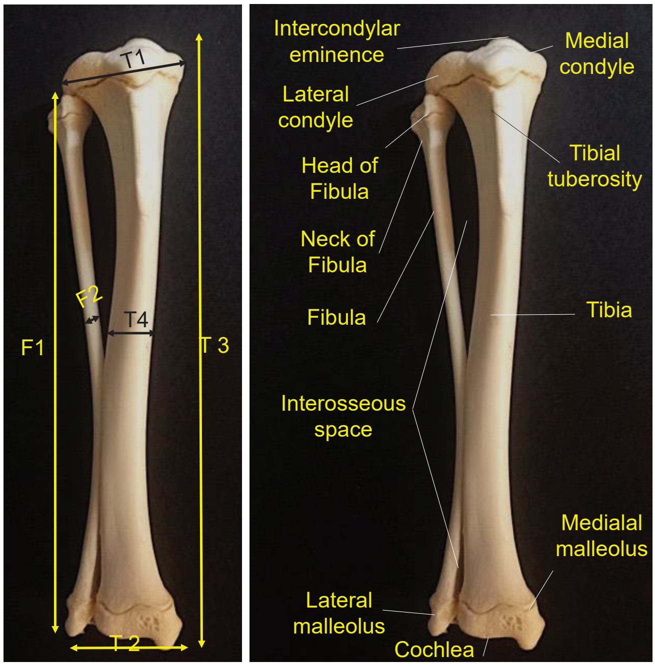

Fig (7): Right Tibia & Fibula of tree Kangaroo. Cranial view. Measurements (left), the anatomical features (right).

Tibia

T 1 Distance from medial to lateral condyle. (2.1 cm)

T 2 Distance from medial to lateral malleolus. (2.1 cm)

T 3 Total length of tibia. (11.1 cm)

T 4 Width of tibial shaft measured at midshaft from medial to lateral. (9 mm)

Fibula

F 1 Total length of fibula. (10.2 cm)

F 2 Width of fibular shaft measured at midshaft from medial to lateral. (3 mm)

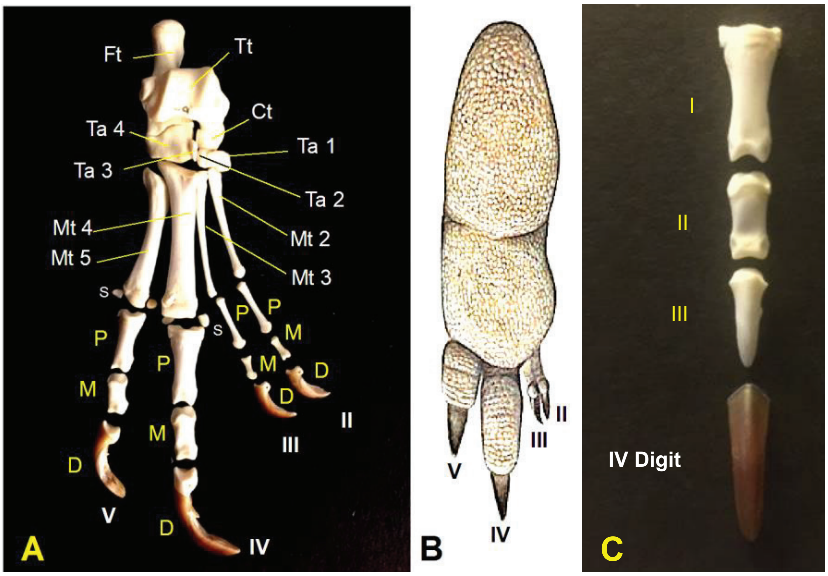

Fig (8): Tarsal bones, Metatarsals and digits (with horny claws) of tree Kangaroo. Dorsal view. (A), the plantar (solar) side of the foot of Lumholtz's tree-kangaroo after Flannery et al., 1999 (B) and the phalanges of the IV digit and the horny claw (C).

Ft fibular tarsal (calcaneus), Tt tibial tarsal (Talus), Ct central tarsal, Ta1,2,3,4 1^{st},2^{nd} ,3^{rd},4^{th} tarsal bones respectively, Mt 2,3,4,5 2^{nd}, 3^{rd}, 4^{th}, 5^{th} metatarsal bones respectively, P proximal phalanx, M middle phalanx, D distal phalanx, s sesamoid bones. Roman numerals refer to digit numbers.

Notice 1) the joined II, III digits and the largest IV digit.

2) The position of the "planter" sesamoid bones in the digits IV, V is at the plantar surface of
proximal extremity of the proximal phalanx. It is put here to show only its size.

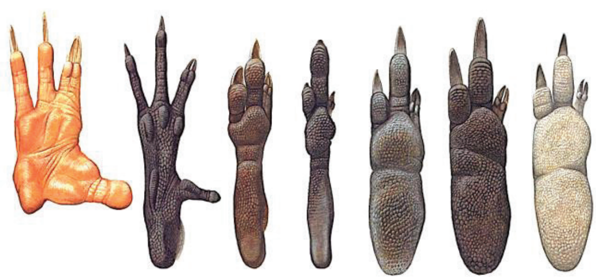

Fig (9): Solar view of:

A Brushtail possum, B Musky rat-kangaroo, C Black Dorcopsis, D Black-footed rock-wallaby, E Bennett's tree-kangaroo, F Grizzled tree-kangaroo, ***G** Lumholtz's tree-kangaroo.*

(Source: Flannery et al., 1999. Retrieved from: http://thetreehare.blogspot.co.uk/)