OPEN ACCESS

Scholars International Journal of Anatomy and Physiology

Abbreviated Key Title: Sch Int J Anat Physiol
ISSN 2616-8618 (Print) |ISSN 2617-345X (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Influence of the Locomotive Function on the Morphology of the Tibia: From A Comparative Study between Two Bipeds and Two Quadrupeds

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DOI: 10.36348/sijap.2022.v05i06.001 | **Received:** 28.05.2022 | **Accepted:** 01.07.2022 | **Published:** 07.07.2022

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Abstract

The mode of locomotion of humans and primates leads to changes in their skeleton. ***Objective**:* Establish a link between the morphology of the tibia and the locomotive function from a comparative anatomical study between the tibias of bipeds, Homo Sapiens (HS) and Pan troglodytes verus (PTV), and of quadrupeds, Canis lupus familiaris (CLF) and Sus scrofadomesticus (SSD). ***Materials and methods:*** It concerned an analytical and comparative study by direct observation involving a sample of 52 tibias. We proceeded by direct observation, to a synthetic analysis of the morphological characteristics of the tibia that we compared in bipeds and in quadrupeds. ***Results:*** The tibial diaphyses of HS and PTV presented the same morphological conformation with an italic S aspect in HS and a varus aspect in PTV. With CLF and SSD, they are straighter and the different faces are distributed differently. The proximal epiphyses are voluminous and massive in both classes. In quadrupeds, they present upper tibial articular surfaces which are deformed backwards and a voluminous anterior tibial tuberosity. The distal epiphyses in quadrupeds are convex with more pronounced creases. ***Conclusion:*** This comparative study allowed us to demonstrate that the locomotive function has a significant impact on the morphology of the tibia.

Keywords: Locomotive function, morphology, tibia, bipeds**,** quadrupeds, Togo.

INTRODUCTION

Bipedalism characterizes mammals that move on both feet. This locomotive function is particular to humans and other primates, and makes them differ from the other mammals that move on the four limbs. It is based on the biomechanical properties of the skeleton themselves induced by the morphological aspect of the bone. We put forward the hypothesis that this bone morphology presents particularities specific to each class and which are linked to the locomotive function. This hypothesis is in accordance with the one of Deloison (Deloison Y, 2009) who thinks that the entire anatomy of the skeleton of a living being is ordered, built for its mode of operation. Furthermore, studies have shown that the anthropometric dimensions condition the posture and movement of walking (Huxley TH, 1863; Schultz AH, 1957). There is therefore inevitably a link between the morphological and anthropometric characteristics of the long bones of the pelvic skeleton and locomotive function.

The aim of the present work was to confirm this hypothesis from a comparative study between the tibias of two bipeds and two quadrupeds.

MATERIALS AND METHODS

We carried out from January, 2017 to June, 2017 within the anatomy laboratory of the Faculty of Health Sciences of Lomé, an analytical and comparative study by direct observation on 52 bone parts of two bipeds and two quadrupeds. The sample was distributed as follows:

- Twenty-two human tibias (Homo Sapiens or HS) including 14 right tibias and 08 left tibias.
- Eight chimpanzee tibias (Pan troglodytes verus or PTV) including 06 right tibias and 02 left tibias.
- Thirteen dog tibias (Canis lupus familiaris or CLF) including 8 right and 5 left.
- And nine pig tibias (Sus scrofadomesticus or SSD) including 05 right and 04 left.

We proceeded by direct observation, to a synthetic analysis of the morphological characteristics that we compared according to each functional class. The following morphological factors were analyzed and compared between the two categories:

- The shape faces and edges of the diaphysis.
- The general appearance of the epiphysis, the shape of the different faces, the shape and appearance of the articular surfaces.

RESULTS

Comparative study of the diaphysis

With HS as it is with PTV, the tibial diaphyses are prismatic, triangular and they describe a long curve in the frontal plane giving the appearance of an italic "S". They each show three faces (antero-medial, antero-lateral and posterior). The antero-medial surface is smooth, flat and subcutaneous. The posterior face is slightly excavated and shows an oblique blunt crest inwards and downwards from the fibular articular surface. With PTV, the diaphysis has the same morphology as with HS but with a slight varus (Figure 1).

Figure 1: Showing the italic S aspect of the tibial diaphyses of man (A) and chimpanzee (B)

With CLF, the diaphysis is also triangular and prismatic at the proximal part, but it becomes rounded at its distal part. It is triangular over its entire height with SSD, but the faces are shaped differently (Figure 2). As a matter of fact, we encounter again an anterior face, a posterior face and a lateral face. The anterior face is smooth and concave. The posterior face is excavated in its upper 1/3 and convex in its lower 2/3. The lateral face is slightly convex outside and flattened in its upper 1/3.

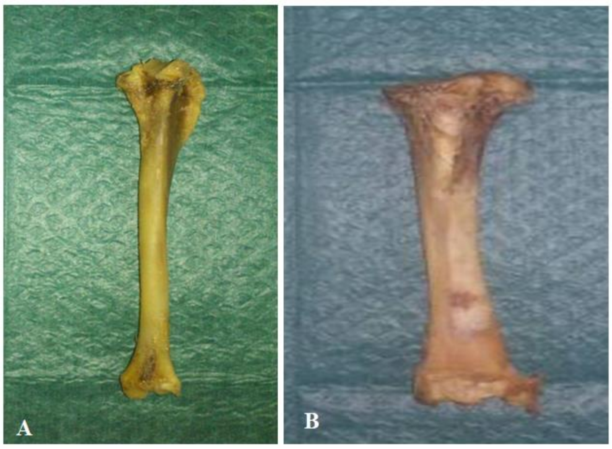


Figure 2: Showing the appearance of the tibial diaphyses of: Dog (A); triangular at the top, then rounded at the middle part and at the bottom; Pig (B); triangular over all its height

The edges of the diaphysis demarcate the faces. With HS, the anterior edge results from the anterior tibial tuberosity, describes an italic « S » curve in its upper part and descends to the medial malleolus. With PTV, the anterior edge is discreetly concave in a medial way. The medial edge is protruding and ends on the posterior edge of the medial malleolus with both HS and PTV. The interbony edge is sharp with HS and PTV and it bifurcates at the bottom.

With SSD, the diaphysis shows a very protruding anterior edge that descends from the tibial tuberosity to join the lateral part of the distal epiphysis. The interbony edge disappears in its lower part and the medial edge is slightly curved inwards and it bifurcates at the bottom. The anterior edge is very prominent with dogs but it disappears at the union of the proximal 1/3 and the distal 2/3 of the diaphysis. The interbony edge is slightly protruding.

Comparative study of the proximal epiphysis

It is voluminous, elongated transversely with the 4 species with two enormous tibial condyles (medial and lateral) deformed backwards. With HS and PTV, the proximal epiphysis shows an anterior bony projection which is the anterior tibial tuberosity. We also find on the upper face of this epiphysis two bony thorn-like projections that connect two articular surfaces on the median line. These two articular surfaces have a rounded and oval shape and are excavated. They are upper, as plateaus but have a posterior inclination at the bottom. With SSD and CLF, the anterior tibial tuberosity is highly developed. It is voluminous and goes up to the upper part of the proximal epiphysis (Figure 3). The upper tibial articular surfaces are located at the posterior part of the upper face. They are also rounded but they are more convex and continue backwards and downwards on the posterior surface of the proximal epiphysis. The upper medial tibial articular surface is rounded. The backward and downward inclination is more pronounced in the two quadrupeds. The projection of the tibial spines is very little pronounced in quadrupeds. The medial condyle is rounded with SSD, rounded and slightly excavated with CLF. The lateral condyle excavated downwards and forwards with SSD is more excavated backwards and downwards with CLF.

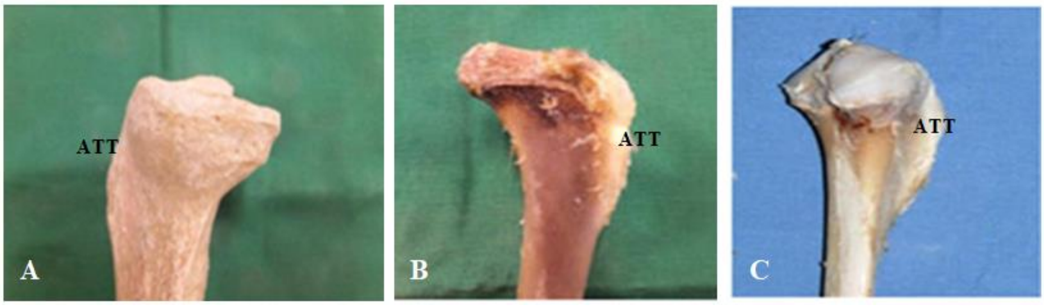
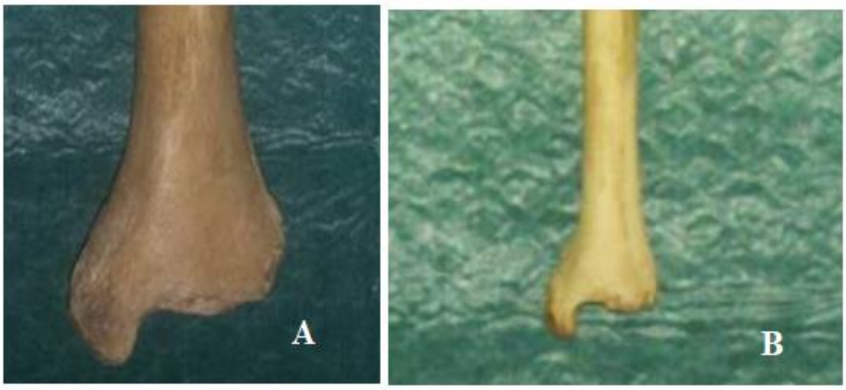


Figure 3: Showing the appearance of the human proximal tibial epiphyses (A); of the dog (B) and the pig (C) with the difference between the articular surfaces and the ATTs. ATT = Anterior Tibial Tuberosity

Comparative study of the distal epiphysis

It is less voluminous than the proximal epiphysis; it is flattened from front to back and shows to describe five faces demarcated by the edges of the bone with bipeds (PTV and HS). On the other hand, with SSD and CLF (quadrupeds), these different faces do not seem to be well individualized. The lower articular surface is rectangular with two well-pronounced sagittal concavities and a very prominent antero-posterior crest in quadrupeds, whereas in bipeds this lower articular surface is rectangular with a slight transverse convexity and a blunt antero-posterior crest (Figure 4).



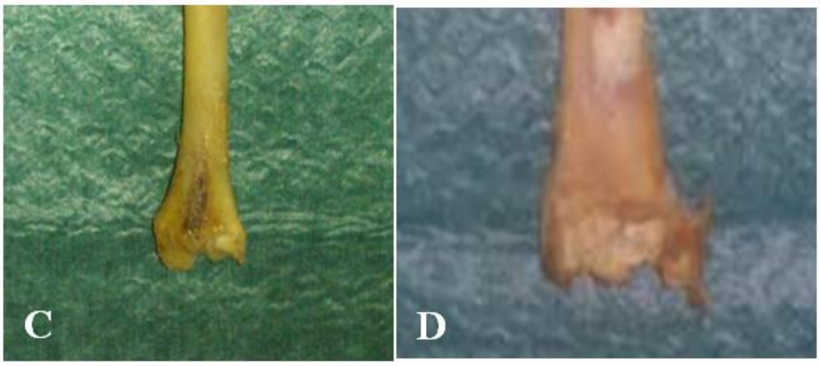


Figure 4: Showing the appearance of the distal tibial epiphyses of man (A); chimpanzee (B), dog (C) and pig (D). Two well-pronounced sagittal concavities and a very prominent antero-posterior crest in dog (C) and pig (D)

DISCUSSION

The relationship between the morphology of the long bones, particularly those of the pelvic limb and the erected position, has been the subject of little work. The choice of comparative anatomy on bone pieces as with Senut (Senut B, 1978) enabled us to highlight the particular morphological characteristics of each group and thus to deduce the differences. In our methodology, in addition to HS, we have chosen PTV because it represents the closest biped to HS (Alexander R, 2004). On the other hand, the quadrupeds were selected on a criterion of compliance with weight proportionality in relation to the two bipeds selected. This choice made it possible to have bone samples with the same proportions, thus facilitating the analytical and comparative study. However, this comparative morphological study did not take into account the metric differences observed on these tibias studied. In fact, it was an exclusive descriptive and comparative anatomical study.

Thus at the diaphyseal level, all the tibias examined display curvatures which do not necessarily seem to be linked to the erected position. The presence of these curvatures would rather be linked to the effect of traction of the muscles which are inserted on the different diaphyseal faces of these bones. In the category of bipeds (HS and PTV) this tensile action of the muscles plays an important role in the shape of the diaphysis and thus in the locomotive function. In PTV for instance, Deloison (2009) explained this morphological difference by the terminal insertion of the tibial anterior muscle. This terminal insertion, which is done on the base of the first metatarsal and the medial cuneiform with HS, is done only on the medial cuneiform in PTV. This would explain the varus morphology of the tibia in this animal. This varus shape gives it a supination function which also gives its pelvic member a prehension function enabling it to grab the branches during its movement. Furthermore, the "S" italic aspect of the human tibia makes it straighter than the other tibias examined. This rectilinear aspect and evolution of the homini knee and ankle constitute a criterion of human bipedalism (Frelat MA *et al*., 2017). According to these authors, this morphology enables the bringing together of the knee and the feet when standing and when walking.

The morphological characteristics linked to the locomotive function are more visible at the level of the proximal epiphyses. The convex shape deformed behind the tibial plateaus with the two quadrupeds is explained by the functional position in flexion of the knee joint. This functional position results in close posterior contact between the femoral condyles and the posterior part of the upper tibial articular surfaces in the functional position of the knee. Additionally, permanent flexion of this joint in quadrupeds induces traction of the entire extensor system on the anterior tibial tuberosity. This would therefore lead to an excessive development of the anterior tibial tuberosity and would explain the voluminous appearance of this anatomical entity in quadrupeds. On the other hand, the development of the tibial spines mass, which is more prominent in bipeds, proves the importance of the stabilizing effect played by the crossed ligaments of the knee in the erected position.

The articular surfaces of the distal epiphyses in both classes have a morphology that is more related to the distribution of pressures related to body weight. With bipeds, these articular surfaces are flat whereas with quadrupeds they are hollow. This can be explained in the latter by a distribution of the pressures on the four limbs. Additionally, the hollow aspect of these surfaces can be explained by an extreme stacking of the articular surfaces of the ankle with these quadrupeds during propulsion when walking. On the other hand, in bipeds, the distribution of these pressures is concentrated on the two pelvic limbs. This inescapably induces morphological and structural consequences at the level of the articular surfaces. A study carried out in bipedal and quadrupedal marsupials (Carlson *et al.*, 2013) analyzed radiologically the bone density of the subchondral bone at the level of the distal epiphysis of the tibia. This study, like other studies (Nowak MJ *et al.*, 2010), demonstrated that the bone density of the subchondral bone of the distal epiphysis of the tibia is greater in bipeds than in quadrupeds.

CONCLUSION

This work enabled us to highlight a tibia morphology closely linked to the locomotive function. The anatomical specificities of this bone in bipeds, although they are common, nevertheless show particularities that make it possible to distinguish between a purely human bipedalism and a bipedalism specific to other primates.

REFERENCES

- Alexander, R. M. (2004). Bipedal animals, and their differences from humans. *Journal of anatomy*, *204*(5), 321-330.
- Carlson, K. J., Jashashvili, T., Houghton, K., Westaway, M. C., & Patel, B. A. (2013). Joint loads in marsupial ankles reflect habitual bipedalism versus quadrupedalism. *PLoS One*, *8*(3), e58811. https://doi.org/10.1371/journal.pone.0058811.
- Deloison, Y. (2009). Le squelette et la bipédie, une clé pour comprendre l'origine de l'homme: le pied. *Rhumatologie Pratique*; octobre, 14-17.
- Frelat, M. A., Shaw, C. N., Sukhdeo, S., Hublin, J. J., Benazzi, S., & Ryan, T. M. (2017). Evolution of the hominin knee and ankle. *Journal of Human Evolution*, *108*, 147-160.
- Huxley, T. H. (1863). Evidence as to man's place in nature. University of Michigan Press, *Ann Arbor Paperbacks*, AA-24, 184pp.
- Nowak, M. G., Carlson, K. J., & Patel, B. A. (2010). Apparent density of the primate calcaneo-cuboid joint and its association with locomotor mode, foot posture, and the "midtarsal break". *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists*, *142*(2), 180-193.
- Schultz, A. H. (1937). Proportions, variability and asymetry of the long bones of the limbs and the clavicles in man and apes. *Hum boil*, 9, 281-328.
- Senut, B. (1978). Contribution à l'étude de l'humerus et de ses articulations chez les hominidés plio-pleistocènes. *Cahiers de paleo-anthropologie*, 1981. Ed. CNRS, Paris, 141p.