

Locomotor Anatomy of Patas Monkeys (*Erythrocebus patas*)

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I. INTRODUCTION

Patas monkeys (*Erythrocebus patas*) are the largest and most divergent of the guenon group. They are considered a predominately terrestrial species that inhabit a variety of dry, seasonal habitats across northern Africa between the equator and Sahara, from western Ethiopia to Senegal and southwards into northern Tanzania (Lernould 1988). Patas monkeys are closely related to vervet monkeys (*Cercopithecus aethiops*) and the two are often sympatric. Field researchers note patas monkeys' large home range and long daily travel (Hall 1965; Chism and Rowell 1988; Nakagawa 1989, 1999; Isbell et al. 1998; Pruetz 2009).

Patas monkeys are often singled out among cercopithecines as locomotor specialists that are uniquely adapted to ground life in woodland savannas using high speed running (Hall 1965). Consequently, anatomical studies focus on possible structural bases that underpin this distinct pattern, for example, the digitgrade posture of the foot (Wood 1973); less flexible vertebral column (Hurov 1987); short manual and pedal phalanges (Kingdon 1988); and longer limb lengths (Strasser 1992; Gebo and Sargis 1994).

Our investigation addresses the general issue of evaluating how "specialized" patas monkeys are from other cercopithecines. Specifically we ask: To what extent have patas monkeys diverged in locomotor anatomy from vervet monkeys? We contribute new data to assess the anatomical specializations of patas monkeys.

II. MATERIALS and METHODS of DISSECTION

Our study is based on whole body dissections of patas and vervet monkeys that combine analyses of all body segments and muscle groups with skeletal dimensions.

We use standardized methods in dissections of whole animals to provide quantitative information on body segments and muscle groups (Grand 1977; Zihlman et al. 2011). External measurements of body segments are taken prior to dissection. On one side of the body, the forelimb is detached from the trunk at the shoulder joint and weighed, the hindlimb, at the hip joint. The tail is weighed as a unit. Each limb is then separated into segments and weighed, forelimb: arm, forearm, hand; hind limb: thigh, leg, foot. Tissues are separated and weighed: muscle, bone, skin. On the other side, each muscle is detached and weighed with its tendon. The skeleton is cleaned using dermestid beetles.

Limb and tail masses are calculated relative to total body mass; segments are calculated relative to total segment mass. Muscles are grouped according to function and relative percentages are calculated. Limb bones are measured, and intermembral, brachial, and crural indices, determined.

III. RESULTS

Relative mass of body segments are very similar: patas have a slightly heavier head/trunk and notably less massive tail (**Figure 1a**). Segment masses within the forelimb (arm, forearm, hand) and hind limb (thigh, leg, foot) are similar in patas and vervet (**Figure 1b**). The extensors in several muscle groups are relatively heavier in the patas monkeys (**Figure 2**). All four limb indices are greater in patas than in vervets (**Table 2, Figure 3**). Based on external linear measurements, patas tail length is 52.6% of total body length, and 59.9% in vervets.

IV. DISCUSSION

The similarity in body and segment proportions of patas and vervets reflect their shared quadrupedal locomotion, close evolutionary relationships, and the guenon "ground plan" (Chism and Rowell 1988; Anapol et al. 2005; this study). However, patas and vervet monkeys are not simply larger or smaller versions of each other because muscle groups contrast in proportions and indices differ. In the patas forelimb, the elbow, wrist, and digital (finger) extensors suggest relatively more power than in vervets'. In the hind limb, the patas and vervet are similar in the ratio of knee extensors (quadriceps femoris) to flexors, and plantiflexors (ankle joint extensors, gastrocnemius and soleus) to dorsiflexors, but differ in relative proportions of invertors and pedal digital extensors.

The patas' higher brachial and crural indices reflect elongated forearm and leg segments. The digitigrade foot posture further extends the functional hind limb length and a longer stride. Patas monkey hand and foot digits are relatively shorter than those in vervets, whereas patas carpals and metacarpals and tarsals and metatarsals are relatively longer (Wood 1973; this study). Their differences in the invertors and the digital extensors of the toes reflect the absence of a plantigrade posture in the patas foot during walking (Wood 1973).

V. SUMMARY and CONCLUSIONS

- Patas share similarities with vervets in mass proportions of the head/trunk and limbs, with differences in the tail that reflect their shared quadrupedal locomotion, close evolutionary relationship, and guenon body plan.
- Antagonistic muscle groups indicate differences in force of motion at the elbow, wrist and ankle and foot between patas and vervet monkeys.
- Patas monkeys have long radii and tibiae that reflect the higher brachial and crural indices and longer limb lengths.

Table 1. Sample.

Specimen ID	Sex	Body Mass (g.)
<i>Erythrocebus patas</i>	Adult Male	11523.0
<i>Erythrocebus patas</i>	1.5 yr Female*	4088.5
<i>Cercopithecus aethiops</i>	Adult Male	6450.0
<i>Cercopithecus aethiops</i>	Adult Female	3500.0

*Female patas monkeys can conceive at age 3 yr. (Chism et al. 1984).

Figure 1a. Percent Segment Proportions to TBM in Patas and Vervet.

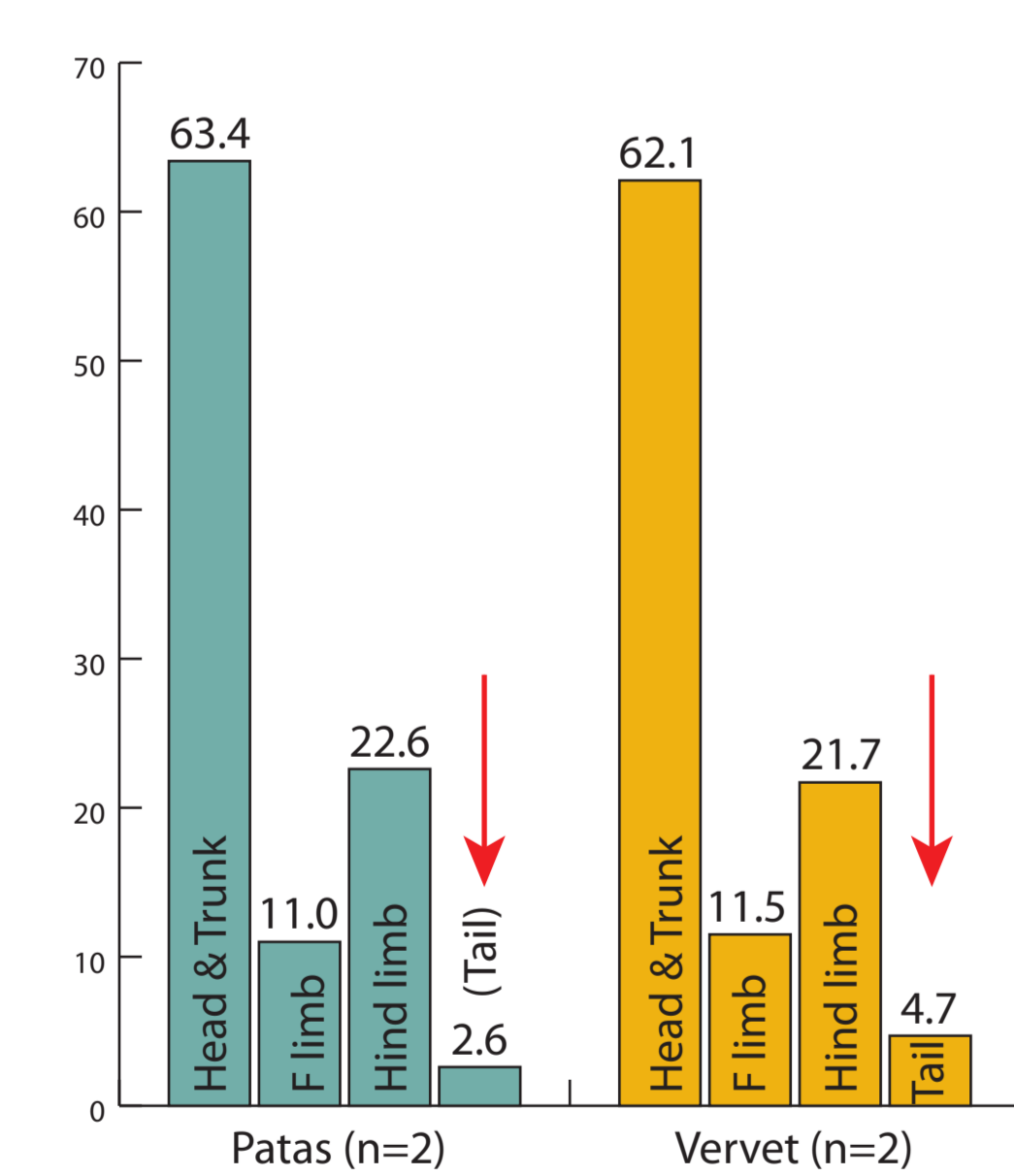


Figure 1b. Percent Segment Proportions to Total Limb Mass.

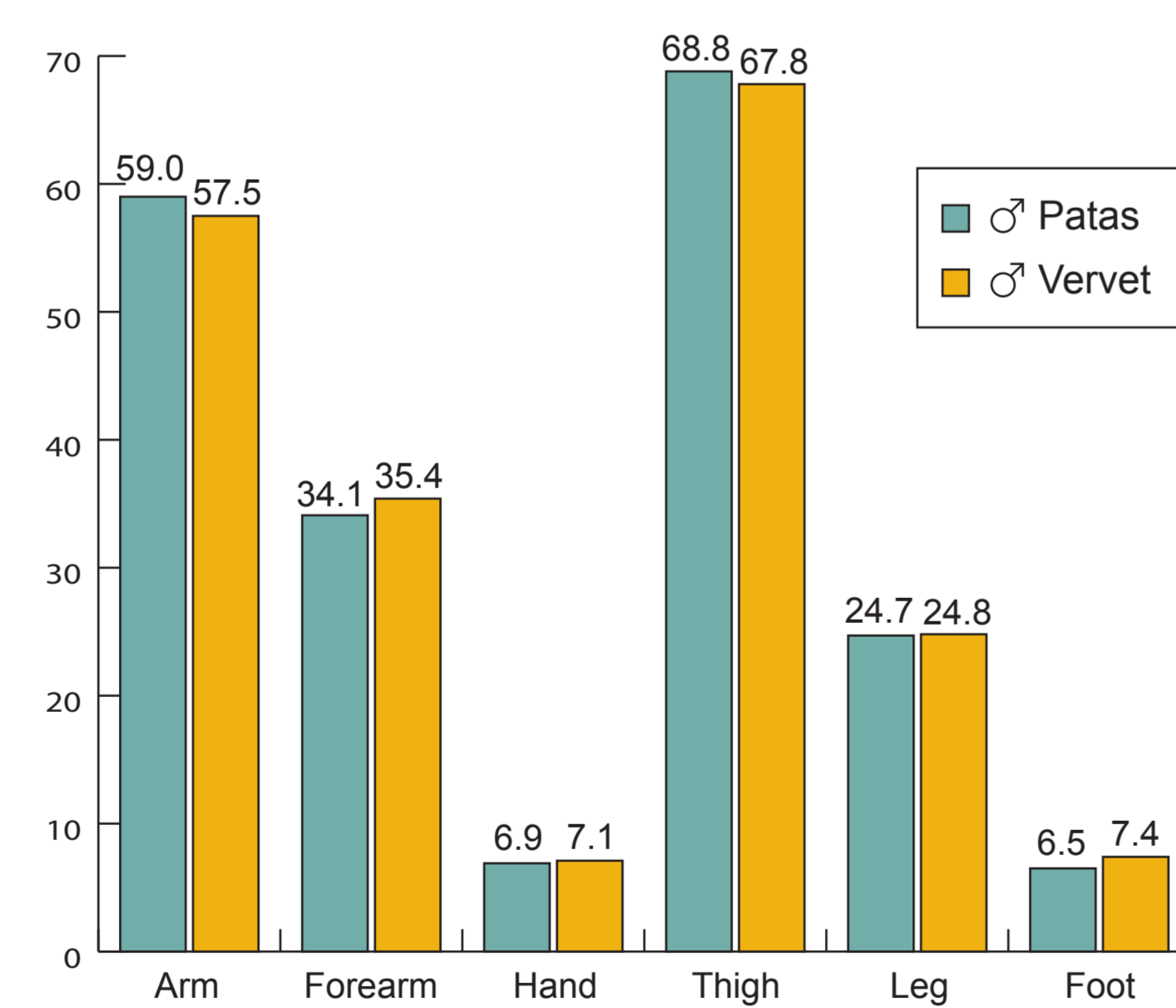


Figure 2. Ratios of Most Distinctive Muscle Groups.

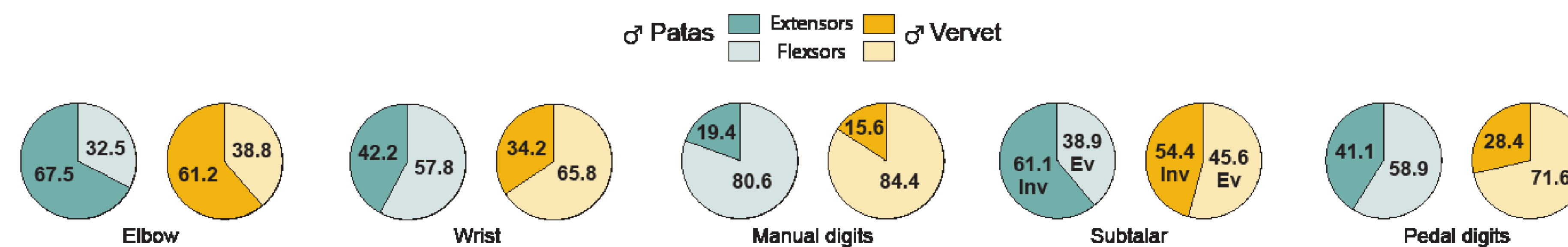


Figure 3. Limb Bones with Lengths (mm).

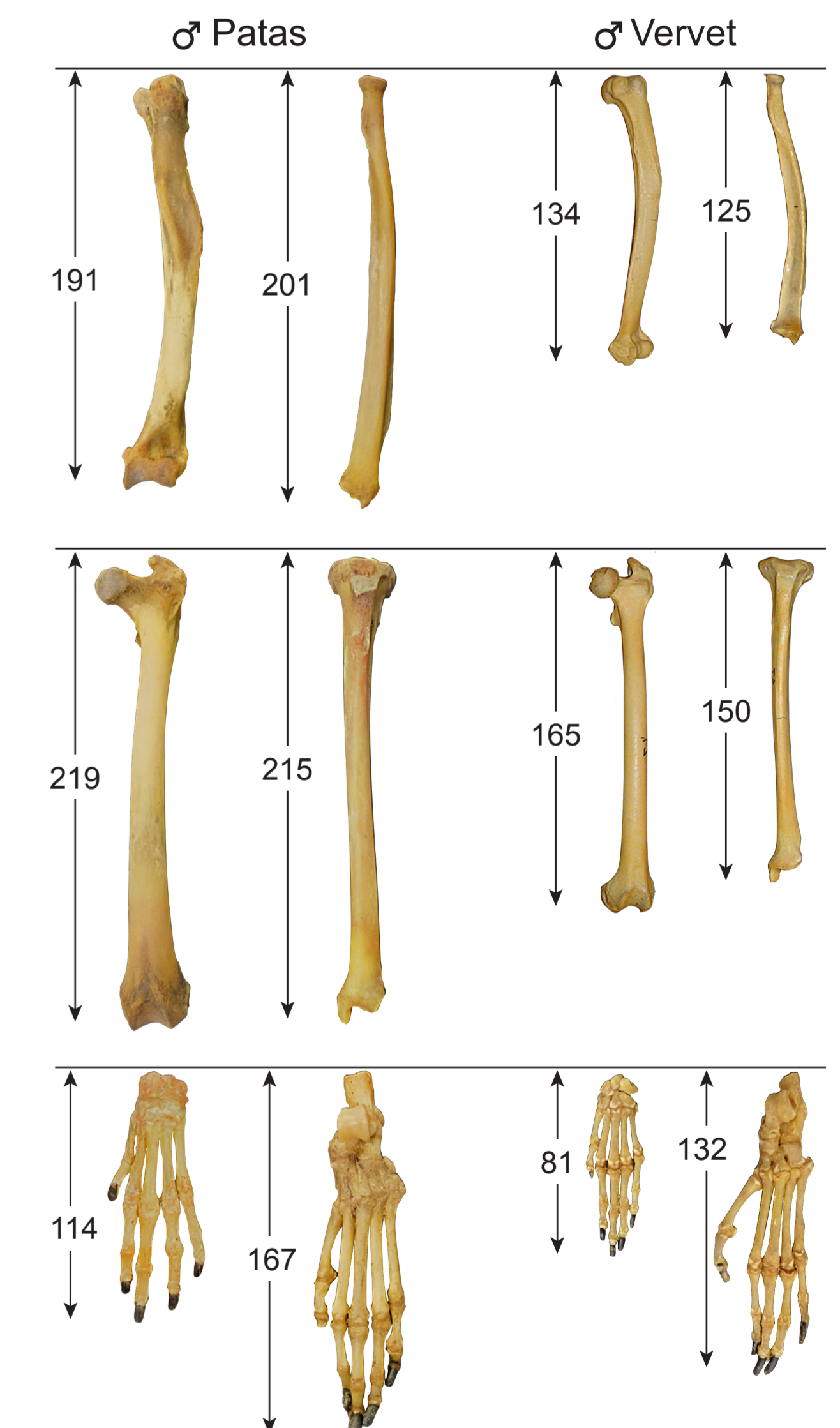


Table 2. Bone Indices.

Indices	Patas	Vervet
Intermembral Index	90	83
Brachial Index	105	95
Crural	98	95
Humero-femoral	87	82

Female patas not available.

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