Functional Regions of the Trunk in Chimpanzees (*Pan paniscus*) and Langurs (*Semnopithecus entellus*): A Comparison of Deep Back Muscles

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I. INTRODUCTION

The trunk forms the body's core, and the vertebral column is its keystone scaffolding. Through it, the head connects to the core, and the limbs are secured via the pectoral and pelvic girdles. The spine divided by vertebral regions – cervical, thoracic, lumbar, sacral, caudal – anchors a chain of deep back muscles. The muscles provide integrity to the thorax, regional strength to back segments, and movement to the skull, rib cage, pectoral and pelvic girdles, and in the case of monkeys, the tail. This study compares whole intact spines, their regional musculature and lengths, vertebral morphology, and curvature between a pronograde monkey (*Semnopithecus entellus*) with a long lumbar region, and an orthograde ape (*Pan paniscus*) with a short lumbar region. We investigate the functional implications of contrasting back morphologies on locomotion in langur, chimpanzee, and human.

II. MATERIALS and METHODS

Four adult chimpanzees and four adult langurs were dissected following the methods of Grand (1977, 1997; Underwood et al., 2013). The back musculature of one adult *Homo sapiens* was also dissected. **Table 1**. Deep back muscles are removed and weighed by functional region: Cervical-nuchal crest to C7; Thoracic-T1 to last rib; Lumbar-last rib to top of ilium; Sacral-top of ilium to distal sacrum; Caudal-distal sacrum to tip of tail. **Figure 1**. The muscle mass from each region is calculated as a percentage of total back extensor muscle.

Table 1. Sample of Adult Females and Males.

Specimen ID	Sex	Body Mass (g.)
Pan paniscus	Female	35500
P. paniscus	Female	37000
P. paniscus	Male	40800
P. paniscus	Male	42500
Semnopithecus entellus	Female	10545
S. entellus	Male	13909
S. entellus	Male	18438
S. entellus	Male	23523
Homo sapiens	Female	69600

III. RESULTS

Chimpanzees compared to langurs have more muscle in three back regions: cervical (21.7 vs 7.6%); thoracic (39.8 vs 17.3%); sacral (14.6 vs 9.5%) and are similar in the lumbar region (23.9 vs. 28.3%). However, the langur tail takes up 37.2% of total back musculature. **Figure 2**. Thus, 75% of langur musculature is concentrated in the lower back segments - lumbar, sacral and caudal - compared to the chimpanzees' 40.0%. The lumbar region in *Homo sapiens* is 41.2%, notably heavier than in chimpanzee or langur.

IV. DISCUSSION

The musculoskeleton of the back demonstrates differences in functional morphology in orthograde and pronograde trunks (Keith, 1903, 1923; Schultz, 1930, 1961, 1969). Both chimpanzees and langurs use quadrupedal locomotion, but the anatomy underlying their bodies differs. The langur flexes and extends the back between the thoracic and lumbar regions. Laterally extended transverse and spinal processes of the lumbar vertebrae increase surface area for the attachment of muscle acting on the lumbar-sacral-caudal segments. The chimpanzee's vertebral configuration restricts movement and stabilizes the lumbar region. **Figure 3**.

Relative lengths and morphologies of the skeletons, and regional distribution of vertebral musculature, highlight differences between chimpanzee and langur. The linear dimensions of the chimpanzee's cervical and thoracic regions and a high percentage of muscle (60%) correspond to the emphasis on the role of the upper limbs' in climbing and suspension. The langur's long lumbar-sacral-caudal region parallels the high percent of muscle (75%) and reflects the contribution of the back and tail in quadrupedal leaping and running in the trees and on the ground (Ripley, 1967). Despite a large difference in length of the lumbar regions of chimpanzee and langur, the muscle masses are similar.

(DISCUSSION CONTINUED)

Lateral profiles of the chimpanzee and langur trunks illustrate the differences, notably the slight lumbar curve in the *P. paniscus* spine. **Figure 4**. Lumbar wedging measured on individual vertebral bodies estimates the direction and amount of curvature of the spine (Williams, 2011). The influence of back muscle on the lumbar spine is not readily apparent from disarticulated vertebrae. Intact trunks from our lab offer an additional reference point.

A single lumbar vertebra, however, can be diagnostic of an orthograde body (Williams, 2012; Williams & Russo, 2015). An early fossil ape, *Morotopithecus*, about 20 myr preserves a lumbar vertebra similar to that of a chimpanzee (Walker & Rose, 1968; Maclatchey, 2004). The morphology of the medially restricted transverse and spinal processes suggest a locomotor shift to an emphasis on upper body suspension and climbing. The lumbar vertebrae in *Homo sapiens* are further modified for habitual bipedal locomotion, a departure from that of chimpanzees. **Figure 5**.

The musculoskeletal system of the vertebral column is responsive to locomotor forces. In particular, the lumbar portion of the spine forms a lordodic curve in 1) macaques trained to walk bipedally (Hayama, 1992); 2) great apes that are not of extreme mass (e.g. *P. paniscus*); 3) humans from birth through around 12-18 months old when bipedal stance and movement develop. We see in the lumbar region of the *Pan paniscus* trunk, a slight lumbar curve and wedging of the lumbar vertebrae not found in *Pan troglodytes* (Williams, 2011). **Figure 4**. This configuration of the lumbar region may be due to bipedal tendency, supported by observations on the ease and frequency of *P. paniscus* bipedal locomotion in the wild and in captivity (D'Aout et al. 2004; Mori, 1984; Myers Thompson, 2002; Zihlman, 1987).

The human lumbar region has 41% of back muscle and together with thoracic and lumbar accounts for 77.5%. These percentages reflect an expanded potential for movement in flexion, extention, and rotation. Rotational motions at the hip and torso in forward progression are countered by arm swinging during bipedal locomotion (Elftman, 1939, 1944; Ducroquet et al., 1968). The increased muscle mass, pronounced lumbar lordosis, and broad and wedged vertebrae provide support of the trunk over the lower limbs during bipedal locomotion.

V. SUMMARY and CONCLUSIONS

- **Langurs (*Semnopithecus entellus*) have more musculature in their lower backs (lumbar, sacral and caudal regions) for quadrupedal running and leaping compared with chimpanzees (*Pan paniscus*).**
- **Chimpanzees (*Pan paniscus*) have over double the thoracic deep extensor muscles as langurs (*Semnopithecus entellus*), although both have similar relative muscle mass in the lumbar region.**
- **Differences in mass-length proportions of the back and in vertebral morphology reflect body constructs underlying 1) pronograde vs orthograde and also 2) orthograde quadruped (chimpanzee) vs orthograde biped (human).**
- **The functional complex of this body region - the bony spine, the attached muscles, the individual vertebrae - offers insight into the locomotor adaptation of langur, chimpanzee and human.**

Figure 1. Dissection Methods of Deep Back Muscles

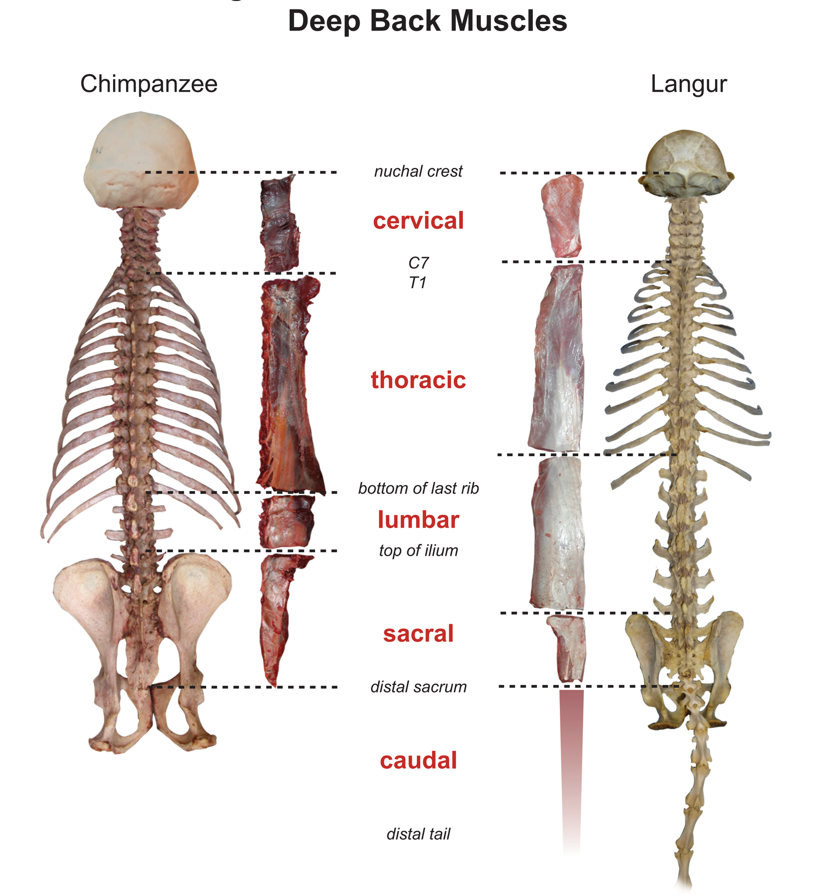


Figure 2. Back Muscle Segments as % of Total Back Muscle

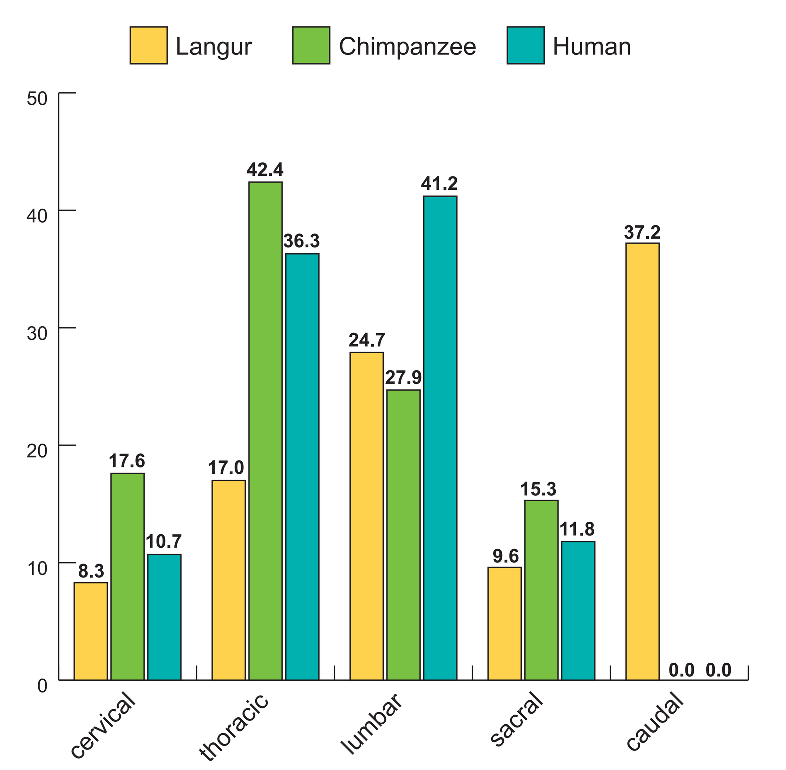


Figure 3. Lateral and Anterior Lumbar

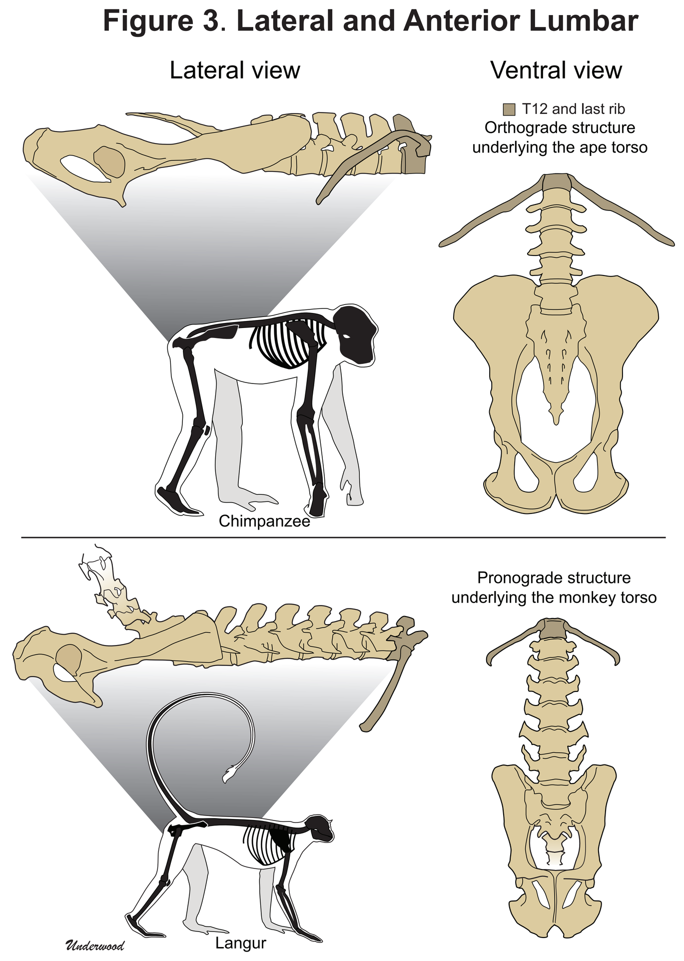
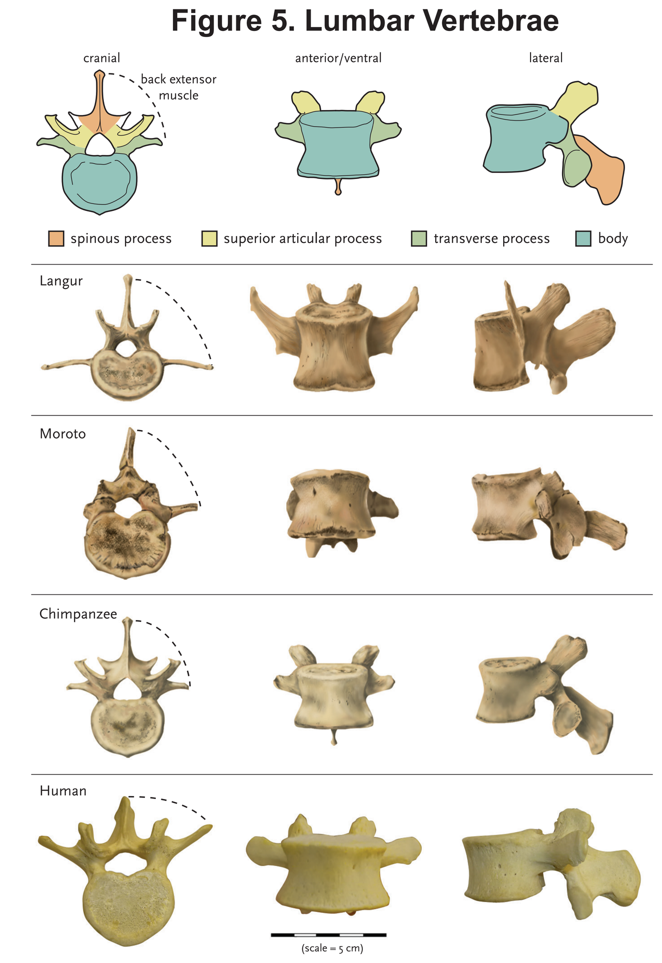


Figure 4. Lateral View of Intact Trunks

Figure 5. Lumbar Vertebrae



VI. ACKNOWLEDGMENTS & BIBLIOGRAPHY

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