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 spine, regional muscles and lengths, vertebral morphology, and curvature between a primate and langur (Semnopithecus entellus) with a short 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-lab 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.

III. RESULTS

Chimpanzees compared to langurs have more muscle mass 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 28.5%). 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 musculoskeletal system of the vertebral column is responsive to locomotor forces. In particular, the lumbar portion of the spine forms a lordotic curve in 1) macaques trained to walk bipedally (Hayamara, 1992); 2) great apes that are not of extreme mass (e.g. P. paniscus); 3) humans from birth through around 12-18 months when bipedal stance and movement develop. We see in the lumbar region of the Pan paniscus spine, 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, extension, and rotation. Rotational motions at the hip and torso in forward progression are countered by arm swinging during bipedal locomotion (Elliott, 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.

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