Profiling Primates: Anatomical Methods for Data Collection, Analysis and Comparison.

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I. INTRODUCTION

In 1699 Edward Tyson first explored the ape body through whole body dissection and description of an infant chimpanzee and placed its structure as falling between a monkey and human. Anatomical studies of apes expanded in the 19th century, through dissections by R. Owen, T.H. Huxley, and others. SL Washburn (1951) revived comparative anatomy and integrated it into anthropology through his emphasis on functional complexes and adaptation across living and fossil species. Based on whole body dissection of primates and other mammals, T. Grand (1977a; 1977b) developed standardized methods for data collection and quantitative analysis for comparing individuals across age, sex, and species. These methods serve as a basis for generating questions about function and for exploring hypotheses about adaptation based on data.

II. MATERIALS and METHODS of DISSECTION

Here we visually represent how data collection unfolds through dissection and show a few results of data analysis and comparison. A three-day old female hoolock gibbon (*Hoolock leuconedys*) from the Gibbon Conservation Center represents the method. She weighed 462 grams at the time of death, was frozen and thawed prior to our dissection.

Dissection methods consist of two complementary parts. One side of the body is designated the **SEGMENT SIDE (A)** and the other, the **MUSCLE-BY-MUSCLE SIDE (B)**. Each component generates specific data and results.

Segment side. The forelimb is detached at the shoulder joint (with deltoid), the hind limb at the hip joint; each limb is weighed (**A2**). Then the segments of each limb are separated and weighed: the arm, forearm, and hand of the forelimb; the thigh, leg, and foot of the hind limb (**A3**). Within each segment the soft tissue, muscle and skin, are separated from bone, and each tissue type is weighed.

Muscle-by-muscle side. On this side, each muscle or muscle group is removed and weighed. Here we show the arm and forearm muscles, skin and bone (**B3**).

IV. RESULTS and DISCUSSION

From the analyses, a whole body picture emerges of the baby hoolock's body composition, limb proportions, and segment distribution. The findings are then compared to an adult of the same species and an infant of another species.

Infant-adult comparisons. The baby's forelimbs are 16.8% and hind limb, 15.6%, similarly the adult limbs are 16.5% and 16.0%, respectively. However, the mass distribution within the forelimb and hind limb segments differ between the infant and adult. The infant arm is 36.5% of the forelimb mass and the hand, 25.2%, compared to the adult arm at 49.0% and hand, 14.3%. The infant's thigh is 45.4% of the hind limb, and the foot, 22.9%, whereas the adult thigh is 56.5%, the foot, 15.1% (Zihlman, Mootnick, Underwood, 2011) (**Fig 1, 2**).

Functional muscle groups are expressed as percents of the total muscle mass. For example, in the infant gibbon, elbow flexors are 58.6%, extensors, 41.4%; in the adult these percents are 72.0% and 28.0% respectively (**Fig 3**).

The limb proportions of infant and adult represent the species pattern related to locomotor adaptation, whereas their differences reflect function. The infant's relatively light arm and thigh segments and relatively heavy hands and feet reflect its clinging abilities and absence of locomotor independence at this stage of its life.

Infant gibbon and infant macaque comparison. Limb proportions contrast in the two species: infant macaque forelimbs, 11%; infant gibbon, 16.8%. The difference reflects the long and heavy forelimbs of the apes compared to monkeys, whereas the hind limbs are similar in the two 15% and 15.6% (Grand 1977b). Relative to body weight, the gibbons hands are 5.5% of body mass, feet, 3.6%, compared to the macaque at 1.2% and 2.6% respectively, which reflects forelimb emphasis of gibbons for suspension and macaques as quadrupeds with hind limb dominated locomotion (**Fig 4**).

In documented comparisons limb proportions separate the four genera of gibbon-siamangs (Zihlman, et al, 2011). Body composition, limb proportions, and muscle proportions show how male gorillas and orangutans diverge in their locomotor anatomy (Zihlman, McFarland, Underwood, 2011). Infant chimpanzees have less than half the muscle of adults and are dependent on them (Bolter and Zihlman 2012), whereas bovid infants at birth have proportionately as much muscle as adults, and are running within an hour of birth (Grand 1991).

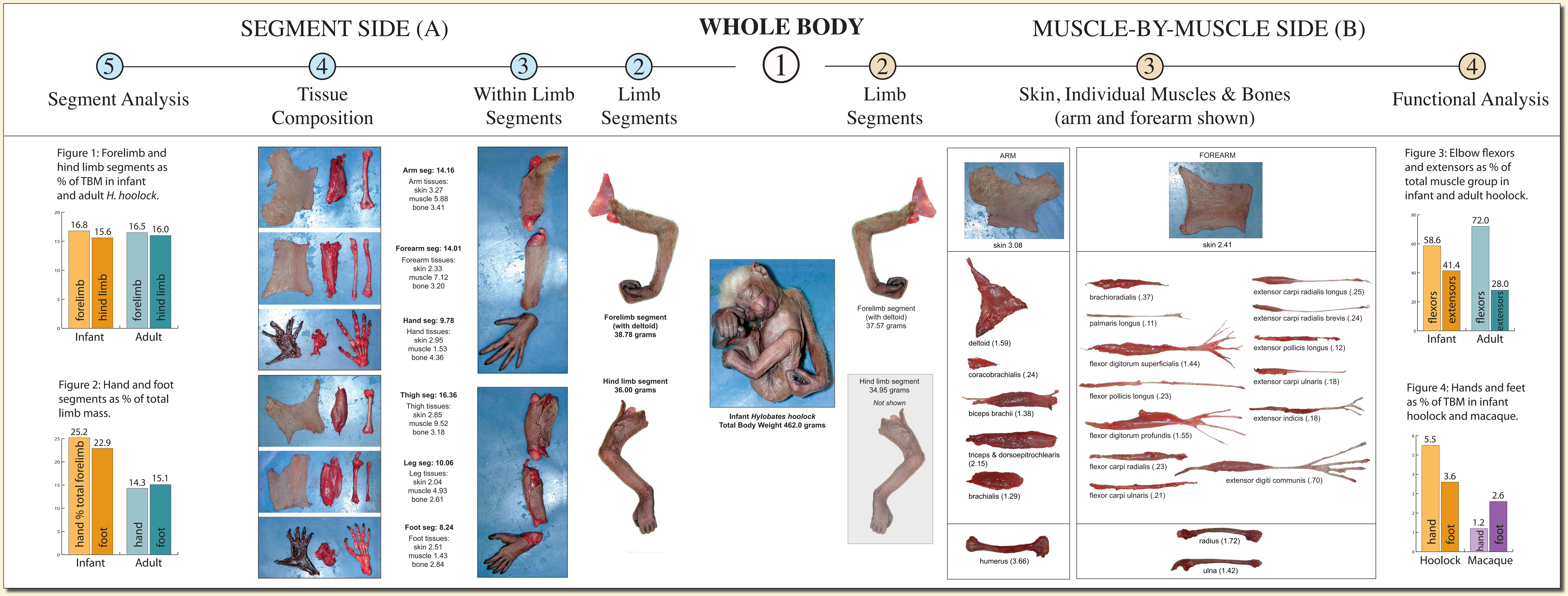

Figure 1: Forelimb and hind limb segments as % of TBM in infant and adult *H. hoolock*.

Figure 2: Hand and foot segments as % of total limb mass.

Figure 3: Elbow flexors and extensors as % of total muscle group in infant and adult hoolock.

Figure 4: Hands and feet as % of TBM in infant hoolock and macaque.

III. METHODS of ANALYSIS

Body composition is determined by adding up all the muscle dissected and weighed from each body segment and then determining its percentage to total body mass (TBM). Similarly, all the bone from the limbs, head and trunk, is added and taken as a % of total body mass. Skin is treated in the same way.

Limb proportions. The mass of the limbs is determined by doubling the mass from the forelimb segment and calculating its percentage to total body mass. The hind limb segment is analyzed the same way.

Segment distribution. Within each limb, the distribution of the mass to the segments can be determined by taking each as a % of total segment mass. For example, the contribution of the hand segment is determined by taking it as a % of the total forelimb mass. The foot is taken as a % of the total hind limb mass.

Muscle Proportions. To determine the relative mass of different muscle groups, for example, elbow flexors to extensors, each functional group is taken as a % of the total weight of flexors and extensors.

V. CONCLUSION

The methods of dissection and analysis provide a rich database that increase the overall data collection from a single specimen and provide a platform for more complex analyses and comparisons. Published results support genetic distinctions among the hylobatids, demonstrate species-specific anatomical patterns between gorillas and orangutans, and show how the body transforms in composition and proportions from infant to adult chimpanzee. The raw and relative data on primate bodies add to our understanding of adaptation and generate new questions.

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