I. PROJECT TITLE, PRINICIPLE INVESTIGATOR AND LOCATION

Project Title: Locomotor energetics in sifaka: contexts and consequences of terrestrial locomotion using arboreal anatomy

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Location: Comparative Biomechanics Laboratory, D103; Department of Anatomy and Neurobiology, NEOMED

II. ABSTRACT

Bipedal locomotion is rare among mammals, making it difficult to study the functional morphology and selective pressures associated with its evolution. The human fossil record preserves a gradual accumulation of the human-like traits we associate with upright bipedal walking gaits that are thought to make bipedal locomotion mechanically efficient. Modern human bipedalism is energetically efficient, but terrestrial quadrupedalism and bipedalism in living apes are equivalent to each other in terms of cost and both are more costly than human bipedalism. At present, the energetic costs of bipedal locomotion in other primates are not well-known. Sifakas, a type of lemur who use a bipedal gait when moving terrestrially, present an ideal opportunity to ask what aspects of anatomy and locomotor energetics may have favored the evolution of obligate bipedalism in the hominin lineage but not in other lineages. Sifakas practice bipedal locomotion in the wild but do not have the same anatomical specializations seen in humans. Examining the efficiency and context of sifaka bipedalism will elucidate necessary anatomy and ecologies for obligate bipedalism to evolve. This study explores the comparative energetic costs of sifaka terrestrial bipedal locomotion and arboreal vertical clinging and leaping (VCL). Energy expenditure in captive and wild sifakas (*Propithecus verreauxi*) engaging in VCL and bipedal locomotion will be measured using doubly labeled water. As the frequency of terrestrial, bipedal locomotion increases, energy expenditure should increase. Lemur habitats are becoming increasingly deforested (potentially mirroring the context of hominin bipedal evolution), and we further expect energy expenditure to be greater in subjects who must locomote terrestrially more frequently. This project has the potential to further our understanding of the evolution of hominin bipedalism, its ecological context, and its anatomical correlates.

III. SIGNIFICANCE OF THE RESEARCH

Sifaka offer a potentially productive test case for studying the context and consequences of terrestrial bipedal locomotion in an arboreally-adapted primate. This study offers a novel contribution to our appreciation of the adaptive landscape of human locomotor evolution by advancing our understanding of the energetic costs associated with terrestrial locomotion in the arboreal-adapted sifaka. Much research on the evolution of terrestrial bipedalism has understandably focused on apes but moving beyond our family will provide much-needed context and comparative datasets to explore whether human bipedalism has a unique energetic footprint that may have favored the evolution of habitual terrestrial bipedalism in our lineage. Sifakas converge on a number of traits traditionally used to infer bipedal locomotion in hominins (e.g. an anterior foramen magnum and associated orthograde posture, a dorsally-oriented ischium, a short, wide ilium, and low intermembral index). Because sifaka lack many of the human adaptations for striding bipedalism, it is likely that their terrestrial locomotion is more energetically costly than their habitual arboreal modes of locomotion, which may have further implications for their success as they are forced into more open environments. Results of this work will not only contribute to our understanding of the hominin transition from arboreal to terrestrial locomotion but have real-world implications for species conservation efforts of the endangered sifaka.

IV. GOALS AND OBJECTIVES

This project seeks to understand the energetic consequences of habitat change and the use terrestrial locomotion by an arboreally adapted primate, the sifaka. This will help to contextualize the evolution of hominin terrestrial bipedalism. This project's exploration of the locomotor behavior and energetic changes associated with habitat change in Madagascar will provide novel insights into the selective pressures that have been proposed to favor the evolution of primate bipedalism.

We hypothesize that sifaka terrestrial locomotion is more costly than arboreal gaits. Sifaka anatomy is specialized for arboreal vertical clinging and leaping, not terrestrial bipedal galloping. Thus, we predict that time periods during which sifakas engage in longer bouts of terrestrial bipedal locomotion will be associated with higher total energy expenditure than time periods relying on arboreal locomotor bouts.

V. INVESTIGATIVE METHODS

The objectives will be addressed primarily through lab-based experiments at the Duke Lemur Center. We have measured total energetic expenditure through doubly labeled water (DLW), activity and movement energetics via accelerometers, and locomotor frequencies using cameras, we will be able to track how increased reliance on terrestrial, bipedal locomotion influences the locomotor and overall energy budget in a primate possessing anatomical similarities to early hominins. Data have already been collected and the project needs assistance processing the video-based data.

VI. DATA ANALYSES

Quantitative data on the relationship between locomotor behavioral frequencies and energy expenditure metrics will be analyzed using linear mixed models using custom-written R code. We expect increased frequency of terrestrial bipedal locomotion to significantly increase energy expenditure

VII. CONTRIBUTION TO OVERALL PROJECT

Analyses of possible associations between locomotor modes and energy expenditure will contribute to the Gride-Potter Lab's research efforts to understand the functional influences on musculoskeletal form in primates and potential implications for their locomotor evolution. Potential research products will include 1) a student presentation at the annual NEOMED student research conference, 2) student authorship on a research presentation at the annual conference of the American Association of Biological Anthropologists, and 3) student authorship on an eventual manuscript summarizing research findings.

Summer Research Fellow Training/Mentoring Plan

Over my 15 years at NEOMED, I have mentored seven postdoctoral research fellows, two graduate students, and 41 pre-doctoral trainees (i.e., medical students, undergraduate students, and high school students). I am committed to fostering a positive, rewarding research experience for all students in my laboratory. In the current context, this goal will be achieved through the mentoring program described below.

First, the fellow will be trained to participate in every phase data analysis, interpretation, and dissemination. This involvement will promote mastery of several skills necessary to accomplish holistic biomechanical research, such as the analysis of quantitative data and the use of common software packages (e.g., MATLAB and R). Opportunities for medical students to gain experience with *in vivo* biomechanical research are rare, and the skills gained through involvement with this project should substantially broaden the fellow's expertise. Additionally, I will mentor the fellow in a structured literature review, providing the student with the necessary theoretical and empirical background to understand the impetus for our research and the chosen methodology for addressing the research questions. Where merited, the fellow will be given authorship on any presentations and publications stemming from this project, even after the student is no longer actively working in the laboratory.

The student will be given the opportunity to participate in weekly brown bag seminars and journals clubs sponsored by the NEOMED Musculoskeletal Biology Research Focus Area. Additionally, the fellow will participate in all Young Laboratory meetings.

All research will take place in the NEOMED Comparative Biomechanics Research Lab (D-103), collaboratively run by Drs. Young, German, and Grider-Potter. The Comparative Biomechanics Lab has all of the equipment and computer resources needed to carry out this research.

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