I. PROJECT TITLE, PRINICIPLE INVESTIGATOR AND LOCATION

Project Title: An Empirical Investigation of Functional Variation in Trabecular Bone Morphology

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

II. ABSTRACT

Bone researchers have long assumed that trabecular bone form might be structurally optimized to resist the common loading regimes. However, few empirical data exist to directly associate variation in trabecular bone morphology with functional variation in load resistance. In this research project, we will use 3D printing to create physical models that precisely vary aspects of trabecular number, thickness, and spacing. Models will be loaded using a universal material testing machine, allowing us to quantitatively diagnose how variation in trabecular form impacts the capacity for load resistance.

III. SIGNIFICANCE OF THE RESEARCH

Trabecular bone, also known as cancellous or spongy bone, is the generic name given to the network of bony struts that lie in the internal aspect of most long bones, particularly in the epiphyseal and metaphyseal regions. Because trabecular bone is 1) proximate to limb joint surfaces (and therefore may experience pronounced loading during locomotion) and 2) metabolically very active throughout life, bone researchers have long assumed that trabecular bone form might be structurally optimized to resist the common loading regimes. Various measures of trabecular bone volume, shape, and orientation have been cited in the literature as reliable indicators of activity levels and the magnitude and direction of loading history. However, most previous studies are correlational or based on computer models. Few empirical data exist to directly associate variation in trabecular morphology with functional variation in load resistance.

IV. GOALS AND OBJECTIVES

The goal of this research will be to use 3D printing to construct a set of physical models representing a range of variation in trabecular number, thickness, and shape. By precisely varying the number, thickness, and spacing of these struts, we will mimic variation in trabecular morphology in a quantitative, controlled manner. These models will then be loaded in using a universal testing machine, allowing us to systematically test for associations between specific aspects of trabecular shape and variation in overall strength (i.e., capacity for load resistance prior to structural failure). Ultimately, these results will help inform which specific aspects of trabecular bone morphology are the most informative in trying to diagnose function.

V. INVESTIGATIVE METHODS

Volumetric models will be created in the free, open source modelling program Blender (www.blender.org). Each model will consist of two flat plates connected by a network of linear struts arranged in a lattice pattern. Models will be created along a gradient of variation in trabecular number, thickness, and spacing. Each computer model will then be ported and 3D printed using a resin printer. Models will be loaded in axial compression (i.e., pushing the two flat plates of the models towards each other) using an Instron EletroPuls E3000 universal testing machine, allowing us to precisely measure the ultimate strength of each model in resisting compression (i.e., the amount of force, in Newtons, required to fracture the model).

VI. DATA ANALYSES

Quantitative data on the material strength of each model will be analyzed using full-factorial three-way analyses of variance (ANOVAs) in the statistical program R. Three-way ANOVA will allow us to statistically test for the independent and synergistic effects of trabecular spacing, number, and thickness on overall strength.

VII. CONTRIBUTION TO OVERALL PROJECT

Analyses of possible functional variation in trabecular bone morphology will contribute to Young Lab research efforts over the past decade to understand the mechanistic underpinnings of musculoskeletal anatomy as it relates to locomotor performance in mammals (e.g., Young 2005, 2009; Young et al. 2010; Russo and Young 2011; Young et al. 2014; Boyer et al. 2019; Foster et al. 2019; Smith et al. 2020; Young et al. 2020; Mossor et al. 2022; Magrini et al. 2023). 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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