TAWIRI Research Proposal

Titel: Influence of substrate dynamics on locomotor performance of wild chimpanzees in the Issa Valley

Introduction

Biological anthropologists have long presented several theories on primate locomotor evolution and reconstructions of hominin behavior and the selective pressures they faced. Many early fossil hominins would have moved and foraged in savanna-mosaic paleohabitats and not in tropical forests common to most extant apes today. Compared to tropical forests, these savanna-mosaic habitats would have elicited different selective pressures associated with reduced tree density and increased seasonality (Senut et al. 2018, Lindshield et al. 2021). In the absence of direct fossil evidence, quantitative studies of locomotor ecology of wild, extant primates are key to gain insights into the evolution of locomotor adaptations (Rose 1976, Hunt 1994, Thorpe et al. 2007). In particular the variation in substrate is an important factor influencing limb joint kinematics and kinetics of extant primates (Janisch et al. 2024).

Chimpanzees (*Pan troglodytes*) are unique among nonhuman great apes as they live across a wide range of different habitats, presenting a perfect opportunity to investigate how large-bodied, semi-arboreal apes adapt its positional (postural and locomotor) behavior and terrestriality to savanna habitats (Drummond-Clarke et al. 2021). In particular, we want to study the influence of substrate variation during locomotion in the arboreal environment and compare it to terrestrial locomotion and explore evolutionary hypotheses about adaptation to dry, open habitats as a driver for hominin and hominid evolution. We want to achieve this goal by using cutting-edge analytical tools to better understand how wild chimpanzees adjust locomotor kinematics to respond to ecological variation in substrate mechanics and how these adjustments affect locomotor performance.

Our knowledge of biomechanics, animal behavior, evolution, and ecology has been greatly improved with the introduction of video recording techniques and in particular the introduction of motion capture methods using multiple, high-speed cameras to quantify animal movement in three-dimensional (3D) space (Demuth et al., 2023). Initial studies were inevitably carried out in laboratory environments, as the cost, fragility, and size of such specialized cameras did not allow their use in harsh field conditions or provide sufficient flexibility for recording in variable environments. With the possibility of such new tools, we will gain valuable new data on the locomotor adaptions in wild chimpanzees and how they navigate their environment. This research will also further the possibility of three-dimensional motion capture in wild animals.

Statement of the Problem and Justification

Much of our knowledge of wild ape locomotion comes from laboratory studies or very few individuals in similar habitat. Very few studies have started to look at chimpanzee locomotion in the savanna-mosaic habitats as in Issa Valley (Drummond-Clarke et al. 2021). With the different challenges apes face in these habitats such as greater predator pressure and temporally and spatially sporadic food sources these selective pressures could have been drivers of special locomotor adaptations such as bipedalism as a more efficient mode of terrestrial travel (Sockol et al. 2007, Rodman & McHenry 1980, Leonard & Robertson 1995). Despite the suggested link between increased terrestriality and the appearance of bipedal adaptations, there is support of the strong arboreal component in hominin ecology. For example, fossil hominins show morphological adaptations that are considered advantageous for arboreal locomotion including long upper limbs, mobile shoulder, elbow and wrist joints as well as curved phalanges (Senut 2018, Ward 2002). Therefore, the fundamental question of early hominin evolution remains as whether bipedal locomotion evolved as an arboreal adaptation, or a savanna-mosaic environment acted as a selective driver of terrestriality.

General Aim of the Research

With state of the art methods we want to obtain high-quality data of chimpanzee locomotion and the substrate the animals use to investigate how wild chimpanzees adjust their locomotor kinematics and kinetics to respond to ecological variation in substrate mechanics and how these adjustments affect locomotor performance. To do so we will collect video data in 2D and 3D and measurements of the substrate they utilize. By collecting locomotion data on the chimpanzees in the Issa Vally we can then also start comparing their locomotion to chimpanzees that live in tropical forests to help unravel differences and explore different evolutionary theories. Studies such as this proposal are crucial to help shed light on the understanding of locomotor adaptations such as bipedalism, and the importance of the environment on ape and hominin evolution.

Specific Aims of the Research

Aim 1) We will use multi-camera, high-resolution, high-speed videography to document the locomotor kinematics and kinetics of chimpanzees moving their natural habitat. For this, we will sample terrestrial and arboreal locomotion on a wide range of substrates varying in diameter, inclination and compliance, quantifying a range of kinematic variables associated with locomotor performance during quadrupedalism and leaping.

Aim 2) We will quantify the morphology of the arboreal substrates employed for locomotion using proven remote-sensing methods. Specific measurements include substrate diameter, the three-dimensional orientation and height above ground as well as compliance of the branches and tree species.

Methodology

The methods we will use to record wild chimpanzee locomotion and measure substrate variation are described in detail in Dunham et al. (2018) and Janisch et al. (2024). All methods of our study are non-invasive to the animals. Animals will be recorded from a distance at all times.

Specific Aim 1: We will use multi-camera, high-resolution, high-speed videography to document the locomotor kinematics and kinetics of chimpanzees moving in their natural habitat.

<u>Video Recordings:</u> For 2D recordings we will follow wild chimpanzees in the Issa Valley and record their locomotion with modified GoPro Hero 12 cameras (Back-bone) with C-mount zoom

lenses at a frame rate of 120fps. Our choice of lenses enables us to easily adjust aperture and zoom as well as focus the camera at a variety of focal lengths and record the animals at various distances Cameras are mounted to lightweight tripods to stabilize the video footage while still permitting quick movement through the vegetation while filming apes on the move. In general, focal individuals can be recorded from a greater distance and direct interaction with the animals is not required. We will record quadrupedal gait, bipedal walking, vertical climbing (ascent and descent) and leaping in the trees.

Camera traps: Once we have observed and followed the chimpanzees for a couple of weeks and know their preferred trees and branches, we will attach two camera traps to get additional locomotion recordings from the animals locomoting in the trees.

Three-dimensional kinematics of leaping: For 3D recordings we will use two or three stationary synchronized cameras to track the three-dimensional movement of the animals and the locomotor substrate. Animals will be observed and followed until a good spot can be found to place the cameras and wait for the animals to move. Once the 3D recordings start, cameras cannot be moved anymore until camera calibrations are finished. To calibrate the cameras a object of a known length has to be moved through the space where the event of interest occurred. Additionally, we also move a checkerboard of a known size in front of each camera to calibrate focal length and lens distortion. For estimating gravity, we also throw a colorful tennis ball in front of all three cameras. For a detailed review of our methods please see Janisch et al. (2024).

Specific Aim 2: We will quantify the morphology of the arboreal substrates employed for locomotion using proven remote-sensing methods.

Substrate measurements: In addition to the 3D recordings of the primate leaps, we will also collect measurements of substrate properties following the protocols outlined in Dunham et al. (2018). A forestry-grade rangefinder (TruPulse 200x “missing 3D line setting”, Laser Technology Incorporated) will be used to measure inclination of the launching and landing support relative to gravity, the straight-line distance between the launching and landing supports, the support height above the ground, as well as the horizontal distance from the researcher to the target tree. This final measurement was used to calculate diameter of the launching and landing supports from digital photographs taken with a Nikon camera with a 55–250-mm zoom lens, noting the focal length used during the photographs (i.e., distance meter method for remote measurement, Galbany et al. (2016) and described in Dunham et al. (2018). Finally, whenever possible, we also note down tree species of the launching and landing supports, and measured their compliance using a force gauge apparatus, as described by Van Casteren et al. (2013, 2016) and Dunham et al. (2018). For this, we throw a stiff rope over a substrate by attaching one end of the rope to a 12oz throw bag. We have found that by using a pendulum swing underhand toss technique, we were able to launch the throw-line over substrates up to just over 10m in height. We use a steel carabiner to attach the throw line to a test marked by a series of loops separated by known distances. While standing on the test apparatus base to stabilize the force gauge, we record the force required to displace the substrate to each loop along the test rope. We then construct a force-displacement curve with the slope of the regression line representing the compliance. This measurement is more time intensive and will therefore be carried out once recordings are finished. For a detailed description of the method please see Dunham et al. (2018).

Feasibility: The feasibility of collecting 2D and 3D kinematic data on free-ranging primates has been demonstrated by my recently published papers on arboreal locomotion in wild primates with identical methods to study the influence of substrate variation on locomotor kinematics in strepsirrhines and catarrhines. “Protocol to record and analyze primate leaping in 3D in the wild (2024) *Journal of Experimental Zoology”* and “Ecological and phylogenetic influences on limb joint kinematics in wild primates (2024). *Zoological Journal of the Linnean Society*.”

Expected Output:

This research will contribute valuable new locomotion data on wild chimpanzees navigating through savannah and grassland habitat and enable new insights into their adaptations to this environment. This will be the first study obtaining 3D data of wild chimpanzees and further our our understanding of adaptations to dry, open habitats as a driver for hominin and hominid evolution. The outcome of this research will be published in peer-reviewed journals and presented on international conferences.

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