Skeletons Reanimated: Avian Validation of Tyrannosaur Pose Reconstruction

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Introduction

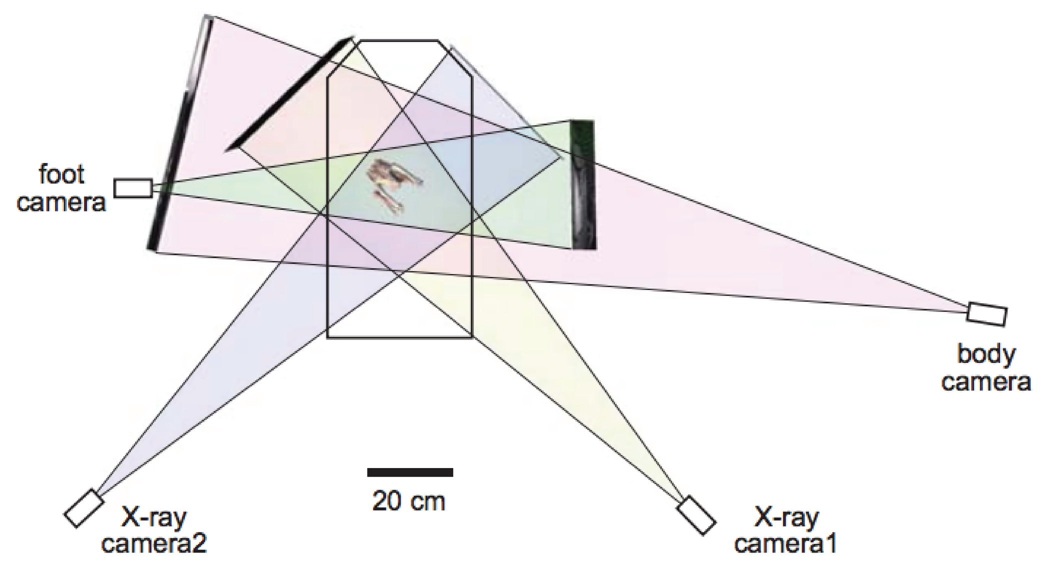
How does a fossilized *Tyrannosaurus rex* skeleton excavated in the field become a lifelike reconstruction in the American Museum of Natural History? Though *T. rex* is extinct, studying its extant relatives, birds, provides insight on the locomotion of this dinosaur.

Background

Walking is deceptively complex, involving the coordinated interaction of multiple bones and soft tissues. During each step, a foot pushes on the ground to support and propel the body. Such loading peaks at mid-stance (mid-step), when the foot presses downward with a purely vertical force. In a previous study of *T. rex* locomotion, Gatesy et al. (2010) were able to constrain the number of plausible mid-stance poses using 2D measurements of avian movement. Birds walk bipedally, just as their theropod dinosaur ancestors did. By identifying the rules governing the ways in which birds use their legs for locomotion, we can apply these constraints to reanimate the now static legs of *T. rex*.

Methods

X-ray Reconstruction of Moving Morphology (XROMM) was employed to reconstruct the orientations of the pelvis and leg bones of a helmeted guineafowl (*Numida meleagris*) during mid-stance.

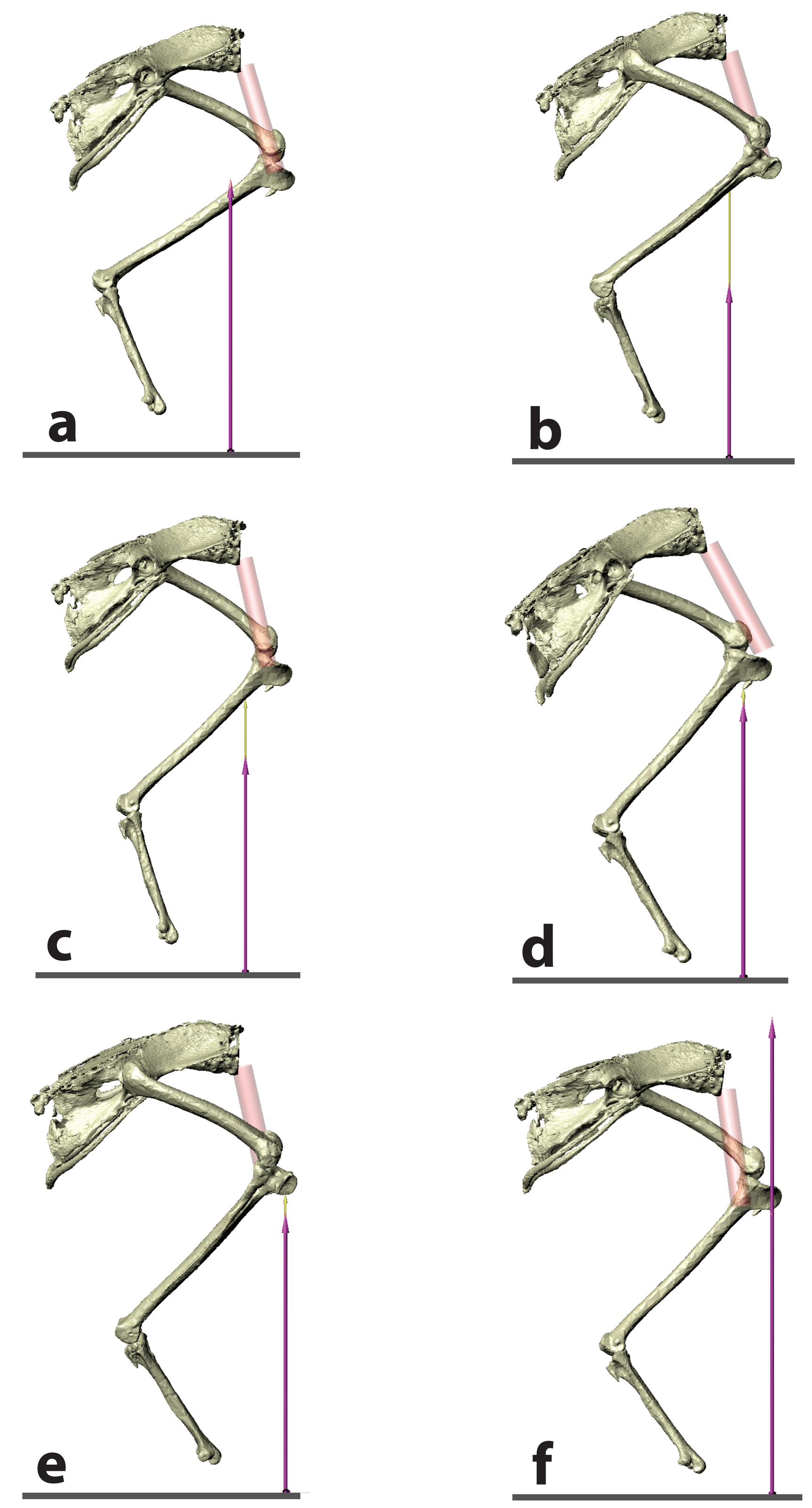


XROMM merges biplanar x-ray videos with bone models derived from CT scans, producing animations for accurately measuring 3D movement.

Synchronized force plate recordings were used to calculate the magnitude, position, and orientation of the ground reaction force (GRF). Mid-stance frames were sorted and analyzed based on bird speed and distance of the knee from the GRF. Attention was also paid to whether the bird was accelerating, decelerating, or moving at a steady pace during mid-stance.

Results

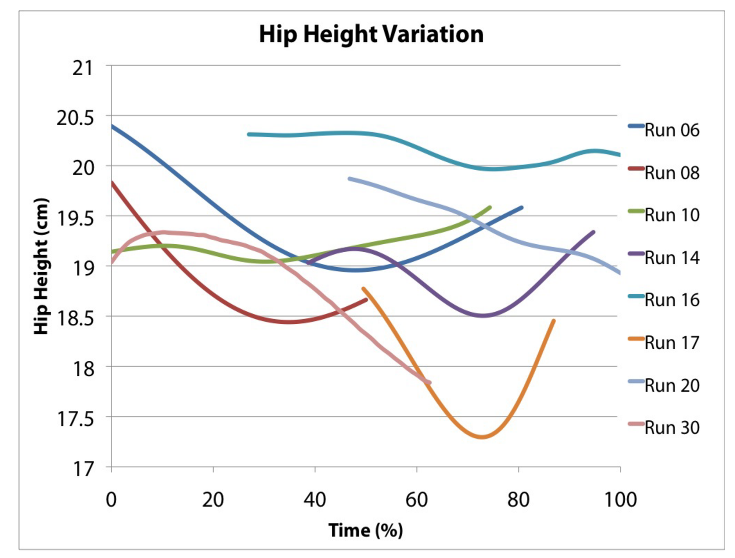
Analysis of mid-stance frames from eight trials revealed that if the bird is decelerating or walking at a steady pace, the GRF will be behind the knee at mid-stance. However, if the bird is accelerating, the GRF will be in front of the knee at mid-stance. As such, one of the constraints used by Gatesy et al. (2010)—that the GRF must be behind the knee at mid-stance—is not valid. Additionally, there is no apparent relationship between bird speed and mid-stance pose.

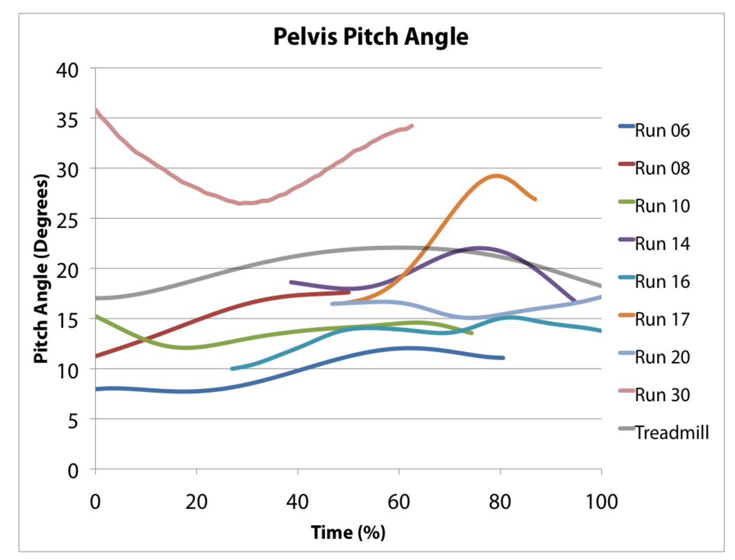


Six mid-stance frames of the pelvis and hind leg bones show that this pose is highly variable. The GRF (purple vector) varies greatly in magnitude and may be behind the knee (poses **a-c**), at the knee (pose **d**), or in front of the knee (poses **e** and **f**). Additionally, the GRF does not always target the center of mass (red cylinder).

Discussion

A surprising number of disparities exist among the mid-stance poses. Possible explanations for this variation are changes in hip height and pelvis pitch angle (see graphs below) throughout each trial. The bird would have to walk in one direction, at a steady speed, in the exact same way multiple times, for variables such as hip height and pevlis pitch angle to be constant.





Futher Direction for Study

Gathering additional data points through the analysis of other individuals may allow us to further constrain the number of plausible mid-stance poses. New data points may also reveal trends that are not made apparent by the few data points we currently have.

References

Gatesy et al. 2010. Constraint-based exclusion of limb poses for reconstructing theropod dinosaur locomotion. Journal of Vertebrate Paleontology, 29:2, 535-544.

Kambic et al. 2014. Long-axis rotation: a missing degree of freedom in avian bipedal locomotion. The Journal of Experimental Biology, 217: 2770-2782.