Plateosaurus was a biped – proof from kinematical computer modeling

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When Friedrich von Huene mounted two skeletons of *Plateosaurus* in the Tübingen Geological Museum he assumed the animal to be a biped. His reasoning was sound, despite many previous, contemporary and later attempts to prove quadrupedal stance for them. This is shown here via computer-aided analysis of the range of motion of the elbow joint and via kinematic and kinematical computer modeling, using MSC.visualNastran 4D, a commercially available solid-body modeling software.

Computed tomography scans of the forelimb of *Plateosaurus* were assembled in Rhinoceros 3.0, a NURBS modeling software. Comparison with recent taxa (*Alligator missisippiensis*, *Struthio camelus* and *Gallus gallus*) confirmed that pronation of the hand past a grasping posture, in which the palm are directed medially, is practically impossible. This digital manipulation of 3D data corroborates recent findings of other researchers, who used 2D files.

With the manus excluded from locomotion, only an obligate bipedal stance remains possible. In order to test this hypothesis, a digital model of *Plateosaurus* was created in Maya by inflating generic bodies until they just covered a laser scan of the mounted skeleton in Tübingen. Then, reasonable muscle volumes were added to produce a 3D digital file for kinematical analysis.

The model was cut into functional units (e.g. hip region, upper leg, lower led, metatarsus etc.), imported into MSC.visualNastran 4D, and the various body parts were given adjusted densities depending on their respective volumes of bone, muscles, inner organs and air volumes (lungs, air sacs). Now, physical constraints were added in place of the natural joints. For initial analyses, only constraints with one degree of freedom were used (rotary joints), as these are a close enough model for most joints (knee, ankle, elbow etc). For more complicated joints (e.g. intervertebral joints) it is possible to change the direction of the rotational axis at any time depending on the respective problem under investigation. In all joints, position or torque can be set as a function of time.

Now, a variety of models were run in order to investigate whether *Plateosaurus* could stand stably in a bipedal posture, and would remain stable during basic important motions:

Balance center of gravity test: a non-sectioned model to calculate the center of gravity, which rests roughly 40cm anterior to the acetabulum. This requires slightly bent legs to support the animal in a bipedal stance.

Balance standing posture: a stiff model (no joint can move in any way), resulting in a stable standing position on the hind legs only as predicted from the previous test.

Balance power need (knee): a model with a moveable knee, resulting in only minuscule forces needed to keep the balance posture in the knee.

Balance power need (hip): a model with a moveable hip, resulting in only minuscule forces needed to keep the balanced posture in the hip.

Mobile neck and tail: a model with vertically (run 1) and laterally (run 2) movable tail and neck, resulting in no significant instability of the bipedal balanced posture even during sudden up/down (run 1) or left/right (run 2) movements of the tail and/or neck.

Head to ground: a model with mobility in the entire vertebral column, resulting in no instability during movements directing the head to the ground.

Laying down and getting up: a model with mobility in all joints of the extremities as well as the vertebral column, resulting in controlled descent to a stable resting position and a controlled ascend into a standing bipedal posture.

These results show that *Plateosaurus* could not locomote on four limbs, but could stand, move, drink, lie down and get up with a reasonable safety margin when positioned in a bird-like bipedal stance.