A Palaeogravity calculation based on weight and mass estimates of *Gigantoraptor erlianensis*

Stephen W. Hurrell
email: papers@dinox.org

First Published: 24 July 2019

Cite: Hurrell, S.W. (2019). A Palaeogravity calculation based on weight and mass estimates of *Gigantoraptor erlianensis*. http://dinox.org/hurrell2019d

Abstract

There is great interest in calculating accurate values for Earth's palaeogravity. One fundamental technique to quantify palaeogravity is to compute weight against mass estimates of ancient animals. This technique is applied to the gigantic bird-like dinosaur *Gigantoraptor erlianensis* LH V0011 specimen. The results indicate a palaeogravity of 0.61g ± 20% is a reliable estimate for 80 Ma.

Key words: Palaeogravity, *Gigantoraptor erlianensis*

1. Introduction to palaeogravity

A more extensive introduction to the study of palaeogravity was given in Hurrell (2018). The key points identified in that publication were:

- There has been great interest in calculating palaeogravity with a number of authors speculating that ancient life might indicate palaeogravity was less than the present average of 1g (9.81 m/s²).[1]

- The weight-mass method was identified as one of the most accurate ways to calculate palaeogravity from ancient life. It can be calculated from:

$$g_a = w_a / m$$

where g_a is palaeogravity at some predefined age, w_a is the weight at that age and m is the mass. Since mass never varies it does not need a subscript to denote its age.

- Accurate values of weight and mass are required to apply this technique. Weight can be determined from the strength of leg bones, and mass can be determined from model reconstructions and tissue density.

- The study of Hurrell (2018) observed that a wide divergence of mass estimates seemed to be mainly due to variation in the size estimates of the gut volume. Better palaeogravity estimates might therefore be obtained from studying carnivore theropod dinosaurs which should not be subject to such high subjectivity.

The specimen chosen for this study of palaeogravity was the bird-like dinosaur *Gigantoraptor erlianensis* LH V0011.

[1] See for example: Harlé (1911), Kort (1947), Pennycuick (1992, 2008, 2016), Hurrell (1994, 2011, 2012, 2014a, 2014b, 2018, 2019a, 2019b, 2019c), Carey (2000), Mardfar (2000, 2012, 2016), Erickson (2001), Sato *et al* (2009), Scalera (2003a, 2003b), Strutinski (2012, 2016a, 2016b), and Maxlow (2014).

2. *Gigantoraptor erlianensis*

The discovery of *Gigantoraptor erlianensis* was accidently documented on film. Chinese palaeontologist Xing Xu was re-enacting the discovery of *Sonidosaurus* by digging out a thighbone for a Japanese film documentary in April 2005. As he wiped the bone clean, he suddenly realized it was part of the leg bone of a gigantic unidentified theropod.

Xu *et al* (2007) described the gigantic bird-like dinosaur from the Late Cretaceous of China in the science journal *Nature*. The new non-avian dinosaur, *Gigantoraptor erlianensis*, appeared to be related to a smaller group of feathered theropods known as Oviraptorosauria. Most significantly, the gigantic *Gigantoraptor erlianensis* showed many birdlike features and appeared to be closely related to species known to be covered in various types of feathers. Xu *et al* (2007) thought it seemed likely that *Gigantoraptor erlianensis* also had feathers. At the very least, it might have retained arm feathers from its ancestors, if not other types of feathers.

The *Gigantoraptor erlianensis* LH V0011 specimen was remarkable for its gigantic size. It was about 300 times as heavy as basal oviraptorosaurians. The estimated length was 8 metres in total, while it stood 3.5 metres high at the hip. Its skeleton consisted of a nearly complete mandible, several vertebrae, a nearly complete right scapula, much of the forelimbs, partial ilium, and nearly complete pubes and hind limbs. Paul (2010) noted that giant eggs, up to 0.5 metre long and arranged in enormous rings up to 3 metres across, were probably laid by big oviraptors such as *Gigantoraptor erlianensis*.

The presence of seven sets of lines of arrested growth suggested that the *Gigantoraptor erlianensis* specimen probably died during its eleventh year of life. The animal was inferred to be a young adult judging by the bone development.

The specimen was found in the Iren Dabasu Formation, Erlian basin, in Inner Mongolia. Unfortunately the age of this formation remains controversial. An age of 80 Ma has been assumed for this study and this should be within ± 10 Ma of the true age.

Figure 1.

A skeleton of the gigantic bird-like dinosaur, *Gigantoraptor erlianensis*, on display at the *Dinosaurs of China* exhibition at Wollaton Hall, UK, in 2017.

3. Mass estimates from body volumes

The mass of a dinosaur can be estimated by reconstructing a model and using the calculated volume and tissue density to work out the mass of the living animal. However, as the well-known palaeontologist Paul (1988, p134) explained: "Estimating the mass of a fossil species is not an exact science." He considered that the margin of error of an accurately restored model was probably about ± 15% even when the skeletal restoration was not missing any major sections. Certainly most estimates fall within this range with only a few outliers.

For the purposes of this palaeogravity calculation we need to specify an optimal mass estimate, or a "best guess", for the specimen. A key aspect of picking an optimal mass estimate from the range of possible options is to understand why mass estimates vary. These are the key factors to consider:

- Unfortunately there is still a great deal of confusion between weight and mass and this has resulted in some palaeontologists trying to produce low mass estimates to conform to weight. Paul (1988, p130) for example explains how he used weight calculated from bone dimensions "to expose implausibly high mass estimates … so a higher mass estimate should be examined critically." All this general confusion between weight and mass has undoubtedly reduced many mass estimates to unreasonably low values.

- Conway *et al* (2013) have recently criticised "shrink-wrapped" reconstructions, arguing that many of these skinny reconstructions cannot be accurate. They note that while palaeontological artists have been keen to portray most dinosaurs as slim, sleek animals where every muscle can clearly be seen, no living mammal, reptile or bird has such "visible" anatomy. They argue that the use of modern "high-fidelity" musculoskeletal reconstructions indicates that these skinny "shrink-wrapped" reconstructions have gone too far. To illustrate just how unlikely some of these reconstructions are they used the same "shrink-wrapping" method on modern-day animals to produce virtually unrecognisable skinny versions of modern animals.

- Some palaeontologists have decided to completely ignore weight estimates from bone dimensions. The differences between weight and mass estimates are so great for large bipeds that Hutchinson *et al* (2007) concluded that: "...it is almost certain that these scaling equations greatly underestimate dinosaur body masses... Hence, we recommend abandonment of their usage for large dinosaurs." This would indicate that the mass estimates of palaeontologists following this line of reasoning will not be influenced by the general confusion between weight and mass.

It is therefore expected that mass estimates that use "shrink-wrapped" reconstructions will be in the lowest range possible, providing a very useful indication of the minimum mass possible, but probably lower than reality. Palaeontologists who have decided to disregard weight estimates from bone dimensions will be more likely to provide the best mass estimates.

Many reconstructions assume the average tissue density of theropod dinosaurs was in the 0.8 to 1 tonne cu.m^{-1} range and this obviously affects the mass estimates by a large amount. There clearly isn't any generally consensus on one consistent value since different densities are used even within the same study - Hutchinson *et al* (2011) for example used 0.807, 0.85, 0.87 and 0.985 tonne cu.m^{-1} for different specimens of *Tyrannosaurus rex*. Life today has an average tissue density of about 0.97 tonne cu.m^{-1}. This average value includes the lung volume, typically between 5 to 6 % of body mass for a range of life from small to large. It would seem unlikely that theropod dinosaurs would need lungs that were nearly twice the size of present-day life, so estimates of 10% allowances for lungs seem excessive. Even if we assume that lung volume is 10% instead of a more typical 6% maximum, the average tissue density would only be 0.93 tonne cu.m^{-1}. Similar reasoning implies that the tissue density excluding the lungs is 1.03 tonne cu.m^{-1}, not the 1 tonne cu.m^{-1} often assumed for these calculations. Many studies also assume that there were additional isolated air-sacs within dinosaur bodies to reduce their mass. However, the buoyancy effect of the lungs means that living animals can float in water because they are slightly less dense while a drowned animal sinks in water once the lungs are full. Since dinosaur fossils are often recovered from the bottom of ancient rivers or lakes it would indicate that their tissue density was similar to today's life when they drowned. It would therefore seem unlikely that dinosaurs contained any isolated air-sacs that reduced their mass by a substantial amount. Taking all these considerations together, an average tissue density of about 0.95 tonne cu.m^{-1} seems a more reasonable estimate allowing for an extra-large lung volume of about 8% (even though this is unproven) with only minimal extra air-sac structures. One further complication is that scale models of *Gigantoraptor erlianensis* depict an outer covering of feathers that would reduce the density of the model. Density estimates set at 0.95 tonne cu.m^{-1} are for "naked" reconstructions that have no outer covering such as feathers. The reconstruction of

Gigantoraptor erlianensis clearly has feathers that would have reduced the average density. Accordingly average tissue density has been reduced to 0.93 tonne cu.m-1 for this bird-like specimen.

Paul (2010, 2016a, 2016b) estimated the mass of *Gigantoraptor erlianensis* as approximately 2 tonne, based on his skeletal reconstruction of the LH V0011 specimen.

One useful check of mass is to measure a commercially available model and compute the mass for that reconstruction using the volume mass estimate apparatus described by Alexander (1989, p19-20). The model chosen was a *Gigantoraptor* CollectA ©2009 model scaled at 1/45. This indicated a scaled mass of 2.31 tonne with a tissue density of 0.93 tonne cu.m-1.

Certain assumptions need to be made to produce a "best guess" optimal mass estimate: the lower estimate of 2 tonne by Paul (2010, 2016a, 2016b) is probably a "shrink-wrapped" reconstruction with a low density estimate, the reference model gave an estimate of 2.31 tonne allowing for the feathers included on the reconstruction. Trying to remove all sources of possible error indicates a reasonable average mass estimate would be about 2.3 tonne, assuming the *Gigantoraptor erlianensis* specimen was an optimal size and density.

4. Weight from bone dimensions

The weight of the *Gigantoraptor erlianensis* specimen can be directly calculated from the strength of its leg bones. The standard metric unit for weight is newton but the incorrect unit of kg or tonne has been widely used in most previous studies. I have highlighted it is really a force by denoting weight as either kg(f) or tonne(f). A kg(f) force would be multiplied by 9.81 to convert it to the standard metric unit of newton.

Anderson *et al* (1985) studied the bones of a range of mammals to see if there were any rules that would allow them to estimate the weight of an animal from just its leg bones. This would be very useful for extinct animals such as dinosaurs.

The Anderson team chose to study the major leg bones which are often well preserved in otherwise incomplete fossils. A good indication of the weight of present-day animals is the circumference of the upper leg bones – the humerus and the femur. The bones were measured where they were the thinnest, and so the weakest, usually about half way along the length of the bones. These two circumferences were then added together to give the total circumference. Bipedal animals only need the femur circumference.

The Anderson team used statistical analysis to define the equation for a bipedal animal:

$$W = 0.00016.c^{2.73}$$

where: W = body weight in kg(f), and c = femur circumference in mm.

This equation can be used to estimate the body weight of a bipedal animal from just the femur bones. One use of these equations would be to calculate the weight of extinct animals and the Anderson team applied their equations to a number of dinosaurs. Most dinosaurs should have been close to the best fit

Mass and weight estimates in tonne for *Gigantoraptor erlianensis* LH V0011				
Mass from models tonne				
Reference	Mass	Notes	Density tonne/cu.m	Volume cu.m
Paul (2010,2016a,2016b)	2.00	See pages 152,153	0.87	2.30
Model	2.31	Collect A © 2009	0.93	2.48
Best estimate	**2.30**		0.93	2.47
Weight from leg dimensions tonne(f)				
Reference	Weight	Notes		
Xu et al (2007)	1.40			
Bone dimension	1.40	Bipedal calculation		
Best estimate	**1.40**			
Within ±	20%			
Palaeogravity	**0.61**			
Average age	80			

Table 1.

Mass and weight estimates in tonne for the *Gigantoraptor erlianensis* LH V0011 specimen.

line, and certainly within ± 30%, but the calculated results indicated dinosaurs that were much lighter than anyone had ever thought possible.

Since the bone results were published in 1985 the mass of dinosaurs based on volume methods have been reduced to try to agree with these super-light-weight estimates for dinosaurs. Since the two methods give very different results some palaeontologists, as noted previously for Hutchinson *et al* (2007), advised abandoning the use of the formula based on leg bones entirely, since they cannot get dinosaurs' mass small enough to agree with the bone weight calculations. These types of criticisms encouraged Campione *et al* (2012) to slightly modify the original Anderson *et al* (1985) formula to produce increased weight estimates for larger dinosaurs more in line with the volume mass estimates.

The original Anderson *et al* (1985) formula was chosen to calculate the weight estimates in this study.

Xu *et al* (2007) used the Anderson *et al* (1985) equation to calculate a weight estimate of 1.4 tonne(f). This estimate was confirmed in a separate calculation using the bone dimensions.

5. Palaeogravity

Palaeogravity was calculated using the standard formula previously described:

$$g_{80} = w_{80} / m$$

Palaeogravity for the *Gigantoraptor erlianensis* LH V0011 specimen was estimated as 0.61g at approximately 80 million years ago.

6. Accuracy

The *Gigantoraptor erlianensis* LH V0011 specimen was placed within a ± 20% accuracy band for palaeogravity estimates.

7. Suggested Citing Format

Hurrell, S.W. (2019). A Palaeogravity calculation based on weight and mass estimates of *Gigantoraptor erlianensis*. http://dinox.org/hurrell2019d

8. Publication History

First published at dinox.org: 24 July 2019.

9. References

Alexander, R. M. (1989). Dynamics of dinosaurs and other extinct giants. Columbia University Press.

Anderson, J.F., Hall-Martin A., Russell D.A. (1985). Long-bone circumference and weight in mammals, birds, and dinosaurs. J. Zool. London, 207, 53-61. https://doi.org/10.1111/j.1469-7998.1985.tb04915.x

Campione, N. E., & Evans, D. C. (2012). A universal scaling relationship between body mass and proximal limb bone dimensions in quadrupedal terrestrial tetrapods. Bmc Biology, 10(1), 1. https://doi.org/10.1186/1741-7007-10-60

Carey, S. W. (2000). Earth, Universe, Cosmos. 2nd edition. University of Tasmania. http://www.utas.edu.au/codes/publications/publications-for-sale

Conway, J., Kosemen, C. M., Naish, D., & Hartman, S. (2013). All yesterdays: unique and speculative views of dinosaurs and other prehistoric animals. Irregular books. ISBN-13: 978-1291177121

Erickson, W.C. (2001). On the Origin of Dinosaurs and Mammals. USA. http://www.frontier-knowledge.com/earth/papers/Origin%20of%20Dinosaurs%20and%20Mammals.pdf

Harlé, E. (1911). Le vol de grands reptiles et insectes disparus semble indiquer une pression atmosphérique élevée.

Hurrell, S.W. (1994). Dinosaurs and the Expanding Earth. Oneoff Publishing. ISBN 0 952 2603 01.

Hurrell, S.W. (2011). Dinosaurs and the Expanding Earth (3rd edition). OneoffPublishing.com. ISBN 0 952 2603 70. http://oneoffpublishing.com/dee_hardback.html

Hurrell, S.W. (2012). Ancient Life's Gravity and its Implications for the Expanding Earth. In *The Earth Expansion Evidence: A challenge for geology, geophysics and astronomy. International School of Geophysics, Erice, Sicily, Italy*. ISBN-13: 978-8854856936 https://hdl.handle.net/2122/8838

Hurrell, S.W. (2014a). A New Method to Calculate Palaeogravity Using Fossil Feathers. NCGT Journal, v. 2, no. 3, September, 2014. p29-34. https://dinox.org/publications/Hurrell2014b.pdf

Hurrell, S.W. (2014b). Can we calculate palaeogravity? Liverpool Geological Society members evening presentation: 28th October 2014.

Hurrell, S. (2018). A palaeogravity calculation based on weight and mass estimates of *Giraffatitan (=Brachiosaurus) brancai*. https://dinox.org/hurrell2018a

Hurrell, S. (2019a). Palaeogravity calculations based on weight and mass estimates of four *Tyrannosaurus rex* specimens.
https://dinox.org/hurrell2019a

Hurrell, S.W. (2019b). A palaeogravity calculation based on weight and mass estimates of *Acrocanthosaurus atokensis*.
http://dinox.org/hurrell2019b

Hurrell, S.W. (2019c). Palaeogravity calculations based on weight and mass estimates of two Coelophysis bauri specimens.
http://dinox.org/hurrell2019c

Hutchinson, J. R., Ng-Thow-Hing, V., & Anderson, F. C. (2007). A 3D interactive method for estimating body segmental parameters in animals: application to the turning and running performance of Tyrannosaurus rex. Journal of Theoretical Biology, 246(4), 660-680.
https://doi.org/10.1016/j.jtbi.2007.01.023

Hutchinson, J. R., Bates, K. T., Molnar, J., Allen, V., & Makovicky, P. J. (2011). A computational analysis of limb and body dimensions in Tyrannosaurus rex with implications for locomotion, ontogeny, and growth. PLoS One, 6(10), e26037.
https://doi.org/10.1371/journal.pone.0026037

Kort, K. (1949). Das Wachen der Erde und die Wanderung der Kontinente. Hannover.

Mardfar, R. (2000). The relationship between Earth gravity and Evolution. Iran.

Mardfar, R. (2012). The Relationship between Gravity and Evolution of Animals and Plants – The Theory of the Increasing Gravity. In *The Earth Expansion Evidence: A challenge for geology, geophysics and astronomy*. *International School of Geophysics, Erice, Sicily, Italy*. ISBN-13: 978-8854856936
http://www.aracneeditrice.it/aracneweb/index.php/pubblicazione.html?item=9788854856936

Mardfar, R. (2016). Increase of Earth Gravity and Bio-Evolution: The Increasing Earth Gravity Theory. LAP LAMBERT Academic Publishing. ISBN-13: 978-3659971075

Paul, G. S. (1988). Predatory dinosaurs of the world: a complete illustrated guide. Simon & Schuster. ISBN-13: 978-0671619466

Paul, G. S. (2010). The Princeton Field Guide to Dinosaurs. Princeton University Press, Princeton.

Paul, G. S. (2016a). The Princeton Field Guide to Dinosaurs: 2nd edition. Princeton University Press, Princeton. ISBN-13: 978-0691167664

Paul, G. S. (2016b). Dinosaur Mass Table.
http://assets.press.princeton.edu/releases/m10851.pdf

Pennycuick, C. J. (1992). Newton rules biology. Oxford University Press. ISBN-13: 978-0198540205

Pennycuick, C. J. (2008). Modelling the flying bird (AP Theoretical Ecology Series) Elsevier. ISBN-13: 978-0123742995

Pennycuick, C. J. & Pennycuick, S. (2016). Birds Never Get Lost. Matador. ISBN-13: 978-1785890482

Sato K, Sakamoto KQ, Watanuki Y, Takahashi A, Katsumata N, Bost C, Weimerskirch H. (2009). Scaling of Soaring Seabirds and Implications for Flight Abilities of Giant Pterosaurs. PLoS ONE 4(4): e5400. https://doi.org/10.1371/journal.pone.0005400

Scalera, G. (2003a). The expanding Earth: a sound idea for the new millennium. In *Why expanding Earth? A book in honour of OC Hilgenberg*. Istituto Nazionale di Geofisica e Vulcanologia-TU Berlin.
http://hdl.handle.net/2122/1152

Scalera, G. (2003b). Gravity and expanding Earth. Atti del 21° Convegno Nazionale GNGTS.
http://hdl.handle.net/2122/2035

Strutinski, C. (2012). Contradictory Aspects in the Evolution of Life, Possibly Hinting at Gravitational Acceleration Through Time. In *The Earth Expansion Evidence: A challenge for geology, geophysics and astronomy. International School of Geophysics, Erice, Sicily, Italy*. ISBN-13: 978-8854856936
http://www.aracneeditrice.it/aracneweb/index.php/pubblicazione.html?item=9788854856936

Strutinski, C. (2016a). Wachsende Schwerkraft–Triebfeder der Evolution.
http://wachsende-erde.de/web-content/bilder/strut/Strutinski-Wachsende Schwerkraft.pdf

Strutinski, C. (2016b). The Lilliput Effect – a response of life to increasing gravity?
https://dinox.org/publications/Strutinski2016_Lilliput_Effect.pdf

Maxlow, J. (2014). On the Origin of Continents and Oceans: A Paradigm Shift in Understanding. ISBN-13: 978-0992565206.

Xu, X., Tan, Q., Wang, J., Zhao, X., & Tan, L. (2007). A gigantic bird-like dinosaur from the Late Cretaceous of China. *Nature*, *447*(7146), 844.
https://www.nature.com/articles/nature05849