Virtual reconstruction and biomechanical analysis of the Magdalenian perinate Wilczyce 11

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Virtual Reconstruction and Rapid Prototyping of the Skeleton

The Magdelanian perinate Wilczyce 1 is one of the best preserved infants yet discovered from this time period. It is dated to c. 13500 cal BP (Irish et al. 2008) and as such, is an important source of information on human developmental biology from this time period.
The remains were scanned over 2 days at the Institute of Ethnography and Archeology, Warsaw in the Autumn of 2011 by the author. The rmains were all scanned using a custom structured light scanner based upon the 3d3 solutions system and was calibrated especially for scanning very small objects. Following data acquisition, the reconstruction was carried out at the Glover laboratory for Digital Osteology on a dedicated workstation.
Reconstruction used a combination of Flexscan, Geomagic, 3DSMax and Avizo 7.0.
An example of the detail in the original scans can be seen below. These can be used for morohometric studies where the original material is too small, or too fragile, to be handled directly. Copies of scans will be available to other researchers, on request, after the conclusion of this project.

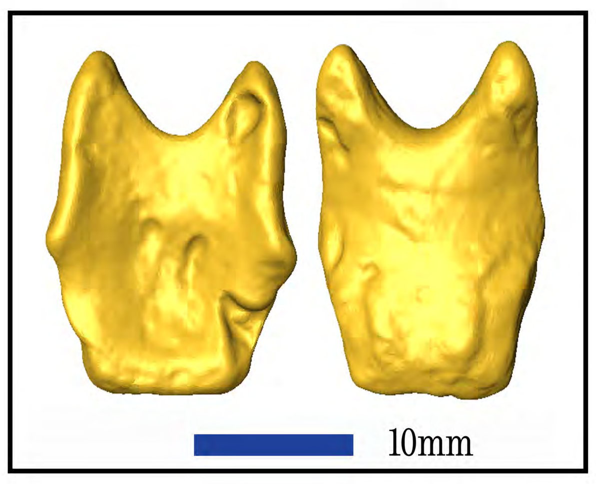
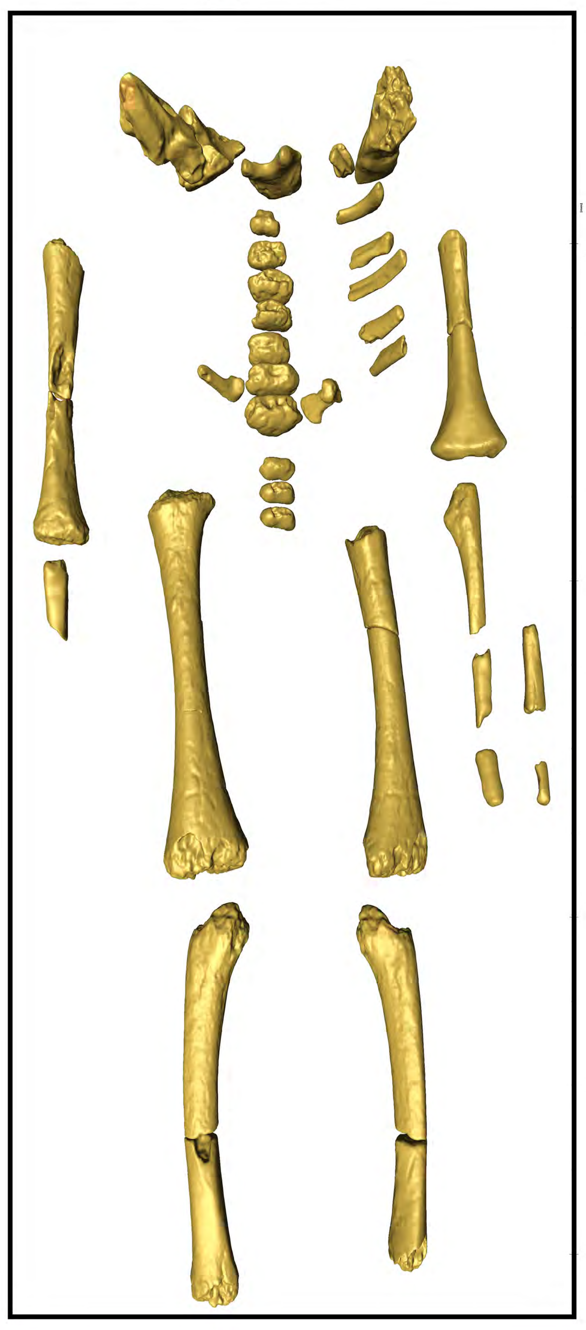


Fig. 1. (left).Rendering of surface scan of Pars Basilaris.

FIg. 2 (right). Rendering of current reconstruction. Scan QR code below to view a rotating model.



Due to the fragile nature of the material, conventional casting is not an option for making reprodcutions of the fossil. It was therefore decided to attempt rapid prototyping of the scans obtained. The scans were printed by fused deposition modelling using the following parameters by Fripp Desgin Consultancy in Sheffield, UK:
ZCORP spectrum 510
ZP 150 Powder
ZB 60 Binder
Cyanoacrylate infiltrate
Layer thickness: .089mm.
Whilst this method does not generate as high a surface resolution as achieved through stereolithography, it is a good compromise on price. The cost of printing a skeleton this size is c. £3-400 using fused deposition as opposed to well over £1000 using SLA.
The casts in question are available for handling and inspection. They are useful as a teaching aid, as it is very rare to be able to handle juvenile fossil remains directly.

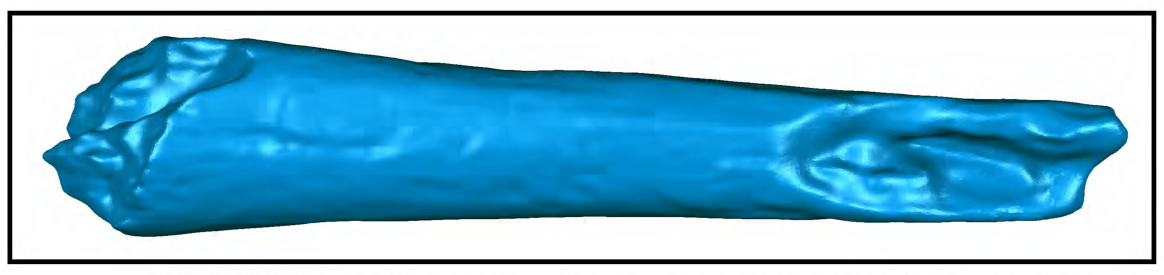


Fig. 3. Rendering of surface scan of right humerus

Biomechanical properties of the Long Bones

Introduction

The Wilczyce 11 skeleton preserves all the major longbones. Here, biomechanical properties for the humeri, femora and tibiae are presented for the intervals along which natural breaks occured.

Methods

Cross sections where extracted from the scans at natural breaks using the contour tool in Geomagic, These polylines were then scaled and measured using tpsdig.
The comparative sample consists of individuals from the large collections of medieval and post medieval faoetal and neonatal material curated at the University of Sheffield. The sites used in this study were Newcastle Blackgate, (Medieval), Bolsover Castle (Medieval), St Hilda's Church, Newcastle (Post Medieval). Full numbers for each group are given in a separate table.
For the comparative sample, measurements were taken in tpsdig from scaled x-rays obtained using a Nomad Pro unit. Properties were calculated for all longbones using a formatted Excel sheet following the eccentric ellipse model from O'Neill and Ruff (2004) to ensure consistency of results. Unfortunately, little in the way of cross sectional geometric properties from juvenile fossils have so far been published at the margins under investigation (Cowgill's 2010 data is for the 50% margin and residuals only are published). Please note that due to the small size of the comparative sample, I do not present any more advanced statistical analyses, in order to avoid giving a distorted view of the data.

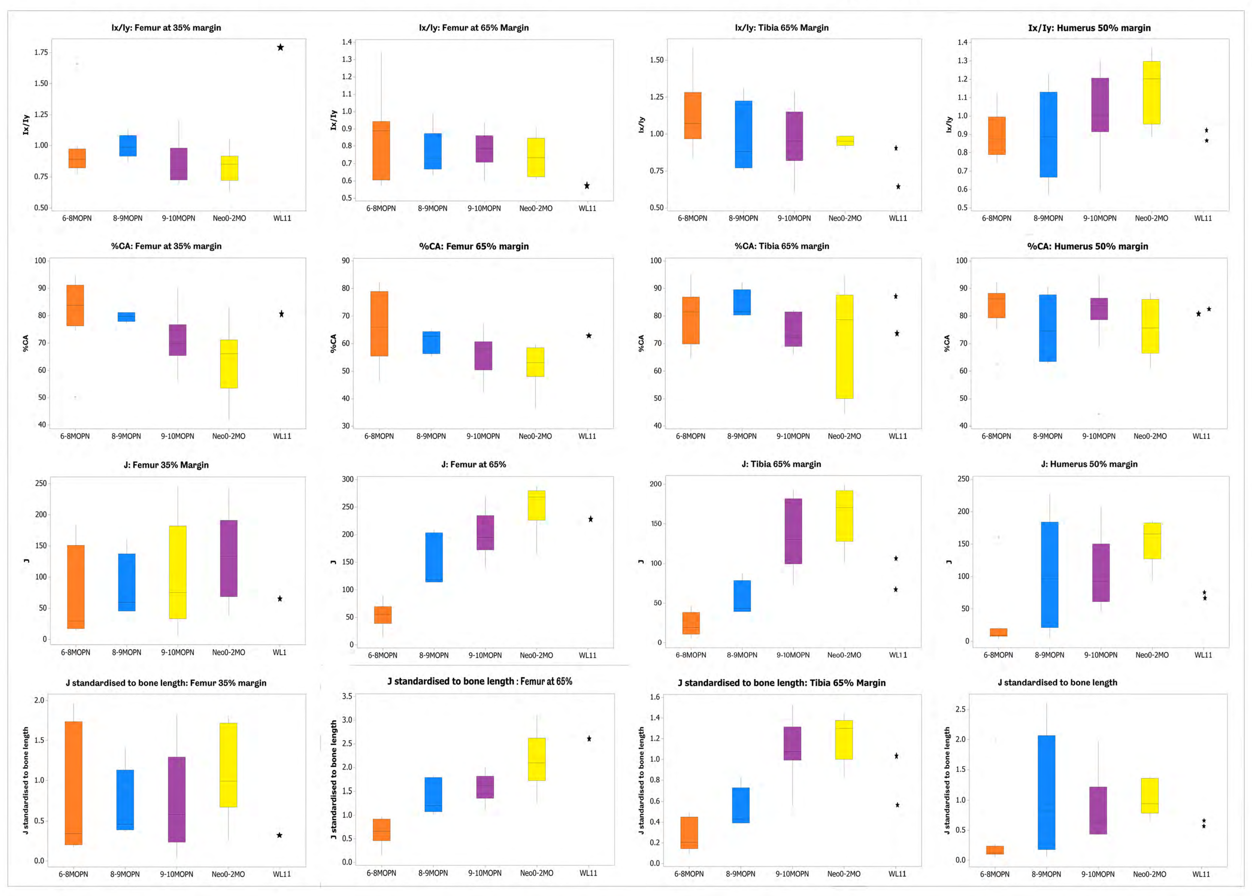
Bone	6-8MO	8-9MO	9-10MO	Neo 0-2MO	Total
Tibia 65%	10	4	7	5	26
Fem 65%	8	6	14	9	38
Femur 35%	8	5	14	9	37
Humerus 50%	13	6	13	6	38

Table 1. (left)
Comparative sample composition

Fig. 4 (right) Boxplots of cross sectional properties for Femur, Tibia and Humerus

Results

It appears that Wilczyce 11 has a mixture of shape indices, which all indicate that the individual was a late term foetus or perinate, in agreement with Irish et al. (2008). It would appear that both standardised and unstandardised data for this individual alidn it more with Holocene individuals than with Pleistocene ones at the moment, although these results are undergoing more analysis as further data becomes available. It may be the case that the biomechanical signal observed at these margins is different, hence the difference between mine and Cowgill's (2010) results. Overall due to the more fine grained nature of the sample we can see some trends emerging, albeit visually for present.



Torsion of the Longbones

Introduction

Torsion of the longbones, and humeral torsion in particular has been under debate in the litereature as to its evolutionary significance (e.g. Larson 2007, , Pontzer et al. 2009, Rhodes and Churchill 2009, Tardieu 2010 and references therein). Torsion of the humerus has also come under re-investigation from a developmental perspective (e.g. Cowgill 2010, Barros 2012). Tibial torsion is also a phenomenon of interest to paediatricians.
As an important Upper Palaeolithic infant, Wilczyce 11 can contribute new data to this debate. The preservation of Wilczyce 11 is such that I am able to report on the diaphyseal torsion of the right humerus and tibia respectively.

Methods

Torsion was calcluated by defining two longitudinal planes through the diaphysis in Geomagic: one for the proximal articulation and one for the distal. The angle between the planes was calculated from a screenshot in tpsdig. This was carried out 3 times for each bone and the mean value taken.

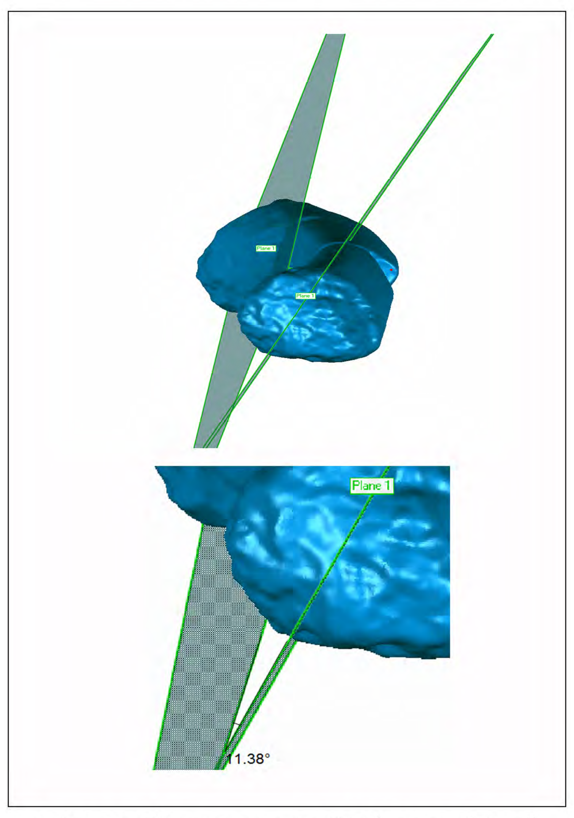


Fig. 5. Placement of Planes (Top) Closeup of angle measurement in tpsdig (Bottom)

Results

Tibial torsion is 11.6°. This is broadly similar to values reported by Stahelli (2008). She reports normal values at birth of 5° up to 15° at full maturity. It also fits with the values reported for earlier hominins by Ponter et al. (2009) who give a mean value of 15.3°. The angle for humeral torsion is 57.2°, which is slightly above the value given by Cowgill (2010) for active groups. Cowgill however agregated her data for all individuals from 0-2 years of age, so more detailed work on this age group is being undertaken.

Conclusions

I demonstrate here the effectiveness of using virtual reconstructions for osteological analysis and the benefits of rapid prototyping I also demonstrate that Wilczyce 11 is biomechanically similar to other perinatal material.
Humeral torsion is within the range expected for a young individual from an active group and tibial torsion is within the range expected, but more detailed work is required.

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