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Jérémy Duveau, Franck Multon, François Marchal, Dune Anduze, Gilles Berillon. Walking with hominins: from the reconstruction of a plausible anatomical model to gait energetics in Neandertals. Methodological aspects. Colloque Annuel de la Société de Biomécanique, Société de Biomécanique, Oct 2019, Poitiers (FR), France. pp.S519-S520, 10.1080/10255842.2020.1715003 . hal-04058850

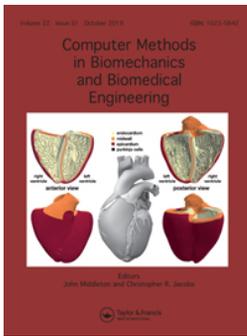
**HAL Id: hal-04058850**

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Submitted on 5 Apr 2023

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# Computer Methods in Biomechanics and Biomedical Engineering

ISSN: (Print) (Online) Journal homepage: <https://www.tandfonline.com/loi/gcmb20>

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To cite this article: J. Duveau, F. Multon, F. Marchal, D. Anduze & G. Berillon (2019) Walking with hominins: from the reconstruction of a plausible anatomical model to gait energetics in Neandertals. Methodological aspects, *Computer Methods in Biomechanics and Biomedical Engineering*, 22:sup1, S519-S520, DOI: [10.1080/10255842.2020.1715003](https://doi.org/10.1080/10255842.2020.1715003)

To link to this article: <https://doi.org/10.1080/10255842.2020.1715003>



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Published online: 22 May 2020.



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# Walking with hominins: from the reconstruction of a plausible anatomical model to gait energetics in Neandertals. Methodological aspects

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## 1. Introduction

Bipedalism as preferential locomotor mode is considered essential in the hominins' phylogenetic history (e.g., Darwin 1871; Harcourt-Smith and Aiello 2004; Fleagle and Lieberman 2015). However, simulating the locomotion of fossil species is usually a difficult challenge. On the one hand, as motion data are not accessible and soft tissues are not kept in the fossil record, functional inferences can only be based on osteological characteristics, such as body proportions, joint angles or the relative thickness of cortical bone (e.g., Lovejoy and Trinkaus 1980; Holliday 1997; Steudel-Numbers and Tilkens 2004; Ruff 2009). On the other hand, fossil osteological assemblages are most of the time very fragmentary (e.g., Wood and Lonergan 2008; Richmond and Hatala 2013), which complicates such

inferences. Nevertheless, some fossil human taxa, such as Neandertals, appear sufficiently complete in order to undertake reliable biomechanical analyses of the musculo-skeletal system (e.g., Chapman et al. 2010).

Here we report a study that aims at simulating the Neandertal gait from a specific plausible anatomical modelling and estimating the corresponding gait energy expenditure, focusing on methodological tasks.

## 2. Methods

### 2.1. Neandertal anatomical model

First, it was necessary to reconstruct a plausible anatomical model of the Neandertal locomotor system (including the pelvic girdle and both lower limbs) using available remains representing several individuals (Figure 1). Indeed, although the Neandertals locomotor anatomy is relatively well known compared to other fossil taxa, no complete skeleton has been discovered so far so that we have a chimeric view of what the locomotor anatomy of Neandertals was (Sawyer and Maley 2005).

The Neandertal anatomical model was based on the most complete Neandertal skeleton in our possession (La Ferrassie 1). Missing or fragmented anatomical parts of the lower limbs or pelvic girdle have been reconstructed from areas common to other morphologically close Neandertal bones (e.g., the coxal bone from Kebara 2, the right foot from La Ferrassie 2) after being scaled. When the material was too fragmentary to be able to completely reconstruct a bone, it was modelled from a mirror image from the same bone of different laterality. The re-articulation

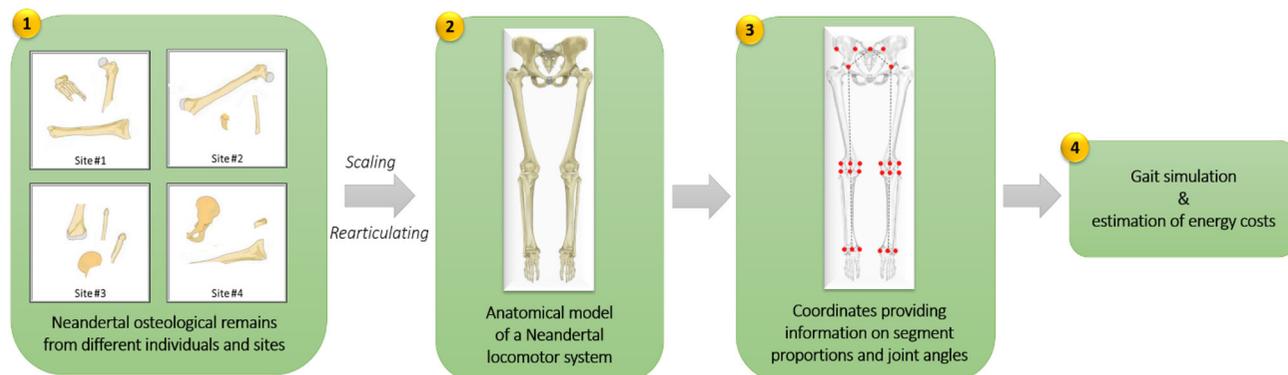


Figure 1. Methodological approach used in order to simulate walking and estimate associated energy costs.

between different bones was carried out on the basis of our knowledge of the joint surfaces and spaces in anatomically modern humans and in accordance with the recommendations of the International Society of Biomechanics (Wu et al. 2002).

## 2.2. Simulation of Neandertal walk

This plausible anatomical model was used as input in a tool of simulation to generate a plausible Neandertal walk; this tool has previously been validated in current species (humans and other primates), based on the proportions of body segments and joint angles (Nicolas et al. 2009).

## 3. Results and discussion

Although our focus here is essentially methodological, the different possibilities of the reconstructions of the Neandertal locomotor system will be presented. The characteristics of the simulation will be detailed as well as the modifications made in order to adapt it to the fossil record. Biomechanical simulations and associated energy expenditures estimates, that are still in progress, will be detailed and confronted with the results obtained in anatomically modern humans in order to discuss whether the slight differences usually described in the locomotor anatomy of these two taxa result in functional differences.

## 4. Conclusions

This transversal study between biomechanics and paleoanthropology provides original information on the locomotor behavior of Neandertals, a key element in their evolution. From a methodological point of view, it also opens up access to similar studies for other fossil hominin taxa less well known than Neandertals.

## Funding

This research is conducted within the frame of the CNRS-INEE International Research Network IRNGDRI0870 and the ANR-18-CE27-0010-01 HoBiS. The first author is currently granted funding for a doctoral degree (Muséum national d'Histoire naturelle, Paris, France).

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**KEYWORDS** Neandertal; anatomical model; gait; energetics

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