Testing the reliability of the rearticulation of osteological primate pelves in comparative morphological studies

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INTRODUCTION

An underlying issue in morphological studies of both neontological and palaeontological osteological material is the potential mismatch between the anatomical position of bones in the body and in postmortem reconstruction. This is inherent in situations requiring the rearticulation of multiple pelvic bones (Fig. 1). A detailed understanding of the variation introduced by rearticulation of osteological remains is unclear at present, but would be valuable, as such methodologically introduced variation could inadvertently affect functional interpretations. This research uses geometric morphometrics based on full-body CT scans of several species of primates to determine the degree to which virtual rearticulations of the pelvis deviate from their shape in cadaveric specimens, and whether this potential deviation obscures inter- and intra-specific variation.

Fig. 1. Pelvic anatomical conditions frequently encountered in osteological collections.
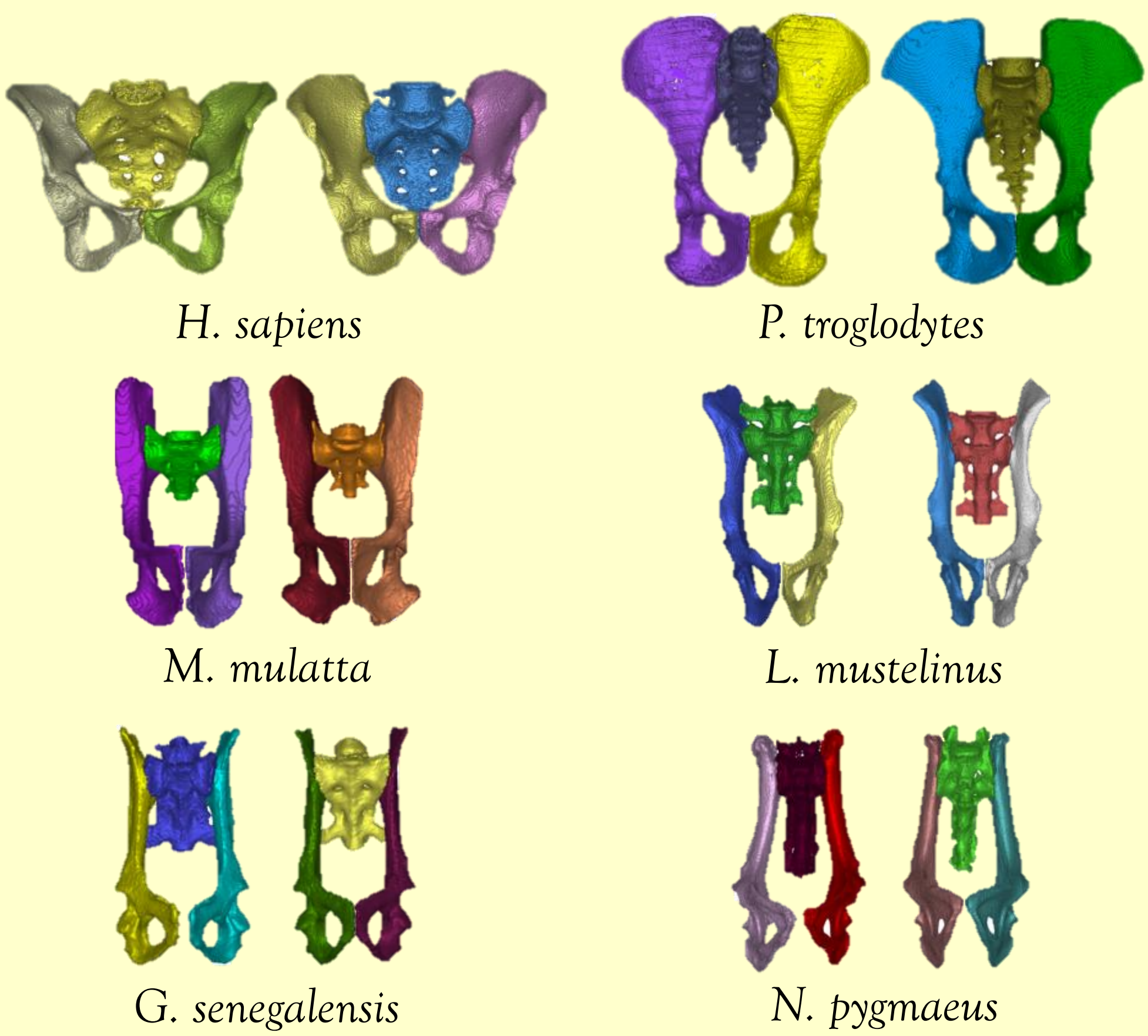
MATERIAL AND METHODS

Fig. 2. Virtual 3D models of pelvis for the six primate species included in this study. Left: female; right: male.

H. sapiens · *P. troglodytes* · *M. mulatta* · *L. mustelinus* · *G. senegalensis* · *N. pygmaeus*
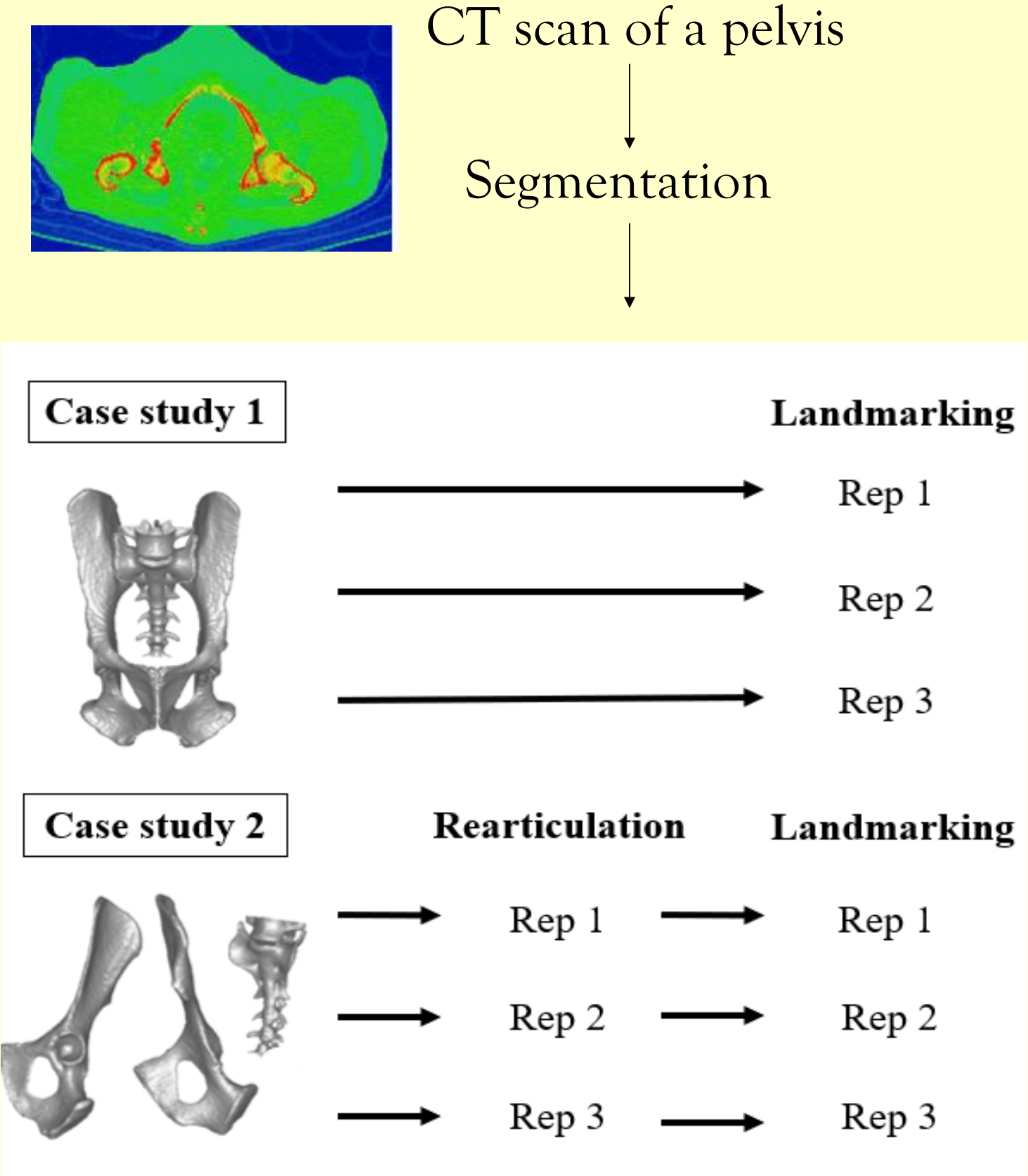

Fig. 3. Data acquisition protocol. 'Rep' means repetition and refers to the repeated landmarking and rearticulation.
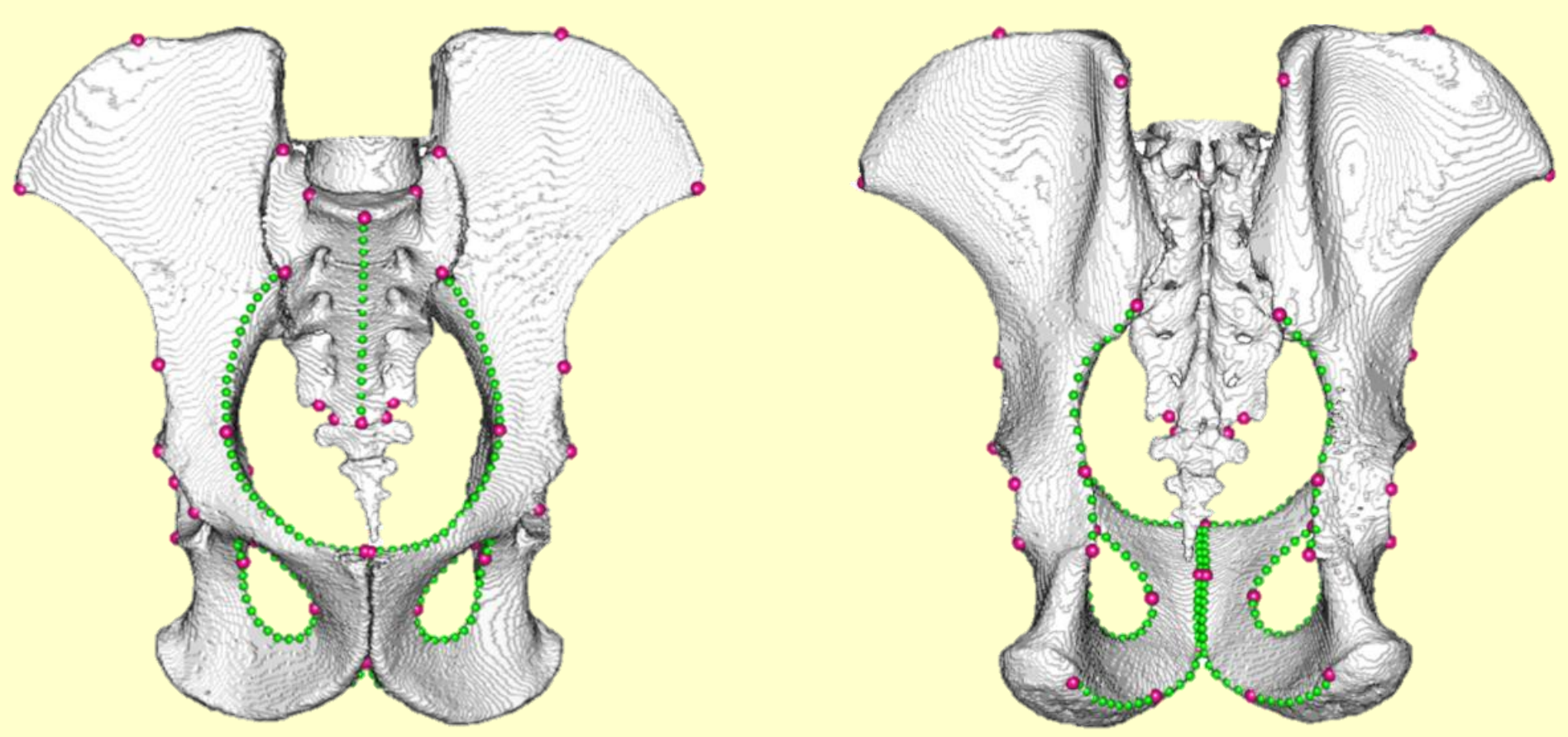

Fig. 4. 53 landmarks (pink), and 215 semilandmarks (green) distributed along 11 curves placed on the 3D pelvic model of a chimpanzee.

Analyses of the 3D shape
Shape space principal component analysis
Nested Procrustes MANOVA (shape - species/individual)

Analyses of the pelvic linear diameters
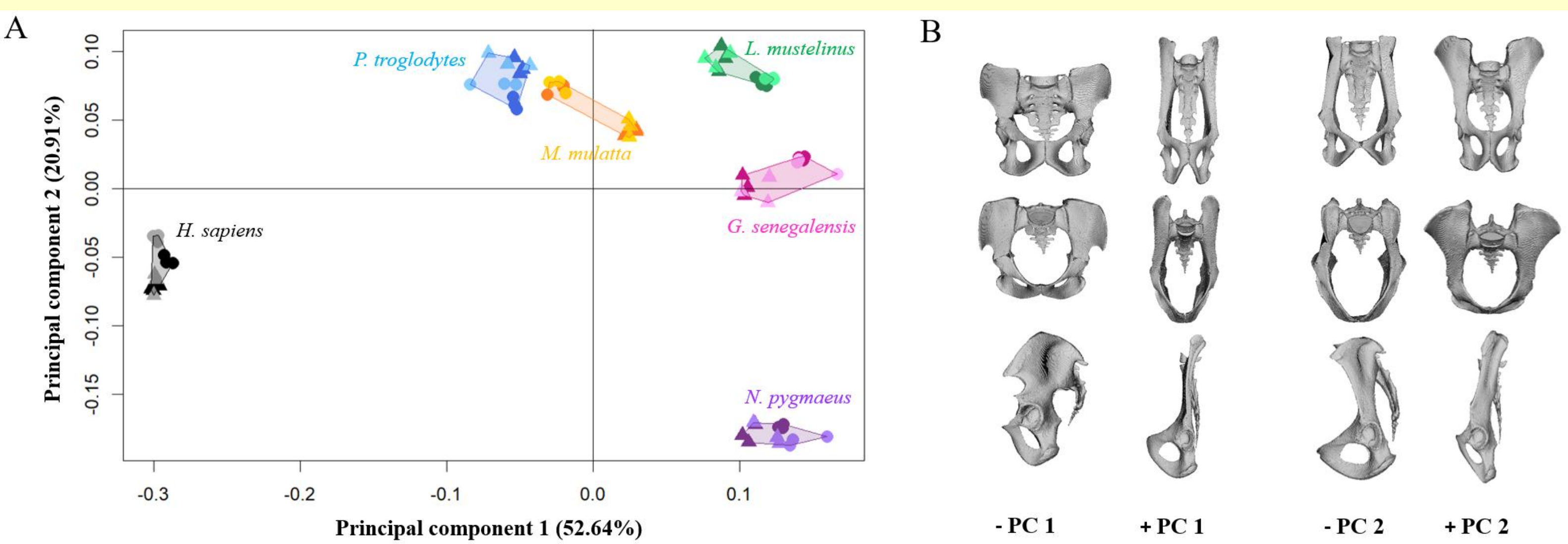[Mean cadaveric – mean rearticulated]/mean of both * 100

RESULTS

Fig. 5. A) Shape space principal component analysis showing the main shape variation of the sample. Triangles: females; circles: males; dark colours: cadaveric individuals; light colours: rearticulated individuals. B) Pelvis shapes at the maximum and minimum PC1 and PC2 scores.

Cadaveric sample	Df	SS	MS	R²	F	Z	p-value
Species	5	1.31085	0.262170	0.89296	258.256	10.970	0.001
Species/Individuals	6	0.13277	0.022128	0.09044	21.798	14.635	0.001
Residuals	24	0.02436	0.00115	0.01660			
Total	35	1.46798					
Rearticulated sample	Df	SS	MS	R²	F	Z	p-value
Species	5	1.37853	0.275705	0.89623	148.454	9.7309	0.001
Species/Individuals	6	0.11504	0.019174	0.07479	10.324	13.2006	0.001
Residuals	24	0.04457	0.001857	0.02898			
Total	35	1.53814					

Table 1. Results of the nested Procrustes MANOVA on the cadaveric sample (case study 1) and on the rearticulated sample (case study 2). Df: Degrees of freedom; SS: Sum of squares; MS: Mean squares; R²: R squared; F: F statistic; Z: effect sizes.
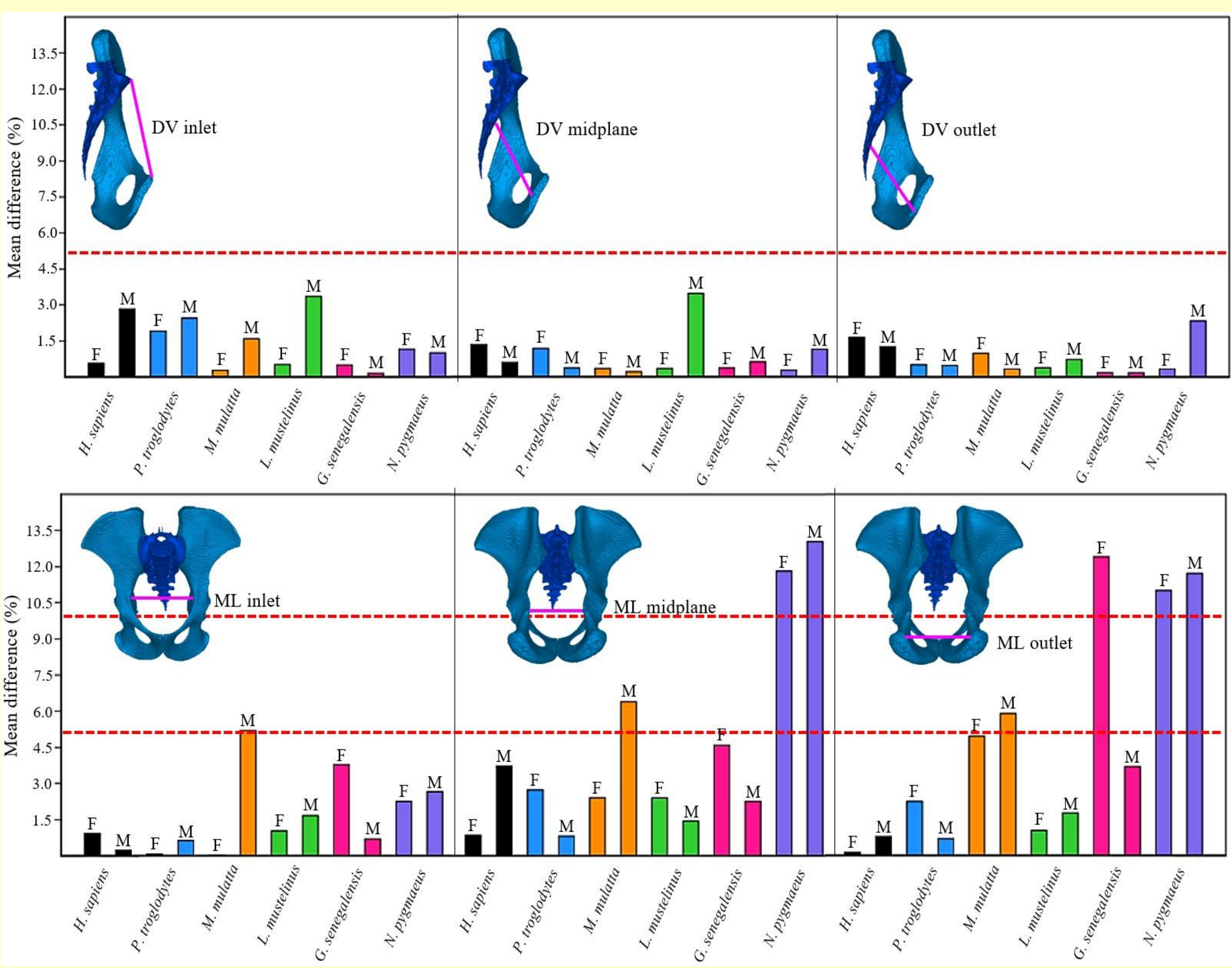

Fig. 6. Percentual differences of the linear measurements between cadaveric and rearticulated pelves. Dashed lines indicate mean differences of 5% for the dorso-ventral (DV) diameters and of 5% and 10% for the medio-lateral (ML) diameters. F: Females; M: males.

DISCUSSION AND CONCLUSIONS

The current study represents the first assessment of the potential shape variation (both in 3D and in linear dimensions) introduced by the rearticulation of dry bones in primate comparative anatomy. The results show that, although the 3D shape of the pelvis does not seem markedly affected by the rearticulation, the medio-lateral pelvic linear dimensions of small-bodied species with relatively small pubic joints and a wide pubic gap can be underestimated. To avoid the uncertainties of pelvic rearticulation in such species, anatomically connected pelves can (and perhaps should) be included, but care should be taken for specimens with dried soft tissue that is likely to have shrunk and to have reduced any existing pubic gap. Finally, the described protocol can be adapted to other anatomical structures that requires manual rearticulation to be analyzed in anatomical connection, such us the vertebral column or the articulation of the cranium and the mandible.