Covariation between mineralized area and shape of the rib cross section in *Homo sapiens* and *Pan troglodytes*: implications for the interpretation of *Australopithecus africanus* Sts-14 ribcage

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Like many other anatomical structures, the ribcage has changed its morphology and configuration throughout primate evolutionary history. Unfortunately, ribs usually appear broken in the fossil record, which challenges the interpretation of their morphology. In this context, it has been observed that the mineralized area of the rib cross section at the midshaft (Min. Ar. Mid.) could be informative not only about the functional differences in the upper and lower thorax, but also could explain potential interspecific biomechanical changes during evolution [1-3]. As these changes may also be associated with the shape of the rib cross section at the midshaft (Sh. Mid.) [2,3], studying the covariation between both parameters could be interesting in order to understand thoracic biomechanical evolution in hominins from a fragmentary fossil record [2].

This issue was assessed through the analysis of the internal rib microstructure via micro-CT of 5 typical ribs of the *Australopithecus africanus* Sts-14 from the Ditsong National Museum of Natural History (Pretoria, South Africa) and the complete set of ribs of ten modern humans (*Homo sapiens*) (120 ribs) from the Universidad Autónoma de Madrid (Spain) and ten chimpanzees (*Pan troglodytes*) (130 ribs) from the American Museum of Natural History (New York, U.S.A.). Once digitized, the cross section at the midshaft of each rib was extracted using the software Amira 5.4.0. The Min. Ar. Mid. was quantified by Fiji software while the Sh. Mid. was measured using 2D geometric morphometrics in Viewbox 4 software. Eventually, the covariation between both parameters was studied by running a linear regression using MorphoJ software.

The results show that the Min. Ar. Mid. and the Sh. Mid. covariate in the typical ribs such that ribs with a rounded Sh. Mid. will have a larger Min. Ar. Mid. than ribs with a mid-laterally flattened Sh. Mid. This relationship can be extrapolated to a comparative analysis where it is observed that mid-laterally flattened Sh. Mid. and low Min. Ar. Mid. is related to *H. sapiens*' typical ribs while rounded Sh. Mid. and large Min. Ar. Mid. is related to *P. troglodytes*' typical ribs even though chimpanzees may also have typical ribs with a human-like pattern. In addition, it can be seen that Sts-14 ribs' pattern of covariation is similar to that of *P. troglodytes*. Nevertheless, the correlation between the Min. Ar. Mid and the Sh. Mid. is not observed in atypical ribs (costal levels 1, 2, 11 and 12, also 13 in *P. troglodytes*) due to the contrast between their mid-laterally flattened Sh. Mid. and their high Min. Ar. Mid.

The pattern of covariation between the Min. Ar. Mid. and the Sh. Mid. in the typical ribs could be a response to the different thoracic biomechanical needs of *P. troglodytes* and *H. sapiens*. The non-bipedal posture of *P. troglodytes* causes the weight of the head, neck and upper trunk to go through the ribs to reach the upper extremities. Furthermore, since their breathing is hypothetically diaphragmatic, it can be said that chimpanzees' ribs are subjected to greater mechanical stress than those of *H. sapiens* due to their bipedal posture and pulmonary respiration [1,2,4]. This makes *P. troglodytes* ribs need a larger Min. Ar. Mid. to resist the strong muscular activity [1] and a rounded Sh. Mid. to make it structurally possible. The fact that some chimpanzees' typical ribs follow a human-like pattern of covariation could be explained by differences in weight or sex in the tested individuals, but further research would be needed about this hypothesis. Even though the correlation between the Min. Ar. Mid and the Sh. Mid. in Sts-14 ribs is associated to that on *P. troglodytes*, it should be questioned whether inferences can be made from this result about the similarity of their ribcages due to ontogeny since it is proposed that Sts-14 is not fully adult [5].

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