Supplementary Information

“The femur of *Orrorin tugenensis* exhibits morphometric affinities with both Miocene apes and later hominins.”

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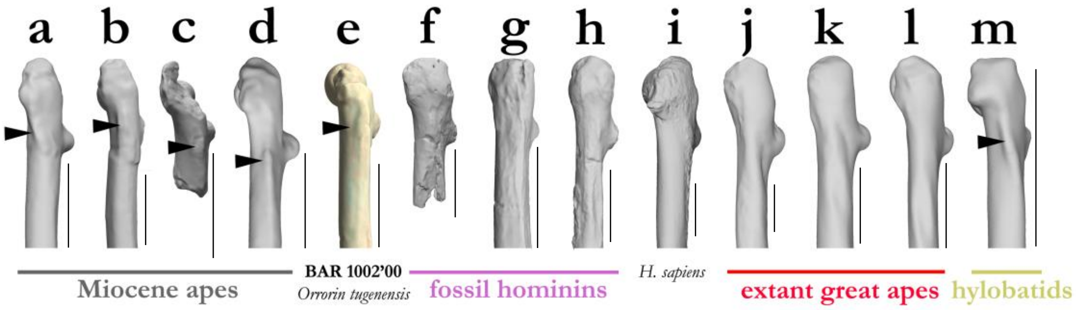
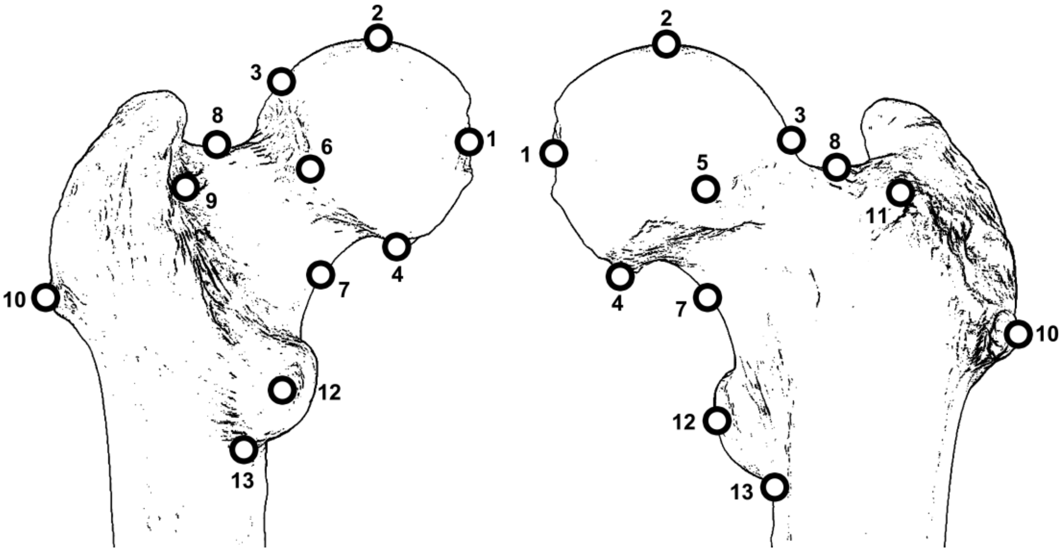
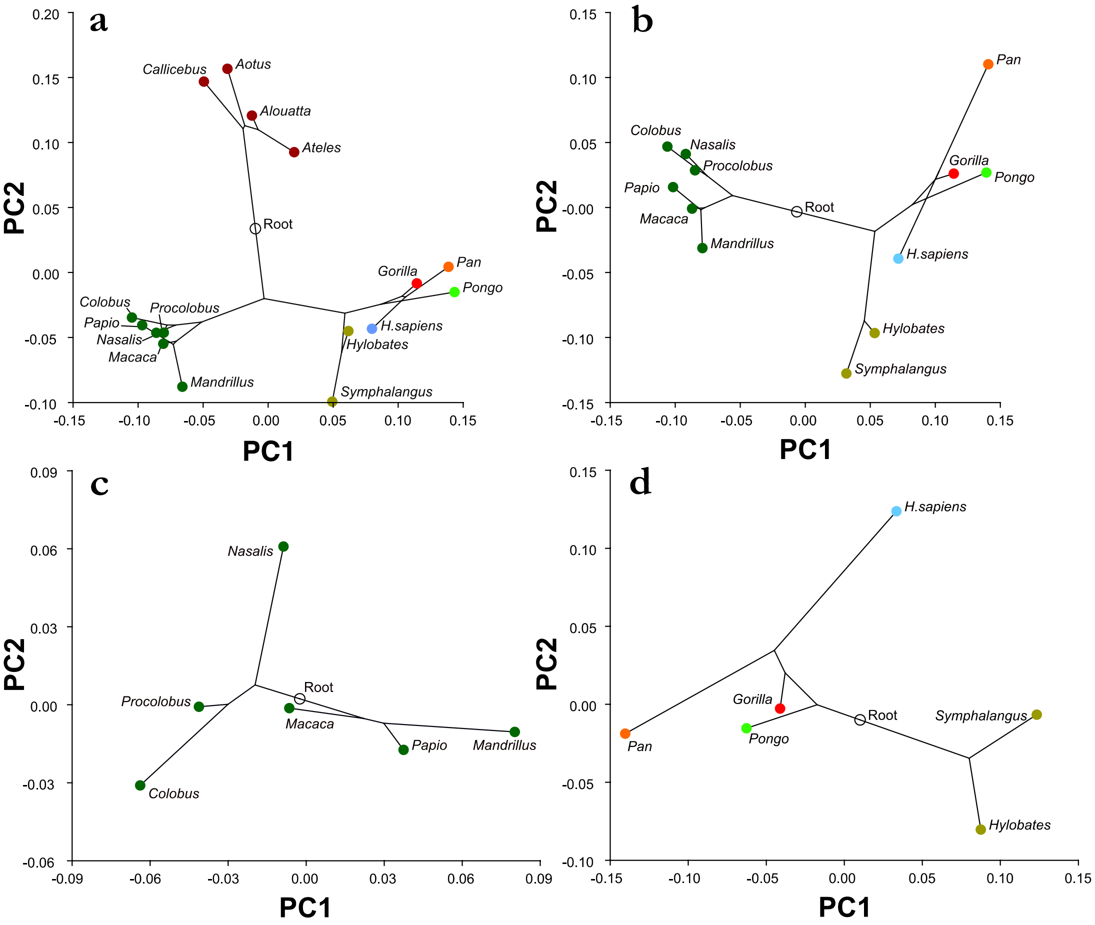
Supplementary Figures



Supplementary Figure S1. Morphological comparison of BAR 1002'00 with selected proximal femora analyzed in this study (lateral view). (a) IPS 18800 (reversed), *Hispanopithecus laietanus*; (b) IPS 41724 (reversed), cf. *Dryopithecus fontani*; (c) BMNH-M-16331, *Equatorius africanus*; (d) KNM-MW 13142A (reversed), *Proconsul nyanzae*; (e) BAR 1002'00, *Orrorin tugenensis*; (f) SK 97 (reversed), *Paranthropus robustus*; (g) A.L. 288-1, *Australopithecus afarensis*; (h) KNM-ER 1481, early *Homo*; (i) *Homo sapiens*; (j) *Gorilla gorilla*; (k) *Pan troglodytes*; (l) *Pongo pygmaeus*; (m) *Hylobates*. The arrows indicate a laterally protruding gluteal tuberosity. All specimens were scaled to similar mediolateral breadth. Scale bars represent 5 cm.



Supplementary Figure S2. Landmarks used in this paper, as seen on a human left proximal femur in posterior (left) and anterior (right) views. See Supplementary Table S1 for description of the three-dimensional coordinates. Points from the head and neck give an accurate depiction of the relative size of the head as well as height and length of the femoral neck. These traits have been shown to be related to the degree of mobility that is possible at the hip joint[31,42,71,72]. Points on the greater trochanter capture its maximal lateral and anterior projection, dimensions which probably reflect differences in gluteal function[32,33,71,73]. Finally, two points were collected on the lesser trochanter to quantify its relative size and the direction of its projection from the femoral shaft. The lesser trochanter is the insertion site for the iliopsoas muscle, the major flexor of the hip, and changes in lesser trochanter position partially reflect differences in iliopsoas lever arm length[71].



Supplementary Figure S3. Phylogenetic signal in the proximal femur shape of extant anthropoids. Phylogenetic tree mapped into the morphospace defined by the two first principal components (PCs) of our extant sample of: (a) anthropoids, tree length: 0.12264600, **p<0.0001**; (b) catarrhines only, tree length = 0.08988361, **p<0.0001**; (c) cercopithecids only, tree length: 0.01720490, **p<0.05**; and (d) hominoids only, tree length: 0.06267011, **p=0.1187**. Phylogenetic structure is found in all cases with the exception of extant hominoids, which might be partially caused by the large shape differences between the closely related *Pan* and *H. sapiens*. Tree lengths are in units of squared Procrustes distance. P-values refer to the permutation test against the null hypothesis of no phylogenetic signal (100,000 randomization rounds).

Supplementary Tables

Supplementary Table S1. Description of landmarks on the proximal femur used in this study.

Number	Type	Description
Femoral Head		
1	II	Middle of *fovea capitis* (a)
2	II	Most proximal point on the femoral head
3	II	Most proximal point on the facet margin
4	II	Most distal point of the facet margin
5	II	Most anterior point of the facet margin
6	II	Most posterior point of the facet margin
7	II	Maximum point of constriction on ridge running from lesser trochanter to the femoral head
Greater Trochanter		
8	II	Deepest point of the proximal neck
9	II	Deepest point of the trochanteric fossa
10	II	Most lateral point of greater trochanter (b)
11	II	Proximomedial extension of the greater trochanter on the anterior aspect of the femur
Lesser Trochanter		
12	II	Tip of lesser trochanter
13	II	Most distal point of the lesser trochanter

The description of the landmark type is after Bookstein[74]. (a) In *Pongo*, center of the femoral head as in Harmon[27]. (b) Richmond and Jungers[6] estimated that the lateral edge of the greater trochanter in BAR1002'00 was slightly abraded, lacking ca. 2-3 mm of bone. Our analysis is based on the actual point on the bone.

Supplementary Table S2. List of extant specimens (n = 422) used for this study by species (subspecies for African apes) and sex.

—Hominoids—					
		Males	**Females**	**Unknown**	**Total**
Homo sapiens **(n = 76)**					
	Andaman Islanders (d)	11	10	8	29
	Australian Aborigines (d)	3	3	8	14
	Late Stone Age South Africans (e)	8	4	1	13
	Point Hope Ipiutak (f)	15	15	0	30
Gorilla **(n = 77)**					
	Gorilla beringei beringei (a)	2	3	0	5
	Gorilla beringei graueri (c)	13	9	0	22
	Gorilla gorilla (b)	24	26	0	50
Pan **(n = 88)**					
	Pan paniscus (c)	7	9	0	16
	Pan troglodytes schweinfurthii (c)	7	7	14	28
	Pan troglodytes troglodytes (b)	19	25	0	44
Pongo **(n = 16)**					
	Pongo spp. (f)	9	6	1	16
Hylobatidae (n = 16)	(h)				
	Symphalangus syndactylus	1	1	1	3
	*Hoolock hoolock**	3	6	0	9
	Hylobates klossii	1	1	0	2
	Hylobates agilis	1	1	0	2

*Due to the small sample size of hylobatids, in most analyses all the specimens were treated together at the family level. For the phylogenetic analyses, where the taxa and not the individuals constitute the real sample, and in order to inspect shape differences between the gibbons and the larger siamangs, we differentiated *Hylobates* and *Symphalangus* following a more traditional classification. However, current taxonomy based on molecular studies recognizes four different genera of hylobatids, the holoock gibbon having its own genus[75,76].

Supplementary Table S2. Continued.

—Cercopithecid monkeys—	(h)				
		Males	**Females**	**Unknown**	**Total**
***Macaca* (n = 26)**					
	Macaca fascicularis	1	3	1	5
	Macaca fuscata	2	0	0	2
	Macaca nemestrina	3	1	0	4
	Macaca brunna	1	3	0	4
	Macaca arctoides	0	1	0	1
	Macaca mulatta	0	2	0	2
	Macaca nigra	0	1	0	1
	Macaca tonka	3	3	0	6
	Macaca thibetana	1	0	0	1
***Mandrillus* (n = 6)**	*Mandrillus sphinx*	2	3	1	6
***Papio* (n = 10)**	*Papio hamadryas*	4	2	4	10
***Nasalis* (n = 8)**	*Nasalis larvatus*	6	2	0	8
***Procolobus* (n = 8)**	*Procolobus badius*	5	0	3	8
***Colobus* (n = 9)**					
	Colobus angolensis	3	1	0	4
	Colobus guereza	2	0	2	4
	Colobus sp.	0	0	1	1
		Males	**Females**	**Unknown**	**Total**
—Platyrrhine monkeys—	(h)				
***Ateles* (n = 9)**					
	Ateles geoffroyi	1	2	1	4
	Ateles fuscieps	1	1	0	2
	Ateles paniscus	0	1	0	1
	Ateles belzebuth	1	1	0	2
***Alouatta* (n = 30)**	*Alouatta seniculus*	9	12	9	30
***Callibebus* (n = 13)**					
	Callicebus donacophilus	1	2	1	4
	Callicebus moloch	5	1	1	7
	Callicebus cupreus	1	1	0	2
***Aotus* (n = 30)**					
	Aotus trivirgatus	8	10	0	18
	Aotus azarae	6	4	2	12

(a) Virunga isolates (Royal Museum of Central Africa); (b) Cameroon and some gorilla males from Democratic Republic of Congo (Powel-Cotton Museum); (c) Democratic Republic of Congo (Royal Museum of Central Africa; American Museum of Natural History, Mammalogy); (d) Natural History Museum London, Anthropology; (e) University of Cape Town; (f) American Museum of Natural History, Anthropology; (g) Borneo, Sumatra (American Museum of Natural History, Mammalogy; Natural History Museum London, Mammalogy); (h) American Museum of Natural History, Mammalogy.

Supplementary Table S3. List of fossil specimens used in this analysis.

Plio-Pleistocene hominins		
	Taxon	**Age**
AL 333-3	*Australopithecus afarensis*	3.2 Ma [77]
AL 288-1	*Australopithecus afarensis*	3.18 Ma [77]
KNM-ER 1472	*Homo* sp.	1.88 Ma [78]
KNM-ER 1481	*Homo* sp.	1.88 Ma [78]
KNM-ER 1503	*Homo* sp. / *Paranthropus boisei*	1.88 Ma [78]
SK 82	*Paranthropus robustus*	1.8–1.5 Ma [79]
SK 97	*Paranthropus robustus*	1.8–1.5 Ma [79]
KNM-WT 15000	*Homo erectus/ergaster*	1.6 Ma [78]
Miocene hominoids		
	Taxon	**Age**
KNM-MW 13142 A	*Proconsul nyanzae*	17.9 Ma [19]
BMNH-M 16331	*Equatorius africanus*	ca. 15 Ma [80]
IPS 41724	cf. *Dryopithecus fontani*	11.9 Ma [81]
IPS 18800	*Hispanopithecus laietanus*	9.6 Ma [81]
BAR 1002'00	*Orrorin tugenensis*	ca. 6 Ma [82]

Supplementary Table S4. Minimum Procrustes distances amongst extant hominoid groups and fossil specimens.

	three first closest groups			**Procrustes distance**		
	First	**Second**	**Third**	**d1**	**d2**	**d3**
Hylobatidae	BMNH-M-16331	KNM-MW 13142A	IPS41724	0.159	0.162	0.166
Pongo	*Pan*	*Gorilla*	Hylobatidae	0.129	0.154	0.179
Gorilla	BMNH-M 16331	*Pongo*	*Pan*	0.149	0.154	0.185
Pan	*Pongo*	*Gorilla*	BMNH-M 16331	0.129	0.185	0.220
H. sapiens	KNM ER1481	IPS41724	AL288-1	0.137	0.155	0.158
KNM-MW 13142A	BAR1002'00	SK82	AL333-3	0.143	0.150	0.158
BMNH-M 16331	IPS18800	*Gorilla*	Hylobatidae	0.145	0.149	0.159
IPS41724	*H. sapiens*	BMNH-M 16331	IPS18800	0.155	0.164	0.165
IPS18800	BMNH-M 16331	Hylobatidae	BAR1002'00	0.145	0.177	0.177
BAR1002'00	KNM-MW 13142A	AL333-3	AL288-1	0.143	0.161	0.161
AL333-3	SK82	KNM-MW 13142A	AL288-1	0.133	0.158	0.159
AL288-1	KNM ER1472	*H. sapiens*	AL333-3	0.156	0.158	0.159
SK82	AL333-3	SK97	KNM-MW 13142A	0.133	0.145	0.150
SK97	SK82	AL333-3	KNM ER1481	0.145	0.162	0.167
KNM ER1472	AL288-1	KNM ER1481	KNM WT15000	0.156	0.158	0.162
KNM ER1481	*H. sapiens*	SK82	KNM ER1472	0.137	0.151	0.158
KNM WT15000	KNM ER1481	AL333-3	KNM ER1472	0.158	0.159	0.162

The three closest centroids and respective Procrustes distances are shown. Caution is advised when making inferences involving KNM ER 1472, since the anterior portion of its greater trochanter is believed to be pathologic[83].

Supplementary Table S5. Bonferroni *post hoc* multiple comparison of femoral head size relative to neck height in extant anthropoids.

	Gorilla	*Pan*	*H. sapiens*	*Pongo*	Hylobatidae	*Macaca*	*Mandrillus*	*Papio*	*Nasalis*	*Procolobus*	*Colobus*	*Ateles*	*Alouatta*	*Callicebus*
Gorilla	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pan	1.000	--	--	--	--	--	--	--	--	--	--	--	--	--
H. sapiens	1.000	1.000	--	--	--	--	--	--	--	--	--	--	--	--
Pongo	**0.000**	**0.000**	**0.000**	--	--	--	--	--	--	--	--	--	--	--
Hylobatidae	1.000	1.000	0.884	**0.000**	--	--	--	--	--	--	--	--	--	--
Macaca	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	--	--	--	--	--	--	--	--	--
Mandrillus	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	1.000	--	--	--	--	--	--	--	--
Papio	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	1.000	1.000	--	--	--	--	--	--	--
Nasalis	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	1.000	1.000	1.000	--	--	--	--	--	--
Procolobus	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	1.000	1.000	1.000	1.000	--	--	--	--	--
Colobus	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.698	1.000	1.000	1.000	1.000	--	--	--	--
Ateles	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	1.000	1.000	0.475	1.000	0.152	**0.021**	--	--	--
Alouatta	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.081	1.000	**0.005**	0.678	**0.001**	**0.000**	1.000	--	--
Callicebus	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	1.000	1.000	1.000	1.000	1.000	1.000	**0.001**	**0.001**	--
Aotus	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.914	1.000	1.000	1.000	1.000	1.000	**0.000**	**0.000**	1.000

Significant differences ($p<0.05$) are marked in bold.

Supplementary Table S6. Bonferroni *post hoc* multiple comparison of biomechanical neck length relative to proximal femoral centroid size in extant anthropoids.

	Gorilla	*Pan*	*H. sapiens*	*Pongo*	Hylobatidae	*Macaca*	*Mandrillus*	*Papio*	*Nasalis*	*Procolobus*	*Colobus*	*Ateles*	*Alouatta*	*Callicebus*
Gorilla	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pan	1.000	--	--	--	--	--	--	--	--	--	--	--	--	--
H. sapiens	**0.000**	**0.000**	--	--	--	--	--	--	--	--	--	--	--	--
Pongo	1.000	0.753	**0.000**	--	--	--	--	--	--	--	--	--	--	--
Hylobatidae	**0.015**	**0.002**	**0.007**	1.000	--	--	--	--	--	--	--	--	--	--
Macaca	1.000	1.000	**0.000**	1.000	1.000	--	--	--	--	--	--	--	--	--
Mandrillus	**0.021**	**0.006**	1.000	1.000	1.000	0.814	--	--	--	--	--	--	--	--
Papio	1.000	0.364	**0.013**	1.000	1.000	1.000	1.000	--	--	--	--	--	--	--
Nasalis	1.000	1.000	**0.001**	1.000	1.000	1.000	1.000	1.000	--	--	--	--	--	--
Procolobus	1.000	0.674	0.074	1.000	1.000	1.000	1.000	1.000	1.000	--	--	--	--	--
Colobus	1.000	1.000	**0.000**	1.000	1.000	1.000	0.728	1.000	1.000	1.000	--	--	--	--
Ateles	1.000	0.527	**0.029**	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	--	--	--
Alouatta	**0.000**	**0.000**	1.000	0.152	1.000	**0.001**	1.000	1.000	0.682	1.000	**0.018**	1.000	--	--
Callicebus	**0.000**	**0.000**	1.000	0.830	1.000	**0.036**	1.000	1.000	1.000	1.000	0.099	1.000	1.000	--
Aotus	**0.000**	**0.000**	0.739	0.205	1.000	**0.001**	1.000	1.000	0.835	1.000	**0.024**	1.000	1.000	1.000

Significant differences (p<0.05) are marked in bold.

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