

Hominin Femur finding from Banjarejo: Its morphological character and taxonomical position

Sofwan Noerwidi¹, Rusyad Adi Suriyanto², Ashwin Prayudi² and Harry Widiyanto¹

¹Balai Arkeologi Provinsi D.I. Yogyakarta, Indonesia

²Laboratory of Bioanthropology and Paleoanthropology, Universitas Gadjah Mada

ABSTRACT

Recently, Banjarejo became an important prehistoric site for Quaternary research because of its significant faunal and hominin remains. This study aims to describe a new finding of the hominin femur specimen from the site and its taxonomical position in human evolution. The specimen was identified by morphological and metric descriptions of the external feature of the femur. Then, comparative study to *Homo erectus* (n=2), *Homo neanderthalensis* (n=8), *Homo heidelbergensis* (n=1), prehistoric *Homo sapiens* (n=44), *Australopithecus africanus* (n=1), *Paranthropus robustus* (n=2), also non-human primate including *Pongo* (n=1), *Macaca* (n=1) and Gibbon (n=1) using bivariate and multivariate statistical analysis presented the specimen in the evolutionary perspective. This study shows the morphological and metric character of Banjarejo specimen located between *Homo erectus* and prehistoric *Homo sapiens* population sample. Further study should be addressed to investigate the cultural and chronological context of the hominin specimen.

Keywords: hominin, human evolution, Banjarejo, Quaternary

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INTRODUCTION

Banjarejo is administratively located at Gabus District on the eastern part of Grobogan Regency, Central Java. The physiographical condition of Banjarejo is a region located in an elongated shape of the Randublatung Depression, which covers Purwodadi, Cepu, and Bojonegoro (van Bemmelen, 1949). The depression is located between two anticlines mountains of Kendeng to the south and the Rembang Zone of Northern Mountain. Lowlands at around 20m above sea level dominated the morphological condition of the depression, with Lusi River and its ancient terraces located inside. Hills with up to 280 m asl altitude dominate the northern side of Randublatung Depression, which is part of the karstic hills of Rembang Zone, and the southern side of the depression, which is part of Kendeng Mountain (Fathoni, 2016). The synclinal zone of Randublatung Depression has formed caused by subsidence activity part of isostatic equilibrium of the region through the tectonic subduction process during the Late Tertiary (Datun et al., 1996).

In 2015, locals of Banjarejo site found an almost complete *Bubalus paleokarabau* cranium at the terrace of Lusi River and reported to the author. Since then, the recognition of quaternary paleontological potentials of the site began. BPSMP Sangiran identified the fossils and artifacts and conducted an exploration excavation at Ngrunut locality in 2016 (Rahmat, 2016). The excavation was continued to 2018 when they found an

accumulation of 872 fossils at the Kuwojo locality, which dominantly by Proboscidean fauna (Widiyanta, 2018). There is identification of other faunal remains in this research, including *Bovidae*, *Cervidae*, *Gavialis*, *Crocodylus*, Gastropoda, and catfish. The research placed the site's chronological position in the upper part of the Lidah Formation around the Mid Pleistocene (Widiyanta, 2020). They also identify paleoenvironment alteration of the depression from a condition near the shoreline (wave zone) to a terrestrial condition as savanna and open forest.

An important recent discovery at Banjarejo site is a fragment of hominin femur from the Lusi River terrace in 2019 and conserved in the BPSMP Sangiran. There is no analysis work conducted on this first hominin specimen from the site. Consequently, the identity of this important specimen is still unknown. This study aims to identify hominin findings from the site, also its taxonomical position and implication to the history of human evolution in Java.

METHODOLOGY

Material

- a. Main Material: The primary material of this study is a fragment of proximal diaphysis of hominin femur from Banjarejo, found by Pak Modin (Budi Setyo Utomo) a conservation activist of the site.
- b. Comparison Material: The materials used for comparison

includes *Homo erectus* (n=2)

of Southeast Asia (Table 1).

No	Site / Origin	Taxa	Total
1	Taforalt	<i>Homo sapiens</i>	39
2	Gilimanuk	<i>Homo sapiens</i>	2
3	Java	<i>Homo sapiens</i>	3
4	Trinil	<i>Homo erectus</i>	2
5	Krapina	<i>Homo neanderthalensis</i>	5
6	Spy	<i>Homo neanderthalensis</i>	3
7	Arago	<i>Homo heidelbergensis</i>	1
8	Swartkrans	<i>Paranthropus robustus</i>	2
9	Swartkrans	<i>Australopithecus africanus</i>	1
10	Sumatra	<i>Pongo</i>	2
11	SE Asia	<i>Gibbon</i>	1
12	Java	<i>Macaca</i>	1

Table 1. Site or origin sample used in this study

from Trinil, *Homo neanderthalensis* (n=8) from Krapina and Spy, *Homo heidelbergensis* (n=1) from Arago, prehistoric *Homo sapiens* (n=44) from Taforalt, Gilimanuk, and Java, *Australopithecus africanus* (n=1), and *Paranthropus robustus* (n=2) from Swartkrans, also non-human primate including *Pongo* (n=1) from Sumatra, *Macaca* (n=1) from Java and *Gibbon* (n=1) from unknown precise location

No	Abbreviation	Definition
1	M15	Vertical diameter of column femoralis
2	M16	Sagittal diameter of column femoralis
3	M17	Maximum circumference of column femoralis
4	M18	Vertical diameter of caput femoralis
5	M19	Transversal / sagittal diameter of the caput femoralis
6	M20	Maximum circumference of the caput femoralis

Table 2. Abbreviation and definition measurement on proximal epiphysis of femur

Tool

- a. Caliper, used for measuring the diameter aspects of the femur
- b. Tape meter, used for measuring the circumference aspects of the femur

Method

The analysis was conducted to determine the taxonomic identity of the femoral head of Banjarejo site by comparing morphological and morphometric characters to populations of *Homo sapiens*, *Homo erectus*, *Homo heidelbergensis*, *Homo neanderthalensis*, *Paranthropus robustus*, *Australopithecus africanus*,

No	Variabel
1	Diameter antero-posterior 70%
2	Diameter medio-lateral 70%
3	Tebal cortical 70%
4	Minimum circumference 70%

Table 3. Measurement variables on diaphysis of femur.

and other non-human primate groups, including *Pongo*, *Gibbon*, and *Macaca*.

Morphometric comparisons were carried out using measurement variables proposed by Martin and Saller (1957). The following table is the definition of the measurement variable on proximal epiphysis of the femur (Table 2).



Figure 1. Comparison of femur: 1. Modern *Homo sapiens* (original), 2. Prehistoric *Homo sapiens* from Gilimanuk (original), 3. *Homo erectus* Trinil 2 (replica), 4. *Homo erectus* Trini 1 (replica) and 5. Banjarejo hominin (original)

Measurements on the femur diaphysis of Banjarejo specimen cannot be done using the classic morphometric variables proposed by Martin and Saller (1957) due to the conservation condition of the specimens. However, several measurements could be made based on the technique proposed by Ruff (2003) on the 60% - 80% segment of the diaphysis, including (Table 3).

Metric comparative analysis was performed using PAST software (Paleontological Statistics) version 3.25, developed specifically for paleontological analysis (Hammer, 2018). Comparative studies conducted were including bivariate and multivariate comparisons. A bivariate comparison was performed on two related variables, such as comparing

M15 vertical diameter and M16 sagittal diameter of the femoral column on some populations using a biplot graph representation. A 60% of ellipse distribution was set to limit the population's distribution, which connects all specimens in the specific population.

Multivariate comparative analysis was conducted to compare correlated variables, such as measurements of the column and femoral head. This multivariate comparison was performed using Principal Component Analysis (PCA) for a continuous data value, with some conditions: the use of a correlation matrix because all measured variables are correlated, the separation between groups, and a technique of replacing missing data by

calculating the mean value. The PCA biplot chart presentation also used a 60% ellipse to limit one population distribution to others.

RESULTS

Morphological Analysis: The general morphological feature of the femoral

even fused with the superior head part. Thus, the femoral head is not perfectly rounded. For example, the femoral head shape, such as the latter form, is founded in Artiodactyl and Perissodactyl (France, 2009).

On the medial section of the femoral head of Banjarejo site, there were

No	Variabel	Banjarejo	Gilimanuk LX	Kresna 11*	Trinil F II**	Trinil F III**	Trinil F IV**	Modern Human*
1	Diameter antero-posterior 70%	27	27	26	22,5	22,3	29,3	26-30
2	Diameter medio-lateral 70%	30	28	33	27	24,1	29,3	27-31
3	Tebal cortical 70%	8-10		5-8				5-9
4	Minimum circumference 70%	94	94					

Table 4 Comparison of measurement result on diaphysis of the femur. Sources: * Puymeraïl et al. (2012), ** Ruff et al. (2015)

head from Banjarejo site is perfectly rounded, almost half-sphere with a long femoral column shape, allowing for some locomotion, including flexion, extension, abduction, adduction, internal rotation, and external rotation (White and Folkens, 2005). This kind of femoral shape, which supports those locomotion types, is usually shared by primates, especially human femurs (Figure 1). In comparison, animals with an anterior-posterior and limited rotation femur locomotion usually have an oval and flattened femoral head with a short femoral column,

traces of *fovea capitis*. This anatomical trail is a small non-articular depression around the middle of the femoral head, where the *ligamentum teres* connects between the femoral head and the acetabulum on the *os coxae*.

Morphometric Analysis

- Bivariate analysis

Bivariate analysis was made based on several measurement techniques

proposed by Ruff (2003) on the 60% - 80% segment of the femur diaphysis in Table 4.

The results of the measurements can be used as materials for a comparative study of two variables of Banjarejo specimens with prehistoric *Homo sapiens* of Gilimanuk LX specimen and several *Homo erectus* specimens from Sangiran (Puymerail et al., 2012) and Trinil (Ruff et al., 2015) (Table 4). The following graphic resulted from the biplot matrix on anteroposterior diameter versus mediolateral diameter comparison between Banjarejo specimen to other femurs.

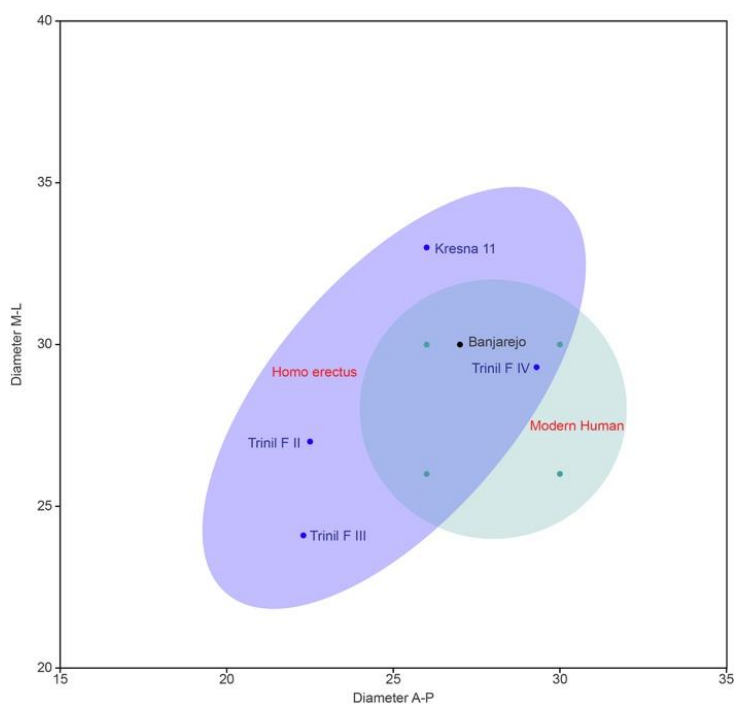


Figure 2. Biplot comparative graphic of diameter anteroposterior vs mediolateral diameter between Banjarejo specimen to *Homo erectus* and *Homo sapiens*

Based on the comparative analysis of the two measurement variables (Figure 2), the Banjarejo specimen located in the distribution slice of population distributions between *Homo erectus* and *Homo sapiens*. The anteroposterior diameter of Banjarejo specimen is slightly larger than Kresna 11, slightly smaller than Trinil F IV, but much larger than Trinil F II and Trinil F III. Then the mediolateral diameter of the specimen is slightly larger than Trinil F IV, smaller than Kresna 11, but much larger than Trinil F II and Trinil F III.

Furthermore, based on the thickness ratio of the femur cortical diaphysis, it is known that the Banjarejo specimen is slightly thicker than the Kresna 11 specimen from the Sangiran Site with a cortical thickness of between 8-10

mm (see Table 4). Based on a comparative study on morphology and morphometry to femur diaphysis of Kresna 11, Trinil specimens, and prehistoric *Homo sapiens* mentioned above, it is concluded that the femur diaphysis of the Banjarejo specimen belongs to early hominin.

- Multivariate analysis

The analysis using PCA was performed on three variables of the femoral column and head, namely, M15 (vertical diameter of column), M16 (sagittal diameter of column), M17 (column circumference), M18 (vertical diameter of caput), M19 (transverse or

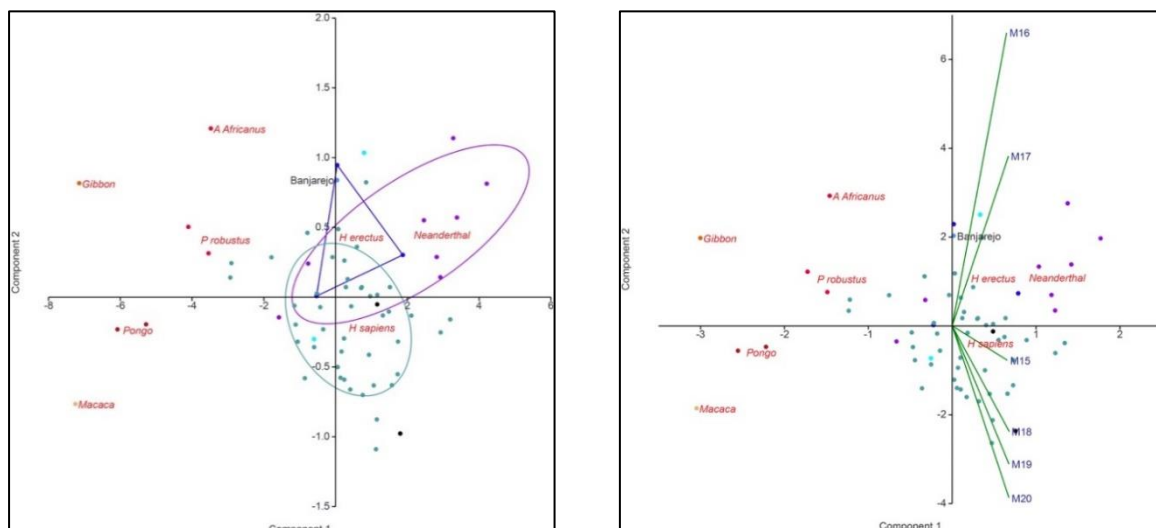


Figure 3. Biplot graphic of PCA represents component 1 vs Component 2 on femoral head and column. Left = Population distribution, Right = With variable representation

sagittal diameter of caput), and M20 (caput circumference).

The PCA plot graph (Figure 3) shows that the distribution of all hominin populations except *Paranthropus* and *Australopithecus* located to the right of Component 1, meanwhile the distribution of all non-human primate populations located to the left of the component. Consequently, it could be stated that the hominin population, except *Paranthropus* and *Australopithecus* have a larger size of the femoral head compared to the non-human primate population. Among these hominin populations, Neanderthal has a relatively larger size of femoral head and column compared to other hominin populations. However, *Homo erectus* specimens are in the slice distribution between *Homo sapiens* and Neanderthal samples.

The figure also shows that the entire early hominin population distribution,

including *Homo erectus* and *Homo neanderthalensis*, are located above Component 2. Meanwhile, the distribution of *Homo sapiens* population is located near the axis of the component. Therefore, it could be stated that the early hominin population has the size of M16 (vertical diameter of column) and M17 (column circumference) larger than the *Homo sapiens* population. Amongst the early hominin populations, Neanderthal had diverse sizes of M16 and M17, compared to the specimens from Trinil and Banjarejo, which are in proximity and tended to have larger size of M16 and M17 than the other *Homo sapiens* population.

CONCLUSION

This study presents the Banjarejo specimen in a distribution slice of population distribution between *Homo erectus* and *Homo sapiens* based on

comparative analysis of two variable measurements on femur diaphysis. Based on the thickness ratio of femur cortical diaphysis, the Banjarejo specimen is slightly thicker than the *Homo erectus* and modern *Homo sapiens* specimens.

Furthermore, based on the column and femoral head morphometric analysis result, it is concluded that Banjarejo specimen generally has a matching size to early hominin populations, particularly to the Neanderthal. Specifically, the specimen has larger M16 (sagittal diameter) and M17 (column circumference) sizes compared to the *Homo sapiens* population mean size, but close to the *Homo erectus* specimen from Trinil. In conclusion, this study places the proximal epiphysis femur fragment from Banjarejo site belong to the early hominin, tentatively assigned as *Homo erectus*. Further study is needed to answer chronological position of the hominin by metric dating of the femur and/or its lithological context.

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Prehistory studies in Indonesia in the last 40 years.

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