

The Gona pelvis, and sexual dimorphism in *Homo erectus* compared with living hominoids

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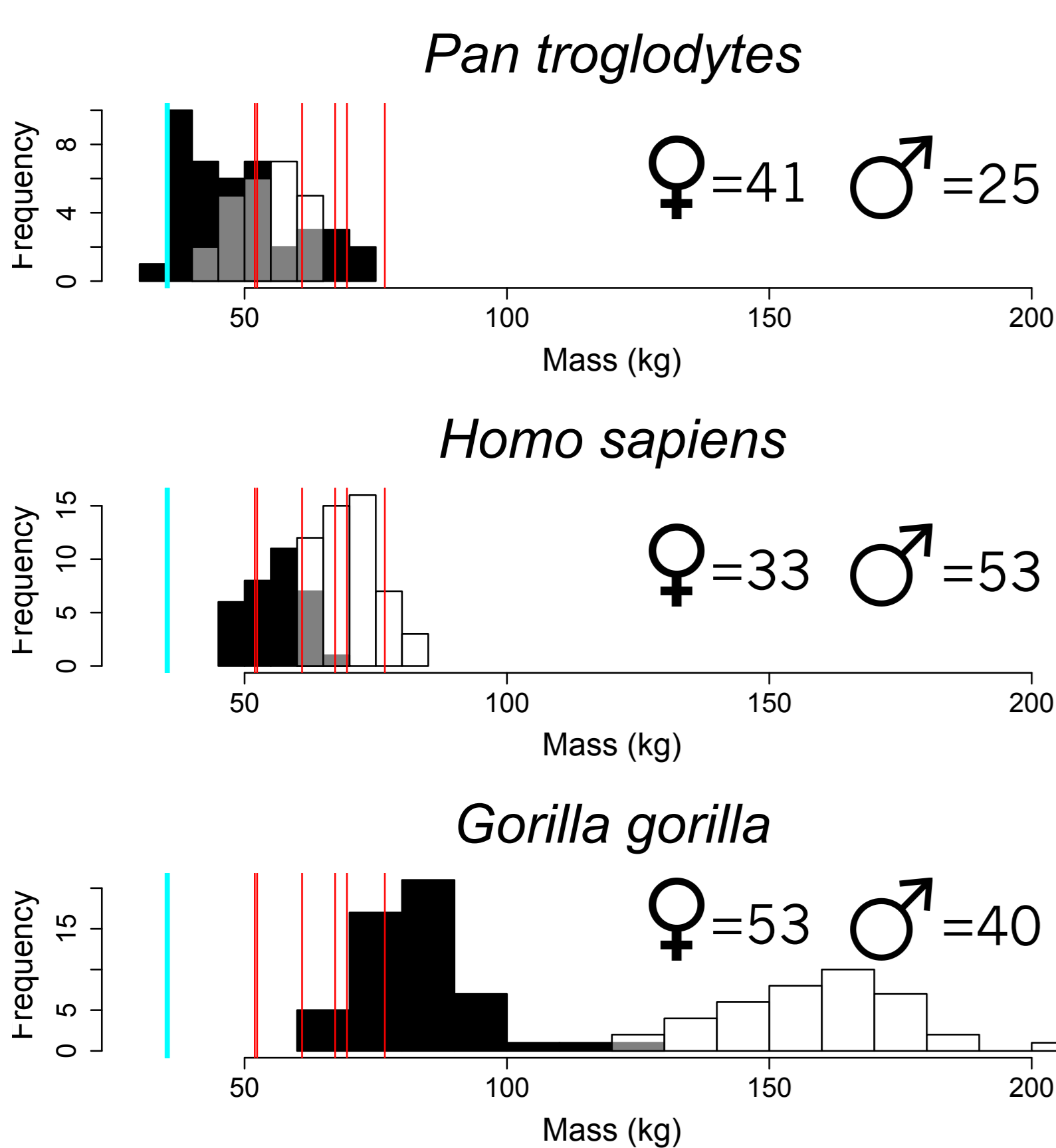


Background

BSN49/P27 ("Gona") is a relatively complete hominin pelvis from 0.9-1.4 mya deposits of the Busidima Formation in Ethiopia. Simpson et al. (2008, 2014) attributed the fossil to a female *Homo erectus* on the basis of its anatomy, small size and provenience. Ruff (2010) noted that Gona's hip joint size is markedly smaller than all other fossils attributed to the genus *Homo*, implying greater sexual dimorphism in *H. erectus* and more intrasexual (male) variation than previously recognized. He suggested perhaps the specimen was a late-surviving australopith, and disagreed with the implication that erstwhile female *H. erectus* specimens (e.g., OH 28) might actually be male. Neither party compared the amount of inter- and intrasexual variation implied by Gona to that found in living apes that can serve as alternate models of size variation. As Simpson et al. (2014) have recently and convincingly argued Gona is *H. erectus*, a reappraisal of body size variation this species is timely.

I test **four hypotheses** about *H. erectus* variation, making different assumptions. First, *H. erectus* body mass dimorphism is not greater than that observed in living hominoids (H_01). Next, implied levels of intrasexual variation in *H. erectus* males (H_02) and females (H_03) can be found in living apes. Finally, overall variation in *H. erectus*, regardless of sex, is observable in living hominoids (H_04).

Materials & Methods



Left: Black = females, white = males, gray = overlap. Blue line is Gona and red lines are Early Pleistocene *Homo* (smallest to largest: ER 1472, D4167, ER 1481, ER 3228, OH 28, and WT 15000).

Body masses (kg) are estimated from femur head diameters (FHDs) for recent humans and wild-shot African apes. Fossil FHDs, actual or estimated from acetabula, are from Ruff (2010).

FHD is converted to body mass using equations from Ruff (2003) for apes, and the average of McHenry's (1992) and Grine et al.'s (1995) equations for humans and *H. erectus*.

Resampling is used to assess the likelihood of observing *H. erectus* levels of size variation in living species with larger sample sizes. For each hypothesis, individuals of each species are sampled at random, and a test statistic is calculated as: (**H_01**) the mean of six males divided by a female; (**H_02**) the coefficient of variation (CV) of six males; (**H_03**) the ratio of the smaller of two randomly sampled females; and (**H_04**) the CV of seven individuals with one being the smallest in the sample. Resampling and calculation of test statistics are repeated 5,000 times for each hypothesis. P-values are presented as the frequency of resampled ratios at least as extreme as *H. erectus* values, and the significance level is set to $P < 0.004$ based on Bonferroni adjustment.

Summary & Implications

Australopith status is unnecessary to explain the small size of the Gona pelvis. Gona puts *H. erectus* sexual dimorphism outside the range of extant chimpanzees and humans, but easily within the range of modern gorillas. This is in line with other evidence of substantial size variation in *H. erectus*, as noted by Simpson et al. (2014). High levels of sexual dimorphism seem to characterize hominin taxa from >3 to at least 1 mya. Dimorphism may not have decreased to modern human-like levels until later in the Middle Pleistocene (Royer et al., 2009).

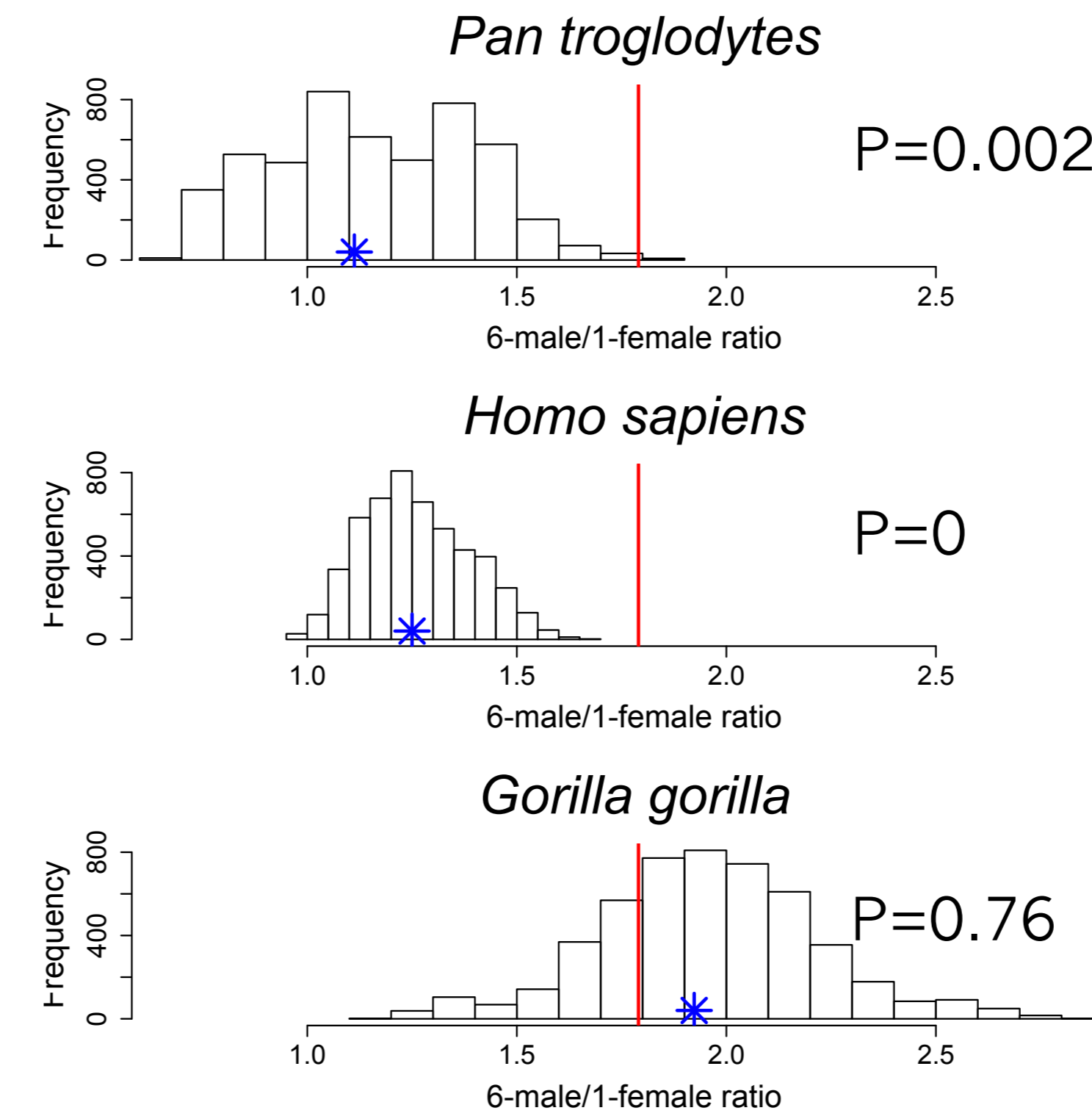
Although levels of intrasexual variation in *H. erectus* were higher than is usually seen in extant hominoids, the Bonferroni adjustment to the significance threshold suggests *H. erectus* values are not unexpected given the number of comparisons made.

It is difficult to associate dimorphism levels in fossil species with specific social or mating behaviors (Plavcan, 2000), and high dimorphism found here may not reflect male competition or polygyny. Brain size and other correlates of energetics in *H. erectus* point to a cooperative breeding strategy (Iler et al., 2012). *H. erectus* may have therefore exercised a unique ecological strategy, in which small female body size and cooperative breeding reduced both energetic demands on mothers and resource competition between members of society.

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H_01 : Sexual dimorphism

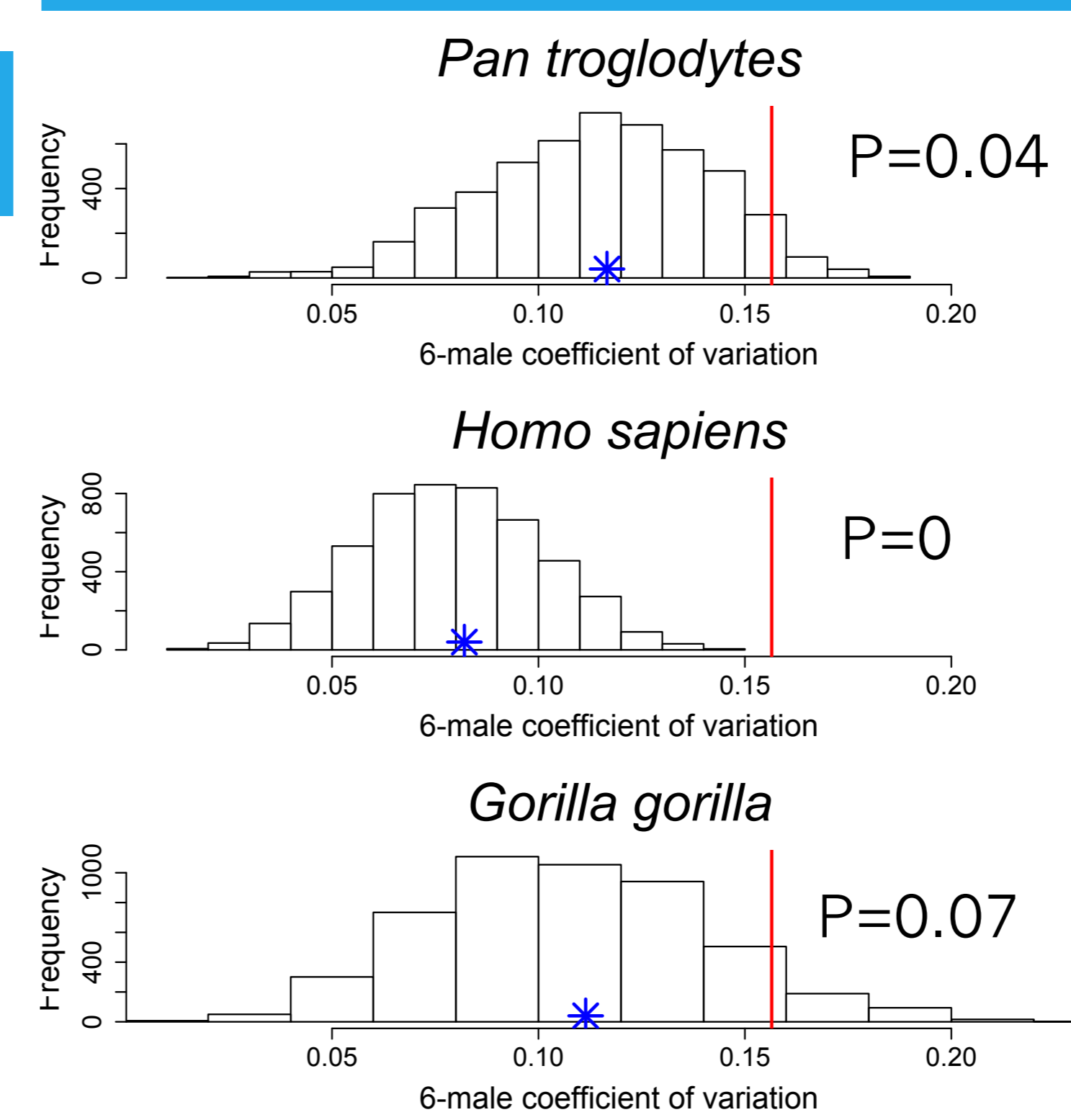


The hypothesis assumes Gona is female and the other six fossils are male. It predicts that the *H. erectus* ratio of dimorphism ($=1.79$, red line) can easily be found in extant samples of six males and one female.

The average resampled dimorphism ratios are essentially identical to the empirical ratios of male/female averages (blue stars).

The *H. erectus* level of sexual dimorphism is significantly higher than human and chimpanzee values, but is not uncommon in gorillas.

H_02 : Intrasexual male variation

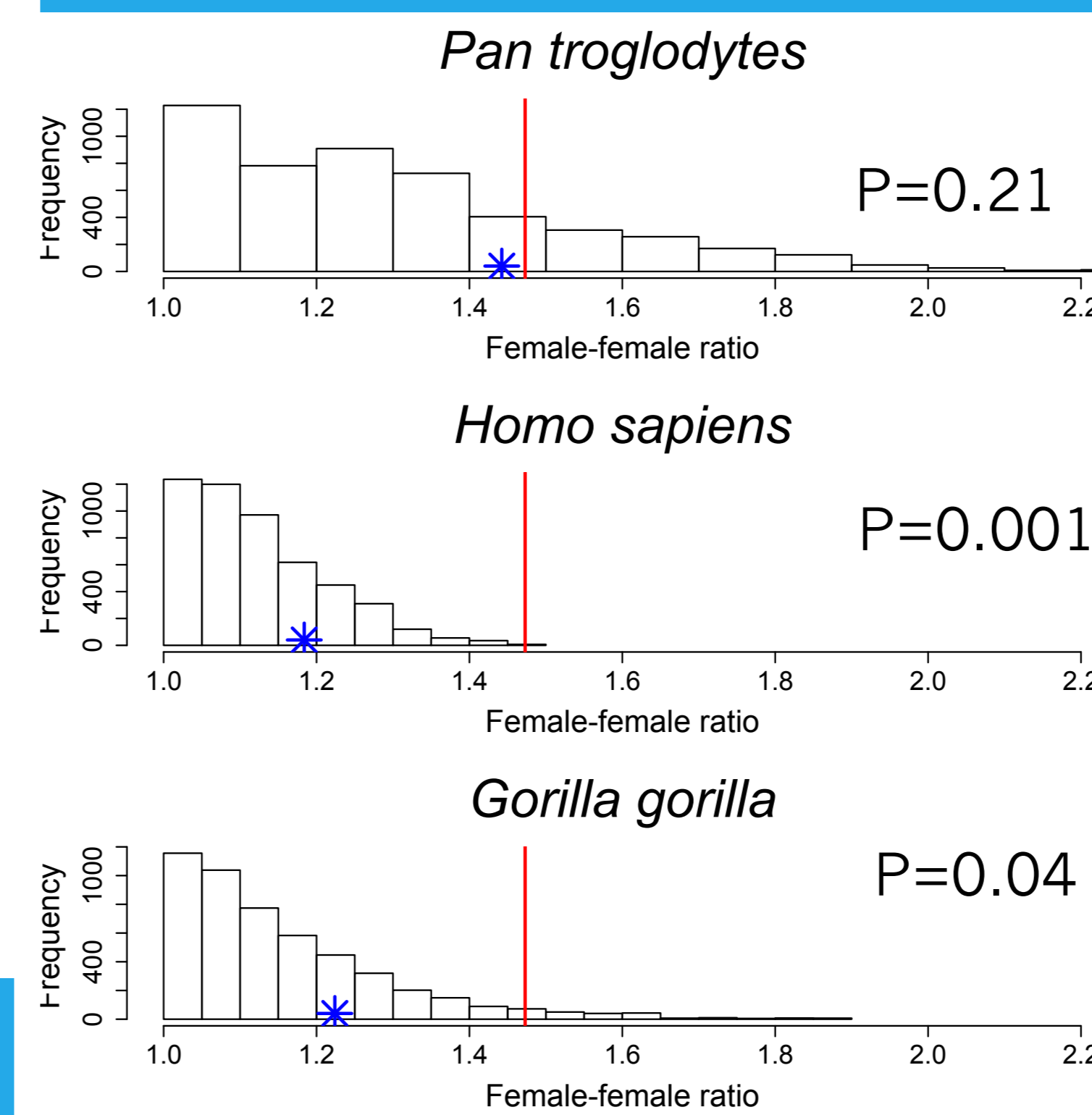


In accord with H_01 , this hypothesis assumes the six non-Gona fossils are males, and predicts that their CV ($=0.16$, red line) can easily be found in extant samples of six males.

The average resampled CV of each species is essentially identical to the actual value of the full male sample (blue star in the left plots).

The implied *H. erectus* level of male variation is rarely sampled, but not significantly different, from chimpanzees and gorillas, and it is never sampled in humans.

H_03 : Intrasexual female variation

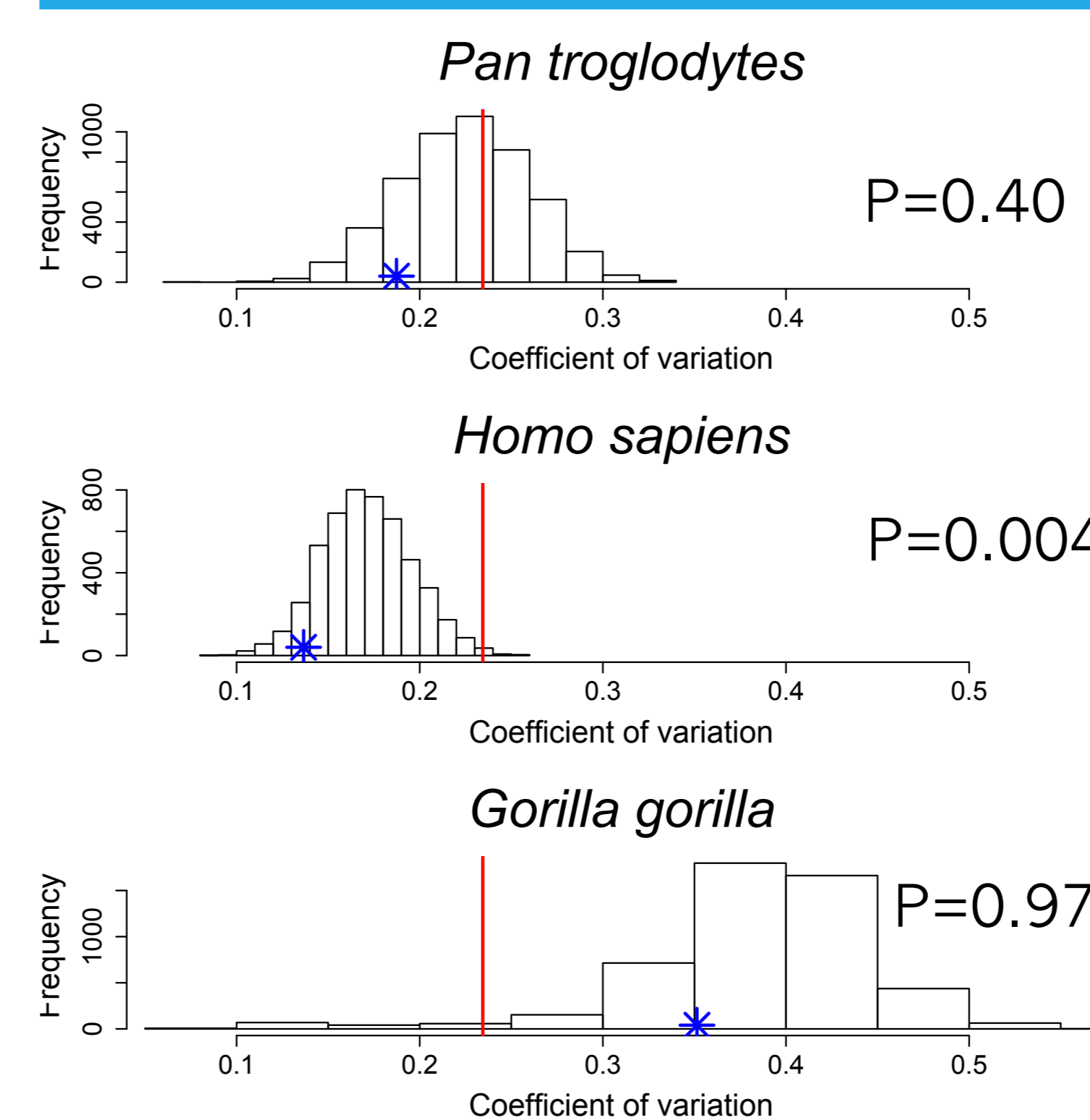


This hypothesis treats the possibility that Gona is at the small end of a larger female size range, by assuming the next smallest fossil (ER 1472) is also female. The hypothesis predicts that their proportional difference (1.47) can be found in random pairs of females.

Pairwise proportional differences slightly underestimate female variation as measured by the mean method (blue star in the left plots).

The hypothesis is rejected for humans, but not for gorillas or chimpanzees.

H_04 : Overall variation



The hypothesis assumes Gona is female, and the other six fossils could be male or female. It predicts that the full fossil CV ($=0.23$) can easily be found in extant samples including the smallest specimen in the sample and six others regardless of sex.

The inclusion of the smallest specimen in the calculation of each species' CV slightly overestimates full-sample values (blue star in the left plots).

The fossil-level of variation is very rare in humans, not uncommon in chimpanzees, and low by gorilla standards.

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