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Variation within the Krapina Frontal Sample and a Descriptive Note on the Newly Associated Frontal Specimen, Kr 27–28

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Abstract

The Hrvatsko Zagorje region of Croatia has yielded numerous, important Paleolithic finds. Most prominent among these are the Neandertal fossils from Krapina Rockshelter. These fossils have proven to be a rich source of data for testing hypotheses about Neandertal evolution, adaptation, and behavior. This study reports on an analysis of sex-related sample bias within the Krapina frontal sample as well as individual sex identifications for select Krapina frontal specimens. Krapina samples for two supraorbital variables exhibit a probable overrepresentation of females, while a much smaller sample for a third supraorbital variable exhibits a probable overrepresentation of males. Following from the analysis of sex-related sample bias, probability-based sex estimation were possible for nine of the Krapina frontals. This paper also describes a newly associated frontal bone from level 4, Kr 27–28. This specimen comprises the central squama, frontal sinus, and right supraorbital portions of the frontal bone. The specimen is adult and likely male.

INTRODUCTION

The Krapina hominid fossils comprise the largest sample of Neandertal remains from a single site. Although the sheer size of the collection means that there are a few well-preserved cranial specimens such as Kr 3 and Kr 6, the vast majority of the cranial collection is fragmentary, thus confounding its interpretation. The frontal bone (n=51) is the best represented cranial element among the Krapina collection and has figured prominently in previous analyses *(1–3)*. Six of the specimens preserve large portions of the frontal (Kr 1, Kr 3, Kr 4, Kr 6, Kr 23, Kr 27–28), but most of the other forty-seven specimens are fragmentary (see Table 1).

This study reports on the pattern of sex-related variation within the Krapina frontal sample. Specifically, the sex-related sample bias in the Krapina frontal sample is assessed individual specimens are provided with probability-based sex identification estimates. A secondary purpose of this paper is the description and analysis of the recently associated specimen Kr 27–28. This specimen comprises the fourth best preserved of the Krapina frontals and is also the most robust of the well-preserved specimens.

TABLE 1

Frontal Specimens from Krapina.

Primary Spec. #	Other Spec. #	Specimen Name	Description	Level
1	31.9, 34.9, 39.4	»A«	Juvenile calvarium.	8
3	18.13, 34.2, 19?	»C«	Partial cranium.	4
4	34.5, 37.13	»D1«	Right calotte.	4
6	14, 18.7, 22, 37.2, 40.2	»E«, »Fr 1«, »To 2«	Partial cranium.	3
20		»Pa 4«	Left frontoparietal with metopic suture.	
23	44	»Fr 2«	Central supraorbital region and inferior squama.	
24		»Fr 3«	Juvenile right supraorbital.	
25		»Fr 4«	Central frontal squama.	
26		»Fr 5«	Central squama fragment.	4
28	27, 37.9	»Fr 6«, »Fr 7«, »To 9«	Right inferior frontal preserving posterior sinus wall from midline and torus from lateral of medial as well as a major portion of central squama.	4
29		»Fr 8«	left fragment of squama and superior supraorbital border.	
30	37.12	»Fr 9«, »To 12«	Right supraorbital segment and squama.	4
31		»Fr 10«	Central frontal squama.	
31.2			Stephanion fragment.	3
31.3	33.7		Lateral frontoparietal.	3
31.4			Stephanion fragment.	
31.5			Juvenile posterior squama fragment.	4
31.6			Juvenile posterior squama fragment.	
31.7			Central squama fragment.	4
31.8			Stephanion fragment.	
31.10	33.32		Juvenile left frontoparietal.	
31.11			Juvenile squama fragment.	3
31.12			Juvenile stephanion fragment.	
31.13			Juvenile squama fragment.	
31.14			Squama fragment.	
31.15			Squama fragment	4
31.16			Squama fragment	
31.17			Posteromedial squama fragment.	
33.1			Left frontoparietal from stephanion	
33.6			left anteroinferior frontoparietal fragment, inferior to stephanion	
33.10			Left frontoparietal.	
33.15			Right inferior frontoparietal.	
33.17			Right inferior frontoparietal.	4
33.18			Juvenile inferior squama fragment.	4
33.23			Juvenile left frontoparietal fragment.	
33.26			left superior frontoparietal	3
33.28			Juvenile left frontoparietal.	
33.29			Right stephanion fragment.	
33.30			Right frontoparietal from stephanion.	4
34.11			Central frontoparietal fragment.	4
34.38			Inferior squama fragment?	
37.1		»To 1«	Left lateral supraorbital.	4
37.3		»To 3«	Right lateral supraorbital.	
37.4		»To 4«	Left lateral supraorbital.	
37.5		»To 5«	Left lateral supraorbital.	3
37.6		»To 6«	Left lateral supraorbital.	4
37.7		»To 7«	Left midorbit supraorbital.	2
37.8		»To 8«	Left lateral supraorbital.	4
37.10		»To 10«	Right lateral supraorbital.	4
37.11		»To 11«	Right mid-lateral supraorbital.	
37.14			Anteromedial supraorbital fragment.	

TABLE 2

Overall Measurements of Kr 27–28 and other Krapina Frontals.

Specimen	Max. Upper Facial Breadth[1] (mm)	Min. Frontal Breadth[2] (mm)	Bi-*Frontomalar Orbitale*[3] (mm)	*Frontomalar Temporale – Frontmalar Orbitale* (mm)	Index of Postorbital Constriction[4]
Kr 3	118.5	98.8	105.4	11.8	119.9
Kr 4	128.1	103.0	114.2	11.1	124.3
Kr 6	116.8	98.2	106.1	10.0	118.9
Kr 23		90.9			
Kr 27–28	122.4	99.1	109.7	11.0	123.6

[1] M43; [2] M9; [3] M43(1); [4]Max. Frontal Breadth / Min. Frontal Breadth x 100

MATERIALS

The Krapina Frontal Sample

Table 1 lists the Krapina frontal specimens. Although frequently referred to by alphabetical designations, the modern inventory system organizes all the Krapina hominids by numbers *(4)*. Table 1 is sorted by the primary specimen number used to refer to specimens throughout this paper. Also listed are all the specimen numbers that comprise a given specimen, as well as the traditional alphabetical or numerical designations. The strength of the Krapina sample, frontal and otherwise, lies in the preservation of same anatomical regions for multiple individuals. This asset provides a window onto intrapopulational variation possibly unmatched for any other premodern hominid. The sample includes four partial crania (Kr 1, Kr 3, Kr 4, Kr 6), three specimens that preserve large portions of the frontal (Kr 23, Kr 27–28, Kr 31) and twelve supraorbitals (Kr 24, Kr 30, Kr 37.1, Kr 37.3 – 37.8, Kr 37.10, Kr 37.11, Kr 37.14).

Krapina 27–28 (Figures 1a,b)

The connection between Krapina 27 and 28 was made following the discovery of a third connecting piece of frontal among the Krapina fauna remains. This third specimen was identified by T.D. White according to Radovčić (pers. comm.), although T.D. White (pers. comm.) does not recall making the association with Kr 27 and Kr 28. The entire specimen, when reconstituted, is fourth in frontal completeness after Kr 3, Kr 4, and Kr 6. As such, this specimen adds immensely to the frontal sample. Krapina 28 consists of Kr 37.9 and Kr 28. Kr 37.9 (»Torus 9«) is most of a robust right supraorbital torus and a small portion of frontal squama and temporal fossa. Articulating with the internal frontal sinus wall and a small portion of external squama, Kr 28 (»Frontal 7«) consists of a posterior sinus wall and squama that extends as far as 46 mm posterosuperiorly from the torus. Kr 27 (»Frontal 6«) is a central portion of frontal squama that measures 49 mm wide and 37.3 mm anteroposteriorly. It articulates inferiorly with the as yet unnumbered fragment of posterior sinus wall. Together, Kr 27 and the sinus wall portion articulate with the posterior sinus wall and approximately 8 mm of external squama of Kr 28.

Although the juncture between the external squama of Kr 27 and 28 is not tight due to slight erosion of the break surfaces, the two articulate fairly well internally as do the posterior sinus wall fragments. The articulation between the new posterior sinus wall fragment and Kr 27 is very tight. The specimen acquired from the fauna is a much lighter shade of tan than the other portions, and this is likely due to the fact that the faunal specimen was not shellacked while the other portions were (although different local depositional environments may also have been a factor).

When Kr 27 and Kr 28 are articulated via the piece from the faunal sample, it is possible to calculate an estimated upper facial breadth of 122.4 mm by doubling the upper hemifacial breadth of 61.2 mm. As a measure of overall size, Krapina 27–28's upper facial height falls in between the two smaller adult crania, Kr 3 (118.5 mm) and Kr 6 (116.8 mm), and the larger estimated value for the Kr 4 cranium (128.1 mm) (see Table 2). This intermediate position is also reflected in other gross dimensions such as the *frontomalar temporale – frontomalar orbitale* chord and minimum frontal breadth (see Table 2).

Two incised marks are apparent on the posteroinferior most aspect of the temporal fossa squama, inferior to and slightly anterior to *frontotemporale*. The marks run in a diagonal manner from posteroinferior to anterosuperior. They are parallel to each other with the less distinct superior one running for 3.1 mm from the posterior break and the inferior one for 4.1 mm. Two characteristics indicate that they *might* be cutmarks as opposed to vascular grooves or muscle markings: 1) they run in the exact opposite orientation than the clear muscle markings that are present anterosuperiorly running parallel to the temporal line; and 2) their depth and linearity. Examination under microscope reveals that the edges of the grooves are rounded and not distinct suggesting that if they are cutmarks, their edges have been slightly eroded.

External squama (Figure 1a). The external squama of Kr 27 exhibits a sagittal torus comparable to that of Krapina 25. The sagittal torus is a true shelving between the two hemifrontals. No projection off of the right half of the external squama is present, rather the right squama is entirely displaced above the left half of the squama.

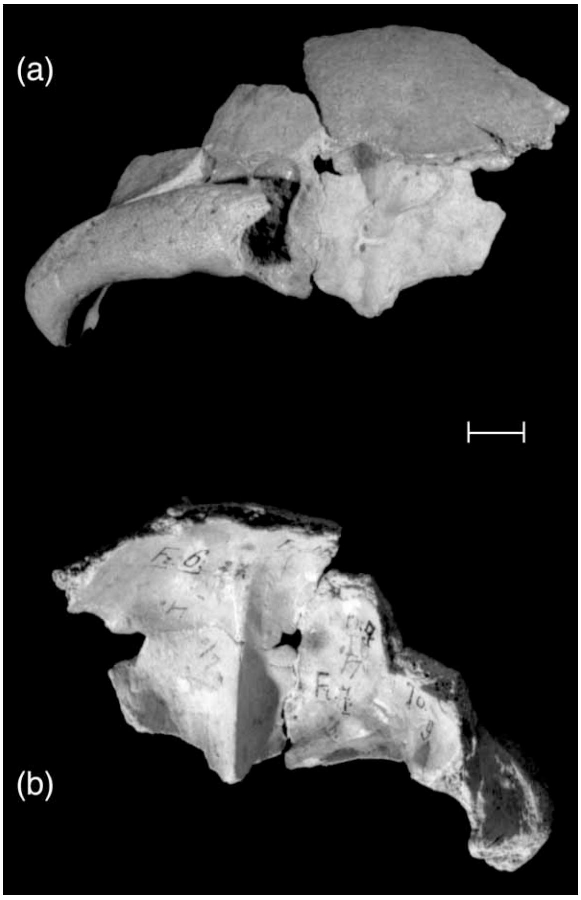

Figure 1. *Kr 27–28: (a) anterior and (b) posterior. Scale is 1 c.m.*

Unlike Kr 4 and 25, there appears to be no mirroring of the external asymmetry by the *cristae falx cerebri*, internally.

Frontomalar suture. The articular surface for the zygomatic is somewhat different from the other Krapina specimens. This seems to be mainly related to the dramatic bulge of the torus laterally that results in a strong overhang of the suture. Although many of the Krapina tori exhibit a dramatic thickening at lateral (*e.g.*, Kr 4, 37.1, 37.3, 37.5, 37.10; see *2–5*), only Kr 28 has torus matter overhanging the frontomalar suture, laterally. Aside from this overhang, the articular surface is similar to the roughly triangularly shaped frontomalar sutures of Kr 4 and Kr 6. An index of relative size of the articular surface was estimated using mediolateral and anteroposterior dimensions. As measured by this index, Krapina 28 has the second largest frontomalar suture of the Krapina frontals (see Table 3). However, in raw dimensions, it has neither the deepest nor the broadest articulation.

Temporal fossa. Krapina 28, along with the left side of Kr 3, possesses the most weakly developed temporal line in the *frontotemporale* region among the Krapina frontals. However, the temporal fossa surface is exceedingly rugose indicating a powerful anterior temporalis muscle. The surface is more rugose than on Krapina 4, but Kr 4's temporal line is much more robust and distinct, while Kr 28's line is almost indistinguishable from the rugosity of the temporal fossa. Only specimen 37.10 exhibits a more rugose temporal fossa surface in the region of the *frontotemporale*.

Supraorbital region (Table 4). Krapina 28 preserves a 49.4 mm length of right lateral supraorbital torus extending medially from *frontomalare temporale* to a crescent-shaped break just medial to the supraorbital notch. The orbital rim is rounded like Kr 37.6 and thus is one of the least sharp of all of the Krapina supraorbitals. Krapina 28 exhibits one of the most robust supraorbital tori in the sample, being more robust than even Kr 4. Only Kr 37.4 and Kr 37.10 possess thicker (superoinferiorly) tori. Kr 28 is also the most projecting of the tori. When the clearly subadult specimens Kr 1 and Kr 24 are excluded, Kr 28 falls more than 2 standard deviations above the mean for midorbit projection and more than 1 standard deviation above for lateral projection (see Table 4). However, the

TABLE 3

Measurements of the Frontomalar Suture.

Specimen (side)	Breadth[1] (mm)	Length (mm)	Index	Area[2] (mm^2)
Vi 202 (right)	9.6	17.1	56.1	82.1
Vi 224 (left)	9.2	15.5	59.4	71.3
Vi 260 (right)	8.2	19.7	41.6	80.8
Vi 262 (right)	8.4	15.8	53.2	66.4
Vi 279 (right)	6.8	11.5	59.1	39.1
Vi 261 (left)	10.2	14.8	68.9	75.5
Vi 284 (right)	9.4	17.5	53.7	82.3
Kr. 6 (right)	9.8	15.0	65.6	73.3
Kr. 4 (right)	9.3	13.0	71.5	60.8
Kr. 27/28 (right)	9.9	12.4	79.6	61.5
Kr. 37.1 (left)	8.0	13.0	61.8	51.8
Kr. 37.5 (left)	9.0	10.9	82.4	49.3
Kr. 37.6 (left)	9.9	16.0	62.1	79.5
Kr. 37.8 (left)	9.1	12.7	72.1	57.8
Kr. 37.10 (right)	9.6	14.4	66.6	69.0

[1] Not the same as *frontomalar temporale – frontomalar orbitale*.
[2] The index of frontomalar suture size = Breadth/Depthx100.

TABLE 4

Measurements of the Supraorbital Region.

		Projection[1]			Thickness	
	Lateral	Midorbit	Medial	Lateral	Midorbit	Medial
Krapina 27–28	23.0	26.0	–	13.2	12.0	–
Adult Neandertals[2]						
Mean	24.8	23.7	21.7	12.5	11.0	18.9
95% bootstrap C.I.[3]	23.9–25.7	22.9–24.5	20.5–22.9	11.9–13.2	10.4–11.6	17.1–20.5
SD	2.0	1.9	2.2	1.5	1.6	3.2
N	17	20	12	21	23	12
Krapina (adults)[4]						
Mean	24.3	23.9	19.4	12.5	10.7	14.8
95% bootstrap C.I.[3]	23.5–25.2	23.3–24.6	17.5–20.8	11.6–13.4	9.7–11.6	11.9–16.6
SD	1.4	1.2	1.7	1.6	1.8	2.6
N	8	11	3	11	13	3
Vindija (adults)[5]						
Mean	22.1	18.9	–	10.6	8.6	–
95% bootstrap C.I.[3]	20.6–23.5	16.9–21.1	–	10.3–11.0	8.2–9.1	–
SD	1.8	2.9	–	0.5	0.6	–
N	5	6	–	5	5	–
Adult UP Moderns[6]						
Mean	19.5	16.0	13.0	8.8	6.2	18.5
95% bootstrap C.I.[3]	17.7–21.4	14.0–17.9	10.8–15.6	8.1–9.5	5.6–6.9	17.0–20.0
SD	3.6	3.7	4.1	1.6	1.6	3.3
N	14	14	10	20	20	18

[1] Medial, midorbit, and lateral were originally defined by Smith and Ranyard (*2*). Rather than being actual points, the landmarks refer to definable parasagittal planes along the supraorbital region. Medial lies on the orbital segment of the supraorbital torus (or supercilliary arch) just lateral to the medial orbital margin. This landmark invariably corresponds to the thickest and highest points on the torus. Lateral corresponds to the thickest point on the lateral segment of the torus that is lateral to a parasagittal plane that passes through frontotemporale. Midorbit corresponds to the thinnest point on the torus between medial and lateral.

[2] The Adult Neandertal sample comprises: La Chapelle, La Ferrassie I, Guattari 1, La Quina V, Forbes Quarry, Spy I and II, St. Césaire, Feldhofer, La Chapelle, Sacocopastore 2, Krapina (Kr) 3, Kr 4, Kr 6, Kr 28, Kr 37.1, Kr 37.3, Kr 37.4, Kr 37.5, Kr 37.6, Kr 37.7, Kr 37.8, Kr 37.10, and Kr 37.11.

[3] Standard bootstrap confidence interval estimate for the mean with 10,000 bootstrap samples. »C.I.« = confidence interval.

[4] Sample consists of: Krapina (Kr) 3, Kr 4, Kr 6, Kr 28, Kr 37.1, Kr 37.3, Kr 37.4, Kr 37.5, Kr 37.6, Kr 37.7, Kr 37.8, Kr 37.10, and Kr 37.11.

[5] Excludes Vi 224, 279, and clear infant, Vi 227. Sample consists of Vindija (Vi) 202, Vi 260, Vi 261, Vi 262, Vi 284, Vi 305.

[6] The Adult Upper Paleolithic Modern sample comprises: Cromagnon 1 – 4, La Madeleine 1, Abri Pataud 1, Engis (1) 2, Oberkassel F, Oberkassel M, Podbaba, Kelsterbach, Paderborn, Stetten 1 and 2, Mladeč 1, 2, and 5, Brno 2, Dolni Vestonice 3, and Pavlov.

projection of the superoinferiorly thicker specimen, Kr 37.4, could not be measured since its anterior torus is missing. In addition to its robusticity, Krapina 28's torus is the most continuous in thickness from midorbit to lateral. Its shape when viewed anteriorly is similar to that of Kr 4, albeit much thicker and broader. There is a slight decrease in thickness from lateral to midorbit followed by a gradual increase from midorbit toward the medial point. Below the maximum preserved height of the torus lies a broad and deep supraorbital notch. It lies approximately 30.2 mm lateral of the midline.

Frontal sinus. Krapina 28's sinus is very large and extends more laterally than even the sinus of Kr 6 (see Table 5). The sinus extends 44.8 mm lateral of the midline into the right supraorbital torus. Among other Krapina specimens for whom this can be measured, the next greatest lateral sinus projection is found in Kr 23 (37.5 mm). Krapina 4's frontal sinus extends 31.2 mm lateral

TABLE 5

Lateral Extent of the Frontal Sinus.

Specimen (side)	Midline – most lateral point of sinus (mm)	Upper hemifacial breadth[1] (mm)	Index of lateral sinus extent[2]
Vi 224 (left)	23.4	54.5	43
Vi 261 (left)	35.3	58.1	60.8
Vi 284 (right)	32	58.6	54.6
Kr 28 (right)	44.8	61.2	73.1
Kr 4 (right)	31.2	64.0	48.8
Kr 23 (left)	37.5	–	–
Vi 305 (left)	25.2	–	–
Vi 227 (left)[†]	14.5	59.1	24.5
Vi 308 (left)	23.7	–	–

[1] Upper hemifacial breadth is one half of Upper Facial Breadth (Martin no. 43). For specimens that only preserve one half of the frontal, it is measured as a chord connecting *frontomalare temporale* with the midline.

[2] Index = 100*(Midline to most lateral point of sinus / Upper hemifacial breadth)

of the midline. When this lateral projection is measured as a proportion of upper facial breadth, Krapina 28 clearly has the largest sinus (70.7% versus 50.1% for Krapina 4). The height of the sinus at the highest point on the external torus is 19.3 mm. At least 5 major lobes of sinus are present on the right side. The most superomedial lobe of Kr 28's right sinus lies on the midline. Its inferomedial-most lobe also crosses over to the left side. Both of these project posteriorly more than the other sinus lobes, because they lie in the gutter that runs through the base of the frontal crest. This gutter is not apparent on specimen 23, the only other specimen where such a structure would be discernible without complex radiographic techniques. The gutter extends superiorly into the squama proper, and thus is an exception to Vlček's *(6)* assertion that the Neandertal frontal sinus is limited to the internal torus.

Internal aspect (see Figure 1b). A strongly protruding and thin frontal crest runs superiorly as a single unit for approximately 36 mm from the inferior break. At about this point it splits and flattens and becomes two slight *cristae falx cerebri*, separated by a very shallow sagittal sulcus. The sulcus is only palpable for approximately 15 mm and then the entire structure becomes rather torus-like, which is similar to that exhibited by Kr 25. Squamal thickness varies considerably and reflects the deep and shallow convolutions of the frontal lobe of the brain. Thickness measurements range from 2.5 mm to 6.7 mm.

Summary. Kr 27–28 enhances our understanding of the Krapina Neandertals. While not exhibiting the thickest or most projecting supraorbital torus, it is larger than average for both Krapina as well as Neandertals, in general. Most other dimensions as well as aspects of anatomy for Kr 27–28 fall larger or more robust than average, although not extremely so. The one way that Kr 27–28 is extreme is in the size of its frontal sinus. The sinus not only extends more laterally than other specimens from Krapina (and Vindija, see Table 5), it also extends further into the frontal squama than is usual for Neandertals.

Comparative Samples

The approach taken to analyze sex-related sample bias and make sex identification estimates in this study requires appropriate comparative adult human samples with known or accurately estimated sex identifications. Samples of three recent human populations were used. Forty-nine crania (24 female, 25 male) from the German Neolithic site of Altendorf were included. Second, fifty-four Euroamerican crania (23 female, 31 male) drawn from the Hamann-Todd anatomical collection (n=43) and the University of Wyoming Human Skeleton Repository (n=11) were measured. Finally, forty-three Northwest Plains Amerindian specimens (13 female, 30 male) from the U.W. Human Skeletal Repository were measured. While sex was osteologically estimated for the Altendorf (by F.H. Smith) and U.W. Human Skeletal Repository (by G.W. Gill & R. Weathermon), sex was known from death certificates for the Hamann-Todd individuals. Measurements of the Altendorf specimens were courtesy of F.H. Smith, while all other measurements were taken by both the author and A. Hofbauer.

METHODS

Perhaps the greatest strength of the Krapina fossil collection is that multiple individuals are represented for many anatomical parts. The frontal sample is one of the best in this respect and, thus, offers a perspective on Neandertal intrapopulation (i.e., individual, sex-related, and age-related) variation that is unmatched. Unfortunately, because most of the frontal specimens are fragmentary, sex estimation for the Krapina frontal sample is not straightforward. Without knowledge of the sex composition of the Krapina frontal sample, it is possible that we may incorrectly interpret its anatomy. For example, if the sample contains an overrepresentation of males, it will appear more robust than would a random sample drawn from the same population. Thus, Smith and Ranyard's *(2)* conclusion that the late Neandertal frontals from Vindija Cave appear more modern like compared to the early Krapina Neandertal frontals could be a function of an overrepresentation of males in the Krapina sample.

This study employs a modified version of a method employed previously to analyze sample bias in the Krapina sample *(5)*. The main differences between the present analysis and the previous one are that the present analysis takes a partially non-parametric approach and it relies on different comparative samples with better sex identification data. The analysis employed in the present study consists of three steps. First, a model of intragroup (i.e., derived from the within male and within female variation from each comparative sample) is applied to test the hypothesis that no significant intergroup variation is present in the Krapina sample. Second, if significant intergroup variation is found for a particular variable, then skewness is used to assess which, if either, sex is likely overrepresented. Third, probabilities for sex-group membership are assigned to individual fossils based upon the analysis of intrasample variation performed in step one.

In order to test the hypothesis that no significant intergroup variation is present in the Krapina sample, we must first determine which variables significantly covary with sex. Analysis of sex-variable covariance is complicated by the fact that the X and Y variables are of different types. Sex is categorical while the measurements are continuous variables. Because we are examining correlation between a categorical variable and a continuous variable, neither Chi-square tests nor regressions can be used. Among standard, conventional, test statistics, the student's *t*-test is often used in this situation *(7)*. However, the Student's *t*-test only compares the means of two groups. A more appropriate test, is Point Biserial Correlation. Although biserial correlation was originally developed during the 1920s and 1930s, an accurate correlation coefficient was not refined until the 1950s *(8, 9)*. Point Biserial Correlation is preferable to a two--sample *t*-test of means, since it directly addresses the degree of relationship between the two elements of a category and a given continuous variable.

Once sex-variable covariance is analyzed, an All Paired Ratios (APR) analysis is performed on sex-covarying variables in order to test the hypothesis that no significant intergroup variation is present. The APR analysis consists of determining a distribution of ratios from repeatedly sampling pairs from the same sex. Although the distribution was based on all three modern comparative samples, pairs were only drawn from sex subsamples of the same population. Thus, even though the total ratio distribution is based on the intragroup variation for three different populations, the distribution is not affected by interpopulational variation. Furthermore, this approach is non-parametric and thus avoids skewness problems associated with non-log transformed ratio data.

Only intergroup variation that is greater than what is seen within the same sex group will result in significant sample bias. If at least one of the Krapina possible specimen pairs exhibits a ratio larger than ninety percent of the distribution of intragroup ratios drawn from the modern comparative samples, then the hypothesis that no significant intergroup variation is present in the Krapina sample is falsified. If significant intergroup variation is found for a variable, then sample skewness is calculated to assess whether or not one sex is overrepresented in the sample.

The third step in the analysis is to assess the probability that a pair drawn from the Krapina sample represents both sexes. The proportion of the intragroup model ratio distribution that is greater than the observed ratio for the Krapina pair is the liklihood that the Krapina pair represent male and female, given the model used. Model-based probabilities are assigned to all possible Krapina pairs for variables that significantly covary with sex. Probabilities of less than 0.10 are reported and regarded as significant indications of sex group membership.

RESULTS

Of six supraorbital variables examined, three significantly covary with sex: Medial Thickness ($p<0.001$), Midorbit Thickness ($p=0.018$), and Lateral Thickness ($p=0.007$). Interestingly, supraorbital projection did not significantly covary with sex among the modern comparative samples. For all three of the thickness variables, Krapina's maximum paired ratio was significantly greater than what would be expected for solely intragroup variation (see Table 6). Thus, for these three variables, the null hypothesis that no significant intergroup (between the sexes) variation exists in the Krapina sample is falsified. Krapina sample skewnesses for the three variables are –1.626 for Medial Thickness, 0.010 for Midorbit Thickness, and 0.903 for Lateral Thickness. Only three specimens comprise the Krapina Medial Thickness sample: Kr 3, Kr 4, and Kr 6. Kr 3 and Kr 4 both exhibit large Medial Thickness values (16.6 mm and 16.0 mm versus 11.9 mm). Thus the Krapina Medial Thickness sample is biased in that it has disproportionately larger, perhaps male, values than it does smaller ones. The Midorbit and Lateral thickness Krapina samples are larger (n=13 and n=11, respectively) and are represented by many of the same specimens. The positive Krapina sample skewness values for both the Midorbit and Lateral Thickness variables indicate that these samples have an overrepresentation of smaller values, likely those of females.

In terms of individual Krapina specimen sex estimation, Krapina pairs that exhibit ratios that are signifcantly greater than what is expected of a pair drawn from the same sex group are given in Table 7. For all three variables, Kr 6 is clas-

TABLE 6

All Paired Ratios Analysis Results: Is More Than One Sex Significantly Represented?

Variable	90th Percentile Ratio	95th Percentile Ratio	Maximum Krapina Ratio	P^1
Medial Thickness	1.243	1.331	1.395	0.030
Midorbit Thickness	1.614	1.897	2.043	0.033
Lateral Thickness	1.426	1.591	1.561	0.057

[1] Proportion of the modern human intragroup ratio distribution that is greater than the largest Krapina paired ratio.

TABLE 7

Krapina Pairs That Are Likely Different Sexes.

Variable	Pair	Ratio	P1	Female	Male
Medial Thick.	Kr 4 & Kr 6	1.345	0.043	Kr 6	Kr 4
	Kr 3 & Kr 6	1.395	0.030	Kr 6	Kr 3
Midorbit Thick.	Kr 37.5 & Kr 37.7	1.700	0.081	Kr 37.5	Kr 37.7
	Kr 27–28 & Kr 37.5	1.714	0.077	Kr 37.5	Kr 27–28
	Kr 37.5 & Kr 37.10	1.786	0.066	Kr 37.5	Kr 37.10
	Kr 37.4 & Kr 37.5	2.043	0.033	Kr 37.5	Kr 37.4
Lateral Thick.	Kr 37.4 & Kr 37.5	1.455	0.086	Kr 37.5	Kr 37.4
	Kr 37.4 & Kr 37.8	1.481	0.079	Kr 37.8	Kr 37.4
	Kr 6 & Kr 37.4	1.561	0.057	Kr 6	Kr 37.4

[1] Proportion of the model intragroup ratios distribution that greater than the ratio observed for the Krapina pair.

sified as female. For two of the variables, Midorbit Thickness and Lateral Thickness, Kr 37.5 is classified as female and Kr 37.4 is classified as male. Kr 37.8 is classified as female for one variable, Lateral Thickness, and Kr 27–28, Kr 37.7, and Kr 37.10 are all classified as male for a single variable, midorbit thickness. Kr 3 and Kr 4 are both classified as male for Medial Thickness.

DISCUSSION

A more traditional approach to sorting out whether or not the Krapina frontal sample exhibits sex-related sample bias would be to apply standard osteological sexing techniques, specifically subjective assessments of individual robusticity followed by an attempt at sex classification. The present study is essentially a more objective and quantitative approach that, although it analyzes anatomical variation that can be observed subjectively, is readily replicable. Assuming that the modern human model for sex-variable covariance and intragroup variation is applicable, the Krapina samples for all of the sex-covarying variables exhibit significant intergroup sex variation. Krapina samples for two of the variables, Midorbit Thickness and Latreral Thickness, exhibit overrepresentations of females. The sample for the third sex-covarying variable, Medial Thickness, is small (n = 3) with two of the specimens falling as males and the third as female.

A previous study of sample bias among the supraorbital fossils from both Krapina and Vindija *(3)*, that did not employ modern analogies in its analysis, indicated that it is unlikely that the Krapina sample is male or old adult biased. Given the resampling simulation methods employed, Ahern *et al.*'s *(3)* analysis could not specifically discern whether or not the Krapina frontal sample had an overrepresentation of females, although the authors suggested that this and/or an overrepresentastion of yound adults/adolescents was likely. The issue of age-related sample bias in the Krapina frontal sample was not specifically dealt with in the present paper's analysis. However, since adult age variation and sex variation often manifest themselves in similar fashions (i.e., adolescent and young adult anatomy can be confused for female anatomy *(5)*), the apparent 'female' overrepresentation in the Krapina Midorbit and Lateral Thickness samples could be young age overrepresentation or a combination of too many female and young in the sample.

The sex identifications of individual Krapina frontal specimens are 'best bet' identifications for the more fragmentary supraorbital specimens (e.g., Kr 27–28, Kr 37.4, Kr 37.5, and Kr 37.8). No better data is available for these specimens regarding their sex. However, sex identifications for the better preserved specimens, Kr 3, Kr 4, and Kr 6, should be based upon more than the results provided here, since identifications must be based on the gestalt of the specimens, whenever possible. In previous works *(1, 4, 10, 11)*, Kr 3 has been identified as female, while the present study identifies it as possibly male, given the thickness of the medial browridge. The prior identifications have been based on Kr 3's small size, non-projecting browridges, and gracile facial skeleton. Among the modern humans examined for this present study, no significant correlation was found between sex and browridge projection. Although Kr 3's small size and gracile facial skeleton are suggestive that it is a female, perhaps its designation as such should be more qualified given the current analysis. On the other hand, the present results regarding Kr 4 as male and Kr 6 as female are much more in line with past works *(1, 4)*. Schaefer *(12)* interpreted Kr 6 as male based upon the project of the supraorbital torus and the receding frontal. Yet, most others *(1, 4)*, have regarded the specimen as female based on its small size. The results of this study concur with the identification of Kr 6 as female. Again, browridge projection does not seem to be a good indicator of sex, while thickness does.

CONCLUSIONS

Sample sex composition is essential for making most other interpretations about a sample, Krapina or otherwise. If one sex is overrepresented, the sample as a whole will appear different, perhaps significantly so, from a random sample of the same size drawn from the same population. That the Krapina frontal sample appears to have an overrepresentation of females indicates that the actual population from which the sample is drawn was likely more robust than the sample suggests. This is important, in particular, for how the Krapina and Vindija frontal samples are compared. The Vindija sample appears less robust and more like early modern humans compared to Krapina. Such difference cannot be attributed to an overrepresentation of males in the Krapina sample, given the present study's results. Furthermore, Ahern *et al.*'s *(3)* analysis indicates that an overrepresentation of females in the Vindija sample cannot explain the Krapina-Vindija frontal differences. Thus, we are forced to accept that the Krapina – Vindija differences are likely real.

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