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Preservation Bias in the Hominid Krapina Sample? A Randomization Approach

ADAM VAN ARSDALE

Department of Anthropology
University of Michigan
Ann Arbor, MI 48109
USA
E-mail: avanarsd@umich.edu

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Abtstract

The processes which led to the formation of the Krapina hominid sample have been extensively debated with important implications for the interpretation of Neandertal behavior. This paper enters the debate by examining the issue of preservation bias between different skeletal elements within the sample. A null hypothesis of equal preservation among the different elements with deviations from expectation the result of chance alone is tested using an integrated set of re-sampling methodologies. While initial observations suggest an excess of cranial and mandibular elements relative to expectations, additional examination of the quantitative parameters of the sample suggest these findings are consistent with a model based solely on randomness. The null hypothesis, consistent with expectations of intentional burial, can therefore not be rejected. The implications of these results are discussed as they relate to interpretations of the taphonomic processes responsible for the Krapina hominid sample.

INTRODUCTION

The hominid sample from Krapina represents one of the largest known Paleolithic assemblages *(1, 2)*. The assemblage has been the subject of numerous debates regarding the taphonomic processes responsible for its preservation. Among the ideas proposed for preservation status of the Krapina remains are cannibalism *(3–6)*, burial *(7),* and secondary burial practices *(8)*. The interpretation of linear striations on numerous bones as either cut marks or preparation marks has been one important line of evidence in the debate. However, the relative abundance of different skeletal elements has also played a role in resolving the formation vectors responsible for the Krapina sample. This paper further examines the potential significance of the Krapina skeletal element distribution for this determination.

Several factors, in addition to the large size of the sample, make the Krapina distribution noteworthy. Among the intriguing characteristics of the sample is a large number of typically rare elements, such as sixteen patellae and more than seventy identifiable vertebral elements. In contrast, several large bones such as the tibia, radius, and ulna, appear in relatively modest numbers. If certain elements are over-represented relative to other elements it might provide an insight into the processes which led to the formation of the Krapina sample. The resolution of these processes has potentially important consequences for the interpretation of symbolic behaviors among Neandertals.

TABLE 1

MNI calculated for each skeletal element based only on specimens specifically described as adult. Cranial MNI are based on the most preserved temporal bones, the most abundant element. Rib MNI are based on the first rib only. Hand and Feet MNI are based on the most abundant single bone within each category.

Element	MNI	Right	Left	Proximal	Mid-shaft	Distal
Cranium	18	17	18	–	–	–
Mandible	13	–	–	–	–	–
Cerv. vert.	6	–	–	–	–	–
Thor. vert.	3	–	–	–	–	–
Lum. Vert	6	–	–	–	–	–
First rib	4	3	4	–	–	–
Scapula	8	8	5	–	–	–
Clavicle	6	4	6	–	–	–
Pelvis	4	4	3	–	–	–
Humerus	8	8	8	0	3	8
Radius	8	8	1	8	3	1
Ulna	6	6	5	5	4	1
Hand	4	4	1	–	–	–
Femur	4	3	4	3	4	2
Patella	10	6	10	–	–	–
Tibia	5	5	4	4	5	3
Fibula	8	6	8	5	8	3
Foot	8	4	8	–	–	–
TOTAL:	129	86	85	–	–	–

The question of interest here is whether the observed differences in the distribution of skeletal elements within the Krapina represent a real difference in their preservation. The null hypothesis used in this analysis is that the various elements are equally likely to be present in the Krapina sample. One of the aims of this paper is to consider the qualities of the Krapina human skeletal element distribution and what information they provide without overlaying, *a priori,* possible interpretive models. However, as discussed in greater detail below, a rejection of or support for this hypothesis can inform an understanding of what taphonomic processes are at play.

The null hypothesis of equal preservation with deviations expected from randomness alone can be interpreted in two ways. The first interpretation is based on the goal of this analysis to consider the quantitative aspects of the Krapina sample without applying *a priori* expectations about the nature of processes involved in its formation. In this view, the null hypothesis is a model based on the expectations of randomness alone. No model based on bone density, human or animal modification of the materials or other taphonomic processes derived from experimental and theoretical work outside of the Krapina site, are used to generate expectations for what should and should not be preserved within the sample. Instead, the sample is treated only with regard to its internal properties; which bones are preserved in what quantities.

In reality however, the null hypothesis of random deviations from equal expectations can also be viewed as a depicting the expectations of a specific taphonomic model. Specifically, one based on the expectations of intentional burial. Relative to other possible vectors of bone accumulation and preservation, a process of intentional burial is most likely to produce a distribution of equal part presentation (although see 9).

METHODS AND RESULTS

In order to conduct this analysis, the Krapina sample was first divided into eighteen different skeletal element categories representing different segments of the body *(10)*. For each category an MNI for that element was produced on the basis of examination of the materials by the author and the Krapina hominid illustrated catalog *(11)*. Several points about this process must be outlined. First, for categories consisting of multiple bones, such as the skull, the most abundant elements within that category served as a proxy MNI for the category as a whole. In the case of the skull, the temporal bones were in greatest identifiable abundance and were therefore used to gene-

TABLE 2

MNI calculated for each skeletal element based only on all specimens, excluding only those which represent obvious infant or young juvenile individuals. MNI values are calculated in the same manner as those in Table 1.

Element	MNI	Right	Left	Proximal	Mid-shaft	Distal
Cranium	22	18	22	–	–	–
Mandible	16	–	–	–	–	–
Cerv. vert.	6	–	–	–	–	–
Thor. vert.	3	–	–	–	–	–
Lum. Vert	7	–	–	–	–	–
First rib	4	3	4	–	–	–
Scapula	11	11	8	–	–	–
Clavicle	8	7	8	–	–	–
Pelvis	4	4	4	–	–	–
Humerus	10	10	10	0	6	9
Radius	8	8	3	8	5	1
Ulna	9	8	9	5	8	1
Hand	4	4	1	–	–	–
Femur	6	5	6	3	6	2
Patella	10	6	10	–	–	–
Tibia	5	5	5	4	5	3
Fibula	9	9	9	5	8	3
Foot	8	4	8	–	–	–
TOTAL:	150	102	107	–	–	–

rate the categorical MNI. This process was also applied to elements of the hand, foot, and vertebrae (divided between cervical, thoracic, and lumbar units). The MNI value for the ribs was generated on the basis only of first rib preservation owing to difficulties in accurately identifying numerical rib elements below the first. The rib MNI may therefore be an underestimation of MNI relative to other categories.

Finally, two approaches were taken towards treatment of the variation in age of the individual specimens. The first approach considered only obvious and identified adult specimens (Table 1). MNI generated for this approach reflect only those of bones specifically identified as adult individuals. However, since accurate categorical age estimates are difficult for some of the bones, particularly shaft fragments, a second approach treated the entire sample with the only exclusions being obvious infant/young juvenile individuals (Table 2). An attempt was made to exclude immature individuals because of the obvious preservation difference between immature and mature skeletal material.

Results of the cataloguing of categorical MNI data are found in Tables 1 and 2. In addition to the categorical data, MNI were also calculated for each side of the sided elements and for proximal, mid-shaft, and distal categories of shaft elements. These data serve as the basis for subsequent analyses conducted here.

In order to test whether or not the differences in element presence observed within the Krapina sample exceed expectations based on randomness a series of resampling analyses were conducted. The first of these analyses simply compared the observed distribution to equivalent, randomly generated samples. The total number of categorical MNI »parts« were distributed with equal probability between eighteen different bins representing each of the eighteen skeletal element categories. For example, the data utilizing only adult specimens preserves 129 total categorical MNI parts. Therefore, these 129 »parts« were then placed randomly into each of the eighteen different elements. This simulated distribution was then compared to the observed Krapina distribution for each of the eighteen elements. This process was repeated 10,000 times, each time noting whether or not the simulated distribution was equal to, greater than, or less than the observed Krapina distribution for each of the eighteen elements.

A two-sided alpha level of 0.05 was used to assess whether or not the observed Krapina distribution represents a statistically significant excess or deficit of individual elements. These results can be seen in Table 3.

TABLE 3

Results of re-sampling analysis against random expectations. In both treatments of the sample, the cranial and mandibular elements show excessive representation relative to the expectations derived from random sampling alone. Also, the thoracic vertebrae show an under-representation relative to expectations in both treatments. All other skeletal categories show no significant departure from expected levels of preservation.

Element	Adults only	Excluding juveniles
Cranium	excess, $p<0.001$	excess, $p<0.001$
Mandible	excess, $p<0.05$	excess, $p<0.01$
Cerv. vert.	–	–
Thor. vert.	deficit, $p<0.05$	deficit, $p<0.05$
Lum. Vert	–	–
First rib	–	–
Scapula	–	–
Clavicle	–	–
Pelvis	–	–
Humerus	–	–
Radius	–	–
Ulna	–	–
Hand	–	–
Femur	–	–
Patella	–	–
Tibia	–	–
Fibula	–	–
Foot	–	–

The Krapina sample shows an excess of head elements from both the skull and mandible and a deficit of thoracic vertebrae (Table 3). None of the other elements show significant deviations from expectations under a model of randomness. These results are true for both treatments of the sample relating to age with the only difference being a slightly stronger signal of excessive mandibular remains in the treatment which excludes only those specimens obviously representing infant/juvenile individuals. When compared against 10,000 randomly simulated distributions, the observed number of Krapina cranial specimens (temporal bones, specifically) and mandibles were greater than the simulated number in more than 9,750 of the cases. Similarly, the observation of only three thoracic vertebrae was exceeded in more than 9,750 of the cases. The other elements, which are all represented by MNI's of between four and ten, fail to differ significantly from expectations of randomness.

A second question of the sample can be asked at this point in order to put these results into perspective. The first analyses looked at the relative frequency of individual elements within the distribution to identify significant outliers. However, a similar re-sampling process can be used to ask whether or not the sample as a whole differs from a null expectation of randomness. In essence, this second analysis serves as a power check on what can and cannot be said about the distribution of elements within the Krapina sample given the number of elements preserved and the categorical divisions used. While three elements were found to deviate significantly from the null expectations, how many elements, given the properties of the numerical properties of the distribution, would be expected to show significant differences by chance alone?

In this second analysis a re-sampling process identical to the first set of analyses is not only conducted, but imbedded within a second re-sampling process. In this sense, the analysis represents a »nested re-sampling« process. In the first set of analyses, randomly re-sampled preservation distributions were compared to the observed Krapina distribution to identify which elements within the Krapina distribution differed from random expectations. In the nested analysis, a randomly re-sampled preservation distribution is drawn and used as a proxy for the original Krapina distribution. The re-sampled distribution can be viewed as a simulated Krapina distribution with the same basic internal parameters of parts preserved and parts absent, but randomly assorted between the

TABLE 4

Results of nested re-sampling analysis. This table displays the frequency with which the given number of significant differences, out of the eighteen possible categories, were observed based on comparisons against a randomly generated distribution. In no randomized trials were more than nine significant differences observed.

Number of significant differences	Frequency (%)
0	6.3
1	18.3
2	29.0
3	24.1
4	13.5
5	6.0
6	2.1
7	0.4
8	0.2
9	0.1
10	0.0
Mean	2.5
Median	2

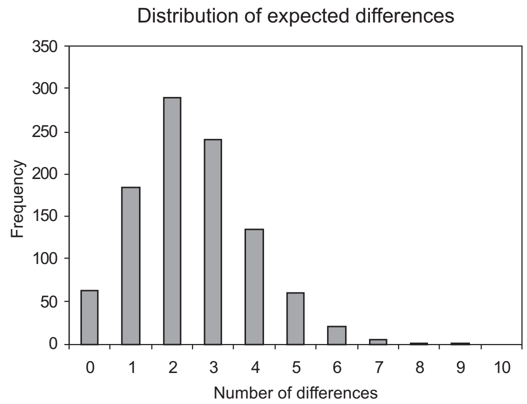

Figure 1. *Histogram displaying the results of a nested re-sampling analysis (see Table 4). Three categorical differences were observed in comparisons between the Krapina sample and randomly sampled distributions. The mean number of differences observed based on random comparisons alone was 2.5.*

different element categories. The same process used to compare the original Krapina distribution to simulated distributions is repeated (in this instance, limited to 1000 trials), but using the new, simulated Krapina distribution instead. This entire process is repeated 1,000 times while keeping track of the number of elements and which elements show significant deviations from random expectations each iteration.

Given the quantitative properties of our sample (again, parts preserved and categorical divisions), the results of the nested re-sampling analysis answer the question of how many significant differences would be expected based on random variation alone. Having observed three significant differences in the initial analyses, the nested analysis should provide information as to whether this is greater or lesser variation than expected on the basis of randomness.

Results for this analysis can be seen in Table 4 and Figure 1. The mean number of significant differences expected by chance alone was 2.5 with a median of two. In 536 of the trials the number of differences were less than observed in the actual Krapina sample, while in 223 of the trials the number of differences were greater than observed in the Krapina sample. Inspecting the histogram of the results (Figure 1) it can be seen that the number of significant differences observed in the Krapina sample fit squarely within the center of the distribution.

DISCUSSION

As stated previously, the null hypothesis employed in this analysis is an attempt to avoid applying external taphonomic model expectations to the Krapina material. It is also, however, a model most likely depicting the expectations of intentional burial. Regardless of interpretive model, it is necessary to more closely consider the two sets of results produced. The first set of results suggests an over-abundance of head elements (both cranial and mandibular) and an under-abundance of thoracic vertebrae. Some caution must be given to the latter of these observations given the difficulty of establishing an accurate MNI based on thoracic vertebral elements and the recognition that were even a single additional specimen added to the MNI count (four instead of three), the results would likely not show a significant deviation from expectations. However, the case for an over-representation of cranial and mandibular parts is more robust. This would seemingly reject the null hypothesis. The over-representation of mandibular and cranial remains and possible under-representation of thoracic vertebral elements suggests a non-random distribution of elements.

However, the results of the first analyses must be interpreted in light of the second analyses. In its context here, the nested re-sampling analysis is acting as a control on the power of the first analysis. Given 18 different element categories and 129 (or 150) MNI parts distributed across those categories, the nested analysis results show how many categories you would expect to find differences by chance alone. Looking at the results presented in Table 4 and Figure 1 it is clear that a finding of two (or three) elements which differ significantly from null expectations is exactly what you would expect to find.

This result does not completely invalidate the initial conclusion that the cranial and mandibular elements are over-represented. It does provide reason to proceed with caution in drawing conclusions about this result. There appears to be an over-representation of cranial and mandibular specimens, but the sample provided by the Krapina site is not large enough to conclude this with statistical certainty. If the sample were larger, it is possible that either more element categories would show significant differences or that the number of categories expected to show significant differences by chance alone would decrease. As the Krapina sample stands now though, and presumably how it will stay, it is not possible to reject our null hypothesis.

The importance of these results for understanding the Krapina sample are that a hypothesis of equal preservation of elements, with deviation from expectation the result solely of random processes alone, cannot be rejected. As stated previously, this can be interpreted as support of the hypothesis of intentional burial. Additionally, these results support the notion that individuals being buried were present in their entirety at the time of burial. These results are consistent with the conclusion drawn by Villa *(12)* that the Krapina sample does not provide enough resolution to distinguish between the differing hypotheses of intentional burial and cannibalism.

Villa *(12)* produces a chart displaying the expected preservation of different elements in burial and non-burial situations. That chart is reproduced below (Figure 2) with the Krapina results added. The Krapina results were scaled to match Villa's roughly 60% preservation rate for cranial elements in burial situations. The results do not differ significantly if the Krapina remains are instead scaled to the 50% cranial preservation rate in

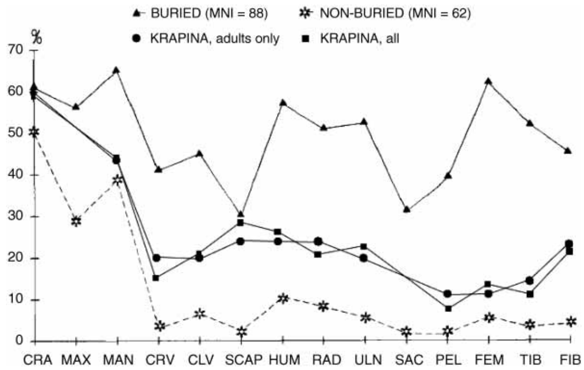

Figure 2. *Depiction of observed levels of preservation across different skeletal elements in Paleolithic burial and non-burial settings (modified from 12). The observed Krapina preservation rates, in both treatments of the sample, appear intermediate to the two categories.*

non-burial settings. Figure 2 clearly shows the Krapina remains appear intermediate in their preservation between the expectations between a burial and non-burial setting.

One possible explanation for the intermediate appearance of the Krapina sample is shallow burial with subsequent trampling activity *(7, 13)*. This process would be expected to result in a large amount of fragmentation and a possible loss of lighter elements, distal elements, and elements geometrically predisposed to breakage. This is in many ways what is observed at Krapina. The shaft fragments show a deficit of proximal and distal elements (Tables 1, 2). In contrast, the patellae, a seldom observed but compact fossil element, appears in high frequency. This might also account for the relatively high appearance of the compact and dense mandibular and temporal elements, as well as the high fragmentation of other cranial elements.

CONCLUSIONS

This analysis tested the hypothesis that the distribution of skeletal elements among the Krapina hominids is the product of an equal likelihood of preservation with deviations the result of chance alone. Using skeletal element MNI data, two sets of analyses were conducted; the first comparing the observed Krapina element distribution to randomly generated simulated distribution. This analysis suggested the presence of an excess number of cranial and mandibular remains and a possible under-representation of thoracic vertebrae. However, a second analysis, consisting of a nested re-sampling approach toward the representation of different elements suggested the mean expectation of significant differences is two to three elements, exactly what is found.

Taken together these results suggest a null hypothesis of equal representation of skeletal parts cannot be rejected. This in turn provides support for the hypothesis of intentional burial among the Krapina hominids. The disparity between the distribution of elements at Krapina and other Paleolithic burial sites can possibly be explained by a suggestion of shallow burial and subsequent trampling.

REFERENCES

1. RADOVČIĆ J 1988 Dragutin Gorjanović-Kramberger and Krapina Early Man: The Foundation of Modern Paleoanthropology. Hrvatski prirodoslovni muzej, Zagreb.
2. WOLPOFF M H 1979 The Krapina dental remains. *Amer J Phys Anthropol 50*: 67–114
3. SMITH F H 1976 The Neandertal remains from Krapina. *Univ Tenn Dept Anth Rprts Invests 15:* 1–359
4. GORJANOVIĆ-KRAMBERGER D 1906 Der diluviale Mensch von Krapina in Kroatien. Ein Beitrag zur Paläoanthropologie. *In:* Walkhoff O (*ed*) Studien über die Entwicklungsmechanik des Primatenskelletes, Volume II. Kreidel, Wiesbaden, p 59–277
5. KLAATSCH H 1923 The Evolution and Progress of Man *(*English translation*)*. Stokes, New York.
6. ULLRICH H 1986 Manipulations of human corpses, mortuary practices and burial rites in Palaeolithic times. *In:* Novotny V V, Mizerova A (*eds*) Fossil Man – New Facts, New Ideas. Anthropos, Brno, p 227–236
7. TRINKAUS E 1985 Cannibalism and burial at Krapina. *J Hum Evol 14:* 203–216
8. RUSSELL M D 1987 Mortuary practices at the Krapina Neandertal site. *Amer J Phys Anthropol 72*: 381–397
9. GARGETT R H 1989 Grave shortcomings: the evidence for Neandertal burial. *Curr Anthropol 30*: 157–190
10. MAREAN C, ABE Y, NILSSEN P J, STONE E C 2001 Estimating the minimum number of skeletal elements (MNE) in zooarchaeology: A review and a new image-analysis GIS approach. *Amer Antiq 66*: 333–348
11. RADOVČIĆ J, SMITH F H, TRINKAUS E, WOLPOFF M H 1988 The Krapina Hominids: An Illustrated Catalog of Skeletal Collection. Mladost, Zagreb.
12. VILLA P 1992 Cannibalism in prehistoric Europe. *Evol Anth 1*: 93–104
13. RUSSELL M D 1987 Bone breakage in the Krapina hominid collection. *Amer J Phys Anthropol 72*: 373–379