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FURTHER INVESTIGATION OF THE SCALE COUNT OF HUMAN HAIR

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In a recent article in this journal, Beeman[1] has published data relative to scale counts of human hair, which he interprets to be at variance with the data of Gamble and Kirk.[2] He states:

1. "The variations in scale count on a single hair would seem to be within the limits of observational error," and
2. "On the basis of these observations, it is the author's opinion that the scale count of a single human crown hair is neither representative of all the hairs of that individual, nor does the scale count differ significantly from individual to individual."

These conclusions appear to be supported by the values listed and the fact that in three out of sixteen cases the variations in counts between hairs from the same individual were greater than the maximum difference in means of different individuals.

It seems evident that the conclusions drawn by Beeman were based partially on improper statistical sampling, and partially on an incomplete comprehension of the necessary method of treating the data. Conclusion 1 depended on data from a single hair from which were obtained one, five, and twenty-five counts. It is scarcely credible that this rather far reaching generality could be drawn from the data for a single hair. In fact, Gamble and Kirk found scale counts on single hairs which varied over a range of as much as 14.2, a variation greater than any but one of Beeman's differences for different individuals. The contrary conclusion reached by Gamble and Kirk was based on 2100 counts which showed ranges for the single hair as great as those for the individual.

Conclusion 2 actually rests on data obtained with 5 counts per hair. While 5 data may, in certain instances, be significant, such an assumption is not justified without proper consideration of the distribution and type of data. Five values from chemical analysis which vary moderately around a single correct value would allow significant treatment. When data show a normal distribution combined with a wide range of values, a great many more observations are necessary to establish a correct mean and a complete

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[1] Beeman, J., "The Scale Count of Human Hair," J. Crim. Law & Criminol., (Police Sci. Sec.) *32*, (5):572 (Jan.-Feb., 1942).

[2] Gamble, Lucy H. and Kirk, Paul L., "Human Hair Studies. II. Scale Counts," J. Crim. Law & Criminol., (Police Sci. Sec.) *31*, (5):627 (Jan.-Feb., 1941).

range. Thus, a single count can fall anywhere within this broad range, and 5 counts must, by chance alone, sometimes fall in such a manner as to give a completely erroneous mean, an incomplete range, and a distorted distribution.

Scale counts of single and multiple human hairs of an individual both yield (a) a normal distribution curve and (b) a wide range of values. As shown by Gamble and Kirk, a mean calculated from less than 75 to 100 values is not representative. It is possible that some hairs may vary so greatly from point to point as to require 500 to 1000 counts to establish a truly representative mean. It is obviously necessary that enough values be collected to yield a typical mean before that mean is to be considered characteristic of the hair.

The Editor's note accompanying Beeman's article, in which it is stated that increasing the number of counts per individual could not reduce the amount of variation between maximum and minimum values is literally true, but entirely beside the point. The discrepancy is not concerned with maximum and minimum values but with differences between means. Since there are no significant means listed, the difference between them cannot be significant. Increasing the number of counts would actually increase the variation between maximum and minimum values and would have the more important effect of increasing the precision of the mean. It should be noted also, that Beeman's method of presenting single hair means could not give the total range for the single hair unless all counts were numerically the same, since the upper and lower values are lost in averaging.

It is clear that the issue is actually one of the validity of sampling. Unless enough areas on the hair are counted to represent all of the possible numbers of scales per unit length, and to yield these values in the same proportion as they occur on the hair, the data cannot completely represent the actual condition of the scales. With scale count ranges which vary by as much as 14 units, it is to say the least, ill-advised to attempt the description of the hair in terms of only 5 counts. In our cases[3] E. J. S., L. T. R., B. B., and D. H., the effect on the means and ranges of reducing the number of counts is quite apparent.

Another source of difficulty which may have been present in the investigation of Beeman is a tendency toward selection of the regions for counting. It has been observed in student use of scale counts that the operator occasionally chooses areas in which the scales are prominent and regular and therefore easy to count, rather than to count random areas which will include all of the variations of the hair. It is necessary to avoid portions of the hair on which the scales have been destroyed (by waving with heat or

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[3] Supra.

Table I

HUMAN HAIR SCALE COUNT MEANS
(No. of Scales per 0.2 mm. Length)

Ind.	No. of counts per hair	Hair 1	2	3	4	5	Average of means	Range of Scale Counts
1	5	22.88	23.74	24.88	25.17	25.74	24.45	2.86
	100	24.17	24.25	24.52	24.50	24.57	24.40	.40
2	5	20.58	22.59	22.88	23.74	25.74	22.82	5.16
	100	23.04	23.04	23.05	22.84	23.15	23.02	.31
3	5	19.16	19.45	22.59	22.88	23.45	21.45	4.29
	100	21.92	21.84	21.98	21.98	22.08	21.96	.24
4	5	22.09*	22.58	23.80	24.54	24.54	23.56	2.45
	100	22.94*	23.84	24.21	24.18	23.87	23.80	1.27
5	5	21.16	21.16	21.74	21.74	26.31	22.45	5.15
	100	22.58	22.92	22.78	22.65	23.12	22.81	.54
6	5	24.88	25.45	26.88	26.88	27.46	26.31	2.58
	100	26.27	26.31	26.28	26.30	26.43	26.31	.16
7	5	22.09	23.07	23.07	26.26	26.75	24.42	4.66
	100	23.52	24.29	24.33	24.39	23.51	24.01	.88
8	5	23.74	24.88	25.45	27.46	28.31	26.03	4.57
	100	26.20	26.17	26.15	26.07	26.24	26.17	.17
9	5	23.17	23.45	23.74	26.88	27.46	24.88	4.29
	100	25.13	25.08	25.10	25.23	25.15	25.14	.15
10	5	25.17	26.31	26.31	26.88	27.74	26.46	2.57
	100	25.41	25.43	25.35	25.41	25.37	25.40	.08
11	5	25.17	26.60	28.03	28.89	29.17	27.60	4.00
	100	28.40	28.36	28.36	28.40	28.40	28.39	.04

* Permanently waved hair.

chemically, etc.), but any further selection must be avoided. In many instances it is only possible to identify all of the scale edges by focussing slightly up and down to bring each edge in sharp focus. Failure to do this will result in low and irregular counts.

In order that the question raised by Beeman be further tested in a manner analogous to his, but with enough counts to have some meaning, a further set of data, shown in Table I, was collected. Five hairs from each of 11 persons were counted, 100 counts being made on each of 55 hairs. In order to test the variations introduced by inadequate sampling, the first 5 counts taken on each of the hairs were abstracted, to yield exactly the same sort of data as that published by Beeman. They were rearranged in the table in the order of ascending values of the smaller number of counts to agree with Beeman's method of presentation.

Examination of the figures presented show the same effect that Beeman found when only five counts were made on a hair, but also show quite decisively that the effect is nullified when 100 counts are made. This is considered to be a clear demonstration that the sampling employed by Beeman was entirely inadequate and that our original conclusions are still not brought into question. Individuals *2*, *5*, and *8*, all show differences in the five count means of about 5 units, with differences of 2 and 3 units common throughout all sets of such means. The largest difference observed in any of the 100 count means is for individual *4* who had a maximum difference of 1.3 units. This was obtained on hair which had been permanently waved, a factor which was earlier noted to produce rather large variations. In no other individual were differences of as much as 1 unit found, i. e., ± 0.5 from the over-all mean, a value which checks well with our earlier findings. It is entirely evident that 5 count means will be expected to give variations between hairs from the same individual which are nearly as great as variations between individuals, as concluded by Beeman, but it is equally clear that the expenditure of enough effort to obtain an adequate number of counts will yield means which are entirely significant as to the individual.

In order to utilize the available data completely, the ranges were tabulated in the same manner as the means and are presented in Table II. The values of the ranges show essentially the same effect as shown by the means. In no case are 5 counts sufficient to establish a range, nor, obviously a distribution. The ranges are, however, in good agreement when 100 counts are taken.

The original statement of Gamble and Kirk as to the significance of scale counts is not a matter of "opinion." In both the original and the present data it is seen that the scale count of a single hair is representative of the individual when enough counts are properly taken to obtain approximately true means and ranges. This does not mean that some exceptions may not be found in a more extensive study. Beeman's case *3* would appear to include one hair which is a definite exception to the rule. If we can assume that this was not the result of accidental contamination, it would require an explanation based on an occasional variable hair which was not encountered in our study. It is well known that body hairs frequently include an abnormal atypical specimen. With no evidence on the point it would not be surprising to find a similar behavior of occasional head hairs. It is notable that in Beeman's 86 hairs and in Gamble and Kirk's 3322 hairs, only one such abnormally high

Table II

HUMAN HAIR SCALE COUNT RANGES

(No. of Scales per 0.2 mm. Length)

Ind.	No. of counts per hair	Hair† 1	2	3	4	5	Over-all range for 5 hairs
1	5	20.0-27.2	21.5-25.7	22.9-28.6	22.9-25.7	24.3-27.2	20.0-28.6
	100	18.6-30.0	18.6-30.0	18.6-30.0	18.6-30.0	18.6-30.0	18.6-30.0
2	5	18.6-24.3	21.5-24.3	18.6-25.7	22.9-25.7	22.9-27.2	18.6-27.2
	100	18.6-28.6	18.6-27.2	18.6-27.2	18.6-27.2	18.6-28.6	18.6-28.6
3	5	17.2-20.0	17.2-21.5	21.5-24.3	21.5-25.7	21.5-25.7	17.2-25.7
	100	17.2-25.7	17.2-25.7	17.2-27.2	17.2-25.7	17.2-27.2	17.2-27.2
4	5	22.1-23.3*	22.1-23.3	19.6-27.0	23.3-25.8	24.5-24.5	19.6-27.0
	100	19.6-28.2*	19.6-28.2	19.6-29.4	19.6-28.2	19.6-27.0	19.6-29.4
5	5	18.6-24.3	17.2-24.3	20.0-22.9	20.0-24.3	25.7-27.2	17.2-27.2
	100	17.2-28.6	17.2-28.6	17.2-27.2	17.2-28.6	17.2-28.6	17.2-28.6
6	5	22.9-28.6	22.9-28.6	24.3-28.6	24.3-28.6	24.3-31.5	22.9-31.5
	100	22.9-31.5	22.9-30.0	22.9-31.5	22.9-30.0	22.9-31.5	22.9-31.5
7	5	19.6-25.8	20.9-27.0	20.9-27.0	25.8-27.0	23.3-29.4	19.6-29.4
	100	17.2-29.4	19.6-31.9	19.6-31.9	17.2-29.4	17.2-31.9	17.2-31.9
8	5	21.5-25.7	21.5-28.6	24.3-27.2	22.9-32.9	24.3-30.0	21.5-32.9
	100	21.5-32.9	21.5-32.9	21.5-31.5	21.5-32.9	21.5-31.5	21.5-32.9
9	5	21.5-25.7	21.5-25.7	22.9-24.3	24.3-28.6	25.7-28.6	21.5-28.6
	100	20.0-30.0	20.0-30.0	20.0-30.0	20.0-30.0	20.0-30.0	20.0-30.0
10	5	24.3-25.7	25.7-27.2	24.3-28.6	25.7-28.6	27.2-30.0	24.3-30.0
	100	20.0-30.0	20.0-30.0	20.0-30.0	20.0-30.0	20.0-30.0	20.0-30.0
11	5	24.3-28.6	25.7-27.2	25.7-30.0	27.2-30.0	25.7-31.5	24.3-31.5
	100	22.9-34.3	22.9-32.9	22.9-32.9	22.9-32.9	22.9-32.9	22.9-34.3

* Permanently waved hair.

† Hair designations correspond to similar hair of Table I.

scale count mean appeared, the highest previous scale counts being 39.7. If by chance such an abnormal hair were evidence in a criminal case, it could not constitute evidence against a suspect unless other hairs indistinguishable from it could be obtained from the individual. In this event, it would be more valuable as evidence than would a normal hair.

The method of individualizing hair through use of scale counts and other factors has been employed in this laboratory for a considerable number of years. During that time it has been unequivocably shown that the method was successful when enough counts were taken, regardless of any abstract argument which can be brought against it.

Without desiring to enter into any controversy in this matter, we nevertheless feel that it is unfortunate that criticism based on an inadequate statistical treatment and incomplete data should be brought before a group of readers many of whom have no familiarity with statistical methods and would find it difficult to judge the correctness of the conclusion involved. It is for this reason only that we have expended the necessary time to demonstrate again the obvious validity of our original conclusions.