A STUDY ON DIFFERENCES IN PHYSICAL DEVELOPMENT BY SOCIO-ECONOMIC STRATA

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1. The author took somatometric measurements on fifty-five school children in the months of January and February, 1941, in Calcutta. Twenty-eight and thirteen of them were the students of Calcutta Corporation Free Primary Schools in Fern Road, Ballygunge and in Bijoy Mukherjee Lane, Bhowanipore, respectively. The remaining fourteen belonged to the Model School in Lansdowne Lane, Bhowanipore. The last one is a public school for which the lower economic groups would rarely be able to find the necessary school fees. On the other hand, average and upper middle class families would consider it beneath their dignity to send their children to a free school. Thus the children in the first two and the last school broadly represent two different socio-economic strata; the first two that of the poor and the last one that of the well-to-do or more of the middle class people.

2. The measurements were taken to collect evidence on the relation between physical development of the child and the economic condition of the family. Therefore, keeping other factors of variation as constant, we can show from this study whether (i) the children of the three schools have the same type of physical development, or (ii) they represent three entirely different types, or (iii) the children of the public school differ significantly from those of the two free schools. Needless to say, two free schools, instead of one, were selected for study as a control to establish the difference between the two economic strata.

3. To avoid variation due to differences of sex, age, region or communities all those measured were six years' old Bengali Hindu boys. Furthermore, since the physical types of Indian people have been shown by several authorities to vary for different castes and communities (Risely; Mahalanobis, Mazumdar and Rao), the distribution of these boys by their caste-groups is given in Table 1 below.

TABLE 1.

school	number			percentage	
	caste hindu	scheduled castes	total	caste hindu	scheduled castes
(1)	(2)	(3)	(4)	(5)	(6)
Ballygunge—free	20	8	28	71	29
Bhowanipore—free	10	3	13	77	23
Bhowanipore—public	11	3	14	79	21
total	41	14	55	75	25

It is apparent from the table that there is no significant difference between the three samples as regards their caste distribution. An application of the Chi-square test on the above frequencies (with due correction for the figures of less than five in two cells) gave a value of 0.122 for two degrees of freedom, while the probability limit at the five per cent level of significance for the same degrees of freedom is 5.991.

4. The measurements taken on the boys were the following: Heights to Vertex, Acromion, Radiale, Stylion, Trochanterion, Tibiale and Sphyrion; Girth of Thorax; and Body Weight. The techniques followed in taking these measurements are those laid down in Rudolf Martin's *Lehrbuch der Anthropologie*. All the measurements were taken on the left side. The boys were clad only in a pair of shorts or small *dhoti*, and the upper part of the body was bare. It was not, therefore, difficult to locate the landmarks for the measurements. The trochanterion could be felt by moving fingers over their clothes, since none of these boys was unusually fat. To eliminate variations in height due to time of the day, the measurements were all taken between one and three in the afternoon. This period was more than three hours after the main meal of the day, but within an hour or two of a small snack. The boys' clothing would weigh very little, certainly less than a pound.

5. *Characters analysed*: Stature; weight; girth of thorax, calculated as the mean of the measurements taken respectively after breathing-in and breathing-out; lengths of femur and tibia, obtained indirectly from heights to trochanterion, tibiale and sphyrion; lengths of humerus and radius, similarly calculated from heights to acromion, radiale and stylion. Table 2 gives the mean values of the above mentioned characters for the three samples separately, and for the pooled data.

TABLE 2

character	mean values			
	Ballygunge free ($n=28$)	Bhowanipore free ($n=13$)	Bhowanipore public ($n=14$)	pooled data ($n=55$)
(1)	(2)	(3)	(4)	(5)
stature	1135.61	1133.54	1181.29	1146.76
body weight	175.71	172.69	192.79	179.34
girth of thorax	548.43	552.54	561.21	552.65
length of femur	270.46	269.08	287.29	274.42
length of tibia	253.21	248.38	266.43	255.43
length of humerus	210.96	202.15	218.21	210.72
length of radius	155.75	156.69	163.93	158.05

Stature, Girth of Thorax and the lengths of limb bones are in millimetres; Body Weight in hectagrams.

It will be seen from the table that the mean values of the public school sample are consistently higher than those of the two free school samples. Between the two free school samples with the exception of the girth of thorax and the radius, the school at Bhowanipore shows a lower value for all the characters than the school at Ballygunge. However, for the girth of thorax and the radius also the differences between the two free school samples are smaller than the corresponding differences between either of them and the public school sample.

6. Table 3 gives the standard deviations and the coefficients of variation of the seven characters for the three samples separately, and for the pooled data.

TABLE 3

character	Ballygunge —free	Bhowanipore —free	Bhowanipore —public	pooled data
(1)	(2)	(3)	(4)	(5)
	Standrd deviation			
stature	52.45	64.81	56.60	56.44
body weight	10.48	30.15	24.07	23.40
girth of thorax	21.85	32.50	43.40	29.85
femur	17.72	21.62	23.89	20.21
tibia	18.06	25.42	22.41	20.02
humerus	11.16	30.88	10.77	18.01
radius	9.45	14.99	14.66	12.00
	coefficient of variation			
stature	4.62	5.72	4.80	4.92
body weight	11.09	17.46	12.95	13.05
girth of thorax	3.98	5.88	7.73	5.40
femur	6.55	8.03	8.32	7.36
tibia	7.13	10.23	8.41	8.19
humerus	5.29	15.28	9.06	8.55
radius	6.07	9.57	8.94	7.65

The standard deviations are the estimates of the population from which the samples were drawn, and have been obtained by dividing the sum of squared deviations from the sample mean by the total degrees of freedom, $n-1$.

Although the characters are seen to have different orders of variability for the three samples, in no case, compared with the available somatometric data from other studies, the variability seems to be beyond the human range. Furthermore, the differences in variability of the three samples are mostly due to sampling fluctuation, and are the result of the small number of boys under consideration. This is shown in Table 4

which gives the values of variance ratio derived from the corresponding variances of the characters for the three samples.

TABLE 4

character	variance ratio		
	Ballygunge (free) & Bhowanipore (free)	Ballygunge (free) & Bhowanipore (public)	Bhowanipore (free) & Bhowanipore (public)
(1)	(3)	(3)	(4)
stature	1.5268	1.1670	1.3084
body-weight	2.3955*	1.6431	1.4579
girth of thorax	2.2124*	3.9453*	1.7833
femur	1.4886	1.8176	1.2210
tibia	1.9811	1.5397	1.2867
humerus	7.6554*	3.1382*	2.4397
radius	2.5162*	2.4066*	1.0455

*significant at P = .05

The table shows that the variance ratios are significant only in seven out of the total twenty-one cases of comparison.

7. Table 5 gives the coefficients of correlation between all characters in the three samples, and for the pooled data.

TABLE 5

Character	coefficient of correlation			
	Ballygunge free	Bhowanipore free	Bhowanipore public	pooled data
(1)	(2)	(3)	(4)	(5)
stature & weight	.8596	.7663	.8227	.8282
stature & girth of thorax	.7269	.8402	.6483	.7337
stature & femur	.7250	.9265	.8535	.8053
stature & tibia	.8649	.9090	.9303	.8920
stature & humerus	.6803	.8149	.9220	.7736
stature & radius	.5604	.9267	.0611	.0728
weight & girth of thorax	.8647	.7488	.8388	.8307
weight & tibia	.5998	.7432	.7781	.6791
weight & humerus	.5369	.6562	.7637	.6228
weight & radius	.4246	.5881	.7126	.5366
girth of thorax & femur	.5748	.7230	.6208	.6215
girth of thorax & tibia	.5947	.7719	.6667	.6295
girth of thorax & humerus	.4847	.6060	.5740	.5361
girth of thorax & hadius	.4953	.8476	.5032	.5806
femur & tibia	.5695	.9246	.8118	.7151
femur & humerus	.4419	.7303	.7470	.5877
femur & radius	.4562	.8541	.4456	.5476
tibia & humerus	.6501	.8905	.8628	.7138
tibia & radius	.5757	.7794	.8943	.6540
humerus & radius	.2048	.6872	.6161	.4235

It will be seen from the table that all the characters are positively correlated with one another and, with the exception of the value of the coefficient between humerus and radius for the Ballygunge-free school sample, which is below the level of significance, (Fisher 1948), the magnitudes of the coefficient are fairly high. The highest values are generally exhibited between the stature and the other characters.

8. Variations in the corresponding values of the coefficients for the samples are not very marked, and in most cases due to sampling fluctuation. This is shown in Table 6 which gives the test of difference between the corresponding coefficients of the three samples.

TABLE 6

t-test of significance of difference between the correlation coefficients[1]

characters	Ballygunge free & Bhowanipore free	Ballygunge free & Bhowanipore public	Bhowanipore free & Bhowanipore public
(1)	(2)	(3)	(4)
stature & weight	0.750	0.426	0.290
stature & girth of thorax	0.801	1.242	0.343
stature & femur	1.883	1.006	0.780
stature & tibia	0.560	0.384	0.797
stature & humerus	0.834	1.273	1.768
stature & radius	2.675(*)	2.320(**)	0.369
weight & girth of thorax	0.912	0.682	0.217
weight & femur	0.122	0.213	0.719
weight & tibia	0.708	0.229	0.796
weight & humerus	0.498	0.605	0.927
weight & radius	0.592	0.601	1.005
girth of thorax & femur	0.693	0.519	0.164
girth of thorax & tibia	0.903	1.057	0.097
girth of thorax & humerus	0.463	0.136	0.285
girth of thorax & radius	1.882	1.918	0.024
femur & tibia	2.601(*)	1.348	1.111
femur & humerus	1.215	0.101	1.125
femur & radius	1.947	2.189(**)	0.030
tibia & humerus	0.196	1.258	1.210
tibia & radius	1.037	0.519	0.458
humerus & radius	1.956	0.342	1.391

(*)-Significant at P=.05

(**)-Significant at P=.01

[1]The test is based on the z transformation of the correlation coefficients as suggested by R. A. Fisher (1948).

The table records a significant difference only in the case of four out of the total of sixty three sets of comparison.

9. It is how evident from the above analysis that the variablity and mutual correlation of the seven characters are of similar order in the three samples. There-

fore, the pooled values shown in column 5 of Tables 3 and 5 would give a proper representation of these parameters. Consequently, the difference between the three sets of data should be ascertained finally from the mean values.

10. In view of the main object of this study, which is to differentiate the three samples according to the physical development of the boys, it is necessary to observe how the three groups behave when all the characters are considered together. Thus, to establish the *group behaviour* of these boys, a multi-variate analysis of the three samples is indispensable. For this purpose the D^2-statistic suggested by Professor Mahalanobis and developed by his school in Calcutta has been used. According to the theoretical implication of this statistic the differentiation is not affected by the differences in sample size of the characters chosen, or by the correlation between the characters. Otherwise, a large sample of some characters, or a very high correlation between some of them could have given an unreal magnification of the *real* difference between the groups, and this cannot be completely eliminated even by the reduced Coefficient of Racial Likeness devised by Professor Karl Pearson (Rao, 1948). The derivation of the D^2 values was as follows.

11. The means of the characters in the three samples were first expressed in terms of the pooled standard deviation units (c.f.col.(5) of Table 3). This is shown in Table 7 below. The characters are now represented by their abbreviation in upper case letters.

TABLE 7

	mean values expressed in pooled standard deviation units		
characters	Ballygunge —free	Bhowanipore —free	Bhowanipore —public
(1)	(2)	(3)	(4)
S	20.1207	20.0840	20.0300
W	7.5090	7.3799	8.2389
G	18.3729	18.5106	18.8010
F	13.3825	13.3142	14.2152
T	12.1095	11.8785	12.7418
H	11.7135	11.2243	12.1100
R	12.8825	12.0603	13.5591

12. A set of transformed characters were then obtained from the coefficients of correlation shown in column 5 of Table 5. These characters are independent of one another, and it will be seen from the formulae used to derive them that besides showing the *distance* between the three samples, these characters would show at any stage

whether an addition of a character is contributing any extra information or not. The transformed characters have been derived from the following formulae: (Rao; 1949, Appendix in Mahalanobis, Mazumdar and Rao, 1949).

transformed characters	*variance* $(y \times y)$
$y_1 = S$	1
$y_2 = W - a_{21}S$	$1 - a_{21}b_{21}$
$a_{21} = b_{21} = r_{s.w}$	
$Y_3 = G - a_{31}S - a_{32}W$	$1 - a_{31}b_{31}$
$a_{31} = b_{31} = r_{s.g}$	$- a_{32}b_{32}$
$a_{32} = b_{32}/cov.(y_2y_2)$	
$b_{32} = r_{wg} - a_{21}b_{31}$	
.....	
$y_p = P - a_{(p.\,p-1)}(P-1) - \ldots - a_{p-1}S$	$1 - a_{(p.\,p-1)}x$
	$b_{(p.\,p-1)}$
	$- \ldots\ldots\ldots$
	$- a_{p-1}b_{p-1}$

The following equations with their variances have been obtained by working out the formulae given in the previous paragraph.

transformed characters	*variance*
$y_1 = S$	1.0000,0000
$y_2 = W - 0.8282y_1$	0.3140,8476
$y_3 = G - 0.7101,5754y_2 - 0.7337y_1$	0.3032,8391
$y_4 = F - 0.1840,7205y_3 + 0.1128,6590y_2 - 0.8053y_1$	0.3372,1485
$y_5 = T + 0.0390,3763y_4 - 0.0573,8392y_3 + 1899,5090y_2 - 0.8920y_1$	0.1914,0321
$y_6 = H - 0.1049,9861y_5 + 0.1003,5043y_4 + 0.0619,2772y_3$ $+ 0.0569,7672y_2 - 0.7736y_1$	0.3938,5271
$y_7 = R + 0.2483,1166y_6 - 0.2284,0037y_5 + 0.0446,6176y_4$ $- 0.3351,1240y_3 + 0.0651,0128y_2 - 0.6726y_1$	0.4772,7257

13. The transformed characters for the three samples can be calculated from these final equations and the mean values with unit standard deviations given in Table 7. This is shown in Table 8. This table gives the final set of the transformed characters, which means that each of the values derived for the three schools from the above

equations has been divided by the standard deviation of the respective transformed character.

TABLE 8

transformed character	Ballygunge —free	Bhowanipore —free	Bhowanipore —public
(1)	(2)	(3)	(4)
y_1	20.1207	20.0840	20.0300
y_2	−16.3365	−16.5127	−16.2300
y_3	18.3617	18.7881	17.9840
y_4	− 9.8421	−10.0024	− 9.4527
y_5	−19.1508	−19.0853	−19.2822
y_6	− 5.4828	− 6.1785	− 5.8082
y_7	− 5.6455	− 5.6061	− 5.2873

Now subtracting the corresponding values and squaring and adding them the D^2 values are calculated for the three samples.

TABLE 9

characters	D^2-statistics		
	Ballygunge (free) & Bhowanipore (free)	Ballygunge (free) & Bhowanipore (public)	Bhowanipore (free) & Bhowanipore (public)
(1)	(2)	(3)	(4)
s	0.0013	0.0550	0.7157
s+w	0.0324	0.6063	0.7956
s+w+g	0.2142	0.8090	1.4422
s+w+g+f	0.2399	0.9606	1.7444
s+w+g+f+t	0.5256	0.9779	1.9069
s+w+g+f+t+h	1.0096	1.0838	2.0440
s+w+g+f+t+h+r	1.0133	1.1505	2.1456

14. The following conclusions emerge out of the D^2 analysis of the data:

(a) All the seven characters have the power to differentiate the groups, but their effect is not uniform for the three sets of comparison.

(b) Stature does not differentiate the two free school samples, but its effect in differentiating the free school samples from the public school sample is fairly well marked, and it is particularly so between the two samples at Bhowanipore.

(c) Body-weight, after stature, contributes very little to the differentiation of the Balygunge-free and the Bhowanipore-public school samples, slightly between the two free school samples, and a little more between the free and the public school samples at Bhowanipore.

(d) The introduction of the girth of thorax somewhat increases the *distance* between the two free school samples, while its effect on the other two comparisons is not so marked. The effect is, however, greater between the free and the public school samples at Bhowanipore than between the free school sample, at Ballygunge and the public school sample at Bhowanipore.

(e) Femur at this stage has the least to contribute to the differentiation between the two free school samples, but appreciable amount between the free and the public school samples at Bhowanipore, and also some between the free school sample at Ballygunge and the public school sample at Bhowanipore.

(*f*) It is interesting to observe that the introduction of tibia and humerus after the above four mesurements sharply increases the *distance* between the two free school samples, but their effect on the free and the public school samples at Bhowanipore is comparatively very little, and that between the free school sample at Ballygunge and the public school sample at Bhowanipore is almost negligible.

(g) Finally, radius has the least to contribute to the differentiation between the two free school samples, but some between the other two comparisons.

15. It is evident from Table 9 that the two free school samples are closer to each other than the position of either of them with respect to the public school sample. This feature is very clearly marked when the D^2 values are calculated from the three measurements generally used to determine the constitutional type of a person, viz. stature, body-weight and girth of thorax. There is no appreciable change in the relative *distance* between the three school samples with the introduction of the length of femur, but, as stated above, the lengths of two other limb bones, viz. tibia and humerus, considerably affect the *distance* between the two free school samples. Since the relative *distance* between the public school and either of the two free school samples remains much the same for all the seven characters, the change due to the lengths of tibia and humerus sharply increase the *distance* between the two free school samples in the final set of the D^2 values for the seven characters. As a result, the *distance* between the two free school samples finally becomes 1.0133, while the *distance* between the free school sample at Ballygunge and the public school sample records a value of 1.1505. Still the public school sample is seen to be further *away* from the two free school samples and the *distance* between the free school sample at Bhowanipore and the public school remains as high as 2.1456.

16. Referring to Table 2 we can see that the boys of the public school are different from those of the free schools in the fact that they are taller, weigh much more, have a broader chest and greater lengths of the limb bones. Between the two free schools again the boys at Bhowanipore show a poorer physique than those at Ballygunge. Thus, although the public school is also at Bhowanipore and the size of the sample obtained from this school is nearly the same as that from the free school at Bhowanipore, there is a marked difference between the types of boys belonging to these two schools. And this difference between these two samples finally confirms

the view that the economic condition of families has indeed a significant bearing on the physique of family members.

17. It is not possible to explain from the present data why the two free school samples are differentiated particularly by the lengths of some limb bones, while they are almost identical as regards the stature and the body-weight. But the fact that, even with the small samples and the few characters under consideration, such differentiations could be detected by the D^2-statistic, indicate the high order of reliability and precision one can expect by using this statistic in biometric studies.

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