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Genetic Variance Estimates and Familial Resemblance for Body Size Traits

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Abstract. To study genetic contribution to complex body size traits, the intrafamilial correlation and regression analyses along with twin study method have been used. The data are based on a sample of 45 MZ and 101 DZ twin pairs, their 125 singleton siblings, 104 fathers and 103 mothers in 146 Punjabi families living in Chandigarh, India. Twin study gives no evidence of inequality of means and variances between zygosities. Within-pair genetic variance ratios, correlations, regressions of offspring on midparent and single parent are all significant at 0.1%, thus indicating strong genetic component. Heritability estimates are higher for longitudinal body traits than the breadth dimensions. The resemblance of the children with the parents of either sex is not equal. Higher maternal influence is indicated for a number of body traits. The results on familial correlations do not support the hypothesis of sex-linked inheritance for any of the traits considered in this investigation. These results have been compared with those from other such studies.

Key words: Genetic variance, Heritability, Familial correlations, Body measurements, Twins, India

INTRODUCTION

In the familial correlation studies done to date, stature and to a lesser extent body weight are the measurements which provide the greatest number of samples for comparisons [for reviews, see 9,12,15,23]. Significant genetic influences upon stature and weight have been documented in these studies. Mueller [15] in his review of 24 such studies, has reported that parent-child correlations for these two traits are considerably higher in

European than non-European samples. There is a great deal of variation among different studies in the reliability of measurements and sample sizes and these have been discussed by Himes et al [12]. The recent trend in this field is studies involving a large number of body traits including stature, weight and subcutaneous fat [11,16,18,19,21,22,30].

Twin studies have also shown high heritability estimates for these morphological traits [5,6,17,18,26], and some studies have also analyzed data both on twins and their families [11,19].

The present study illustrates data involving a number of body traits on Punjabi families with twins. Christian's method of quantitative twin data analysis [2,4] has been used. In the family data, besides intrafamilial correlations, results on some regression coefficients are also presented. The regression coefficients should be preferred over correlations for statistical and theoretical reasons. In fact, their sampling variance is independent of the actual value of the coefficient and they are not affected by selection of parents [8].

MATERIALS AND METHODS

Eighteen body measurements were taken on a sample of 45 MZ and 101 DZ twin pairs along with their first-degree relatives in 146 families: 125 singleton siblings, 104 fathers and 103 mothers. The families belonged to the middle and upper socioeconomic classes of the urban Punjabi population of Chandigarh, India. Zygosity of twins was determined on the basis of concordance for various genetic markers: A_1A_2BO, MN, CcDEe, Kell and Duffy blood groups besides PTC tasting ability and ABH secretor factor. Measurements were taken with standard anthropometric techniques [14]. Both members of twin pairs were measured on the same day, while the other family members were measured in subsequent visits to their households.

The analysis of twin data was done following Christian's method [2-4]. The first step in this analysis was to test the equality of means between MZ and DZ twins for each of the 18 variables studied. The t' test based on the nested or hierarchical structure of twin data [3] was used for this purpose. In this, the among-pair mean squares of MZ and DZ twins were used as the error term because the two members of a pair could not be considered independent of each other. Heterogeneity of variance between zygosities was tested by a two-tailed F' test comparing the sum of the mean squares within and among DZ pairs with the corresponding sum for MZ pairs. Different estimates of genetic variance [2] and heritability coefficients [8] were then calculated.

In the family data analysis, the first problem was that of age and sex differences between individuals for growth traits, since they are known to vary with age and sex even during adulthood. So the data were normalized by converting them into standard scores, thereby eliminating both linear and nonlinear differences. The growth norms used were based on a cross-sectional study of the reference population (unpublished data). The resulting scores would have a mean of zero and standard deviation of 1.0 since the adjustment was made in their own generation both in children and parents. These standard scores were in turn used to compute intrafamilial correlations and regression of offspring on parent for all possible combinations of son, daughter, and offspring, with father, mother and midparent.

RESULTS AND DISCUSSION

Twin Data Analysis

Results of the twin data analysis are presented in Table 1. The t' tests reveal no differences in the means of the body traits considered, indicating that they are not influenced by the type of twinning. There is also no evidence of variance heterogeneity between zygosities. This situation may partly be attributed to high genetic determination of these traits.

These results show that the within-pair estimates of genetic variance are valid for all traits. All these estimates are highly significant ($P < 0.001$). Genetic variance ratios are highest for longitudinal traits. Falconer's heritability estimates also show similar results, stature being more heritable than breadth measurements. There is one comparable study based on similar analysis on Belgian twins [7]. Genetic variance ratios in Punjabi twins are higher, but both studies show significant genetic variability in body traits and both find no heterogeneity of variance.

Table 1 - Twin data analysis: estimates of heritability and genetic variance

Trait	Equality of means t' test	Equality of variances F' test	Estimates of genetic variance: Within-pair F	Within-pair P	Among-component F	Among-component P	Falconer's heritability h^2
Weight	0.05	1.08	12.32	0.000	1.12	0.334	0.56
Stature	−0.17	1.04	16.79	0.000	1.07	0.401	0.74
Sternal height	−0.19	1.02	17.41	0.000	1.05	0.421	0.76
Sitting height	−0.27	1.14	9.39	0.000	1.18	0.270	0.76
Trunk height	−0.25	1.09	14.20	0.000	1.15	0.299	1.06
Biacromial diameter	−0.41	1.05	7.68	0.000	1.09	0.376	0.78
Chest breadth	−0.21	1.02	6.55	0.000	1.08	0.382	0.76
Chest depth	−0.09	1.15	6.42	0.000	1.26	0.194	1.02
Bicristal diameter	−0.43	1.07	7.75	0.000	1.12	0.339	0.58
Maximum hip width	−0.05	1.06	7.64	0.000	1.08	0.381	0.68
Upper extremity length	−0.26	1.04	17.01	0.000	1.07	0.400	0.78
Lower extremity length	−0.13	1.01	13.04	0.000	1.03	0.457	0.86
Upper arm length	−0.19	1.00	7.23	0.000	1.03	0.451	0.72
Fore arm length	−0.26	1.06	11.24	0.000	0.97	0.529	0.96
Hand length	−0.60	1.01	16.64	0.000	1.04	0.439	0.84
Hand breadth	−0.79	1.00	3.25	0.000	1.03	0.447	0.40
Foot length	−0.43	1.00	4.40	0.000	1.04	0.442	0.58
Foot breadth	−0.87	1.10	3.31	0.000	0.96	0.558	0.42

Family Data Analysis

The results of intrafamilial correlation and regression analysis are presented in Table 2. The midparent-offspring and single-parent-offspring correlations and regression coefficients are all significant at 0.001 level of probability, indicating genetic influences on these traits. However, the results in Table 2 show that, in general, longitudinal traits are more heritable than breadth measurements, similarly to what was found in the twin data,

Table 2 - Intrafamilial correlation and regression coefficients for body size traits

Traits	Midparent-offspring (N=264)			Parent-offspring (N=560)			Midparent-son (N=134)	Midparent-daughter (N=130)	Father-offspring (N=280)	Mother-offspring (N=280)	Father-son (N=146)	Father-daughter (N=134)	Mother-son (N=138)	Mother-daughter (N=142)
	r	b	SEb	r	b	SEb	r	r	r	r	r	r	r	r
Weight	0.37***	0.46	0.07	0.32***	0.33	0.04	0.41***	0.35***	0.32***	0.30***	0.33***	0.32***	0.36***	0.23**
Stature	0.49***	0.61	0.07	0.40***	0.39	0.04	0.49***	0.49***	0.39***	0.37***	0.39***	0.40***	0.40***	0.34***
Sternal height	0.47***	0.59	0.07	0.38***	0.37	0.04	0.49***	0.44***	0.37***	0.35***	0.41***	0.35***	0.39***	0.31***
Sitting height	0.47***	0.66	0.08	0.38***	0.40	0.04	0.47***	0.47***	0.38***	0.34***	0.35***	0.43***	0.41***	0.25**
Trunk height	0.28***	0.42	0.09	0.24***	0.24	0.04	0.30***	0.26**	0.19**	0.26***	0.20*	0.19*	0.26**	0.25**
Biacromal diameter	0.42***	0.53	0.07	0.35***	0.35	0.04	0.41***	0.44***	0.31***	0.38***	0.32***	0.30***	0.35***	0.41***
Chest breadth	0.32***	0.37	0.07	0.26***	0.24	0.04	0.28**	0.37***	0.32***	0.18**	0.31***	0.33***	0.15	0.24**
Chest depth	0.28***	0.33	0.08	0.24***	0.23	0.04	0.26**	0.29**	0.35***	0.08	0.32***	0.37***	0.13	- 0.03
Bicristal diameter	0.39***	0.52	0.08	0.33***	0.32	0.04	0.44***	0.34***	0.29***	0.32***	0.34***	0.25**	0.39***	0.26**
Maximum hip width	0.34***	0.43	0.07	0.29***	0.29	0.04	0.40***	0.27**	0.28***	0.26***	0.35***	0.20*	0.31***	0.19*
Upper extremity length	0.48***	0.57	0.06	0.40***	0.37	0.04	0.54***	0.43***	0.33***	0.43***	0.36***	0.31***	0.51***	0.36***
Lower extremity length	0.43***	0.52	0.07	0.35***	0.32	0.04	0.42***	0.45***	0.34***	0.33***	0.34***	0.35***	0.31***	0.36***
Upper arm length	0.41***	0.53	0.07	0.32***	0.31	0.04	0.45***	0.36***	0.29***	0.34***	0.36***	0.21*	0.35***	0.33***
Fore arm length	0.48***	0.59	0.07	0.39***	0.38	0.04	0.50***	0.46***	0.33***	0.43***	0.33***	0.34***	0.46***	0.38***
Hand length	0.45***	0.57	0.07	0.37***	0.35	0.04	0.52***	0.37***	0.34***	0.38***	0.36***	0.32***	0.49***	0.27***
Hand breadth	0.41***	0.51	0.07	0.34***	0.33	0.04	0.49***	0.33***	0.27***	0.38***	0.29***	0.26**	0.45***	0.31***
Foot length	0.45***	0.57	0.07	0.36***	0.34	0.04	0.47***	0.43***	0.36***	0.33***	0.36***	0.37***	0.37***	0.30***
Foot breadth	0.40***	0.53	0.07	0.34***	0.33	0.04	0.43***	0.38***	0.28***	0.36***	0.33***	0.23**	0.35***	0.37***

*P $<$ 0.05, **P $<$ 0.01, ***P $<$ 0.001.

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with the exception of trunk height. The midparent-offspring correlations are consistently higher than the single parent-offspring correlations. These results are compatible with a polygenic inheritance model. But under strict polygenic inheritance, the expected values of r of single parent-offspring and midparent-offspring should be 0.5 and 0.71, respectively. The values obtained are lower than expected, thus indicating that environmental factors are also operating. Other factors, like dominance or epistasis, may also reduce parent-child correlations.

Higher resemblance of children to their mother [28,29] is found in 9 of 18 traits, and distinctly for trunk height, biacromial diameter, upper extremity length, fore arm length, hand breadth and foot breadth. Resemblance to the father is greater for chest measures. That may be due to dominance or epistatic effects or to genotype-environment interactions. Sharma et al [19] have observed significant skewness for a number of morphological traits in both parents and children.

As shown in Table 2, the resemblance of fathers with their children of either sex is significant for all the traits, though there is some difference in the magnitude of correlations. Father-son resemblance is low for trunk height. Similarly, father-daughter resemblance is low though significant for trunk height, hip width and upper arm length. Mother-son correlations are not significant for chest measures but are highly significant for the remaining traits. The resemblance of mothers with daughters is insignificant for chest depth. The results show that fathers as well as mothers resemble more to their sons than to their daughters. Similar results are observed for midparent-son and midparent-daughter correlations, where the daughters are less correlated than sons for 12 out of 18 instances. It may be noted here that the pattern of these correlations is not consistent with a sex-linkage hypothesis for any of the traits considered in this study.

Comparison Among Familial Correlation Studies

Mueller [15] reviewed 24 studies and reported average parent-child correlations in European groups to be 0.37 for stature and 0.31 for weight, vs 0,29 and 0,26 in non-European groups. The correlations obtained in the present study are slightly higher (0.40 for stature and 0.32 for weight). For European groups, higher values were reported by Bayley [1], Tanner and Israelsohn [24] and Gerylovova and Bouchalova [10], although samples size in the former two was smaller than in the present study. Higher parent-child correlations could be caused by positive assortative mating for body size traits in the respective populations [15,19,20]. The problem can be overcome by comparing the midparent-child regression coefficients, these being not affected by assortative mating [8]. The results are shown in Table 3. The regression of child's measurement on that of midparent should be equal to heritability [8]. Thus, the heritability of stature ranges from 31% to 64%, which is considerably less than the values derived by doubling all parent-child correlations in the same studies (44% to 88%). Another interesting feature in Table 3 is that regressions do not always have the same direction and variability as correlations, ie, samples with lowest parent-child correlations do not necessarily have the lowest midparent-child regression coefficients, which is in contrast to Mueller [15].

Studies dealing with body measurements other than stature and weight are few. Comparison has only been possible with the Belgian sample [21], since the other two studies [16,30] do not provide parent-child correlations. The correlations in the Belgian sample

Table 3 - **Midparent-child regression coefficients for stature in seven samples along with the combined *parent-child correlations***

Study	Midparent-son N	Midparent-son b	Midparent-daughter N	Midparent-daughter b	Midparent-child N	Midparent-child b	Parent child correlation r
Present study	134	0.64	130	0.58	264	0.61	0.40
Gerylovova & Bouchalova (1974)	199	0.47	201	0.56			0.44
Tanner et al (1970)	125	0.56	93	0.53			0.43
Wingerd et al (1973)					2746	0.58	0.41
Mueller (1976)	144	0.49	128	0.47			0.27
Malina et al (1976) (White)	216	0.48	168	0.53	384	0.49	0.33
Malina et al (1976) (Black)	192	0.31	230	0.42	422	0.37	0.22

are higher than those of the present study for the majority of traits (stature, sternal height, upper extremity length, upper arm length, bicristal diameter and hip width). Both samples present significant assortative mating for these traits. However, for any worthwhile comparison, regression coefficients should be preferred over parent-child correlations.

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REFERENCES

1. Bayley N (1954): Some increasing parent-child similarities during the growth of children. J Educ Psychol 45:1-21.
2. Christian JC, Kang KW, Norton JA (1974): Choice of an estimate of genetic variance from twin data. Am J Hum Genet 26:154-161.
3. Christian JC, Norton JA (1977): A proposed test of the difference between the means of monozygotic and dizygotic twins. Acta Genet Med Gemellol 26:49-53.
4. Christian JC (1979): Testing twin means and estimating genetic variance. Basic methodology for the analysis of quantitative twin data. Acta Genet Med Gemellol 28:35-40.
5. Clark PJ (1956): The heritability of certain anthropometric characters as ascertained from measurements of twins. Am J Hum Genet 8:49-54.
6. Da Rocha FJ, Salzano FM, Pena HF, Callegari SM (1972): New studies on heritability of anthropometric characteristics as ascertained from twins. Acta Genet Med Gemellol 21:125-134.
7. Dupae E, Defrise-Gussenhoven E, Susanne C (1982): Genetic and environmental influences on body measurement of Belgian twins. Acta Genet Med Gemellol 31:139-144.
8. Falconer DS (1960): Introduction to Quantitative Genetics. Edinburgh: Oliver and Boyd.
9. Furusho T (1974): Genetic study on stature. Jap J Hum Genet 19:1-25.

10. Gerylovova A, Bouchalova M (1974): The relatioship between children's and parents' height in the age range 0-6 years. Ann Hum Biol 1:229-232.
11. Hawk LJ, Brook CGD (1979): Family resemblances of height, weight and body fatness. Arch Dis Child 54:877-879.
12. Himes JH, Roche AF, Thissen D (1981): Parent-Specific Adjustemens for Assessment of Recumbent Length and Stature. Basel: S Karger.
13. Malina RM, Mueller WH, Holman JD (1976): Parent-child correlations and heritability of stature in Philadelphia black and white children 6 to 12 years of age. Hum Biol 48:475-486.
14. Martin R, Saller K (1957): Lehrbuch der Anthropologie. Stuttgart: Fischer.
15. Mueller WH (1976): Parent-child correlations for stature and weight among school ages children: a review of 24 studies. Hum Biol 48:379-397.
16. Mueller WH, Titcomb M (1977): Genetic and environmental determinants of growth of school-ages children in a rural Colombian population. Ann Hum Biol 4:1-15.
17. Osborne RH, DeGeorge FV (1959): Genetic basis of Morphological Variation. Cambridge: Harvard University Press.
18. Sharma JC, Sharma K (1984): Estimates of genetic variance for some selected morphometric characters: a twin study. Acta Genet Med Gemellol 33:509-514.
19. Sharma K, Byard PJ, Russell JM, Rao DC (1984): A family study of anthropometric traits in a Punjabi community. 1. Introduction and familial correlations. Am J Phys Anthropol 63:389-395.
20. Spuhler JN (1968): Assortative mating with respect to physical characteristics. Eugen Quart 15: 128-140.
21. Susanne C (1975): Genetic and environmental influences on morphological characteristics. Ann Hum Biol 2:279-287.
22. Susanne C (1977): Heritability of anthropological characters. Hum Biol 49:573-580.
23. Susanne C (1980): Developmental genetics of man. In Johnston F, Roche AF' Susanne C (eds): Human Physical Growth and Maturation. New York: Plenum Press.
24. Tanner JM, Israelsohn WJ (1963): Parent-child correlations for body measurements of children between the ages of one month and seven years. Ann Hum Genet 26:245-259.
25. Tanner JM, Goldstein H, Witehouse RH (1970): Standards for children's height at ages 2-9 years allowing for height of parents. Arch Dis Child 45:755-762.
26. Vandenberg SG, Strandskov HH (1964): A comparison of identical and fraternal twins in some anthropometric measures. Hum Biol 36:45-52.
27. Wingerd J, Solomon IL, Schoen EJ (1973): Parent-specific height standards for pre-adolescent children of three racial groups, with method for rapid determination. Pediatrics 52:555-560.
28. Wolanski N (1970): Genetic and ecological factors in human growth. Hum Biol 42:349-369.
29. Wolanski N (1975): Similarity of traits in children and parents and the role of maternal regulation of intrauterine life. Anthropol Kozl 2:207-211.
30. Wolanski N (1976): Parent-child correlations in stature, fat tissue, some body proportions and hand and foot size of offspring 2-45 years old. Anthroposko Drustvo Jugoslaviji, Posehna Izdanja 3:109-120.

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