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Genetic and Environmental Influences on Body Measurements of Belgian Twins

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A study of 100 MZ and 67 DZ twin pairs aged 18 to 25 years has shown a highly significant genetic contribution to the following measurements: standing and sitting height; height on tragus; arm length; biacromial, biiliac, and bitrochanteric diameter; weight; circumference of thigh and of upper arm relaxed and contracted; and head length and breadth. The twins were brought up together and of the same socioeconomical, geographical, ethnical, and cultural origin. Zygosity diagnosis was based on 22 to 26 blood groups. The means of the measurements were smaller in MZ than in DZ twins, some of them significantly so. The intraclass correlation coefficients of the MZ cotwins were all significant and greater than those of the DZ cotwins. In families of same geographical origin, sib-sib correlations were somewhat smaller than those of the DZ cotwins, but for the three diameters of the body the order was reversed.

Key words: Height, Weight, Body measurements, Twins

INTRODUCTION

Anthropological measurements have continuous distributions resulting from the combined action of multiple factors, some of genetic origin, some of environmental origin. Twin resemblance has been used to study the influences of these factors on body size: in 1962 Vandenberg [18] summarized six different reports; from these, the only one on adult twins was the study of Osborne and De George [15]. On adult siblings and on several body measurements, investigations are even less numerous: Howells [10], Susanne [16,17]. After the general approach to the quantitative analysis of twin data developed by Falconer [7], Kempthorne and Osborne [11], Haseman and Elston [9], and Kempthorne [12], new approaches have been presented by Christian et al [1], Martin et al [14], Eaves [5], and Christian [2].

To estimate the relative contribution of the genetic factors to the total variance of 13 body measurements, the present authors follow the procedure proposed by Christian et al [1].

MATERIALS AND METHODS

We present results of a study of Belgian same-sexed twin pairs aged 18 to 25 years: 47 MZ and 35 DZ male pairs and 53 MZ and 32 DZ female pairs were examined. The zygosity diagnosis is based on at least 22 blood groups for which details are given in Defrise-Gussenhoven et al [4]. A total of 13 body measurements were taken according to the technique of Martin and Saller [13]. Most of the twins were high-school or university students, born in Flanders or near Brussels. They were brought up together; 58% of them still live with their cotwin, 31% have been separated less than 3 years, 7% more than 3 years, and for the remaining 4% information is lacking.

RESULTS

Most of the calculations are performed with a program that Prof. Christian kindly has sent to us.

Table 1 gives the mean and variance of the measurements in each of the four groups: MZ and DZ males and MZ and DZ females. No significant deviation (at the significance level of 5%) from normality, evaluated by means of a nonparametric Kolmogorov-Smirnov test, has been found. The means of most traits measured were smaller for MZ than DZ twins. However, only for height on tragus in males and for arm length in both sexes, were the differences significant (5% level), as is seen in Table 2. The total variances, estimated by the sum of mean squares within and among pairs [1], also tend to be smaller in the MZ twins (Table 1). In male twins, only the variance of head breadth is larger in the MZ than in the DZ, with P = 0.059 (Table 2). In females, there are more exceptions, ie, for sitting height, arm circumferences, and head length and breadth, but only the last measurement has a probability (P = 0.054) near the 5% value.

In Table 2 the intraclass correlation coefficients ρ, estimated by the difference of among and within mean squares divided by their sum, are also listed. A one-sided test proves them all to be significantly greater than zero (5% level), except for the coefficients for the biacromial and biiliac diameter in DZ males with P = 0.067 and P = 0.052, respectively, and for the biacromial diameter in DZ females with P = 0.058. In the program of Christian et al [1] the difference $\rho_{MZ} - \rho_{DZ}$ is tested for males and females.

TABLE 1. Means and Total Variances

	Mean ($\bar{x}$)				Total variance ($\bar{\sigma}^2$)			
	Males		Females		Males		Females	
Measurement	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ
Standing height	175.0	177.5	163.8	166.1	64.35	83.82	55.58	74.01
Sitting height	92.0	92.5	86.4	87.6	16.99	22.09	28.91	21.90
Height on tragus	161.6	164.2	151.2	153.4	59.45	77.36	52.98	72.95
Arm length	77.1	78.6	71.0	72.7	20.90	27.29	17.94	19.81
Biacromial d.	39.0	39.1	35.7	36.1	7.57	7.57	4.14	4.66
Biiliac d.	27.1	27.6	26.3	26.0	4.67	4.81	7.36	7.67
Bitroch. d.	31.2	31.7	30.7	30.9	4.83	5.81	5.83	7.17
Weight	65.2	68.0	56.0	59.0	116.09	146.01	130.39	168.93
Circumf. upper arm (relaxed)	27.7	28.0	25.9	26.1	10.67	13.29	13.88	13.58
Circumf. upper arm (contracted)	29.3	29.8	26.6	26.7	14.08	15.09	16.12	14.83
Circumf. of thigh	52.8	53.3	53.9	54.9	25.69	35.28	47.74	72.09
Head length	19.2	19.2	18.5	18.5	0.89	1.12	0.77	0.75
Head breadth	15.2	15.3	14.6	14.8	0.83	0.50	0.66	0.39
Number of twins	94	70	106	64	94	70	106	64

TABLE 2. Probabilities of the t' Test and the F' Test for Equality of Means and Variances: Intraclass Correlation Coefficients

	Probability				Intraclass correl. coeff.			
	t' test $H_o:\bar{x}_{MZ} = \bar{x}_{DZ}$		F' test $H_o:\sigma^2_{MZ} = \sigma^2_{DZ}$		Males		Females	
Measurement	♂	♀	♂	♀	MZ	DZ	MZ	DZ
Standing height	0.059	0.057	0.366	0.308	0.908	0.770	0.910	0.645
Sitting height	0.364	0.113	0.351	0.333	0.856	0.646	0.923	0.592
Height on tragus	0.039*	0.070	0.364	0.254	0.901	0.741	0.910	0.634
Arm length	0.043*	0.007*	0.345	0.711	0.887	0.615	0.874	0.488
Biacromial d.	0.860	0.183	1.000	0.635	0.741	**0.259**	0.697	**0.284**
Biiliac d.	0.142	0.556	0.912	0.873	0.787	**0.279**	0.842	0.586
Bitroch. d.	0.149	0.585	0.495	0.453	0.857	0.403	0.862	0.641
Weight	0.087	0.099	0.403	0.351	0.879	0.437	0.860	0.667
Circumf. upper arm (relaxed)	0.611	0.663	0.420	0.945	0.792	0.559	0.872	0.553
Circumf. upper arm (contracted)	0.404	0.951	0.799	0.773	0.823	0.491	0.871	0.581
Circumf. of thigh	0.572	0.367	0.237	0.122	0.800	0.449	0.780	0.542
Head length	0.678	0.807	0.404	0.964	0.857	0.414	0.783	0.480
Head breadth	0.183	0.257	0.059	0.054	0.833	0.355	0.771	0.485
Critical value at 5% level					0.243	0.283	0.229	0.296
Number of pairs					47	35	53	32

P<0.05; non significant values in bold face.

All the intraclass correlation coefficients for MZ pairs are significantly greater than those of DZ pairs with all the P values below 0.03.

In Table 3 the mean squares are listed with the corresponding degrees of freedom. The calculations are based on the same formulas for MZ and DZ pairs. Suppose we have n pairs; x_{1j} and x_{2j} being the observed trait values for the two members of the j-th twin pair, the among and the within mean squares are, for the MZ

$$AMZ = \frac{1}{n-1}\sum_{j=1}^{n} 2(x_{.j} - x_{..})^2 \text{ and } WMZ = \frac{1}{2n}\sum_{j=1}^{n}(x_{1j} - x_{2j})^2$$

$$\text{with } x_{.j} = (x_{1j} + x_{2j})/2 \text{ and } x_{..} = \sum_{j=1}^{n} x_{.j}/n$$

Analogous formulas give ADZ and WDZ mean squares for the DZ twins. Under certain conditions, the analysis of variance of Christian et al [1] allows estimation of the fraction GT of the total genetic variance σ^2_g.

$$GT = \frac{1}{2}\sigma^2_a + \frac{3}{4}\sigma^2_d + (1 - f)\sigma^2_i \text{ with}$$

$$f = \left(\frac{1}{4}\sigma^2_{aa} + \frac{1}{8}\sigma^2_{ad} + \frac{1}{16}\sigma^2_{dd}\right)/\sigma^2_i$$

when only two loci are considered and analogous values for more than two loci [11].

Table 4 gives the values of two estimates of GT and the corresponding probabilities. (1) The "within pair estimate," $\bar{G}WT$ = WDZ − WMZ, is tested by a one-tailed test

TABLE 3. Mean Squares Among and Within Twin-Pairs

	Males				Females			
	MZ		DZ		MZ		DZ	
Measurement	AMZ	WMZ	ADZ	WDZ	AMZ	WMZ	ADZ	WDZ
Standing height	61.39	2.96	74.16	9.66	53.07	2.50	60.87	13.14
Sitting height	15.77	1.22	18.18	3.91	27.79	1.11	17.43	4.47
Height on tragus	56.49	2.95	67.36	10.00	50.59	2.39	59.61	13.34
Arm length	19.72	1.18	22.04	5.25	16.81	1.13	14.73	5.07
Biacromial d.	6.59	0.98	4.76	2.80	3.51	0.63	2.99	1.67
Biiliac d.	4.17	0.50	3.08	1.73	6.78	0.58	6.08	1.59
Bitroch. d.	4.48	0.34	4.07	1.73	5.43	0.40	5.89	1.29
Weight	109.04	7.05	104.90	41.11	121.26	9.13	140.82	28.12
Circumf. upper arm (relaxed)	9.57	1.11	10.36	2.93	12.99	0.89	10.54	3.04
Circumf. upper arm (contracted)	12.83	1.25	11.25	3.84	15.08	1.04	11.72	3.10
Circumf. of thigh	23.12	2.57	25.57	9.71	42.49	5.25	55.57	16.53
Head length	0.83	0.06	0.79	0.33	0.68	0.08	0.56	0.20
Head breadth	0.76	0.07	0.34	0.16	0.59	0.08	0.29	0.10
Degrees of freedom	46	47	34	35	52	53	31	32

TABLE 4. "Within Pair" (ḠWT) and "Among Component" (ḠCT) Estimates of Genetic Variance GT and the Corresponding Probabilities

	Males				Females			
Measurement	ḠWT	P	ḠCT	P	ḠWT	P	ḠCT	P
Standing height	6.70	0.000	−3.04	0.618	10.63	0.000	1.42	0.456
Sitting height	2.69	0.000	0.14	0.490	3.35	0.000	6.86	0.038
Height on tragus	7.05	0.000	−1.91	0.584	10.95	0.000	0.96	0.474
Arm length	4.07	0.000	0.88	0.412	3.94	0.000	3.01	0.145
Biacromial d.	1.82	0.000	1.82	0.035	1.04	0.000	0.78	0.096
Biiliac d.	1.24	0.000	1.17	0.035	1.00	0.000	0.85	0.227
Bitroch. d.	1.39	0.000	0.90	0.121	0.88	0.000	0.21	0.424
Weight	34.06	0.000	19.10	0.160	18.99	0.000	−0.28	0.519
Circumf. upper arm (relaxed)	1.82	0.001	0.51	0.389	2.15	0.000	2.30	0.132
Circumf. upper arm (contracted)	2.59	0.000	2.09	0.159	2.06	0.000	2.71	0.122
Circumf. of thigh	7.14	0.000	2.35	0.299	11.28	0.000	−0.90	0.556
Head length	0.26	0.000	0.15	0.152	0.11	0.002	0.12	0.138
Head breadth	0.09	0.003	0.26	0.002	0.02	0.177	0.16	0.012

F = WDZ/WMZ. All the values are highly significant, except head breadth in girls. (2) The "among component estimate," ḠCT = (ḠWT + ḠAT)/2 with ḠAT = AMZ − ADZ, is tested by a two-tailed test F′ = (AMZ + WDZ)/(ADZ + WMZ). Only a few traits have significant values: biacromial and biiliac diameters and head breadth in males and sitting height and head breadth in females.

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TABLE 5. Sib-Sib Correlation and Mean Intraclass Correlation Coefficients for Males and Females in MZ and DZ Twins

Measurement	Sib-sib	DZ(ρ♂ + ρ♀)/2	MZ(ρ♂ + ρ♀)/2
Standing height	0.59	0.71	0.91
Sitting height	0.40	0.62	0.89
Arm length	0.52	0.55	0.88
Biacromial d.	0.40	**0.27**	0.72
Biiliac d.	0.53	**0.43**	0.81
Bitroch. d.	0.57	**0.52**	0.86
Weight	0.54	0.55	0.87
Circumf. upper arm (relaxed)	0.46	0.56	0.83
Circumf. upper arm (contracted)	0.45	0.54	0.85
Head length	0.31	0.45	0.82
Head breadth	0.35	0.42	0.80
Number of pairs	382	67	100

In bold face: values of DZ twins inferior to those of sib-sib.

DISCUSSION

The tables show that in most of the studied traits, strong evidence for a genetic component of variation GT has been found. A pleasant result is that of head breadth in girls, revealing significant greater total variance for the MZ twin group than for the DZ group (P = 0.054). If we reason, with Christian et al [1], that this difference is rather due to unequal environmental variances with $\sigma^2_{eMZ} > \sigma^2_{eDZ}$ than to greater genetic variation in MZ than in DZ twins, we should use the test for "among component" $\bar{G}$CT (in which the environmental variances are cancelled) instead of the test for "within pair" $\bar{G}$WT. Table 4 shows that whereas $\bar{G}$WT is not significant (P = 0.177), the test for $\bar{G}$CT yields P = 0.012. For head breadth in males we also have $\sigma^2_{MZ} > \sigma^2_{DZ}$ (P = 0.059). However, here we find that $\bar{G}$WT and $\bar{G}$CT are both highly significant (P = 0.003 and P = 0.002). As yet, we have no satisfactory explanation to offer for the exception presented by head breadth in both sexes.

Table 5 shows the sib-sib correlation coefficients (n = 382) found by one of the authors [16] in a study of families of the same geographical origin as our twins. For easy comparison we calculated the mean intraclass correlation coefficient of males and females, first for the DZ, then for the MZ twin pairs. Disregarding sampling errors, we see that length is more heritable than the other characters, a usual finding. The sib-sib correlations are lower than the DZ ones, except for the three diameters of body breadth; this might suggest intrauterine competition in DZ twins making them less alike for the diameters than ordinary sibs.

The covariances of the MZ and DZ twins are due both to environmental and genetic factors [1,6]; but it is not surprising that the MZ correlations are consistently the greatest of the three groups, MZ cotwins having the same genes.

Nearly as great as the correlations for sitting height and arm length are those of weight and arm circumferences; it seems that these traits are not much more influenced by nurture than the length measurement, at least in the present sample of twins brought up together. Two of the three breadth diameters of body are less correlated than the other MZ measurements, again suggesting intrauterine competition for these characters.

The means of all the measurements are smaller in MZ than in DZ twins. The fact that a majority of MZ twins share the chorion or the placenta with their cotwin [3] suggests that perhaps this intrauterine situation is unfavorable for later development.

CONCLUSION

All the studied biometrical characters show a genetic component; of course, as in all anthropometrical studies, the results are relative to the studied population, in its specific environment and time [8]. Since the coefficients of heritability are specific for a particular gene pool and environment, as well as for a particular interaction between genotypes and environments, we have not listed them. However, a gradient of heritability is observed with higher values for body measurements of bone length [16,18], but this gradient is less marked in the present twin data than in parent-children investigations [17].

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