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Effect of Genetic and Environmental Factors on Body Measurements of First, Second and Third Degree of Relatives

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ABSTRACT 203 Punjabi Khatri families residing in Delhi were surveyed for 18 standardised body measurements which included linear measurements, diameters, girths, skinfolds and body weight. Only the adult memebrs of the families were measured and their ages ranged from 17 to 58 years. In addition to nuclear family correlations, correlation coefficients for different body measurements of extended family members living in separate houses were also calculated. Adult sibling correlations of body measurements for parental and filial generations are also reported. Degree of relationship affects the magnitude of correlation between different body measurements. Correlation coefficients for all the body measurements are significant for first degree of relatives. Second degree of relatives do not show statistically significant correlations for arm length, middle finger length, bicristal diameter, arm and calf circumference and skin folds at triceps, subscapular region and calf, while among third degree of relatives, non-significant correlations have been observed for all the body measurements except for height, sitting height and bicristal diameter. Siblings of filial generation show statistically significant correlations for all the body measurements while parental generation sibs are showing statistically non-significant correlations for skinfolds at biceps and subscapular region and calf girth measurement. Magnitude of heritability of body measurements as estimated by mid-parent offspring regression is highest for height followed by longitudinal and transverse masurements and least values are observed for skinfold measurements.

A number of family studies involving parents and their growing as well as adult offspring have been attempted to study the genetic and environmental influence on various body measurements (Hewitt, 1957; Tanner and Israelsohn, 1963; Welon and Bielicki, 1971; Rao et al., 1975; Susanne, 1975; Malina et al., 1976; Mueller and Titcomb, 1977; Roberts et al., 1978; Kaur and Singh, 1981). Parent-child and sib-sib correlations with respect to body measurements are affected by assortative mating and at the same time members of a nuclear family living in the same household share genes as well as household environment. There are no family relationship which allow examination of the role of shared genes independent of household environment except spouse pairs and adoptions. Impact of family environment on body measurements can be deduced by finding out the correlations among second and third degree of relatives because inspite of sharing genes from a common descent these relatives are subject to different home environments. Studies involving second degree of relatives such as avuncular correlation (uncle-niece, uncle-nephew, aunt-niece, aunt-nephew) and third degree of relatives (correlation between cousins) for these anthropometric traits have been very scanty. The only existing study of Byard et al. (1983) is based merely on the stature of avuncular and cousins pairs in addition to parent offspring pairs. Skinfolds of adopted and biological siblings including cousins have also been compared (Bouchard et al., 1980). The effect of household environment on body build for several western samples of parental and their adopted children have also been reported in the literature (Garn et al., 1979; Hartz et al. 1977). Recently Byard et al. (1989) reported the correlations for extended family members living within a common household.

Effects of family environment on body measurements can also be deduced by comparing cor-

relation coefficients of siblings of parental and filial generations. Correlations between adult sibs staying in a common household have also been reported in the literature to study the genetics of a number of body measurements (Howells, 1966; Susanne, 1975, 1977; Roberts et al., 1978 and Paganani-Hill et al., 1981). Mueller (1977) reported adult pairs of siblings of different households. That study included siblings of two generations-siblings of parental generation involving adult sibs (27-62 years) while filial generation sibs of that study were growing children (age 7-12 years) of the same family.

The present study aims at examining the correlations of various body measurements between first degree of relative such as parent-offspring and sib-sib; second degree of relatives (uncle niece, uncle-nephew, aunt-niece, aunt-nephew) and third degree of relatives (correlations between cousins). Correlations of body measurements between adult siblings of two generations, *i.e.* siblings of filial generation (sibs staying together) and siblings of parental generation (sibs who are subject to separate households) have also been presented.

MATERIAL AND METHODS

A set of 18 anthropometric measurements *viz.* height, sitting height, subischial length, weight, arm length, leg length, biacromial diameter, bicristal diameter, bitrochanteric diameter, upper arm, calf, wrist and ankle circumferences, middle finger length and skinfolds at triceps, biceps, subscapular region and at the level of maximum calf girth were taken following the standard techniques of Tanner et al. (1969) on 690 subjects drawn from 203 Punjabi Khatri families, living in South and West Delhi. Punjabis of Delhi of the present study migrated from West Pakistan in 1947-48 and now form one of the population groups of Delhi. Punjabi Khatri considered here constitute a discrete and homogenous Mendelian breeding unit with no consanguinity. Families comprising at least one adult son or one adult daughter of more than 17 years of age and at least one parent below 58 years of age were included. The subjects comprised 131 fathers, aged 41-57 years (mean 49.0 SD 5.0); 174 mothers aged 34-56 years (mean 43.7 SD 5.2), 148 sons aged 17-33 years (mean 21.3 SD 4.0) and 237 daughters, aged 17-34 years (mean 20.1 SD 4.0).

Families of sibs of parents living in Delhi have also been included to study the correlation coefficients with respect to these body measuremnts among second and third degree of relatives. Data of 66 sibling pairs of parental generation were also collected for doing comparison with the siblings of filial generation. Ages of the sibs range from 17-33 years with an average of 21.3 ± 6.1 years and 41-57 years with an average of 45.2 ± 7:0 years in the younger and older generation respectively. The average age difference between the sibs is 3.8 years in filial generation and 4.2 years in the parental generation.

Mean values and standard deviations of various body measurements were calculated for fathers, sons, mothers and daughters and an attempt has been made to study the differences with respect to these traits among two generations. To test the significance of differences student 't' test was done. Both main types and subtype of interclass correlation coefficients were computed. Combined parent-child, sib-sib, mid parent-child, avuncular, and correlation existing between cousins were obtained following the technique of z transformation (Fisher, 1970).

RESULTS

Table 1 shows the means and standard deviations of different body measurements of fathers, mothers, sons and daughters. Sons and daughters showed significantly higher mean values of height, sitting height, subischial length, and leg length than those of their fathers and mothers respectively. Mean values of body weight, diameters, upper arm and calf girth and skinfolds were higher in parents as compared to their same sexed offspring.

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Table 2: Correlation coefficients (r) among first, second and third degree of relatives for various body measurements

Variable	*Parent-child (Father-son Father-daughter, mother-son, mother-daughter) (n = 613)*	*Sig-Sib (Sister-Sister, brother-brother, brother-sister) (n = 303)*	*Avuncular (uncle-niece, uncle-nephew aunt-niece, aunt-nephew) (n = 173)*	*Cousin (Same sex cousins, opposite sex cousins) (n = 120)*
Height	0.47^{3}	0.48^{3}	0.25^{2}	0.24^{2}
Sitting height	0.34^{3}	0.36^{3}	0.22^{2}	0.21^{1}
Subischial length	0.43^{3}	0.46^{3}	0.15^{1}	0.13
Weight	0.40^{3}	0.50^{3}	0.28^{3}	0.10
Arm length	0.35^{3}	0.35^{3}	0.08	0.11
Leg length	0.34^{3}	0.39^{3}	0.15^{1}	0.16
Biacromial diameter	0.31^{3}	0.36^{3}	0.15^{1}	0.11
Bicristal diameter	0.39^{3}	0.49^{3}	0.12	0.21^{1}
Bitrochanteric diameter	0.37^{3}	0.50^{3}	0.29^{3}	0.10
Upper arm circumference	0.27^{3}	0.42^{3}	0.06	0.09
Wrist circumference	0.34^{3}	0.27^{3}	0.02	0.05
Calf circumference	0.40^{3}	0.45^{3}	0.09	0.08
Ankle circumference	0.35^{3}	0.46^{3}	0.17^{1}	0.13
Middle finger length	0.43^{3}	0.49^{3}	0.05	0.13
Skinfolds at:				
triceps	0.32^{3}	0.42^{3}	0.10	0.07
biceps	0.25^{3}	0.37^{3}	0.15^{1}	0.05
subscapular	0.28^{3}	0.47^{3}	0.11	0.04
calf	0.24^{3}	0.42^{3}	0.03	0.10

P values: 1. $P < 0.05$ 2. $P < 0.01$ 3. $P < 0.001$

have been observed as observed for parent-offspring pairs (Table 2). Mid parent-offspring correlations and regression coefficients (Table 5) are consistently higher than parent offspring correlations and had the same direction and variability as the parent-offspring correlations.

Table 3: Parental and filial generation sib-sib correlations for various body measurements

Variables	*Sib-sib correlation for filial generation (n = 303)*	*Sib-sib correlation for parental generation (n = 66)*
Height	0.48^{3}	0.50^{3}
Sitting height	0.36^{3}	0.43^{3}
Subischial length	0.46^{3}	0.42^{3}
Weight	0.50^{3}	0.54^{3}
Arm length	0.35^{3}	0.35^{2}
Leg length	0.39^{3}	0.36^{2}
Biacromial diameter	0.36^{3}	0.42^{3}
Bicristal diameter	0.49^{3}	0.47^{3}
Bitrochanteric diameter	0.50^{3}	0.46^{3}
Upper arm circumference	0.42^{3}	0.31^{1}
Wrist circumference	0.27^{3}	0.33^{2}
Calf circumference	0.45^{3}	0.24
Ankle circumference	0.46^{3}	0.22
Middle finger length	0.49^{3}	0.46^{3}
Skinfolds at:		
triceps	0.42^{3}	0.29^{1}
biceps	0.37^{3}	0.17
subscapular	0.47^{3}	0.26
calf	0.42^{3}	0.28^{1}

P values: 1. $P < 0.05$, 2. $P < 0.01$, 3. $P < 0.001$

DISCUSSION

Non-significant father-mother correlation coefficients for stature suggest that assortative mating for this trait was either absent or too small to affect the correlation. Parent-child, sib-sib and mid parent-child correlations follow a definite gradation among different body measurements indicating the genetic components of their phenotypic expressions, which is greatest for longitudinal skeletal measures followed by transverse diameters, circumferences and least correlations are shown by adiposity related measurments as reported in earlier studies (Susanne, 1977; Kaur and Singh, 1981, 1983). For the measurements which are easily influenced by environment such as weight, soft tissue measurements and skinfolds, correlation between sibs exceeded the

Table 4: Intra familial correlation coefficients (r) for various body measurements

Variable	*Father-Mother (n = 113)*	*Father-Son (n = 106)*	*Father-Daughter (n = 154)*	*Father-Child (n = 260)*	*Mother-Son (n = 140)*	*Mother-Daughter (n = 213)*	*Mother-Child (n = 353)*
Height	0.15	0.51[3]	0.51[3]	0.50[3]	0.46[3]	0.43[3]	0.45[3]
Sitting height	0.07	0.35[3]	0.29[3]	0.32[3]	0.28[3]	0.40[3]	0.35[3]
Subischial length	0.17[1]	0.48[3]	0.44[3]	0.46[3]	0.45[3]	0.40[3]	0.41[3]
Weight	0.19[1]	0.53[3]	0.39[3]	0.45[3]	0.42[3]	0.30[3]	0.35[3]
Arm length	0.04	0.45[3]	0.45[3]	0.44[3]	0.36[3]	0.24[3]	0.29[3]
Leg length	0.25[2]	0.16[1]	0.48[3]	0.35[3]	0.18[1]	0.40[3]	0.32[3]
Biacromial diameter	0.12	0.31[3]	0.26[2]	0.28[2]	0.26[3]	0.38[3]	0.34[3]
Bicristal diameter	0.22[2]	0.55[3]	0.41[3]	0.47[3]	0.46[3]	0.22[3]	0.32[3]
Bitrochanteric diameter	0.19[1]	0.50[3]	0.40[3]	0.44[3]	0.37[3]	0.27[3]	0.31[3]
Upper arm circumference	0.16	0.47[3]	0.18[3]	0.30[3]	0.28[3]	0.24[3]	0.25[3]
Wrist circumference	0.05	0.40[3]	0.32[3]	0.34[3]	0.41[3]	0.30[3]	0.35[3]
Calf circumferrence	0.33[3]	0.55[3]	0.40[3]	0.46[3]	0.35[3]	0.33[3]	0.34[3]
Ankle circumference	0.24[3]	0.39[3]	0.40[3]	0.39[3]	0.38[3]	0.25[3]	0.31[3]
Middle finger length	0.17[1]	0.40[3]	0.51[3]	0.46[3]	0.48[3]	0.36[3]	0.41[3]
Skinfolds at:							
triceps	0.10	0.45[3]	0.41[3]	0.42[3]	0.25[3]	0.23[3]	0.24[3]
biceps	0.11	0.32[3]	0.22[2]	0.25[3]	0.20[2]	0.26[3]	0.24[3]
subscapular	0.27[2]	0.38[3]	0.18[2]	0.26[3]	0.33[3]	0.28[3]	0.30[3]
calf	0.19[1]	0.26[3]	0.25[3]	0.25[3]	0.23[3]	0.23[2]	0.23[3]

P values: 1. P < 0.05 2. P < 0.01 3. P. < 0.001

Table 5: Mid parent-child correlation (r) and regression coefficients (b) for various body measurements

Variables	*Mid Parent-Son (n = 103)*			*Mid Parent-Daughter (n = 146)*			*Mid Parent-Child (n = 249)*		
	r	*b*	*se of b*	*r*	*b*	*se of b*	*r*	*b*	*se of b*
Height	0.61[3]	0.85	0.11	0.64[3]	0.90	0.09	0.63[3]	0.87	0.13
Sitting height	0.45[3]	0.72	0.14	0.48[3]	0.69	0.10	0.46[3]	0.73	0.13
Subischial length	0.60[3]	0.85	0.11	0.57[3]	0.82	0.09	0.59[3]	0.79	0.12
Weight	0.64[3]	0.72	0.09	0.47[3]	0.45	0.07	0.55[3]	0.56	0.07
Arm length	0.56[3]	0.76	0.11	0.52[3]	0.70	0.10	0.54[3]	0.70	0.13
Leg Length	0.21[3]	0.69	0.15	0.57[3]	0.86	0.10	0.44[3]	0.77	0.17
Biacromial diameter	0.39[3]	0.54	0.13	0.44[3]	0.60	0.10	0.42[3]	0.62	0.13
Bicristal diameter	0.68[3]	0.81	0.09	0.37[3]	0.47	0.10	0.52[3]	0.59	0.07
Bitrochanteric diameter	0.59[3]	0.66	0.09	0.43[3]	0.54	0.09	0.50[3]	0.58	0.07
Upper arm circumference	0.50[3]	0.61	0.10	0.25[3]	0.29	0.09	0.36[3]	0.43	0.08
Wrist circumference	0.57[3]	0.79	0.11	0.42[3]	0.53	0.10	0.49[3]	0.69	0.11
Calf circumference	0.59[3]	0.66	0.09	0.47[3]	0.49	0.08	0.52[3]	0.55	0.06
Ankle circumference	0.54[3]	0.70	0.10	0.45[3]	0.54	0.09	0.49[3]	0.60	0.08
Middle finger length	0.57[3]	0.63	0.09	0.54[3]	0.64	0.08	0.55[3]	0.60	0.09
Skinfold at:									
triceps	0.40[3]	0.38	0.09	0.39[3]	0.48	0.09	0.39[3]	0.46	0.08
biceps	0.34[3]	0.33	0.09	0.33[3]	0.38	0.09	0.33[3]	0.35	0.07
subscapular	0.46[3]	0.52	0.10	0.25[3]	0.24	0.08	0.35[3]	0.34	0.06
calf	0.39[3]	0.49	0.12	0.32[3]	0.37	0.09	0.35[3]	0.39	0.08

values: 3. P < 0.001

corresponding correlation between parent-offspring. This may be due to the fact that sibs share a common and relatively more homogeneous environment, prenatal as well as postnatal, than parent-offspring belonging to two different generations as reported in earlier studies (Susanne, 1975, 1977; Bouchard, 1980).

Higher values of correlation with respect to these anthropometric traits among second degree of relatives as compared to third degree of relatives is in line with the previous study (Byard et al., 1983). Correlation coefficients for third degree of relatives with repsect to stature and some other bony traits are higher than the expected value (0.125) because the cousins are of the same generation and in addition to shared genes they share more common environment than avuncular pairs which are genetically more closely related than cousins but belong to two different generations.

Values of correlation coefficients for various body measurements among first, second and third degree of relatives conclude that degree of relationship affects the magnitude of correlations as familial resemblances for first degree of relatives are significant for all the body measurements and second degree of relatives showed significant correlations for longitudinal and transverse skeletal measures, body weight and skinfolds at biceps while among third degree of relatives correlations are significant only for stature, sitting height and bicristal diameter.

Significantly higher correlation coefficients for longitudinal skeletal measures and other measurements involving bones among second and third degree of relatives indicate higher genetic influence on these traits. Soft tissue related measurements among second and third degree of relatives showed lower values of correlation coefficients which is due to greater environmental influence on these traits as these individuals are subject to different home environments. Similar results have been observed when sibships of two generation are compared for adiposity related measurements as younger generations sibs are showing greater similarity for soft tissue related measurements than older generation sibs. These findings indicate a larger component of environmental variance in the determination of these fat tissue related measurements. Younger generation siblings share a similar home environment, which influences their similarity for growth in bones as well as in muscle and fat. Adult parental generation siblings are subejct to different home environments inspite of sharing the similar home environment during childhood and growth, by which time skeletal growth is mostly complete, but fat related measurements and muscles are still subject to change. Thus correlation for stature and other skeletal measures for older generation siblings reflect the common environment experienced during childhood whereas those for circumferences and skinfolds are affected by differing environments of adult life. These results has strengthened the characteristic findings drawn from nuclear family studies that longitudinal and other bony measures are more genetically controlled than soft tissue related measurements.

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