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Gender differences in familial aggregation of adiposity traits in Aggarwal Baniya families

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Abstract

The aim of the present study was to investigate the potential for common genetic and environmental influences on adiposity measures in Aggarwal Baniya families with adolescent children. A cross-sectional study was conducted on 309 Aggarwal Baniya families, including 1539 individuals (271 fathers, 307 mothers, 967 children of both sexes) in New Delhi, India. Anthropometric measurements were measured and various obesity indices were calculated. The prevalence of obesity in this community was high (BMI: fathers, 26.1 kg/m^2; mothers, 29.4 kg/m^2; sons, 16.9-22.4 kg/m^2; and daughters, 16.3-24.5 kg/m^2). Correlation and Heritability was estimated. Most sibling-sibling correlations were larger than the parent-offspring correlations, and all parent-offspring and sibling-sibling correlations were larger than the corresponding spouse correlation except for weight and waist circumference. For the obesity phenotypes, hip circumference and waist hip ratio (WHR) had the highest heritability of 82%, followed by waist height ratio (WHtR, 52%), body mass index (BMI, 49%), weight (46%), waist circumference (45%), and grand mean thickness (GMT, 35%). There is familial aggregation for obesity, as well as gender differences in familial correlations of obesity in children with daughters being more likely than sons to be affected by parental obesity.

Keywords: *Heritability, BMI, WHtR, parent-child correlation, adiposity*

Introduction

Obesity is a health phenomenon that involves both the physical and psychosocial (emotional, social, psychological) well being of humans. Pediatric obesity adversely contributes to children's short and long-term physical and psychosocial health outcomes and is likely to contribute largely to adult-onset morbidity (Chaoyang, 2009). The latent or cumulative effects of obesity in childhood result in higher adult morbidity and premature mortality (Franks, 2010).

Because of the complexity of the problem and the adverse consequences of childhood overweight and obesity, primary prevention is likely the most important intervention. Early action can prevent or minimize obesity and overweight and their associ-

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ated psychosocial, cognitive and health outcomes (Bussey, 1997). Obesity is not a single disorder but a heterogeneous group of conditions with multiple causes. Body weight is determined by an interaction between genetics, environmental and psychological factors acting through the physiological mediators of energy intake and expenditure (Marti, 2004).

The relationships between obesity and inheritance have been explored in a limited fashion and not in the context of parenting. There are twins, adoption and family studies which have established that obesity is highly heritable and individual risk of obesity increases when one has relatives who are obese (Stunkard, 1986; Rice, 1999). Besides, there are studies which support the hypothesis that familial factors (biological and/or environmental) affecting the development of adiposity emerge at specific ages and are related to adiposity of both parents (Whitaker, 1997). Studies have reported high parent-offspring correlation for linear measurements and osseous girths and low values for girth and skinfold measurements suggesting that in measurements relating to skeleton mass, a considerable genetic component is involved (Satwanti, 1985).

Identification of genetic variants related to obesity (Frayling, 2007) suggests that parent-offspring BMI associations are due in part to genetic influences (Maes, 1997). On the other hand, rapid increases in obesity worldwide in recent decades (Stamatakis, 2005; Berg, 2005) are likely attributable to changes in environmental factors (Lake, 1997; Strauss, 1999). It is possible that parent-offspring associations could be due to shared environment, such as socioeconomic position, diet, physical activity levels, and other lifestyle factors (Simonen, 2002; Kivimaki, 2007).

Parental obesity is arguably the strongest determinant of offspring obesity, with measures of offspring fatness increasing linearly with increasing level of parental fatness. Researchers have documented relationships between BMI of parents and their children (Danielzik, 2002). However no published data has reported the heritability of obesity among Baniya community, a homogenous population. The purpose of this study was to investigate, the associations between childrens' BMI and their parents' BMI and their interactions among Baniya population.

Materials and methods

Population under study

The present study was conducted on Aggarwal Baniyas of Delhi. Baniya is generic term used for some communities which basically means a trading community. They are divided into number of subcaste such as Aggarwals, Barnwal, Kesharwani, Mahawar, Maheshwari, Mahur, Mahuri, Mathuria Vaishya, Khandelwals, Oswals, Omar, Rastogis, Sunga, Ghate Banias, Parwars and Porwals. The Aggarwals are generally considered to be the largest and most influential of the Baniya communities from northern India. Aggarwals are largely a trading community. They practice caste endogamy and gotra exogamy.

Recruitment of subjects

Data was collected by multistage, stratified sampling method from 309 Aggarwal Baniyas families located in Delhi, having at least one child in age group of 11-19 years and their respective parents. In total data was collected on 1545 subjects having 271 males, 307 females and 967 children of both sexes. The majority of children resided with their parents in family households. Exclusion criteria included obesity secondary to hypothyroidism, severe debilitating diseases, or cancer. In addition, women who were pregnant or lactating were excluded so were the inter-caste offspring. Participants from a wide range of socio-economic group were enrolled. The study was approved by the Ethical Committee of the Department of Anthropology, University of Delhi and informed consent was obtained from each subject. For minor children consent was obtained from either parent.

Anthropometric measurements

Body weight was measured by using spring balance to the nearest 500 g, stature with the help of Martin's Anthropometer to the nearest mm. Both the measurements were taken according to the techniques described by Weiner and Lourie (1981). As an indicator of fatness-body mass index was calculated as weight (kg) divided by stature (m) square and categorized as normal (< 25.0), overweight (25.0–<30.0), and obese (> 30.0) (WHO, 1998). Waist-to-hip ratio (WHR**)** was calculated by dividing waist circumference by hip circumference. High waist hip ratio was defined as ≥0.9 in men and ≥0.85 in women (WHO, 2000). Waist to height ratio (WHtR) was calculated as the ratio of waist circumference (cm) to height (cm). High WHtR was defined as ≥ .50 for both males and females (Ashwell, 2005). Grand mean thickness (GMT) which is gross measurement of subcutaneous fat is obtained by adding all skinfold thicknesses (biceps, triceps, subscapular, suprailiac, abdominal, calf medial and calf posterior) taken at different sites, divided by the number of skinfold sites (Satwanti et al., 1980).

Statistical analysis

Data was analyzed by using computer software Statistical Package for the Social Sciences (SPSS) version 15.0 for windows (SPSS Inc., Chicago, USA). Descriptive data were expressed as mean values with standard deviations for continuous variables. The degree of familial aggregation was evaluated by an intraclass correlation (Pearson correlation) coefficient (r) after adjusting for age and sex. All analyses were two-tailed and p-value < 0.05 and < 0.01 were considered statistically significant. Coefficient of heritability, which estimates the proportion of phenotypic variance that can be accounted by genetic variance was equal to the regression of the offspring on parent (Falconer 1981) were also estimated for various indices. It is given by $h^2 = V^A/V^P = b$, where, V^A is the additive genetic variance; V^P is the phenotype variance; and b is the regression coefficient.

Results

Full details of the basic characters of our study have been published previously (Gupta and Kapoor, 2010). In brief, the prevalence of adult obesity was 42.7% in women and 21.2% in men. The mean BMI of mothers (29.4 kg/m^2) was higher than that of fathers (26.1 kg/m^2). The mean BMI of children ranged 16.9-22.4 kg/m^2 in sons and 16.3-24.5 kg/m^2 in daughters. The means and standard deviations of various measurements and indices for parents along with t values to compare the sex difference between parents are given in Table 1. Males had statistically significant higher weight and height than females. Though waist circumference was higher in males, hip circumference was much higher in females. Body mass index (BMI) was found to be higher among females. Males had higher mean WHR than females. However, females had higher mean WHtR than males. GMT was found to be higher in case of females. The difference between males and females for all the variables were found to be statistically significant at different probability levels.

The means and standard deviations of various measurements and indices for children are given in Table 2. Among pre-adolescent and adolescent boys and girls, although pre-adolescent boys were lighter and shorter than pre-adolescent girls, adolescent boys were heavier and taller than adolescent girls. Although both hip and waist circumference was higher in pre-adolescent girls than pre-adolescent boys, among adolescent boys and girls hip circumference was higher in girls and waist circumference was higher in adolescent boys. The value of waist hip ratio was also found to higher among per-adolescent and adolescent boys than girls in all age group. The mean value BMI and WHtR were found to be higher among per- adolescent and adolescent girls than boys. GMT values were higher among girls as compared to their counterpart boys.

Table 1: Descriptive statistics of anthropometric variables among fathers and mothers

Variables	Fathers N=271 X±SD	Mothers N=307 X±SD	t-value with level of significance
Weight (kg)	72.8 ±13.12	68.1±11.47	4.74**
Height (cm)	166.7±5.81	152.1±5.51	30.4**
Hip circumference (cm)	98.1±8.42	107.2±10.90	7.12**
Waist circumference (cm)	98.3±11.82	92.0±10.51	11.08**
Body mass index (BMI)	26.1±4.28	29.4±4.77	8.70**
Grand mean thickness(GMT) (mm)	22.9±7.80	32.0±6.90	13.82**
Waist to hip ratio (WHR)	1.0±0.07	0.86±0.07	23.48**
Waist to height ratio (WHtR)	0.59±0.07	0.60±0.07	2.67*

*$P<0.01$
**$P<0.001$

The intraclass correlations for various anthropometric measurements are given in table 3-6. Compared with sons, daughters had higher correlations with their parents for waist circumference. Daughters showed higher correlations with their mothers for height and WHtR and that for weight, hip circumference, BMI and WHR with their fathers. However, boys had higher correlation for height and GMT with their father than girls. All heritability estimates were adjusted for age and sex using multivariate regression analysis. For the obesity phenotypes, hip circumference and WHR had the highest heritability of 82%, followed by WHtR (52%), BMI (49%), weight (46%), waist circumference (45%) and GMT (35%).

Discussion

The prevention of obesity is considered a global health priority, if we are to accomplish this goal, we must explore new ways of thinking. Prevalence of obesity is high and still growing, it is important to understand who is at risk and its probable cause so that preventive measures can be implemented accordingly. Most of the investigations of factors that contribute to high BMI have been limited to environmental conditions and circumstances without consideration of childrens' personal characteristics that may interact with their environments and make them prone to obesity (Sobal, 1989; Kopelman, 2000; Lahmann, 2000; Merchant, 2007). Environmental components influence our food habits, life style etc. however, they do not seem to explain the totality of the variation at the population level that accounts for individual differences in the body fat accumulation. Variability in obesity related outcomes observed among individuals placed in similar controlled environment support the notion that genetic components also wield some contribution (Weinsier, 2001).

Table 2: Age specific descriptive statistics of the anthropometric variables among boys and girls between ages 11 to 19 years

	Age (years)								
	11 X ±SD	12 X ±SD	13 X ±SD	14 X ±SD	15 X±SD	16 X±SD	17 X±SD	18 X±SD	19 X±SD
Boys	N=56	N=58	N=60	N=55	N= 49	N=48	N=54	N=52	N=53
Weight	34.0±4.25	35.9±5.09	52.0±8.53	57.6±12.8	52.7±9.69	55.6±9.37	57.2±6.12	60.6±4.6	65.2±5.7
Height	140.3±3.86	145.6±8.73	158.8±6.9	165.2±4.5	164.4±3.98	165.0±10.85	171.2±4.7	167.7±4.7	170.8±5.3
HC	74.0±4.27	75.1±4.60	87.3±6.53	87.9±13.1	86.5±8.26	88.6±7.03	88.7±4.81	90.6±4.21	92.4±4.70
WC	65.4±6.97	66.2±5.34	76.7±10.4	78.9±10.7	76.3±9.03	76.2±9.27	75.1±6.74	75.9±7.32	83.2±4.31
BMI	17.3±2.09	16.9±1.07	20.6±3.14	21.1±4.46	19.6±4.04	20.4±2.38	19.6±2.34	21.6±2.08	22.4±2.68
GMT	13.6±4.98	11.4±4.88	18.1±7.87	18.4±7.26	15.1±9.20	17.7±5.20	13.3±3.99	15.9±5.00	18.6±3.37
WHR	0.88±.059	0.88±.030	0.88±.071	0.88±.053	0.88±.041	0.86±.055	0.85±.042	0.84±.054	0.90±.034
WHtR	0.47±.050	0.46±.040	0.48±.072	0.48±.065	0.46±.062	0.46±.053	0.44±.041	0.45±.046	0.49±.038
Girls	N=51	N=54	N=52	N=50	N= 50	N=56	N=54	N=56	N=59
Weight	39.6±10.75	39.8±6.93	36.0±9.42	44.6±6.16	49.5±7.68	53.1±6.13	56.6±9.54	59.0±9.7	54.5±7.51
Height	143.2±8.24	145.9±18.84	148.2±7.1	149.4±4.1	155.9±3.98	157.2±4.39	154.4±3.3	154.9±4.4	155.4±4.5
HC	78.8±9.81	80.9±6.96	76.1±10.0	85.9±4.99	90.6±6.25	93.0±4.04	96.4±9.45	91.0±14.9	93.7±8.08
WC	69.8±12.28	67.3±6.59	61.8±8.85	67.1±6.30	74.7±7.49	79.2±8.03	79.0±6.42	79.8±13.6	76.0±8.88
BMI	19.2±4.29	18.0±2.59	16.3±3.46	20.0±2.59	20.3±3.09	21.5±2.11	23.8±4.28	24.5±3.93	22.7±4.13
GMT	18.6±8.40	15.4±4.00	10.2±3.86	15.0±3.77	20.1±5.35	21.4±4.85	26.0±6.94	23.6±6.78	22.3±7.40
WHR	0.88±.059	0.83±.025	0.81±.072	0.78±.037	0.82±.072	0.85±.069	0.82±.034	0.89±.120	0.81±.034
WHtR	0.49±.074	0.45±.040	0.42±.052	0.45±.042	0.48±.050	0.50±.044	0.51±.046	0.52±.087	0.49±.070

Table 3: Mother-daughter correlation of anthropometric variables between ages 11 to 19 years

	Age (years)									h^2
	11	12	13	14	15	16	17	18	19	(%)
Weight	.122	-.041	-.185	.103	-.185	.101	-.247	-.086	.111	2-19
Height	-.034	.215	**-.637****	-.026	-.213	.081	-.008	-.078	-.023	1-64
HC	.197	-.058	-.140	.200	-.198	.017	-.176	-.194	.180	1-26
WC	.085	.043	**-.650****	.232	.081	.131	-.070	-.180	.100	3-45
BMI	.130	-.041	-.255	.183	-.261	.043	-.234	-.067	.142	2-24
GMT	.273	-.189	-.150	.000	.068	.203	-.185	-.031	**.338***	1-35
WHR	-.076	.003	-.132	.262	.060	-.004	.242	-.042	-.069	1-62
WHtR	.130	.033	**-.713****	.227	.047	.160	-.029	-.180	.114	2-52

* $P < 0.05$; ** $P < 0.01$

Table 4: Mother-son correlations of anthropometric variables between ages 11 to 19 years

	Age (years)									h^2
	11	12	13	14	15	16	17	18	19	(%)
Weight	.004	.101	.023	.266	.131	.054	.123	-.219	.061	1-16
Height	-.041	-.013	-.156	.008	-.240	-.094	.016	.201	-.045	2-20
HC	.048	.035	.182	.163	.198	.136	-.011	-.229	-.055	1-14
WC	-.100	-.139	.094	.148	.049	.070	.029	-.147	-.038	2-18
BMI	.071	-.028	.213	.148	.072	-.032	-.012	-.197	-.098	1-13
GMT	-.089	-.109	**.292***	.048	.198	.038	.012	**-.486****	.014	1-32
WHR	-.056	-.166	-.201	-.140	-.020	.087	-.004	.002	.106	1-20
WHtR	-.076	-.258	.141	.046	.011	.055	-.069	-.101	-.139	1-14

* $P < 0.05$; ** $P < 0.01$

Table 5: Father-daughter correlation of anthropometric variables between ages 11 to 19 years

	Age (years)									h^2
	11	12	13	14	15	16	17	18	19	(%)
Weight	.151	-.189	-.057	.034	**.325***	-.150	.246	-.172	.059	2-46
Height	.147	-.100	-.196	-.079	.203	-.037	-.069	-.003	-.099	1-21
HC	-.047	-.104	**-.450****	.092	.276	.030	.202	-.029	.034	2-82
WC	.163	-.156	**-.332***	.068	.130	-.157	.233	.079	-.024	4-37
BMI	.182	-.129	**-.426****	.004	.296	.037	.185	.013	.041	1-49
GMT	.119	.026	-.563	.066	.181	-.033	.270	.016	-.020	1-30
WHR	.244	.039	**.765****	-.133	-.074	-.254	-.209	.216	.013	1-82
WHtR	.187	-.163	-.123	.031	.196	-.062	.207	.177	-.065	2-24

* $P < 0.05$; ** $P < 0.01$

Table 6: Father-son correlation of anthropometric variables between ages 11 to 19 years

	Age (years)									h^2
	11	12	13	14	15	16	17	18	19	(%)
Weight	.121	-.046	-.247	.103	.213	.095	.161	-.138	.051	2-20
Height	.240	.122	-.031	**.293***	.097	-.060	-.159	-.009	-.128	4-33
HC	.089	.023	**-.308***	.117	.119	.151	.093	-.053	-.064	2-30
WC	-.003	-.026	-.201	.085	.167	.149	.209	-.125	.054	1-20
BMI	.186	.017	**-.293***	.152	.086	.116	.188	-.012	-.022	1-23
GMT	.095	.028	**-.272***	.172	.135	.160	.045	-.072	-.067	2-25
WHR	-.124	.019	.091	.035	.059	.106	.198	-.086	.013	1-12
WHtR	.111	.067	-.137	.075	.115	.100	.238	-.044	-.027	2-15

* $P < 0.05$; ** $P < 0.01$

The utilization of correlation between sibs and of variance analysis of sibships is not the ideal methods to determine the extent of genetic involvement. However the fact that environmental factors presents more important contribution to the correlation between sibs than to the parent-child correlation, at least for measurements easily influenced by environment, means that the comparison between intrafamilial correlations permit us to evaluate genetic, environmental and dominance effect (Susanne, 1975).

The results of the present study show that there is a high prevalence of obesity among Baniya subjects with females being more obese as compared to males (Gupta and Kapoor, 2010). The correlation between spouses was not statistically different from zero except for weight and waist circumference. The correlation for stature which is a character liable to an appreciable degree of assortative mating in European populations (Spuhler, 1968) was not statistically significant. The low and statistically non-significant correlations between these measurements of spouses are important, for they indicate that assortative mating for these body dimensions are either absent or so small that they can be neglected in interpreting other intra-familial correlations. However, significant correlation for weight and waist circumference has been observed between spouses. Since spouses are not related by blood, any correlation probably reflects the environmental factors to which the couple is exposed. In addition, these correlations may be due to the effects of assortative marriages (Inoue, 1996). The significant values for weight and waist circumference are in agreement with other findings among Indian populations (Kaur, 1981; Byard, 1985). In a study conducted among Korean nuclear families also nonzero correlations for height, weight, and hip circumference between spouses were observed (Park 2004). The high correlation between fathers and mothers for weight and waist circumference can be explained as due to the common intrafamilial food habits.

Among mother-daughter, significant but negative value of correlation suggests that with decrease in height of one group the height of other group increased, thus showing a secular trend in height between mothers and their daughters. Similarly statistically significant positive correlation has been observed between fathers and their son, thus suggesting maternal and paternal effect on daughter and son respectively as reported in other study (Rao, 1975) also. The results in the present study were consistent with the findings of previous studies (Russel, 1976; Sinha, 2006; Li, 2009; Kunesova, 2010). The results opposite to the present study were found in others studies (Acheson, 1967; Roberts, 1978).

In the present study, heritability of weight and height among Baniya subjects varied from 2 to 46% and 1 to 64% respectively. The findings in the present study were consistent with the other Indian studies (Dasgupta et al., 1997; Raychaudhuri, 2003). In number of studies on Indian population, heritability estimates of more than 1.0 were also observed (Rebato et al., 2005; Salces et al., 2007; Salces et al., 2009). As a whole, heritability of weight was low from parents to children. In our study, we found that hip circumference and WHR had heritabilities higher than that for BMI, WHtR, GMT and waist circumference. This finding is not in concert with the findings in several previous studies which reported that BMI, waist circumference, and skin-fold thickness had heritabilities higher than that for WHR (Katzmarzyk, 2000; Poulsen, 2001; Pausova, 2001; Freeman, 2002; Wu, 2003).

In the present study, heritability estimates ranged from 1% to 82% for hip circumference and WHR, from 1% to 52% for WHtR, from 1% to 49% for BMI, 1% to 45% for waist circumference and from 1% to 35% for GMT. Among the aforementioned studies, only one study (Pausova, 2001) reported that WHR had a higher heritability than BMI. In a study of estimating genetic and environmental contributions in Northern Manhattan study, one study (Juo, 2004) reported substantial genetic contribution to

BMI (36% to 80%), waist circumference (37% to 49%) and skinfold thicknesses (11% to 54%) and 6% to 42% for WHR. There is a study which (Bouchard, 1998) reported heritability estimates for BMI to be 25-40%, whereas another study reported (Katzmarzyk, 2000) heritability of fatness to be 40-60% and that of fat distribution to be 29-48%. BMI represents total body size, waist circumference reflects central fat, GMT is a parameter for subcutaneous fat, WHtR and WHR are used for body fat distribution. Therefore, all the phenotypes are related but may not be influenced by the same genetic factors. To our knowledge, this is the first report of heritability of the adiposity indices among Aggarwal Baniya population. Our results confirm that genetic factors contribute to the familial aggregation of the obesity and its components.

The literature shows that, with regard to stature, parent-child correlations increases very rapidly during the first year, slow down later on, then somewhat decrease during puberty and increase again afterwards (Garn, 1976; Byard, 1989). Salces et al. (2009) also reported lowest heritability during puberty and highest at the end of growth period. This general trend from birth to maturity reflects the growing contribution of the children's own genes. Conversely, the influence of maternal factors on weight gradually decreases from birth up to the age of three (Garn, 1976). However, the results in the present study showed opposite trend as the correlation coefficients for various adiposity measurements were found to be significant in pubertal age periods but were non-significant during post-pubertal period (12-15 year for girls and 14-17 year for boys; >15 year for girls and >17 year for boys respectively). A study on siblings of Basque origin (Rebato, 1997) confirmed that the correlation coefficients of body dimensions also fluctuate during growth, as the degree of genetic determination after puberty was higher with regard to bone measurements but unrelated to weight, which reported higher correlation coefficients than the present study.

There was a gender difference among the children regarding resemblance to parental anthropometric characteristics. Daughters had a higher tendency than sons to resemble their parents, as they were more significantly correlated with their parents than sons. Although it is not known why sons had lower correlations with their parents than daughters, peer group influences may be greater than familial influences on male adolescents. Among Baniya population, daughters showed higher correlations with their parents for waist circumference which was consistent with the finding of other studies (Park, 2006). The heritability of waist circumference among Baniya population varied from 0 to 46% which was higher than reported in another study (Lin, 2005).

In the present study, the observation that sibling-sibling correlation (not shown in tables) for various measurements were higher than parent-child correlations is consistent with the hypothesis that there were significant differences between the environment of parents and children in these populations. Between-generation shift in social class may also have contributed to difference in the environment of parent and child (Russel, 1976). Overall stature showed higher intrafamilial correlation and heritability than weight among Baniya subjects, a common general finding (Rebato et al., 2005) suggesting greater genetic influence on stature and greater environmental effect on body weight.

Our study has several limitations. First, the cross-sectional sampling design does not allow inferences to be drawn with respect to the causal relationships among variables. Second, the study sample is only representative of adult Baniyas residing in Delhi, and findings may therefore not be generalizable to entire Delhi settings. Due to a limited sample size of 1539 subjects, we cannot rule out that there may be additional gender-related differences that we did not have sufficient statistical power to detect. Despite these limitations, this study provides important data regarding the correlation and heritability of obesity related factors among adults in an urban Delhi setting.

Conclusion

We have shown here that, there is familial aggregation as well as gender differences in familial correlations of adiposity traits in children with daughters being more likely than sons to be affected by parental indices of adiposity. Our results confirm that there is an age-related trend in heritability estimates of adiposity traits. Further studies are necessary to investigate specific genetic and environmental factors related to the adiposity.

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