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Evidence for Higher Heritability of Somatotype Compared to Body Mass Index in Female Twins

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Abstract The influence of genetics on human physique and obesity has been addressed by the literature. Evidence for heritability of anthropometric characteristics has been previously described, mainly for the body mass index (BMI). However, few studies have investigated the influence of genetics on the Heath-Carter somatotype. The aim of the present study was to assess the heritability of BMI and somatotype (endomorphy, mesomorphy, and ectomorphy) in a group of female monozygotic and dizygotic twins from childhood to early adulthood. A total of 28 females aged from 7 to 19 years old were studied. The group included 5 monozygotic and 9 dizygotic pairs of twins. The heritability was assessed by the twin method (h^2). The anthropometric measures and somatotype were assessed using standard validated procedures. Significant differences between monozygotic and dizygotic pairs of twins were found for height, endomorphy, ectomorphy, and mesomorphy, and the heritability for these measures was high (h^2 between 0.88 and 0.97). No significant differences were found between monozygotic and dizygotic twins for weight, and the BMI and the heritability indexes were lower for these measures (respectively 0.42 and 0.52). The results of the present study have indicated that the somatotype may be more sensible to genetic influences than the BMI in females. *J Physiol Anthropol 26(1): 9–14, 2007* http://www.jstage.jst.go.jp/browse/jpa2
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Introduction

The human physique is influenced by a variety of environmental factors, such as lifestyle, diet, and physical activity (Bouchard, 1997). Health disorders may also influence the human physique, as well as ontogenetic growth and maturation. Recently, Steegmann (2006) has criticized the classic trend to focus physiological anthropology on natural selection theory rather than on other "less elevated" issues such as heritability. Indeed, research has also shown the influence of genetic factors on anthropometric and body composition measures (Chatterjee et al., 1999; Faith et al., 1999; Hanisch et al., 2004; Hsu et al., 2005).

Obesity among children and adolescents is considered a worldwide epidemic problem that is associated with medical and psychological complications (Faith et al., 1997). The obesity epidemic is explained by factors such as sedentary lifestyles and high caloric diets (French et al., 2001). However, genetic factors have also been described as possible causes for obesity in children and adolescents (Faith et al., 1999; Pietilainen et al., 1999; Bodurtha et al., 1990).

The use of skinfold thickness in children may be unreliable and inaccurate in these types of samples (Reilly et al., 1995; Roche, 1996). Therefore, the BMI is often used to assess children's obesity. The literature presents evidence on the heritability of body mass index (BMI) (Allison et al., 1996; Deng et al., 2006). Heritability of BMI is the proportion of within-population variation in BMI that is attributable to within-population genetic variation of BMI. The variability in adult BMI does not seem attributable to the shared environment (Hewitt, 1997). Since there may be age-specific genetic influences on adiposity (Meyer, 1995), the results from adult studies may not reflect the genetics behind children obesity (Faith et al., 1999). Body mass index estimates of heritability from family studies are generally lower (less than 0.40) than estimates from twin studies (≈0.70) and the latter are believed to be more reliable (Schousboe et al., 2003). Moreover, twin studies have indicated either the presence of sex-specific effects on the heritability of BMI (Bodurtha et al., 1990) or no effect whatsoever (Harris et al., 1995; Pietilainen et al., 1999). However, few studies have assessed samples of

both monozygotic and dizygotic twin children and adolescents (Faith et al., 1999).

The assessment of the somatotype may be used to describe changes on the human physique during lifespan or as a result of physical activities. It may also be used to detect a tendency to the appearance of specific health disorders, i.e. metabolic disorders or mental disorders (Sivkov and Akabaliev, 1999; Herrera et al., 2004). Indeed, the Heath-Carter method of assessment has been widely used for different purposes. Though the somatotype has often been considered as a genetic trait, research has proved it to be also influenced by growth, ageing, exercise, and nutrition (Carter and heath, 1990). The popularity of the method is explained by its simplicity of application, which may be a virtue for epidemiologic studies. Basically the somatotype is expressed quantitatively by a score of three components: endomorphy, mesomorphy, and ectomorphy. The endomorphy represents the relative adiposity, the mesomorphy represents the relative muscle-skeletal magnitude (robustness), and the ectomorphy the relative thinness of the subject (Carter and Heath, 1990).

Several studies have shown a significant effect of genetics on the Heath-Carter somatotypes. Indeed, the literature provides evidence for such an assumption in family studies (Bouchard et al., 1980; Sanchez-Andres, 1995; Katzmarzyk et al., 2000) and also in twin studies (Song et al., 1994; Peeters et al., 2003). However, none of the aforementioned studies have analysed simultaneously the heritability of somatotype and the heritability of BMI in twins.

The aim of the present study was to assess the heritability of BMI and somatotype (endomorphy, mesomorphy, and ectomorphy) in a group of female monozygotic and dizygotic twins from childhood to early adulthood.

Methods

Participants

The participants were selected among female pairs of twins living in urban areas. The selection intended to discard the effect of differential breeding environments and physical activity. All pairs that were selected were bred since birth in the same family environment. Additionally, all the pairs that were selected were involved in similar types of physical activities. For this purpose, physical activity questionnaires for children (PAQ-C) and adolescents (PAQ-A) were used (Crocker et al., 1997). The selected sample included twenty-eight Caucasian female twins aged from seven to nineteen years old. The group included five monozygotic and nine dizygotic pairs of twins. The mean age (standard deviation) of the subjects was 12.6 (4.1) years in the MZ twins and 13.0 (4.2) years in the DZ twins. The parents or legal guardians of the subjects gave their written informed consent to participate in the study. The procedures were approved by the ethics committee of the University Castelo Branco (UCB/RJ) and were according to the Helsinki Declaration of 1975.

Procedures

The zygosity was determined by parental questionnaire. The heritability was assessed by the twin method. The heritability index (h^2) was calculated from the mean variances (S^2) of the monozygotic (MZ) and dizygotic (DZ) pairs of twins by Holzinger's formula (Ghio et al., 1989):

$$h^2=(S^2DZ-S^2MZ)/(S^2DZ) \quad (1)$$

The somatotype profile was assessed with the Carter and Heath (1990) protocol. Lange skinfolds calipers (Beta Technology, Santa Cruz, CA, USA) and Spreading Calipers (Osteolab, UK) were used. The endomorphy was assessed by the following measures: sub scapular skinfold (SBS), tricipital skinfold (TR) and supra spinal skinfold (SSS). The mesomorphy was assessed by the following measures: biepicondylar breadth of the humerus (BBH), biepicondylar breadth of the femur (BBF), medial calf skinfold (MCS), right arm girth (RAG), right leg girth (RLG) and height of the subject. The ectomorphy was assessed by the height and weight of the subjects.

The body mass index (BMI) was calculated as weight (kg) divided by the square of the height (m). The BMI is a measure that has been previously validated for children and adolescents against dual energy radiograph absorptiometry (Pietrobelli et al., 1998). The height was measured to the nearest 0.5 cm using a stadiometer (Holtain, Crosswell, Wales). The weight was measured to the nearest 0.1 kg using a digital scale (Weight Tronix, New York, USA). Both measures were assessed twice and Test-retest reliability for these measures in our laboratory was $\approx$0.99.

Statistics

Data analysis was performed with software SPSS 13.0 (SPSS Science, Chicago, USA). Standard descriptive measures were used (mean and standard deviation). Differences between measures of monozygotic and dizygotic pairs of twins were assessed by the F value, calculated as the dizygotic variance divided by the monozygotic variance (Rodas et al., 1998; Calvo et al., 2002) after the normality assumption was verified with the Shapiro Wilk Test. Associations between variables were investigated with the Pearson Product-Moment coefficient. The significance threshold was set at $p \leq 0.05$.

Results

The results observed in the anthropometric and somatotype measures (endomorphy, mesomorphy, and ectomorphy) are presented in Table 1. The values of the means and the medians were relatively close in all variables and the normality of distribution of the variables was confirmed.

There were significant differences between the variances of the height and somatotype measures observed for monozygotic and dizygotic pairs of twins. The monozygotic twins had higher endomorphy and mesomorphy and lower ectomorphy when compared with the dizygotic twins. The monozygotic

Table 1 Mean, Standard deviations (SD), mean variances (S^2), *F* statistic and heritability index (h^2) of anthropometric and somatotype measures in the monozygotic (MZ) and dizygotic (DZ) pairs of twins.

	MZ			DZ			*F*	h^2
	Mean	SD	S^2	Mean	SD	S^2		
Height (cm)	144	14.1	0.13	146	16.1	2.75	22.2*	0.95
Weight (kg)	40.9	11.2	2.23	40.3	12.0	4.63	2.1	0.52
BBH (cm)	5.4	0.4	0.015	5.3	0.4	0.016	0.9	0.07
BBF (cm)	8.4	0.7	0.002	8.1	0.7	0.027	13.3*	0.92
RAG (cm)	23.2	3.0	0.23	22.0	2.9	1.18	5.1	0.80
RCG (cm)	28.9	4.1	0.85	28.6	4.3	3.43	4.0	0.75
TRS (mm)	14.0	6.9	0.91	13.3	5.0	8.20	9.0*	0.89
SSS (mm)	13.9	8.9	1.32	9.8	4.6	11.16	8.5*	0.88
SBS (mm)	12.6	5.7	1.63	9.9	4.6	6.30	3.9	0.74
MCS (mm)	13.6	6.6	0.65	11.5	3.7	4.47	6.9*	0.86
BMI (kg/m^2)	19.4	3.4	0.50	18.3	2.8	0.87	1.7	0.42
Endomorphy	4.0	1.0	0.01	3.6	1.0	0.30	28.7*	0.97
Mesomorphy	3.8	1.3	0.04	2.9	1.0	0.37	8.4*	0.88
Ectomorphy	2.6	1.0	0.02	3.0	1.3	0.26	12.5*	0.92

* Significant for $p \leq 0.05$.

Abbreviations: BBH=biepicondylar breadth of the humerus; BBF=biepicondylar breadth of the femur; RAG=right arm girth; RCG=right calf girth; TRS=tricipital skinfold; SSS=supra spinal skinfold; SBS=sub scapular skinfold; MCS=medial calf skinfold; BMI=body mass index.

twins were also taller than the dizygotic twins. Heritability (h^2) of the three somatotype measures and of the height were high (comprised between 0.88 and 0.97). There were no significant differences between the two kinds of twins in weight and BMI. These latter variables presented lower and non-significant values of h^2. Other anthropometric variables (biepicondylar breadth of the femur, tricipital skinfold, supra spinal skinfold and medial calf skinfold) also presented differences in the variances between MZ and DZ, as well as high heritability (see Table 1).

The age presented significant associations with the BMI (0.81; $P \leq 0.001$) and with endomorphy (0.78; $P \leq 0.001$) in the DZ group but not in the MZ group. Moreover, the age did not correlate with mesomorphy or ectomorphy in DZ nor MZ. Figure 1 illustrates the association between age and BMI or endomorphy in the two groups of twins. When data from the two groups of twins were pooled together, the same associations were present, but with a lower correlation coefficient (0.54; $P \leq 0.05$ between age and BMI and 0.43; $P \leq 0.05$ between age and endomorphy).

Discussion

The aim of the present study was to assess the heritability of BMI and somatotype (endomorphy, mesomorphy, and ectomorphy) in a group of female monozygotic and dizygotic twins from childhood to early adulthood.

The results of the present study have shown a tendency for a genetic influence on the three somatotype measures that were assessed (endomorphy, mesomorphy, and ectomorphy). The heritability indexes (h^2) for these variables were considerably high (between 0.88 to 0.97). The results failed to demonstrate the same genetic influence on weight and BMI in a sample of monozygotic and dizygotic twins. In our subjects, the heritability for height was high (0.95), confirming the literature (Chatterjee et al., 1999). Moreover, other anthropometric measures also presented high heritability (biepicondylar breadth of the femur, tricipital skinfold, supra spinal skinfold and medial calf skinfold).

Previous studies have shown a significant genetic influence in obesity measures across the life span, from children (Faith et al., 1997), to young adults (Magnusson and Rasmussen, 2002; Hsu et al., 2005) or older people (Selby et al., 1989). Moreover, it has been suggested that the heritability estimations for the BMI are higher in twins and progressively lower in family relatives and even lower in adopted subjects (Bouchard, 1997). The heritability for BMI that we have found is within the limits set by the literature. Previous studies describe lower (Coady et al., 2002) and higher (Allison et al., 1986; Selby et al., 1989; Pietilainen et al., 1999; Deng et al., 2006; Hsu et al., 2005) h^2 values for BMI, compared to the association that we have found (h^2=0.42). The heritability of other measures (body weight, fat mass, lean body mass and sum of skinfolds) has also been found to be higher than our observations (Selby et al., 1989; Hanisch et al., 2004; Hsu et al., 2005). Body mass index estimates of heritability from family studies are generally lower than estimates from twin studies, and the latter are believed to be more reliable (Schousboe et al., 2003). However, several of the aforementioned studies that have described higher h^2 than our observations were family studies (Deng et al., 2006; Hsu et al., 2005). Therefore, the twin assessment issue does not help to explain the results of the present study. Hence, it is possible that environmental factors have influenced the BMI in the

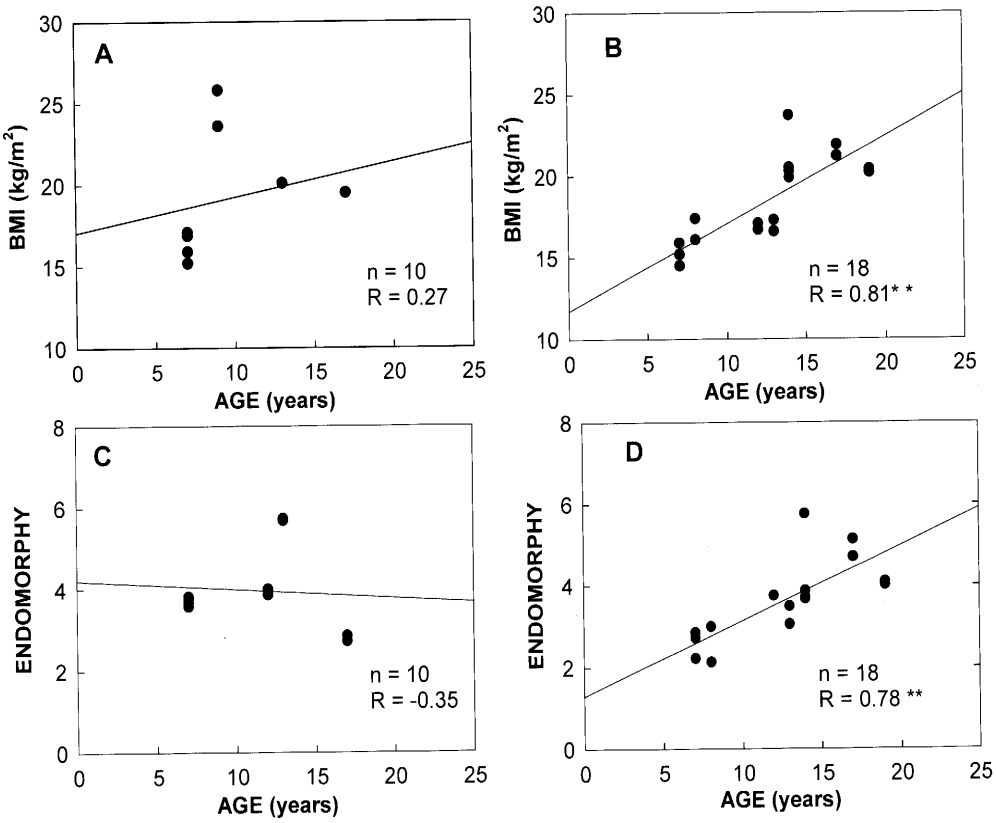

Fig. 1 Associations between age and BMI in the MZ (A) and DZ (B) groups and between age and endomorphy in the MZ (C) and DZ (D) groups.
Abbreviations: BMI=body mass index; MZ=monozygotic; DZ=dizygotic.

group that we have studied. Previous studies (though with the family rather than the twin approach) have also concluded that other than genetic factors influence the familial aggregation of BMI (Magnusson and Rasmussen, 2002). A non-genetic influence in BMI could be due to environmental factors affecting the weight and, subsequently, the BMI in our sample. In modern societies, obesity and overweight strike the whole population from early childhood. However, the mean values that we have observed in BMI (≈19) are typical of female children aged around 12–13 (the mean age of our sample) and cannot be considered as indicators of overweight. Therefore, an environmental effect due to an excessive calorie balance is not supported by our data. The fact that the sample comprised a large variation in the subjects' ages (between 7 and 19 years) could also have influenced the results, since BMI is expected to be age-dependent (Atwood et al., 2006). However, in our sample, the age correlated with BMI and with endomorphy only in the DZ group, but not in the MZ group.

It has been suggested that the heritability of BMI and other obesity-related measures may be biased upwards due to differences in the total variance in monozygotic compared to dizygotic twins (Selby et al., 1989). If this assumption is right, then it is possible that our estimations of the h^2 for BMI may not be so low when compared with the literature.

Several studies have shown a significant effect of genetics on the Heath-Carter somatotypes, but few of them have analysed twins (Song et al., 1994; Peeters et al, 2003). Peeters et al. (2003) describe heritability estimates between 0.21 and 0.89 for endomorphy, between 0.36 and 0.76 for mesomorphy and between 0.16 and 0.76 for ectomorphy, in twins aged ten to eighteen years. Results from familial studies seem to demonstrate a smaller range of h^2, with mean values comprised between 0.42 and 0.68 (Bouchard, 1980; Katzmarzyk et al., 2000). The h^2 values that we have observed for the three somatotypes (between 0.82 and 0.97) are higher compared with the literature. Although Katzmarzyk et al. (2000) have described no sex effects for the heritability of somatotype in families, data from a twin study (Peeters et al., 2003) suggested that the heritability may be higher in females. Therefore, the higher h^2 that we have observed may be partially explained by the gender that we have analysed.

Carter and Heath (1990) have suggested a greater genetic influence on ectomorphy compared to endomorphy and mesomorphy in females. Additionally, Bouchard (1997) has suggested that there is a stronger tendency for the heritability of mesomorphy compared to the heritability of ectomorphy and endomorphy in twins. The results of the present study do not support those observations, since all the three somatotype measures have presented high and very similar values for h^2. Moreover, we have observed that the largest value of h^2 in our sample occurred for mesomorphy, a tendency which is consistent with the suggestion of Bouchard (1997). Sanchez-Andres (1995) and Katzmarzyk et al. (2000) have also described a larger familial aggregation of mesomorphy. The

former study also concluded that environmental factors did not explain a significant proportion of the somatotype. Hence, we have confirmed the high heritability of the Heath-Carter somatotype measures but not necessarily the dominance of heritability in some of the three somatotypes that have been previously suggested (Carter and Heath, 1990; Sanchez-Andres, 1995).

Although the literature presents evidence for a genetic influence on BMI and on the Heath-Carter somatotype, we have not found a simultaneous assessment of the heritability of the two measures in twins. The present study has analysed both associations and the results have indicated that the somatotype may be more sensible to genetic influence than the BMI in females from childhood to young adulthood.

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