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Age trends of sibling resemblance for height, weight and BMI during growth in a mixed longitudinal sample from Sarsuna-Barisha, India

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Abstract

Background: Even though some studies have considered that sibling resemblance remains constant throughout the life cycle, several investigations emphasize the importance of age and its interactions with genetic and environmental factors in determining sibling similarity in several bodily traits. In fact, the study of age changes in familial resemblance is of great importance for the analysis of certain sources of variation observed in growth processes.

Aim: The study examined sibling resemblance for height, weight and body mass index (BMI) in a mixed longitudinal sample from West Bengal, ages 2–19 years, in order to analyse the variations with age of the sibling resemblance for these phenotypes during growth.

Sample and methods: Two hundred and forty-five brothers and 213 sisters from 138 middle-class nuclear families living in a semi-urban area of South Kolkata, India were analysed. The analysis of sibling resemblance was performed through correlations estimated by the maximum-likelihood method. The patterns of different trends of sibling resemblance with age were examined by fitting a cubic non-linear regression to the observed correlations.

Results: The results show clear variations with age in the sibling resemblance for the traits height and weight, though to a lesser extent for BMI. In general, we found the highest correlation values during the period of infancy, a remarkable decrease during puberty, and a trend of increase towards the end of the growth cycle.

Conclusion: The study confirms the effect of age on the degree of similarity among siblings for height, weight and BMI in the sample. The sharp decline of correlation at adolescence can be interpreted in terms of the individual variation in age of reaching the adolescent growth spurt.

Keywords: *Age trends, sibling, resemblance, growth, mixed-longitudinal, India*

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Introduction

Some of the 'classical' studies on sibling resemblance of anthropometric traits claimed that the similarities among these variables as found between the related individuals remained fairly constant throughout life (for a review see Palmer 1934). However, some decades ago, several authors realized that sibling correlations in anthropometric traits do change with the age (Mueller 1976, Rebato et al. 1997, Salces et al. 2002). This has motivated researchers to perform several anthropometric studies on biologically related individuals during growth and at adulthood, in order to investigate the age-related patterns of sibling resemblance and to determine the causes of the observed variation in the light of genetic, environmental and gene–environment interaction (Welon & Bielicki 1971, Rao et al. 1974, Mueller 1977, Bouchard 1980, Byard et al. 1983a, Friedlander et al. 1988, 1989, Kaplowitz et al. 1988, Little et al. 1990, Hauspie et al. 1994, Rebato et al. 1997, 1999, Watanabe et al. 2001).

It has been suggested that age trends in familial correlations for height and weight may be due to either a different genetic contribution at different ages, or due to transient environmental changes. Variable gene expression during different phases of growth and development has been suggested as a possible source of variation in familial resemblance (Byard et al. 1983b, Province & Rao 1985, Livshits 1986, Friedlander et al. 1989, Hauspie et al. 1994). Susanne (1976) has noted that the genetic potential of the individuals is expressed gradually until the post-pubertal stage is complete. In addition, Mueller (1978) has further proposed that the variable magnitude of gene expression may be another possible source of variation in the intra-familial correlation patterns. In addition, transient environmental causes may be capable of modifying familial correlations with age (Brook et al. 1975, Mueller 1978, Bouchard 1980, Byard et al. 1983b, Province & Rao 1985, Friedlander et al. 1989).

The aim of the present study is therefore to examine the sibling resemblance in height, weight and BMI in a mixed longitudinal sample of children and adolescents, aged 2–19 years, from West Bengal, India in order to analyse the variations with respect to age.

Materials and methods

The data comes from a mixed longitudinal sample of siblings (245 brothers and 213 sisters) from 138 nuclear families living in two contiguous villages located in a semi-urban area within the South Suburban Municipality of Kolkata, West Bengal, India. All data were collected by the late Professor S. R. Das from the Anthropological Survey of India, Kolkata. The ages of siblings ranged from 2 to 19 years and the size of the sibships varied between two and five individuals. Most sibships were followed for at least 5 years and in some cases up to 14 years. The average period of observation was 7.5 years for brothers and 7.1 years for sisters. The dominant population in this area during the study period (1952–1966) belonged to three subcastes, namely *Rarhi Brahmin, Dakshin Rarhi Kayastha* and *Vaidya*, which occupy the highest rungs of the Bengali Hindu caste hierarchy in West Bengal, India. These groups of populations possessed a remarkable degree of homogeneity regarding their dietary habits (non-vegetarian), personal and public health practices, and the way of bringing up children. In addition, no appreciable variability among these three caste groups with respect to ABO blood groups, serum proteins and haemoglobins and some red cell enzymes was found (Das 1985). Therefore, for analysis of the data the authors pooled the sample and treated it as one group as was done in previous research (Hauspie et al. 1980).

Height and weight were measured following Martin (1928). Body mass index (BMI) was computed (weight (kg)/height^2 (m^2)) for each individual. Target dates of measurements were the birthdays or half birthdays and were measured within 15 days of the targets. Measurements were taken at 6-month intervals up to the age of 5 years, yearly from 5 to 10 years, at 6-month intervals from 10 to 14 years, and yearly thereafter. Further information regarding the study and the analysed sample can be found in Hauspie et al. (1980).

Sibling correlations for height, weight and BMI were calculated on standard deviation scores (SDS values) of these traits obtained from LMS fits (Cole 1988) to the size-for-age of the three anthropometric variables for both genders separately. Sibling correlations were estimated by the maximum-likelihood method described by Rao et al. (1987) using the program MLECOR, which calculates maximum-likelihood correlations between the siblings. This method weights the correlation for family size (Byard et al. 1991). Approximate sample sizes were estimated by inverting the asymptotic variances of correlation estimates (Rao et al. 1982). The patterns of sibling correlations were smoothed by fitting cubic polynomials.

Results

The descriptive statistics for height, weight and BMI are shown in Table I. Means and standard deviations were calculated in 1-year age groups defined as follows: 2+ corresponds to 2.00–2.99 years, 3+ to 3.00–3.99 years, and so on. The sibling correlations and their statistical significance are shown in Table II for the three analysed variables.

Siblings showed high and significant correlations for height at almost all ages (except at 3 and 16 years), in particular at the age of 19 years ($r = 0.70$), where the observed value exceeded the theoretical value (0.5 between siblings).

Weight also showed a high and significant sibling correlation value almost throughout the whole growth cycle (r varying from 0.30 to 0.51), except at the ages of 2, 16 and 17 years. Correlation estimations for BMI were significant between 6 and 14 years of age ($r =$ 0.26–0.38), as well as at the ages of 3, 4, 18 and 19 years. Overall, the sibling correlations ranged between 0.21 and 0.70 for height, 0.11 and 0.51 for weight, and 0.06 and 0.40 for BMI.

Figures 1–3 give a graphical representations of the various age-related patterns of sibling correlations. The continuous lines show the pattern of estimated age changes in correlations while the broken lines correspond to the fitted cubic polynomial smoothing of these patterns.

Discussion

Sibling resemblance

The results indicated that out of the three studied traits, height in particular follows a polygenic model with high heritability depending on age of the siblings. Nevertheless, it can be stated that the gradient normally observed in adults (Susanne 1975) for, for example the highest heritability for height followed by weight and BMI, was also observed in the growth data of this Indian population. This fact has recently been observed as a general trend of the growing sibling sample studied by Salces (2002) in the province of Biscay, Spain and by Arya et al. (2002) in six Andhra caste populations (India), ranging in age from 6 to 72 years. Some researchers have not only suggested a multifactorial inheritance, but have also provided evidence of a major gene for the inheritance of body height, weight and BMI in various human populations (Livshits et al. 1995, Ginsburg et al. 1998, Rice et al. 1999, Skaric-Juric et al. 2003) although it has not been estimated in the present analysis.

Table I. Age-specific descriptive statistics for height, weight and BMI of the two sexes. *n*, number of individuals; *m*, mean value; SD, standard deviation.

	Height						Weight						BMI					
	Boys			Girls			Boys			Girls			Boys			Girls		
ge	*n*	*m*	SD	*n*	*m*	SD	*n*	*m*	SD	*n*	*m*	SD	*n*	*m*	SD	*n*	*m*	SD
2+	29	84.77	4.95	26	82.12	3.56	31	10.93	1.52	28	9.97	1.00	29	15.16	1.03	26	14.82	0.91
3+	38	92.32	4.47	41	88.78	4.51	37	12.64	1.60	40	11.30	1.27	37	14.72	1.10	40	14.39	1.18
4+	58	97.08	5.34	62	94.63	4.47	58	13.41	1.78	62	12.72	1.46	58	14.19	1.02	61	14.16	1.05
5+	55	102.50	5.62	55	99.71	4.94	56	14.47	1.64	55	13.82	1.63	55	13.79	0.89	54	13.83	1.19
6+	71	107.93	4.55	73	106.62	5.58	71	15.69	1.72	73	15.46	2.04	71	13.45	0.93	73	13.56	1.04
7+	79	113.56	5.15	90	111.24	5.14	78	17.43	2.19	90	16.61	2.02	78	13.50	0.96	90	13.40	1.06
8+	88	117.89	5.11	82	116.96	5.50	86	18.95	2.00	85	18.58	2.37	86	13.59	0.75	82	13.55	1.09
9+	99	123.45	5.22	79	121.69	5.62	98	20.73	2.45	81	20.45	2.46	98	13.57	0.92	79	13.70	0.87
0+	127	127.99	5.32	104	126.85	5.65	127	22.54	2.63	113	22.56	2.97	127	13.72	0.93	104	13.96	1.07
1+	138	131.88	5.37	111	132.72	6.76	137	24.17	2.72	124	25.36	3.98	137	13.88	0.96	111	14.26	1.23
2+	135	136.88	6.03	117	138.71	6.80	135	26.48	3.16	123	28.69	4.81	135	14.10	1.00	117	14.90	1.48
3+	141	142.44	7.13	107	144.03	6.46	141	29.55	4.18	119	32.41	4.95	139	14.50	1.07	106	15.51	1.60
4+	93	149.28	8.72	79	147.55	5.61	100	33.60	5.67	89	35.62	5.49	93	14.95	1.29	76	16.43	1.89
5+	70	156.01	8.18	61	149.81	5.04	74	37.79	6.18	70	38.10	4.30	69	15.55	1.35	60	17.00	1.63
6+	71	160.50	7.50	58	150.55	5.33	74	41.23	5.98	58	39.13	5.13	71	16.03	1.48	57	17.39	2.14
7+	68	163.90	5.80	50	150.56	5.20	71	44.78	5.19	53	40.61	5.28	68	16.64	1.32	50	17.82	1.86
8+	59	165.35	5.92	45	151.21	5.29	59	46.22	5.76	49	40.75	5.48	59	16.87	1.65	45	17.94	1.79
9+	48	165.28	5.28	31	151.69	5.72	47	46.27	5.68	35	40.75	5.65	47	16.90	1.54	31	17.44	1.86

able II. Maximum-likelihood estimated correlations for height, weight and BMI between siblings. No. fam., number of analysed families; *n*, number of analysed pairs of blings; *r*, correlation values; SE, standard error of the estimated correlation.

ge	No. fam.	Height			Weight			BMI		
		n	*r*	SE	*n*	*r*	SE	*n*	*r*	SE
2+	23	42	0.41*	0.16	41	0.31	0.17	38	0.30	0.16
3+	34	48	0.26	0.14	55	0.47**	0.13	56	0.40**	0.13
4+	49	88	0.51***	0.10	99	0.51***	0.10	85	0.29*	0.12
5+	48	71	0.35**	0.11	73	0.37**	0.11	69	0.24	0.13
6+	58	125	0.52***	0.09	167	0.50***	0.09	141	0.33***	0.09
7+	64	137	0.42***	0.09	150	0.42***	0.08	90	0.34***	0.09
8+	64	140	0.41***	0.09	143	0.40***	0.09	128	0.26*	0.09
9+	63	273	0.33***	0.09	173	0.37***	0.08	123	0.38***	0.08
0+	82	246	0.32***	0.08	215	0.39***	0.07	184	0.38***	0.07
1+	89	193	0.30***	0.08	234	0.41***	0.07	184	0.32***	0.07
2+	85	136	0.35***	0.08	218	0.35***	0.07	223	0.29***	0.07
3+	82	169	0.21**	0.08	209	0.32***	0.07	201	0.28***	0.07
4+	70	118	0.27**	0.10	134	0.33***	0.09	114	0.30**	0.09
5+	56	127	0.30*	0.12	114	0.30**	0.10	88	0.18	0.10
6+	47	104	0.21	0.11	104	0.15	0.10	108	0.18	0.10
7+	50	83	0.31**	0.12	86	0.11	0.11	70	0.06	0.11
8+	42	60	0.38**	0.12	61	0.31*	0.11	64	0.34**	0.12
9+	32	48	0.70***	0.09	52	0.42**	0.13	49	0.35*	0.15

≤ 0.05, $^{**}p \leq 0.01$, $^{***}p \leq 0.001$.

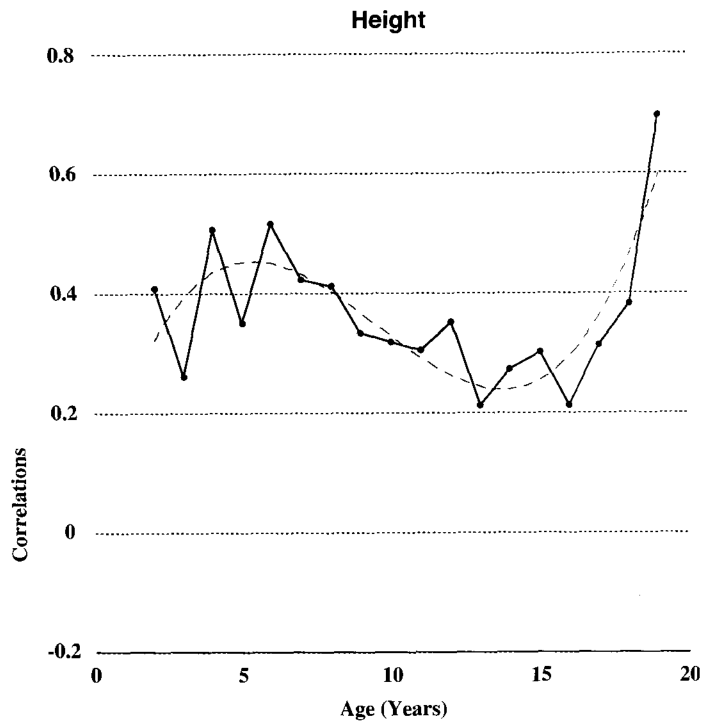

Figure 1. Plot showing how sibling resemblance for height changes with age. The dotted line represents the trend with the age of the estimated correlations.

The estimated correlations for height have exceeded the theoretical value of 0.5 at some ages, indicating that factors other than genetic transmission are contributing to sibling resemblance in this sample. Common nutritional environment in particular might have inflated the values of the observed correlations. It has been hypothesized that heritability of growth is generally reduced in populations suffering from malnutrition, or reared in unfavourable environments. Thus, Silventoinen et al. (2000) have suggested a lower heritability of body height in poor environments. Similarly Arya et al. (2002) have pointed out that the reduced values of heritability may largely be attributable to the effect of extreme environmental conditions. Even though there is not a general agreement on this fact, it seems likely that, in undernourished populations, the environmental component would be more important than the genetic one in the determination of growth variability (Mueller & Titcomb 1977, Katzmarzyk et al. 1999, Lauderdale & Rathouz 1999).

Growth of the Sarsuna-Barisha children has been previously analysed by Hauspie et al. (1980) who noted that 'the mean heights of these children are below the 10th percentile line of the British standards but the growth in height is slightly above the Indian Council of Medical Research Standards' (ICMR 1972). The children in the present study have not shown any signs of undernutrition. Therefore the heritability of growth should not be affected by this environmental condition. It should be kept in mind that the studied sample had a remarkable degree of homogeneity regarding their dietary habits (non-vegetarian) and personal and public health practices. So the heritability of the studied traits would not be reduced due to the heterogeneous nature of the environment.

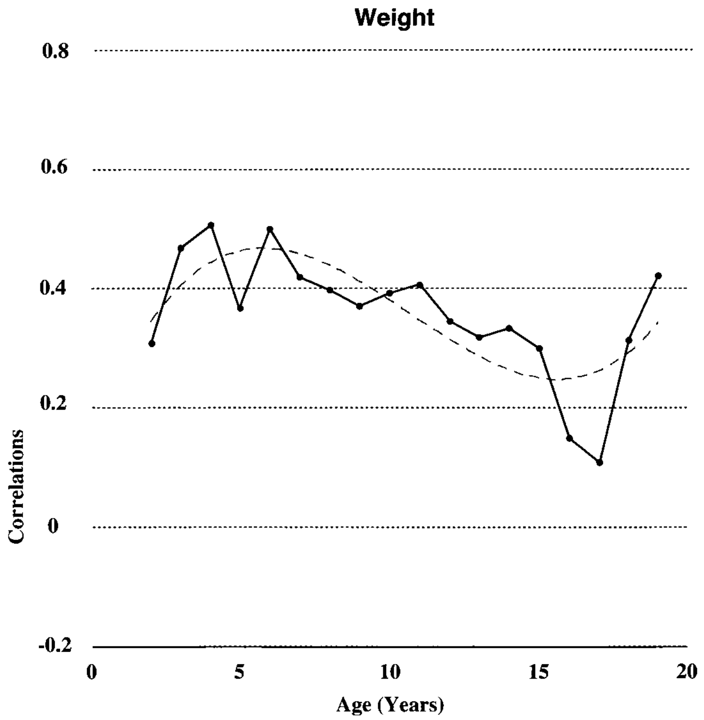

Figure 2. Plot showing how sibling resemblance for weight changes with age. The dotted line represents the trend with the age of the estimated correlations.

Age trends

Our results agree with the findings of several other investigators who have noted age variation in sibling resemblance of different traits, including height and weight (Bayley 1954, Rao et al. 1982, Byard et al. 1983b, Fischbein 1983, Livshits et al. 1995, Nikolova & Susanne 1996, Rebato et al. 1997, 1999, Gu et al. 1997). Almost 30 years ago, Mueller (1976) made a revision of 24 samples of different origin regarding parent–child correlations. He observed that sibling correlations for height during growth vary negatively with age differences of sibs and that they also vary through the age range considered (from birth to 17 years), the highest sibling resemblance being between 3 and 11 years. Recently, Salces (2002), analysing a cross-sectional sample of siblings from the province of Biscay (Basque Country, Spain) for 47 anthropometric and physiological traits, has found that siblings are more similar at the pre-pubertal ages than at adulthood (classified according to pre-pubertal, pubertal and post-pubertal groups).

Several researchers have emphasized the importance of age and its interactions with genetic and environmental factors in determining sibling resemblance in morphological traits. They are fairly unanimous in stating that sibling resemblance is inversely related to the birth order and age difference between the sibs (Palmer 1934, Furusho 1963, Rao et al. 1974, 1975, Byard et al. 1983b, 1988, Province & Rao 1985, Friedlander et al. 1988, 1989, Livshits et al. 1995, Nikolova & Susanne 1996, Gu et al. 1997, Rebato et al. 1997). In order to avoid the age difference between the sibs (one of the sources of variation), it is necessary to have data on relatives measured at the same chronological ages such as the present study in which subjects are measured at fixed target ages. However, since sibs

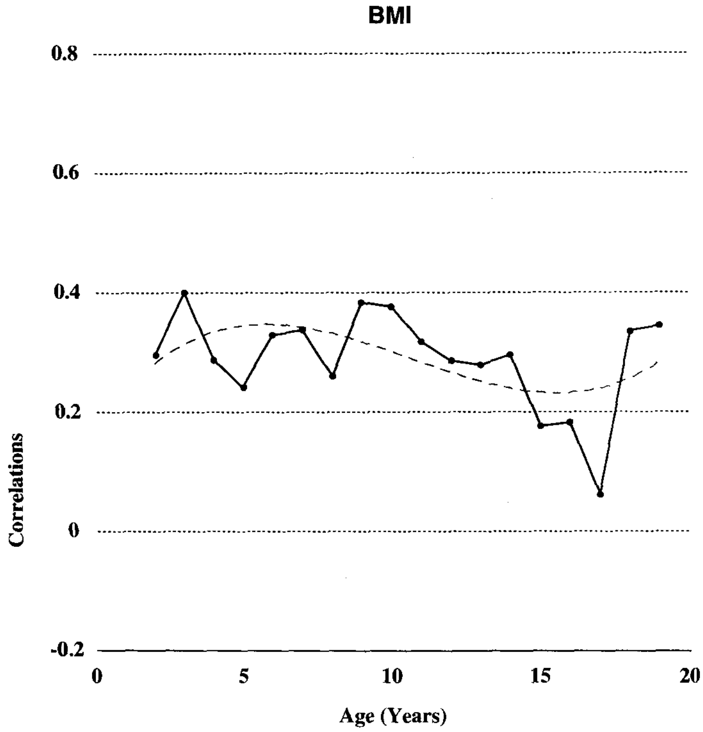

Figure 3. Plot showing how sibling resemblance for BMI changes with age. The dotted line represents the trend with the age of the estimated correlations.

are born in different time periods, therefore, even if they have the same age its effect on the degree of similarity in the common environment persists.

The kind of analysed data (mixed longitudinal) may allow separating several environmental effects from those of gene timing differences, as age was constant within each comparison, and the relatives being compared were at the same stage of gene expression. However, it must be kept in mind that the genes of each individual are active for some time during childhood, but those of his or her sibs (brother/sister) may be active at a slightly different time with varying duration. Although such an explanation has not been proposed earlier, but trends of decline in the correlation pattern during adolescence may be interpreted in terms of different ages of entering the pubertal growth spurt. The studies on twins have demonstrated that even the growth curves in height closely coincide, a small transient difference appears during adolescence, and this fact is also evident in monozygotic twins (Hauspie & Susanne 1998). The difference in maturation rates between boys (mean peak height velocity PHV 14.0 years) and girls (mean PHV 12.5 years) in this sample (Hauspie et al. 1980) may explain the different patterns of familial resemblance as a function of age, and also their decline around puberty. Such an interpretation can be supported from the studies on similarity in physical growth of opposite-sex twin pairs during puberty (Fischbein 1983).

Salces et al. (2003) has recently stated that although sibling correlation in morphological traits are widely reported from various populations only a handful of studies have provided information on the quantification of the mode of transmission. In addition, Kobyliansky et al. (1987) have proposed that age changes in the phenotypic and genotypic correlation between the sibs may also be explored through multivariate analysis on a large number of variables. Sibling resemblance in the parameters of the adolescent growth spurt in height has already been examined by fitting Preece–Baines growth model I to the Sarsuna-Barisha data (Hauspie et al. 1982). A similar analysis can be performed on the remaining variables from this data series and future investigations in these directions may reveal more insights towards the quantification of the genetic mode of transmission of morphological traits during growth.

In conclusion, this study confirms the effect of age on the degree of sibling similarity for height, weight and BMI in this sample of West Bengal children. The sharp decline of correlation at adolescence can be interpreted in terms of the individual variation in age of reaching the adolescent growth spurt. The significant correlation between siblings for these morphological traits is indicative of familial aggregation for height and body mass in this population.

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Résumé. *Arrière plan:* Même si certaines études ont considéré que la ressemblance entre jumeaux demeure constante tout au long de la vie, plusieurs travaux insistent sur l'importance de l'âge et sur ses interactions avec les facteurs génétiques et environnementaux dans la détermination de la similarité gémellaire pour plusieurs caractères physiques. En fait l'étude des changements de la ressemblance familiale est de grande importance pour l'analyse de certaines sources de variation observées au cours de la croissance.
But: Cette étude examine les ressemblances entre germains pour la stature, le poids et la masse corporelle (IMC) dans un échantillon semi longitudinal de l'ouest du Bengale entre les âges 2 et 19 ans, afin d'analyser entre germains, les variations avec l'âge des ressemblances de ces phénotypes au cours de la croissance.
Echantillon et méthode: On a étudié 245 frères et 213 soeurs de 138 familles nucléaires de classe moyenne vivant dans une zone semi-urbaine du Sud-Kolkata (Inde). L'analyse des ressemblances entre germains a été effectuée par des corrélations estimées par la méthode du maximum de vraisemblance. Les différentes tendances de ressemblance fraternelle en fonction de l'âge ont été examinées en ajustant une régression cubique non linéaire aux corrélations observées.
Résultats: Les résultats montrent des variations claires avec l'âge dans la ressemblance fraternelle pour la stature et le poids et à un degré moindre pour l'IMC. Les corrélations sont en général les plus élevées pendant la petite enfance, décroissent fortement pendant la puberté puis tendent à augmenter vers la fin du cycle de croissance.
Conclusion: L'étude confirme l'effet de l'âge sur le degré de similarité parmi les germains de l'échantillon pour la stature, le poids et l'IMC. Le déclin abrupt des corrélations au cours de l'adolescence peut être interprété en termes de variation individuelle dans l'âge d'atteinte du pic de croissance de l'adolescence.

Zusammenfassung. *Hintergrund:* Obgleich einige Untersuchungen in Erwägung ziehen, dass die Ähnlichkeit unter Geschwistern über das ganze Leben konstant bleibt, heben mehrere Untersucher die Bedeutung des Alters, sowie seine Interaktion mit genetischen und Umweltfaktoren für die Beurteilung von Geschwisterähnlichkeit hinsichtlich verschiedener körperlicher Merkmale hervor. In der Tat ist die Untersuchung altersabhängiger Veränderungen von Familienähnlichkeit von großer Bedeutung, um bestimmte Quellen der Variation, die man im Wachstumsprozess findet, zu analysieren.

Ziel: Die Studie untersuchte Geschwisterähnlichkeit für Körperhöhe, Gewicht und Körpermasse-Index (body mass index, BMI) in einer gemischt-longitudinalen Stichprobe aus Westbengalen, im Alter von 2-19 Jahren, um die altersabhängige Variation von Geschwisterähnlichkeit in bezug auf diese Parameter im Verlauf des Wachstums zu analysieren.
Stichprobe und Methoden: Es wurden 245 Brüder und 213 Schwestern aus 138 Mittelklassefamilien, wohnhaft in einem Vorortgebiet im südlichen Kalkutta, Indien, analysiert. Die Analyse von Geschwisterähnlichkeit wurde mit Korrelationen durchgeführt, die über die Maximum Likelihood Methode geschätzt wurden. Die Muster der verschiedenen Trends hinsichtlich der Altersabhängigkeit von Geschwisterähnlichkeit wurden untersucht, indem eine nicht-lineare, kubische Regression auf die untersuchten Korrelationen angepasst wurde.
Ergebnisse: Die Ergebnisse zeigen deutliche Altersabhängigkeit der Geschwisterähnlichkeit für die Merkmale Körperhöhe und Gewicht, und in geringerem Maße auch für BMI. Im Allgemeinen fanden wir die höchsten Korrelationen im Verlauf der frühen Kindheit, einen bemerkenswerten Abfall zur Pubertät, und einen erneut ansteigenden Trend gegen Ende des Wachstumszyklus.
Zusammenfassung: Die Studie bestätigt den Alterseffekt auf das Maß an Ähnlichkeit zwischen Geschwistern für Körperhöhe, Gewicht und BMI in der untersuchten Stichprobe. Der deutliche Abfall der Korrelation während der Adoleszenz kann im Sinne einer individuellen Variation im Alter bei Erreichen des Pubertätswachstumsschubes gedeutet werden.

Resumen. *Antecedentes:* Aunque algunos estudios han considerado que la semejanza entre hermanos se mantiene constante durante todo el ciclo vital, muchas investigaciones resaltan la importancia de la edad y de sus interacciones con los factores genéticos y ambientales, en la determinación de la semejanza entre hermanos para numerosos rasgos corporales. De hecho, el estudio de los cambios con la edad en la semejanza familiar es de gran importancia para el análisis de ciertas fuentes de variación observadas en el proceso de crecimiento.
Objetivo: El estudio examinó la semejanza entre hermanos en la estatura, peso e índice de masa corporal (IMC), en una muestra semi-longitudinal de Bengala Occidental, con edades comprendidas entre los 2 y los 19 años, con el objeto de analizar las variaciones con la edad de la semejanza entre hermanos para estos fenotipos durante el crecimiento.
Muestra y métodos: Se analizaron 245 hermanos y 213 hermanas procedentes de 138 familias nucleares de clase media, residentes en un área semi-urbana de Calcuta meridional, India. El análisis de la semejanza entre hermanos se realizó mediante correlaciones estimadas por máxima verosimilitud. Los patrones de las diferentes tendencias con la edad de la semejanza entre hermanos, fueron examinados mediante el ajuste de una regresión cúbica no lineal a las correlaciones observadas.
Resultados: Los resultados muestran claras variaciones con la edad en el parecido entre hermanos en cuanto a la estatura y peso y, en menor medida, en el IMC. En general, se observan mayores valores de correlación durante el periodo de la infancía, un notable descenso de las correlaciones durante la pubertad y una tendencia a aumentar hacia el final del ciclo de crecimiento.
Conclusión: El estudio ha confirmado el efecto de la edad sobre el grado se semejanza entre hermanos en la estatura, peso e IMC en la muestra analizada. El marcado descenso de la correlación en la adolescencia, puede interpretarse en términos de variación individual en la edad a la que se alcanza el estirón del crecimiento adolescente.