ONSET OF PUBERTY IN MZ AND DZ TWINS

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A twin study on the significance of genetic factors for the variation in peak height and peak weight velocity, as well as in age at menarche and the development of secondary sex characteristics, is presented. Evidence of a rather strong genetic regulation of the occurrence of puberty was obtained in the analysis. The maximal height or weight gain (in cm/year or kg/year) seems to be, at least in girls, less influenced by genetic factors than the age at which it appears.

INTRODUCTION

Twins have been used to study, among other things, the heredity of biological time. This particular branch of human genetics has been called " chronogenetics " by Gedda and Brenci (1975). By this is meant that each individual has a genetically regulated timing of, e.g., puberty, ageing, or death. The study of similarity in this biological timing for MZ and DZ twin pairs is one method whereby an estimation of the heredity of biological time can be made.

Earlier studies of somatic maturation have shown that this is strongly genetically regulated in man. The measure used to estimate somatic maturity has mostly been age at menarche. The MZ twins tend to be much more similar than DZ twins for the timing of menarche (Petri, 1935, Tisserand-Perrier 1953, Gedda and Brenci 1975).

This is an easily accessible measure, but has the disadvantage that it is not possible to make any comparisons between boys and girls. Other criteria of physical maturity, as, for instance, age at peak height velocity, necessitate a longitudinal study of the individuals — and are therefore very time consuming. There are very few longitudinal twin studies and only one, as far as I know, where the twins have been followed longitudinally during puberty.

MATERIALS AND METHODS

In 1964, a longitudinal study of physical and mental growth in twins and controls of matched age (the SLU project) started at the Department of Educational Research at the Stockholm School of Education. The results presented in this paper have been collected in the SLU study. The twins were taken from the 40 largest cities and towns in Sweden and their controls were attending the same classes as the twins. Originally, the sample consisted of 94 pairs of MZ twins, 133 DZ pairs of the same sex, 96 DZ pairs of different sex, and 1194 controls.

Height and weight measurements and a rating of secondary sex characteristics were made twice a year by the school nurses. Individual measurements were thereafter adjusted to specific chronological ages. The school nurses also asked the girls for the age at which menarche had occurred. To get another estimate, all girls

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were asked at the age of 17 about their menarcheal age, according to the recall method. In addition, certain psychological measurements were collected by the school teachers and others. A more detailed description of the project and the methods has been given by Ljung et al. (1974).

The twins and their controls were followed from grade 3, at approximately 10 years of age, to grade 9, at approximately 16 years of age. Since the physical growth had not stopped at that age for many of the boys, additional height and weight measurements were collected for approximately 50% of these, up to and including age 18.

For classifying the like-sexed twin pairs, a morphological diagnosis, according to a special schedule, was applied. This schedule is based on earlier investigations of similarity diagnosis in twins (Essen-Möller 1941, Norinder 1946, Husén 1959). A full description of the zygosity classification of the SLU twins has been given by Ljung et al. (1976).

The methods used in the SLU project for estimating the age at which different criteria of physical maturity were reached are reported, in the following, from a previous thorough description.

(1) " Age at peak height velocity (PHV) and peak weight velocity (PWV) according to a modified ' mid-year-velocity ' method. Individual height and weight measurements were adjusted to specific chronological ages (10.0, 10.5, 11.0 etc.) according to the interpolation method described by Olofsson (1972). The yearly increments (to avoid seasonal effects) were then calculated for each 6 months (10.0, 10.5, 11.0 etc.) by taking the yearly increments from 9.5 to 10.5, 10.0 to 11.0 and so on. The midpoint of the 12 months interval during which the maximum yearly increment occurred was taken as age at PHV or PWV. To examine this, individual growth curves were first plotted using a computer program by Olofsson and Roström (1973) and checked visually."

[Lindgren 1976, pp. 502-503].

Twin pairs with very irregular curves and with two or more peaks of about the same size were excluded. There were 7 MZ pairs and 14 DZ pairs excluded for age at PHV and PWV for this reason.

(2) Age at menarche estimated both on basis of the school nurses' reports and the girls' own statements (the recall method).

(3) Ages at which five successive stages in the development of the secondary sex characteristics were reached according to ratings made by the school nurses twice a year.

" This was done by pictorial criteria after undressing the pupils. In the pictures, however, the breast and pubic hair stages for the girls are combined and so are the genital and pubic hair stages for the boys. The assessment of these pubertal stages can therefore be seen only as rough estimates and cannot readily be compared with results from other investigations (Marshall and Tanner 1969, 1970)."

[Lindgren 1976, pp. 502-503].

The five stages used to rate the development of secondary sex characteristics can verbally be described in the following way.

For the girls

(1) Preadolescent; no pubic hair; no breast development.

(2) Sparse growth of long, slightly pigmented hair over mons veneris.
Breast bud stage; elevation of breast and papilla.

(3) Considerably darker, coarser and more curled pubic hair sparsely spread over mons veneris.
Further enlargement of breast and areola, with no separation of their contours.

(4) Hair is now adult in type, covering mons veneris. Projection of areola and papilla and enlargement of the breast.

(5) Adult pubic hair in quantity and type spread to the medial surface of the thighs.
Mature breast stage; projection of papilla only, due to recession of the areola to the general contour of the breast.

[Trans. from Lindgren 1975, pp. 47-48].

For the boys

(1) Preadolescent; no pubic hair.
(2) Sparse growth of long slightly pigmented hair over mons veneris.
The scrotum and testes have enlarged and there is a slight change in the texture and quality of the scrotal skin.
(3) Considerably darker, coarser and more curly hair over mons pubis.
Growth of the penis as well as scrotum and testes.
(4) Hair of adult type limited to mons pubis. Penis further enlarged in length and breadth and also further darkening of the scrotal skin.
(5) Adult hair in quantity and type, with spread to the medial surface of the thighs.
Genitalia adult in size and shape.
[Trans. from Lindgren 1975, p. 70]

Correlation coefficients between ages at which different criteria of physical maturity are reached are reported by Lindgren (1975). The correlation, for instance, between age at stage 4 and at PHV is 0.63 for girls and 0.76 for boys.

RESULTS

1. Peak Height Velocity (PHV)

A comparison of the similarity in MZ and DZ pairs for age at PHV can contribute to the understanding of the role of hereditary factors in physical maturation. Since MZ twins have the same genetic make-up, they are expected to be similar in the timing of genetically based developmental features. DZ pairs, on the other hand, should not be more similar than ordinary siblings in this respect.

Table 1 gives the average intrapair differences and intrapair correlation coefficients in age at PHV for MZ and DZ pairs.

Table 1. *Average differences and intrapair correlations*[a] *in age at PHV for MZ and DZ twin pairs*

	MZ pairs				DZ pairs					
	Diff. (years)	SD	N	*r*	Diff. (years)	SD	N	*r*	Diff. MZ-DZ	*z*
Boys	0.45	0.45	43	0.85	0.78	0.63	60	0.42	—0.33	—3.30***
Girls	0.40	0.49	39	0.78	0.69	0.73	60	0.39	—0.29	—2.41**

[a] $r = (Vbp - Vwp) / (Vbp + Vwp)$, where Vbp = variance between pairs, and Vwp = variance within pairs. For a more detailed discussion, see Ljung (1966). *** = $p < 0.001$; ** = $p < 0.01$.

Approximately 85-90% of the pairs had complete height measurements for both cotwins, so that an estimation of age at PHV could be accomplished. This means that there is a very small loss of individuals among the twins during the period of investigation.

The average intrapair difference in age at PHV is 0.4 years in MZ vs. approximately 0.7 in DZ pairs. The intrapair correlation is around 0.8 in MZ vs. 0.4 in DZ pairs. The height spurt, thus, seems to take place much more simultaneously in MZ than DZ pairs.

The average peak height differences are shown in Table 2.

Table 2. *Average differences and intrapair correlations*[a] *in peak height for MZ and DZ twin pairs*

	MZ pairs				DZ pairs					
	Diff. (cm/year)	SD	N	*r*	Diff. (cm/year)	SD	N	*r*	Diff. MZ-DZ	*z*
Boys	0.80	0.55	42	0.75	1.18	0.83	60	0.43	—0.38	—2.92***
Girls	0.87	0.69	37	0.48	1.06	0.87	57	0.48	—0.19	—1.26

[a] See note to Table 1.

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For the twin boys, the peak height is more similar among MZ than among DZ pairs. The average intrapair difference in maximal height increase is 0.8 cm/year in MZ vs. 1.2 in DZ pairs. The intrapair correlations are 0.8 in MZ vs. 0.4 in DZ pairs. For the girls, however, this difference is much smaller (0.9 vs. 1.1 cm/year) and insignificant: the intrapair correlations are exactly the same in MZ and DZ pairs ($r = 0.48$).

2. *Peak Weight Velocity (PWV)*

Average intrapair differences in age at PWV are presented in Table 3. The intrapair correlations for MZ and DZ pairs are also given.

Table 3. *Average differences and intrapair correlations*[a] *in age at PWV for MZ and DZ twin pairs*

	MZ pairs				DZ pairs					
	Diff. (years)	SD	N	r	Diff. (years)	SD	N	r	Diff. MZ-DZ	z
Boys	0.65	0.78	43	0.68	0.88	0.78	60	0.38	—0.23	—1.64
Girls	0.34	0.52	38	0.83	0.84	0.92	57	0.50	—0.50	—3.85***

[a] See note to Table 1.

The maximal weight gain seems to take place more simultaneously for female than for male pairs. This is especially true for the MZ twin girls, where the average intrapair difference for age at PWV is only 0.34 years. For the twin boys, the difference between MZ and DZ is not significant. The intrapair correlations also show MZ twin girls to be more similar ($r = 0.83$) than MZ twin boys ($r = 0.68$). This trend is also evident for the DZ pairs (girls, 0.50; boys, 0.38). A possible explanation for the lower male correlations could be that the boys tend to have a double weight peak (Lindgren 1975).

The average differences in maximal weight gain are presented, together with the intrapair correlations, in Table 4.

Table 4. *Average differences and intrapair correlations*[a] *in peak weight for MZ and DZ twin pairs*

	MZ pairs				DZ pairs					
	Diff. (kg/year)	SD	N	r	Diff. (kg/year)	SD	N	r	Diff. MZ-DZ	z
Boys	0.90	0.69	43	0.76	1.28	1.00	57	0.48	—0.38	—2.37**
Girls	0.88	0.76	36	0.57	1.65	1.14	50	—0.07	—0.77	—4.27***

[a] See note to Table 1.

The average intrapair difference in peak weight for MZ twins is approximately 0.9 kg/year. Among the DZ pairs, the difference tends to be smaller in boys (1.3 kg/year) than in girls (1.7 kg/year). The intrapair correlations also show a zero correlation for the DZ twin girls ($r = -0.07$), while the correlation for the DZ boys is substantial ($r = 0.48$).

3. *Age at Menarche*

Age at menarche is based both on information from the school nurses and the girls' own reports at 17 years of age. The nurses' information was used when available (for 20 MZ and

36 DZ pairs); otherwise, the girls' own reports have been taken for granted. A comparison of the two measurements (school nurses' and girls' own reports) has been made by Bergsten-Brucefors (1976).
Table 5 gives the average intrapair differences and correlations for age at menarche.

Table 5. *Average differences and intrapair correlations*[a] *in age at menarche for MZ and DZ female twin pairs*

MZ pairs				DZ pairs					
Diff. (years)	SD	N	*r*	Diff. (years)	SD	N	*r*	Diff. MZ-DZ	*z*
0.29	0.27	28	0.93	0.71	0.66	48	0.62	—0.42	—4.00***

[a] See note to Table 1.

As can be seen from Table 5, MZ cotwins are very similar for age at menarche. The average intrapair difference is only 0.29 years and the intrapair correlation as high as 0.93. DZ cotwins, however, are much less similar (0.71 years on average). Intrapair correlation in DZ twins is somewhat higher than would be expected for ordinary siblings on basis of genetical factors alone. Asking the girls will probably somewhat raise the correlation, both for MZ and DZ pairs, since if one doesn't remember the exact date she will probably check with her sister. The correlations for age at menarche are very similar to the ones presented by Gedda and Brenci (1975), who draw the conclusion that physical maturity is strongly regulated by hereditary factors.

4. Ratings of Secondary Sex Characteristics

The ratings of secondary sex characteristics have been made by the school nurses twice a year, from age 10 to 16, in connection with the height and weight measurements. The procedure has been described by Lindgren (1975).
Figs. 1 and 2 show the intrapair correlations for the MZ and DZ twin pairs, separately for boys and girls.

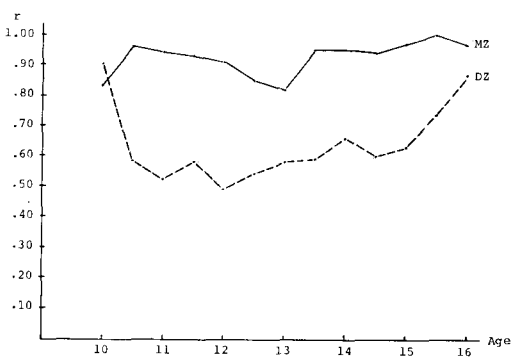

Fig. 1. Intrapair correlations in ratings of secondary sex characteristics. *Boys*.

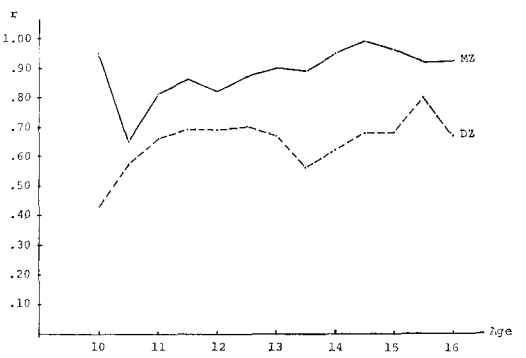

Fig. 2. Intrapair correlations in ratings of secondary sex characteristics. *Girls*.

MZ cotwins are shown to be more similar in the development of secondary sex characteristics during puberty than DZ twins. This can be taken as another indication of greater similarity in physical maturation among MZ in comparison to DZ twins. If the whole period of development of the secondary sex characteristics had been covered, the correlations would approach unity both for MZ and DZ pairs in the beginning and end of the investigation period. As can be seen from Figs. 1 and 2, the whole growth period of the secondary sex characteristics has been covered more fully for boys than for girls.

DISCUSSION

A comparison has been made in this paper of the temporal regulation of physical maturation in MZ and DZ twin pairs. The measures used to estimate physical maturity in the SLU project are age at peak height velocity, age at menarche, and ratings of the development of secondary sex characteristics. In all these respects the intrapair differences for MZ twins are much smaller than for DZ twins.

For a group of the SLU-twins (97 pairs), dental development, which could also be considered as a measure of physical maturity, has been studied (Ryman et al. 1975). The results show a greater similarity in dental development in MZ than in DZ twins. The authors draw the conclusion, that the results " indicated a strong genetic regulation both in boys and girls ". The physical maturity process during puberty, on basis of results from the SLU project, can thus be said to be strongly genetically regulated, at least in our western type of cultural environment. It will therefore probably require very extreme environmental effects or severe illnesses to upset this hereditary biological timing.

Age at peak weight velocity also seems to be more simultaneous in MZ than DZ pairs. There also is a rather strong correlation between age at PHV and age at PWV (0.74 for boys and 0.69 for girls), which means that this result could be expected (Lindgren 1976).

The maximal height or weight gain seems to be less influenced, at least in girls, by genetic factors than the age at which it appears. The maximal height gain is significantly more similar in MZ than in DZ boys. For the twin girls, however, this difference is not significant.

The maximal weight gain is not at all correlated in pairs of DZ twin girls ($r = -0.07$), while there is a substantial correlation in DZ twin boys ($r = 0.48$). Among the MZ pairs the boys also tend to be more similar than the girls.

A possible explanation to the difference between the sexes in these respects could be the generally lower height and weight spurts, on average, for girls in comparison to boys (Lindgren 1975). This would mean, of course, that the differences within pairs of twins in peak height or peak weight would also be smaller on the average.

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RIASSUNTO

Insorgenza della Pubertà in Gemelli MZ e DZ

È stato condotto uno studio gemellare sull'importanza dei fattori genetici nella velocità d'incremento staturale e ponderale, nonché nell'età al menarca e nello sviluppo di caratteristiche sessuali secondarie. L'analisi indica un'elevata regolazione genetica della pubertà. Il massimo incremento staturale o ponderale, almeno nelle ragazze, appare essere meno geneticamente condizionato di quanto non lo sia l'età alla quale esso si verifica.

RÉSUMÉ

Apparition de la Puberté chez les Jumeaux MZ et DZ

Une étude gémellaire a été conduite sur l'importance des facteurs génétiques dans la vélocité maximale d'accroissement de la taille et du poids, ainsi que dans l'âge de la première menstruation et dans le développement des caractéristiques sexuelles secondaires. L'analyse indique un contrôle génétique assez élevé sur la puberté. La vélocité maximale d'accroissement, au moins chez les filles, paraît être moins génétiquement conditionnée par rapport à l'âge de son apparition.

ZUSAMMENFASSUNG

Auftreten der Pubertät bei EZ und ZZ

Zwillingsforschung über die Bedeutung der Erbfaktoren für die Geschwindigkeit des Grössenwachstums und der Gewichtszunahme, sowie des Alters, in dem die Menarche auftritt und sich die sekundären Geschlechtsmerkmale entwickeln. Es ergab sich, dass zumindest bei Mädchen die Maximalwerte des Grössenwachstums und der Gewichtszunahme weniger erbbedingt sind als das diesbezügliche Alter.

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