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Body Size of Twins Compared with Siblings and the General Population: From Birth to Late Adolescence

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Objectives We examined whether and when differences in body size disappear over time and whether twins attain normal final height and body mass index (BMI).

Study design Height, weight, and BMI data of twins at ages 1, 4, and 18 years were compared with data from their nontwin siblings. Second, twin and sibling data were compared with population standards. In addition to height, weight, and BMI, data on body proportions at age 18 years were analyzed.

Results At the age of 18 years, twins were as tall as their siblings but were significantly leaner. Compared with children from the general population, adolescent twins attained the same height and BMI. Birth weight was shown to have a considerable effect on height in adolescent twins.

Conclusions Twins attained normal final height compared with siblings and children from the general population. No differences in BMI were shown between 18-year-old twins and children from the general population, whereas the siblings of twins had increased BMI values compared with the general population. *(J Pediatr 2010;156:586-91)*.

Multiple pregnancy rates have increased in many Western countries during the past decades, which is mainly attributable to the older maternal age and increasing number of infertility treatments.[1-3] It is generally known that twins are smaller at birth than singletons because of a combination of intrauterine growth retardation and shorter gestational age.[4-7] The incidence of twin births in The Netherlands is 1.7%,[8] which means that a considerable number of newborns have a reduced size at birth. Intrauterine growth retardation is not only associated with increased neonatal morbidity and mortality rates,[9] but also with an increased prevalence for development of adult diseases such as the metabolic syndrome and cardiovascular disease.[10] Several studies have shown that the differences in body size between twins and singletons at birth disappeared during childhood, but in a few studies differences remained until adulthood.[11-15] The Louisville Twin Study concluded that the effects of prenatal growth suppression on weight and height appeared to be fully dissipated by age 8,[11] and a Finnish study among 17-year-old twins reported that twins were as tall as singletons, but that boy twins were still leaner.[13] We found in a previous study that at the age of 5 years, female twins were as tall as singleton children, whereas male twins were still somewhat shorter than children in the general population. Furthermore, 5-year-old twins had a lower body mass index (BMI) compared with the general population. In this study, we examined whether these differences disappeared in time and whether twins attained normal final height and weight. Therefore we investigated the growth of twins by comparing them with 2 different groups: their siblings and population standards.

We expanded this comparison beyond the general measures of height, weight, and BMI by adding specific measures on body proportions, such as sitting height, leg length, and arm span. Short children tend to have relatively short legs and tall children relatively long legs.[16] When studying height, it is of importance to take body proportions into account, because intrauterine growth retardation may be related to body disproportions. We hypothesized that the differences in size at birth between twins, siblings, and children from the general population would decrease during infancy and childhood and would have disappeared in adolescence.

Methods

Twin families were recruited from the Netherlands Twin Register, kept by the Department of Biological Psychology at the VU University in Amsterdam, the Netherlands.[17,18] The study was approved by the Central Committee on Research Involving Human Subjects and the institutional review board of the VU University Medical Center of Amsterdam. Written informed consent was obtained from all participants and also from all parents of underage participants.

BMI	Body mass index
NHS	National Health Services
SD	Standard deviation
SDS	Standard deviation score

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As part of a longitudinal project on physical and mental development 184 families of 18-year-old twin pairs and their siblings (n = 98) participated in a test protocol.[19,20] Mean age at assessment was 18.14 years (SD 0.48) in the twin group and 18.78 years (SD 4.89) in the sibling group (youngest 7 years and oldest 35 years of age). We excluded data for several reasons: congenital anomalies (2 twins); severe growth retardation (1 sibling); non-Dutch parents (3 twin pairs); pregnancy or illness (weight data of 1 twin and 2 siblings); unavailability of weight and BMI reference values (28 siblings); unavailability of arm span reference values (7 twins and 23 siblings). Zygosity of same-sex twin pairs (145 pairs) was determined on the basis of DNA polymorphisms (140 pairs), blood group polymorphisms (4 pairs), or questionnaire items on similarity[21] (1 pair). The sample comprised 30 monozygotic male, 33 dizygotic male, 44 monozygotic female, 38 dizygotic female, and 39 dizygotic opposite sex twin pairs and 97 siblings (45% males and 55% females). There were 8 incomplete twin pairs.

Measures

Birth Data. Information on birth weight and length and gestational age was collected with questionnaires at the time of registration with the Netherlands Twin Register, which was shortly after birth of the twins in most of the families.

Age 1 and 4 Years. Twins and siblings were asked to provide the report with growth data measured by the Dutch National Health Services (NHS) from birth to age 4 years. We copied the measurements from the NHS report. To obtain height and weight data of twins and their siblings around the age of 1 year, measurements between the age of 0.75 and 1.25 years closest to the age of 1.0 year were selected from the NHS report (mean age 1.00 years, SD 0.06). For height and weight data around the age of 4 years, we selected the NHS measurements between the age of 3.5 and 4.5 years closest to the age of 4.0 years (mean age 3.90 years, SD 0.18).

Age 18 Years. Around the age of 18 years twins and their siblings were invited to come to our outpatient clinic at the VU University Medical Center of Amsterdam, where height (cm) was determined to the nearest 0.1 cm and weight (kg) to the nearest 0.05 kg with a stadiometer and an electronic scale (SECA, Hanover, Maryland). Sitting height was measured by bringing the horizontal bar of the microtoise into the most superior midline of the head while the child was sitting in the erect position on a special stool. Arching of the back was avoided as much as possible by applying upward pressure to the mastoid processes. Arm span was obtained by measuring the distance between the arms in the stretched position with a plastic tape measure.

Pubertal Development. Stage of puberty was physically determined by the same trained researcher on the basis of secondary sexual characteristics with the stages of development devised by Tanner.[22]

Parental Height. Information on parental height was collected by measurement if present at the test protocol or by questionnaires. Height was available for all mothers and missing in 12 fathers.

Educational Level. Because socioeconomic status has been shown to be a significant covariable of height and weight, it was taken into account in the linear regression analyses. To obtain a proxy for socioeconomic status of the family, the highest educational attainment level achieved within a family (by the father or mother of the twins) was selected. Information on educational level of the family was based on questionnaire data collected when the twins were 3, 7, and 10 years old. Educational level was classified into 3 categories: low (primary or lower secondary education), intermediate (higher secondary education), and high (college or university education). The educational level of the family was missing in 8 families.

Data Calculations

Weight and length at birth were converted to standard deviation scores (SDS) with correction for gestational age with Swedish reference standards, because Dutch SDS reference values for birth weight and length are unavailable.[23] Birth weight SDS was classified into tertiles in twins and siblings to study the relation with height and BMI SDS at age 1, 4, and 18 years.

BMI was calculated as weight (kg) divided by height (m) squared. Standard deviation scores (SDS) were calculated for height, weight, and BMI at ages 1, 4, and 18 with the software package Growth analyzer 3,[24] with the Dutch reference growth charts for the general population from 1997.[25,26] Weight and BMI reference values were available up to age 21 years. Leg length was obtained by subtracting sitting height from height. SDS were calculated for sitting height and leg length with the Dutch age references from 1997.[27] Arm span was converted to SDS according to reference data from the Dutch Oosterwolde study.[28] Arm span reference values were available up to age 18 years. We used the female reference data of 18-year-olds also for females older than 18.5 years because it is very likely that they are fully grown. We excluded males older than 18.5 years for arm span SDS analysis (7 twins and 23 siblings) because it is known that male growth may continue up to age 21 years.[25]

Statistical Analyses

Analyses were performed by use of SPSS-15 (SPSS Inc., Chicago, Illinois) or the structural equation modeling program Mx.[29] An alpha level 0.05 was chosen for all tests. Univariate models in Mx were used to test for the effect of birth order on birth weight and length SDS and the effects of zygosity and sex on birth weight, birth length, height, weight, BMI, sitting height, leg length, and arm span SDS. Mx was used to correct for the dependency among the dependent variables that is present in family data. Next, we tested whether twins differed

Table I. Mean SDS for birth weight, birth length, height, weight, BMI, sitting height, leg length, and arm span of twins and siblings

	Twins		Siblings	
	N	Mean	N	Mean
SDS birth weight*	360	−0.87†	96	0.01
SDS birth length*	327	−0.42†	90	−0.01
SDS height at 1 yr*	270	−0.58†	81	−0.07
SDS weight at 1 yr*	270	−0.58†	81	0.04
SDS BMI at 1 yr*	270	−0.22†	81	0.16
SDS height at 4 yr	221	0.03	57	0.23
SDS weight at 4 yr	221	−0.14	57	0.09
SDS BMI at 4 yr	221	−0.22†	57	−0.08
SDS height at 18 yr	360	0.00	97	0.01
SDS weight at 18 yr	358	0.07	67	0.30†
SDS BMI at 18 yr*	358	0.08	67	0.33†
SDS sitting height at 18 yr	359	0.14†	96	0.06
SDS leg length at 18 yr	359	−0.06	96	−0.04
SDS arm span at 18 yr	353	−0.12	73	0.00

*Mean SDS twins significantly different from mean SDS siblings ($P < .05$).
†Mean SDS significantly different from the general population, i.e. 0 ($P < .05$).

from siblings in mean SDS. Furthermore, data from twins and siblings were compared with data from the general population with SDS. To this end, we tested whether mean SDS of birth weight, birth length, weight, height, BMI, sitting height, leg length, and arm span in twins and siblings differed from the mean of the general population, that is, 0. The effect of pubertal development on mean SDS at age 18 years was tested by including Tanner stage (genital development or breast development) as a covariate.

The following analyses were performed by use of SPSS-15 (SPSS Inc.). A paired *t*-test was used to test whether mean gestational age differed between twin pairs and siblings. Linear regression analysis was conducted to analyze whether birth weight and birth length influenced height or BMI SDS at age 18 years in twins after adjustment for maternal height, paternal height, and educational level. This was tested by mixed-model analyses of variance with birth weight SDS, birth length SDS, maternal height, paternal height and educational level as fixed factors and with family as a random factor to account for the within-family dependence of the dependent variable (height or BMI SDS at age 18 years).

Results

Table I presents the mean SDS for birth weight/length, height (age 1, 4, 18), weight (age 1, 4, 18), and BMI (age 1, 4, 18) of twins and siblings. SDS for sitting height, leg length, and arm span around the age of 18 years are also shown in Table I. Mean gestational age of the twin pairs was 36.9 weeks (SD 2.54), which was significantly lower ($P < .01$) than that of the siblings (40.1 weeks; SD 1.66). Fifty-seven percent of the twin pairs and 97% of the siblings were born at term (gestational age 37 weeks or more). There were no differences in birth weight and birth length between first-born and second-born twins ($P > .05$). No differences were shown in mean SDS between monozygotic and dizygotic twins, nor between siblings of monozygotic twins and siblings of dizygotic twins for birth weight/length, height, weight, BMI, sitting height, leg length and arm span ($P > .05$). Mean SDS were comparable for male and female twins and for male and female siblings ($P > .05$).

At birth, twin weight and length SDS were significantly reduced compared with their siblings and children from the general population ($P < .001$). At the age of 1 year, twins were significantly shorter and had a significantly lower weight and BMI than their siblings and children from the reference population ($P < .01$).

At the age of 4 years, twins and siblings were comparable for height, weight, and BMI ($P > .05$). Comparing twins with children from the general population, there was no difference in height ($P = .75$) and weight ($P = .13$), but the BMI of twins was still reduced ($P = .005$). There were no significant differences in height, weight, and BMI between 4-year-old siblings and children from the general population ($P > .05$).

At the age of 18 years, twins were as tall as their siblings and children from the general population ($P > .05$). Twins had an average weight and BMI ($P > .05$), and siblings had a significantly increased weight and BMI in comparison with the general population ($P > .05$). Regarding body proportions, twins were comparable with their siblings for sitting height, leg length and arm span SDS ($P > .05$). In comparison with the reference population, sitting height was slightly increased in twins ($P = .020$), and leg length was average ($P = .35$). Body proportions of adolescent siblings (sitting height, leg length and arm span) were not different from the reference population ($P > .26$).

All twins were in Tanner stage 4 (10%) or 5 (85%), as was the majority of siblings (stage 4: 13%, stage 5: 68%). Two percent of the siblings were in stage 1; 6% in stage 2; and 8% in stage 3. Tanner data were missing in 5% of the twins and 2% of the siblings. Pubertal development did not significantly affect mean SDS for height, weight, or BMI and was not included as a covariate in the reported analyses.

Table II shows the mean SDS of the lowest, middle, and highest birth weight SDS tertile. The higher the birth weight SDS, the taller and heavier twins were at age 1, 4, and 18 years (except for BMI SDS age 18). Classifying birth length SDS into tertiles in twins provided similar results (data not shown). When birth weight SDS was classified into tertiles in siblings, no relation was seen between birth weight and height or BMI SDS at age 18 years (data not shown). In regression analysis (Table III), after adjusting for educational level, birth weight SDS and parental height predicted twin height at age 18 years significantly ($P < .05$). For every centimeter increase in maternal or paternal height, adolescent height SDS increased 0.06 or 0.05, respectively. Furthermore, for every increase in birth weight SDS of 1.0, height SDS at age 18 years increased 0.25. Birth length SDS did not contribute significantly to height SDS at age 18 years ($P = .93$).

To verify the finding of the above-average BMI in siblings, we analyzed a sample of questionnaire data of 18-year-old twins and siblings (unrelated to the twin families mentioned above). When the twins were 18 years of age, the twins (mean age 18.79 years, SD 0.40; 35% males and 65% females) and their siblings (mean age 19.63 years, SD 3.83; 46% males

Table II. Mean SDS for birth weight, birth length, height, and BMI of twins by birth weight SDS tertiles

	Lowest tertile		Middle tertile		Highest tertile	
Birth weight SDS tertiles	N	Mean	N	Mean	N	Mean
SDS birth weight	120	−2.05	120	−0.75	120	0.19
SDS birth length	109	−1.35	107	−0.18	111	0.25
SDS height at 1 yr	89	−0.87	91	−0.61	90	−0.32
SDS BMI at 1 yr	89	−0.60	91	−0.25	90	0.20
SDS height at 4 yr	65	−0.43	74	−0.02	82	0.46
SDS BMI at 4 yr	65	−0.49	74	−0.38	82	0.13
SDS height at 18 yr	120	−0.36	120	0.08	120	0.29
SDS BMI at 18 yr	120	0.06	119	0.05	119	0.12

Lowest tertile: BW SDS ≤ -1.21; middle tertile: -1.21 < BW SDS ≤ -0.38; highest tertile: BW SDS > −0.38.

and 54% females) filled out the Dutch Health and Behaviour Questionnaire, a large self-report questionnaire including questions about health, well-being, leisure activities, and behavioral problems.[30] Subjects were asked to report recent height (in centimeters) and weight (in kilograms). After exclusion because of handicap (4 twins), unavailability of BMI reference values (78 siblings) or extreme values (BMI of 1 twin and height of 1 sibling), 800 twins and 171 siblings were eligible for height SDS analysis and 782 twins and 90 siblings for BMI SDS analysis. Twins (mean height SDS −0.01, mean BMI SDS −0.25) were significantly shorter and lighter than their siblings (mean height SDS 0.19, mean BMI SDS −0.02). Compared with the general population, twin children had the same height (P = .93), but a lower BMI (P < .05). Siblings were significantly taller than children from the general population (P < .01), but their BMI was comparable (P = .84).

Discussion

Our study showed that twins attained normal final height compared with their nontwin siblings and compared with children from the general population. At age 18 years, twins had an average BMI, and their adolescent siblings had increased BMI values. In line with our expectations, twin children had a smaller size at birth than their siblings and children from the general population. In accordance with previous literature birth length was less reduced than birth weight when compared with singletons.[11,12] It is known from these studies that the fall off in birth length starts later in pregnancy and is of smaller magnitude than the fall off in birth weight. This may explain our findings that the deficit in height disappeared among 4-year-old twins, but they were still somewhat underweight. Around the age of 18 years twins were as tall as their siblings and children from the general population but were still leaner than their siblings. This is a remarkable finding, because twins and siblings share part of their genetic background and grew up in the same environment. The above-average BMI of the siblings may be in line with the increasing prevalence of overweight in children.[31] The time interval between the reference values[26] and our measurements was about 10 years, and it is very likely that BMI age references will have increased in that time. Another possibility we investigated is that the above-average BMI of siblings could be explained by a higher BMI of the dizygotic siblings. Mothers of dizygotic twins are known to have a higher BMI than mothers of monozygotic twins and singletons.[32-34] In our sample we did not find a difference in BMI between siblings of monozygotic and dizygotic twins, but this remains a question to be elucidated in larger studies. A study in Finnish adolescent twins reported that 17-year-old twin boys had reached the same height as singletons but still had a lower BMI.[13] The same tendency, although not reaching significance, was seen in girls. They suggested that the catch-up growth from the lighter birth weight may not (yet) be completed in twin boys. Another study in 16-year-old twins showed that body size tracks from birth to adolescence.[35] Height at age 16 years was predicted by weight and length at birth and parents' height, whereas BMI was predicted by birth weight and parents' BMI. In our dataset, twins in the lowest birth weight category were shorter, and children in the highest tertile were taller than children from the general population. Regression analysis showed that birth weight predicted height at age 18 years in twins. In contrast, no influence of birth weight was shown on BMI in 18-year-old twins. In siblings we saw no effect of birth weight on height or BMI SDS, which may be explained by the normal range of birth weight and the lower number of subjects available for analyses. However, the difference in BMI between twins and siblings in our sample could not be explained by the lower birth weight of the twins. It could be speculated that twins have a lower food intake or a different energy balance. Experimental research in rats showed that food restriction during the early postnatal period, which is probably somewhat similar to undernutrition in human fetuses during the third trimester, programmed rats to remain small and lean in adult life with a lower food intake. These results indicate that the energy balance in rats can be programmed by early nutrition.[36,37] In line with these results is the finding that prepubertal children who were born small for gestational age that did not catch up had a food intake below the recommended energy intake for their age.[38] Regarding the energy balance, it was shown that infants born small for gestational age showed a greater total energy expenditure than appropriate for gestational age control subjects.[39,40] Therefore it would be valuable to study growth, food intake, and the

Table III. Regression analysis in twins with SDS height at age 18 years as dependent variable (adjusted for educational level)

	SDS height at 18 years	
	Coefficient	P value
Maternal height (cm)	0.06	<.001
Paternal height (cm)	0.05	<.001
SDS birth length	−0.09	.93
SDS birth weight	0.24	<.001

energy expenditure in twins, siblings, and singleton control subjects to gain insight into the mechanisms that regulate body weight and thus can help us in the prevention of overweight.

There were no significant differences between twins and siblings in body proportion. Sitting height in adolescent twins was increased compared with the reference population, which was in line with the (nonsignificant) tendency of a shorter leg length and arm span. The finding of the slightly elevated sitting height in twins does not seem to be of much importance, because it is only an increase of 0.14 SDS, from which no major conclusions can be drawn.

Because of the limited number of siblings in this study, we also looked at data collected by questionnaire from an ongoing study in adolescent twins and siblings.[30] We were particularly interested whether there would also be a difference in BMI between adolescent twins and siblings. Indeed, siblings had a higher BMI than twins in the questionnaire sample, but in contrast to the test protocol sample, siblings were slightly taller than twins. It has to be noted, however, that although the sample size of the questionnaire study was larger, it concerned self-reported data in contrast to the test protocol data. Another limitation of the questionnaire sample is the larger response rate among female twins. ■

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50 Years Ago in The Journal of Pediatrics

Pyloric Stenosis in Premature Infants

Wilson MG. *J Pediatr* 1960;56:490-7

In reading this descriptive and interesting report describing 5 cases of premature infants with pyloric stenosis, it is striking to realize what has changed and yet what has remained remarkably similar in diagnosing and treating this rare entity in premature babies. Reading the descriptions of the cases by Wilson, I was immediately struck by the amount of detail in describing the courses of these children and the diagnostic challenges; a writing skill that has been lost in current case study reports. In addition, it is hard not to be reminded of our current dependence on imaging and testing when one reads these detailed descriptions and notices that palpation of the pyloric olive was a consistent and early finding by the astute clinicians. Today, the use of ultrasonography has nearly completely replaced the clinical skill of palpating the "olive," a skill that is often only used after the diagnosis has been made and the child is under general anesthesia simply to demonstrate to students and house staff what is described in textbooks. The author's conclusions that pyloric stenosis in infants is a "clinical diagnosis" and that reliance on imaging studies may "delay an operation unnecessarily" are conclusions that are often overlooked in today's health care systems. This article also causes one to take pause to realize that the surgeons of this time were performing these procedures with patients under local anesthesia as the only safe option, compared with our current use of safe general anesthesia to perform these procedures, many of which are done with a laparoscopic approach.

Despite the many differences there are several notable similarities. The time from initial symptoms to diagnosis of premature infants with pyloric stenosis remains prolonged. Similar to the time of the initial publication, the multiple competing medical problems these premature infants suffer from are often a distraction from the true diagnosis of pyloric stenosis. In addition, similar to what happens among both premature and full term infants, early in the course of disease the symptoms are often attributed to reflux or type of feeding and treatment for reflux or change in feedings may provide brief improvement of symptoms. As clinicians in a highly technology–dependent health care system, it is important that we review the history of our craft to be reminded that astute clinical judgment and careful clinical examination must remain essential tools in the care of patients.

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