In the present study, we evaluated whether childhood differences in body height between singletons and twins persist into adulthood. Data from the Medical Birth Register of Norway were linked with data from the Norwegian National Conscript Service. This study used data on the 457,999 males who were born alive and without physical anomalies in single or twin births in Norway during 1967–1984 and who were examined at the mandatory military conscription (age 18–20 years; 1985–2003). For sibling comparisons, the authors selected the 1,721 sibships of full brothers that included at least 1 male born in a single birth and at least 1 male born in a twin birth (4,520 persons, including 2,493 twins and 2,027 singletons). An analysis of the total study population using generalized estimating equations showed that the twins were 0.6 cm (95% confidence interval: 0.4, 0.7) shorter than were the singletons after adjustment for a series of background factors. The fixed-effects regression analysis of the sibships that included both twins and singletons showed that the twins were 0.9 cm (95% confidence interval: 0.6, 1.2) shorter than were their singleton brothers. The study suggests that male twins born in Norway during 1967–1984 were slightly shorter in early adulthood than were singletons.

body height; cohort studies; siblings; twins

Abbreviation: GEE, generalized estimating equations.

It has been well documented that twins are shorter at birth than are singletons and that a difference in body height remains for at least a few years after birth (1–4). It is unclear, however, whether the difference persists into adulthood. Some studies of children or adolescents have suggested that the difference disappears during childhood (1, 5). On the other hand, 1 study indicated that the growth spurt of boys ends earlier in twins than in singletons, leading to an increased difference in height between singletons and twins in late adolescence (6). We identified 6 studies in which differences in adult height between singletons and twins were examined (6–11). However, the results of these 6 studies are difficult to interpret, partly because the results were inconsistent and partly because adjustment for parental characteristics was not made in 5 of the studies (6, 7, 9–11).

Comparing siblings is a powerful method to control for familial characteristics. We are aware of only 1 study that compared the adult heights of twins and singletons within the same families (8).

The aim of the present study was to determine the difference in adult body height between singletons and twins. To improve controls for confounding familial characteristics, we included analyses of siblings and estimated singleton-twin differences within families. Available data on Norwegian conscripts permitted such analyses for males.

MATERIALS AND METHODS

Study design and population

We conducted a historical birth cohort study. Data from the Medical Birth Register of Norway, which contains information on all newborn children in Norway from 1967 to the present, were linked with register data from the Norwegian
National Conscript Service and the national statistics agency, Statistics Norway. During the period 1967–1984, there were 517,215 registered infant boys born alive and without physical anomalies in either single or twin (monzygotic or dizygotic) births. Data on body height, measured at the time of the mandatory military conscription, were available for 460,381 persons (89.6% of the original cohort). The loss to follow-up was 10.9% among the singletons (0.9% died during infancy and 10.0% were lost for other reasons) and 16.1% among the twins (5.6% died during infancy and 10.5% were lost for other reasons). Because our focus was on adult height, the study base was restricted to the data on the 457,999 men who were conscripted the year they reached the age of 18 years or older. Within this study base, there were data on 86,241 sibships of 2 or more men in which all men were full brothers. For our sibling comparisons, we selected the sibships that included at least 1 man born in a single birth and at least 1 man born in a twin birth. Altogether, there were 1,721 sibships with 2 to 6 full brothers (4,520 persons, including 2,493 twins and 2,027 singletons). In the sibships with data on only 1 twin along with 1 or several singletons, the missing co-twin may have been a female or a male who was disabled or had died. Military conscription in Norway is mandatory only for able-bodied males.

The study is part of a large register-based project. Approval was given by the Norwegian Data Inspectorate before the project started.

Measurements

Data on body height in centimeters were obtained from the Norwegian National Conscript Service. Data on the number of children born at each birth, birth year, birth month, birth order (among all of the mother’s live-born children, with the twins in a pair given the same birth order), birth length (centimeters), gestational age at birth, and maternal age and marital status at delivery were obtained from the Medical Birth Registry. The mother’s total number of children was calculated using data from Statistics Norway. Data on the highest attained maternal and paternal educational levels, categorized here as low (<11 years), medium (11–13 years), and high (>13 years), and information that permitted individuals to be identified as brothers (maternal and paternal serial numbers) were obtained from Statistics Norway. Age at conscription was calculated as the year in which the person was conscripted (obtained from the National Conscript Service; 1985–2003) minus his birth year.

In the total study population (n = 457,999), data on birth order were missing for 2,925 persons, on maternal marital status at delivery for 694 persons, on birth length for 5,573 persons, on maternal educational level for 1,893 persons, on paternal educational level for 6,417 persons, on paternal serial number for 3,920 persons, and on maternal serial number and the mother’s total number of children for 151 persons.

Statistical analyses

We used Stata, version 11 (StataCorp LP, College Station, Texas) for statistical analyses. The difference in height between singletons and twins was examined with 2 different linear regression approaches: 1) a generalized estimating equation (GEE) analysis of the total study population and 2) a fixed-effects regression analysis of the sibships that included both twins and singletons. In both approaches, height in centimeters was the dependent variable, and twin status (twin vs. singleton) was the principal predictor.

In the analysis of the total study population, all the twins were compared with all the singletons. Given that the observations were not perfectly independent because of clustering in sibships, a GEE approach was chosen. This GEE analysis was conducted assuming an exchangeable correlation structure. We adjusted for potential confounders by including background factors in the models: birth order, which was entered as a continuous term; a dummy variable for being firstborn; maternal age at delivery as a continuous term (years); and a dummy variable for being older than 34 years of age. Birth year (1967–1969, 1970–1974, 1975–1979, or 1980–1984), birth season (winter, spring, summer, or autumn), maternal marital status at delivery (married or not married), the mother’s total number of children (1, 2, 3, 4, 5, or >5), maternal educational level (low, medium, or high), paternal educational level (low, medium, or high), and age at conscription (18 years, 19 years, or ≥20 years) were entered as categorical terms. Gestational age at birth was considered an intermediary variable and was not included in the model. To determine whether the singleton-twin difference in height varied with the age at conscription, we conducted a supplementary GEE analysis in which the interaction term “twin status × age at conscription” was included.

To compare the heights of singletons and twins within the same families, we conducted a fixed-effects regression analysis of the sibships with at least 1 twin and at least 1 singleton. This approach controlled for all unmeasured factors that were the same for all members of a sibship. To adjust for potential confounders that vary between siblings, the following background factors were included in the model: birth order, birth year, birth season, maternal age at delivery, maternal marital status at delivery, and age at conscription. The variables were entered in the model in the same form as they were entered in the GEE analysis. We used listwise deletion for handling missing data and 2-sided P values.

RESULTS

There were no major differences between the original cohort and the total study population (Table 1). A comparison between the singletons and twins in the study population showed that the mean birth length of twins was 3.3 cm lower than that of singletons. The twins were born at lower gestational ages, were less often firstborn, had parents with higher educational levels, and had mothers with a higher total number of children. At military conscription, the mean height of the singletons was 179.9 cm, whereas the mean body height of the twins was 179.4 cm. A Bartlett’s test showed that the variance of the body height was not significantly different in twins and singletons (P = 0.064).

Table 2 shows the characteristics of the sibships that included both twins and singletons. Compared with the total study population, the men in these sibships were more likely
to have highly educated parents. A higher proportion of their mothers were married at delivery and their mothers had, on average, more children. A comparison between the twins and singletons showed that the twins were shorter at birth, were born at lower gestational ages, were less often firstborn, and were more often conscripted the year they turned 18.

A GEE analysis of the total study population (Table 3) showed that the unadjusted difference in height between singletons and twins was 0.6 cm (95% confidence interval: 0.4, 0.7; P < 0.001). After adjustment for age at conscription, birth year, birth season, birth order, and maternal age and marital status at delivery, the within-family difference was still 0.9 cm (95% confidence interval: 0.6, 1.2; P < 0.001).

We conducted a supplementary GEE analysis in which the interaction term “twin status × age at conscription” was included. This analysis showed that the singleton-twin difference in height among men who were conscripted the year they turned 18 years of age was not different from that among men conscripted the year they reached the age of 20 years or older (P = 0.56). Adjustments were made for twin status, age at conscription, birth year, birth season, birth order, maternal and paternal educational levels, maternal age and marital status at delivery, and the mother’s total number of children.

A fixed-effects regression analysis of the sibships that included both twins and singletons (Table 3) showed that the crude within-family difference between singletons and twins was 0.9 cm (95% confidence interval: 0.6, 1.2; P < 0.001). After adjustment for age at conscription, birth year, birth season, birth order, and maternal age and marital status at delivery, the within-family difference was still 0.9 cm (95% confidence interval: 0.6, 1.2; P < 0.001).

DISCUSSION

In the present register-based study of Norwegian males, twins were shorter at military conscription than were singletons. The difference was 0.6 cm when twins were compared with singletons in the total population. When twins were compared with singletons within the same families, the difference was 0.9 cm.

Because the difference in height was larger at birth (3.3 cm), twins seem to have grown more between birth and military conscription compared with singletons. Thus, the difference in body height at conscription may have been due to intrauterine exposures or signals of some kind. There are indications that the intrauterine growth of twins and singletons starts to diverge in the first trimester (12), so children’s growth trajectories may perhaps be determined by physiological signals just after conception (12).

The present study was based on a large national birth cohort. Data on height at military conscription were available for the great majority of the original cohort. There was only a modest difference between twins and singletons in the loss to follow-up for reasons other than infant deaths.
by the interaction analysis suggested that the singleton-twin difference was not different for men who were examined the year they turned 18 years of age and those who were examined when they turned 19 or 20 years of age. However, few twins had been examined after the age of 20 years, so the data did not permit meaningful analyses of the singleton-twin difference after the age of 20 years. If twins grow at a rate similar to that of singletons through the late teenage years but continue to grow for a longer period of time during their twenties than do singletons, twins’ final heights may not be different from those of singletons. In a longitudinal study from Sweden, Ljung et al. (6) found that the growth spurts of boys ended earlier in twins than in singletons. However, the twins and singletons in that study were not examined after the age of 18 years.

In an earlier study of Norwegian conscripts undertaken to determine the relationship between body height and intelligence, Sundet et al. (9) showed the unadjusted heights for male twins and singletons as background data. The twins in their sample were 6,144 males selected from 2 twin registers. The members of one of those registers were born during 1967–1979 and comprise a subgroup of our sample of male twins and singletons. However, the twins and siblings were born before 1960 and were not included in our sample. The singletons were 0.2 cm taller than the dizygotic twins and 0.7 cm taller than the monozygotic twins at conscription, but there was no adjustment for background factors and no sibling comparison. A study of 1 million conscripted men from Sweden (10) gave similar estimates as those reported by Sundet et al. Although those 2 studies showed small singleton-twin differences similar to our estimates, 2 other studies showed larger differences: A difference of 1.5 cm was seen between 131 male 18-year-old twins and 294 male

### Table 2. Characteristics of the Men in the Sibships That Included at Least 1 Twin and at Least 1 Singleton, Norway, 1967–2003

<table>
<thead>
<tr>
<th>Variable</th>
<th>Singletons (n = 2,027)</th>
<th>Twins (n = 2,493)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Mean (SD)</td>
<td>% Mean (SD)</td>
</tr>
<tr>
<td>Born after 1975</td>
<td>32.9 47.7</td>
<td></td>
</tr>
<tr>
<td>Born in summer or autumn</td>
<td>50.5 46.3</td>
<td></td>
</tr>
<tr>
<td>First bornb</td>
<td>46.4 17.6</td>
<td></td>
</tr>
<tr>
<td>Gestational age at birth, weeks</td>
<td>39.9 (2.2) 37.6 (2.7)</td>
<td></td>
</tr>
<tr>
<td>Birth length, cm</td>
<td>51.1 (2.3) 47.7 (2.8)</td>
<td></td>
</tr>
<tr>
<td>Mother married at delivery</td>
<td>94.6 96.7</td>
<td></td>
</tr>
<tr>
<td>Maternal age at delivery, years</td>
<td>25.8 (5.1) 27.5 (4.9)</td>
<td></td>
</tr>
<tr>
<td>Highly educated mother</td>
<td>22.9 23.9</td>
<td></td>
</tr>
<tr>
<td>Highly educated father</td>
<td>25.2 26.0</td>
<td></td>
</tr>
<tr>
<td>Mother’s total no. of children</td>
<td>4.2 (1.5) 4.0 (1.3)</td>
<td></td>
</tr>
<tr>
<td>Height at conscription, cm</td>
<td>180.2 (6.5) 179.3 (6.7)</td>
<td></td>
</tr>
<tr>
<td>Age at conscription, years</td>
<td>18 45.2 51.9</td>
<td>19 52.7 46.1</td>
</tr>
<tr>
<td>&gt;20</td>
<td>2.1 2.1</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: SD, standard deviation.

* Missing data were not included in the analyses.

b Among all the live-born children of the mother.

c More than 13 years of education.

d More than 13 years of education.

e More than 13 years of education.

(10.0% vs. 10.5%). The sample included only males, however, and the consequences of twin status could perhaps be different in females.

Unmeasured familial and parental characteristics may be a source of confounding in studies of body height. That is why our sibling comparison is important. Differences in height between siblings cannot be due to factors that siblings have in common. Thus, within-family differences estimated by fixed-effects regression analysis are indirectly controlled for all unmeasured factors that are shared by siblings in a sibship. The fact that the difference between twins and singletons in the same families was larger than the difference between the twins and the total population of singletons may be a consequence of such a control for unmeasured familial factors (e.g., maternal height). However, the men who were compared with their brothers were members of families with more children and more highly educated parents than were the other men in the study population. Therefore, the results of the sibling comparisons may not be fully representative for the total population of male twins and singletons.

A substantial proportion of the men may not have reached their full adult height at conscription. Some men continue to grow into their early twenties. So, we do not know with certainty whether our estimates reflect differences in final height. The interaction analysis suggested that the singleton-twin difference was not different for men who were examined the year they turned 18 years of age and those who were examined when they turned 19 or 20 years of age. However, few twins had been examined after the age of 20 years, so the data did not permit meaningful analyses of the singleton-twin difference after the age of 20 years. If twins grow at a rate similar to that of singletons through the late teenage years but continue to grow for a longer period of time during their twenties than do singletons, twins’ final heights may not be different from those of singletons. In a longitudinal study from Sweden, Ljung et al. (6) found that the growth spurts of boys ended earlier in twins than in singletons. However, the twins and singletons in that study were not examined after the age of 18 years.

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<table>
<thead>
<tr>
<th>Group</th>
<th>Height Difference, cm</th>
<th>95% CI</th>
<th>Height Difference, cm</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total study populationb</td>
<td>0.6 0.4, 0.7*</td>
<td>0.6 0.4, 0.7*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sibships with both twins and singletonsb</td>
<td>0.9 0.6, 1.2*</td>
<td>0.9 0.6, 1.2*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: CI, confidence interval.

* 2-sided P value <0.001.

d In the analysis of the total study population, the adjustment factors were age at conscription, birth order, birth year, birth season, maternal age at delivery, maternal marital status at delivery, the mother’s total number of children, and maternal and paternal educational levels (n = 446,734). In the analysis of the sibships, the adjustment factors were age at conscription, birth order, birth year, birth season, maternal age at delivery, and maternal marital status at delivery (n = 4,499).

b The singleton-twin difference in the total study population was estimated using a generalized estimating equations analysis.

c The within-family difference between singletons and twins in the sibships was estimated using a fixed-effects regression analysis.
singleton classmates from 40 Swedish cities (6), and a difference of 2.6 cm in final height was seen between 133 male twins and 509 male singletons from Japan (11). However, the samples of those studies were relatively small and not population-based, and they may have given randomly large estimates. Two studies (7, 8), including one in which 360 Dutch twins were compared with their siblings (8), showed no difference in adult height between twins and singletons. However, the twins in those studies had volunteered as members of twin registers, so they may have been a selection of healthy and relatively tall twins. This potential bias could explain the lack of differences. The present study suggests that male twins born in Norway during 1967–1984 were slightly shorter in early adulthood than were singletons.

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