Objective: To examine whether twin birth weight differences relate to subsequent differences in conduct problems at 3 to 4 years of age.

Design: Retrospective cohort study using mothers' reports on twins' behavior, birth weight, and zygosity. A partial sample participated in laboratory visits.

Setting: Jerusalem, Israel.

Participants: All ethnic Jewish families identified by the Israeli Ministry of the Interior as having twins born in 2004 and 2005 were sent mail surveys regarding children's development. Families of twins (n=1319) answered the survey when the twins were 3 years old. Same-sex birth weight–discordant twin pairs (n=112) were selected for the main analyses of the study.

Main Exposure: A birth weight difference of 20.0% or more between the twins.

Main Outcome Measures: Mothers' reports on twins' conduct problems using the Strengths and Difficulties Questionnaire and difference in conduct problems between the lower and higher birth weight twins in birth weight–discordant twin pairs.

Results: In birth weight–discordant twin pairs, the twin with the higher birth weight was reported to have more conduct problems compared with the twin with the lower birth weight in 41.1% of twin pairs, whereas the twin with the lower birth weight was reported to have more conduct problems only in 20.5% of twin pairs. This effect tended to be stronger in dizygotic compared with monozygotic twins.

Conclusions: The findings suggest an effect of birth weight differences on development of subsequent conduct problems. Further studies are needed to clarify the mediating factors of this effect. The results point to the importance of birth history for subsequent development.

In a seminal article, Plomin and Daniels\(^1\) asked, "Why are children in the same family so different from each other?" Their answer concerned genetic differences among siblings and differences in the environmental factors not shared by siblings, which initiate cascades of developmental changes, leading to differential development. In a process called niche picking or niche building, early characteristics may lead individuals to create and seek environments correlated with their traits, an environment that in turn has further effects on the traits of the individual.\(^2\) In this article, we study the role of twins' birth history and weight differences and the possible effect of those factors on subsequent conduct problems.

Different studies define twin birth weight discordance as a weight difference between the 2 fetuses of greater than 15%, 20%, or 25%. This discordance is an important factor in prediction of future pregnancy and neonatal and childhood complications and diseases.\(^3,5\)

The importance of studying conduct problems is evident considering the symptoms associated with conduct disorders. According to the Diagnostic and Statistical Manual of Mental Disorders (Fourth Edition), a conduct disorder is defined as "a repetitive and persistent pattern of behavior in which an individual violates the basic rights of others while also significantly impairing one's own functioning." The estimated lifetime prevalence of conduct disorder in the United States is 9.5% (12.0% among boys and 7.1% among girls), with a median age at onset of 11.6 years.\(^7\) Conduct problems, which do not necessarily fill all the criteria of a conduct disorder, are also prevalent. The prevalence of serious conduct problems among 5- to 16-year-olds in the United States, as estimated by the Strengths and Difficulties Questionnaire (SDQ),\(^8,9\) was found to be on average 5.3% among boys and 4.6% among girls.\(^9\)

Twin studies show genetic and environmental influences on children's conduct problems\(^10,15\) and anger.\(^16\) In addition, an interaction has been reported between genetic and environmental influences in disruptive behavior outcomes such as criminality and conduct problems. When under conditions of low genetic risk, the effect of the environment (parental crimi-
nality or maltreatment) on later disruptive behavior outcomes is somewhat small; under conditions of high genetic risk, the effect of such a risk environment is strong.17,18 This interaction was demonstrated with the MAO-A gene polymorphism.19-23

Animal research24,25 and human research26 propose a relationship between body size and birth weight (which reflect environmental and genetic variables) and aggression, a key factor in children’s conduct problems. Testosterone levels, which correlate positively with physical and verbal aggression and lack of frustration tolerance,27 are also positively correlated with height in early adolescence.28 However, a meta-analysis29 did not find significant birth weight effects on externalizing problems, and the relationship between body size and aggression or conduct problems appears to be a complex one. A longitudinal study20 found that increased aggression at the age of 11 years was predicted by increased body size, height, and weight at the age of 3 years but not at 11 years. This finding suggests a critical period in the influence of body size on aggression. Another study30 showed that twins’ body mass index at birth, but not at 19 months, predicted asymmetry in resource control during a competitive task with an unfamiliar peer at 19 months.

Although the relationship between birth weight and conduct problems is not straightforward when looking at the association between these 2 variables at the population level, differences at the family level may be important. Substantially different birth weights in children growing up in the same family can initiate behavioral differences between them because of the effects of social comparison and parental differential treatment. Birth weight–discordant same-sex twins who share their age, sex, and family environment provide an efficient way to examine the effect of birth weight differences. With a higher likelihood of being physically stronger, the larger twin is more likely to benefit from trying to use physical means to reach desired goals because such behavior is more likely to be successful in reaching those goals. In addition, previous reports have shown evidence of mothers’ preferential treatment for the smaller or weaker twin,31 and the less preferred twin may be more prone to developing conduct problems.32-34

Another potential explanation for these differences comes from a study that examined neonatal temperament among birth weight–discordant twins35 and showed that the smaller co-twin was more reactive to visual and auditory stimuli and provided more positive feedback to the examiner, whereas the larger twin of the pair was more irritable and more difficult to soothe. On the basis of this evidence, we tested the hypothesis that the larger twins have more conduct problems than the smaller twins, using data from a sample of birth weight–discordant twin pairs in the fourth year of life. In addition, we examine different correlates of birth weight to trace potential sources for the effect of birth weight on conduct problems.

**METHODS**

**STUDY PARTICIPANTS**

Participants were families of same-sex twin pairs aged 3 to 4 years. They were part of a larger sample of twins’ families participating in the Longitudinal Israeli Study of Twins, which focuses on children’s social development as influenced by genetics, abilities, and socialization.36,37 An institutional review board approval was obtained, and all ethnic Jewish families identified as having twins born between January 1, 2004, and December 31, 2005, by the Israeli Ministry of the Interior were sent mail surveys regarding children’s development shortly before the twins’ third birthday.

The mail surveys included, among other issues described by Knafo,38 questions regarding pregnancy and delivery, twin zygosity, and several dimensions of twins’ behavior. Of 1319 same-sex and opposite-sex pairs of twins participating at 3 to 4 years of age, data from 799 same-sex pairs were used to investigate the relationship between birth weight and conduct problems, comparing individuals at the population level. This sample provided 112 twins identified as birth weight discordant if there was 20.0% or more birth weight difference between them.

A partial sample of 87 same-sex twin pairs from the greater Jerusalem region also participated in an experimental session at the age of 3 1⁄2 years. During the experimental session, the twins’ height and weight were measured. Families were selected to participate in the experimental sessions solely based on their proximity to the laboratory in Jerusalem. These families did not differ demographically or in birth weight or conduct problems from the larger, questionnaire-based sample.

**OUTCOME MEASURES**

The primary outcome measure, twins’ conduct problems, was assessed using the conduct problems subscale on the SDQ.4 The SDQ is a 25-item instrument asking respondents to indicate whether various symptoms and behaviors are “not true,” “somewhat true,” or “certainly true” of the child. The SDQ measures conduct problems, peer problems, emotional symptoms, hyperactivity/inattention, and prosocial behavior, with 5 items for each subscale. This questionnaire is widely used for screening, longitudinal monitoring of therapeutic effects, and scientific research,40 and its subscales have been shown to have good internal reliability.41 The conduct problems scale includes items such as “often fights with other children or bullies them” and “often lies or cheats,” as well as other items referring to stealing, temper tantrums, and defiance. The items were averaged to form a single conduct problems score. In previous research,40 correlations were found between parents’ and teachers’ reports on the SDQ for the total difficulties score and for the conduct problems score, indicating the good quality of mothers’ reports, which were used in the present study.

Twins’ body size and birth history were reported by mothers. Specifically, mothers described each twin’s weight, Apgar score, length of stay in the neonatal intensive care unit (NICU), and current physical size compared with other children in their kindergarten class (rated on a 3-point scale in which 1 indicates smaller; 2, same as most children; and 3, larger). To validate mothers’ reports, we obtained data from hospital medical records on a partial sample (n=32), which showed that mothers were highly accurate in their reports of birth weight and height in early adolescence.28 How-
large sample included 270 monozygotic (MZ) and 501 dizygotic (DZ) same-sex twin pairs, as well as 28 pairs for which zygosity could not be determined. Of these, 112 were birth weight–discordant twin pairs, including 79 DZ and 29 MZ pairs and 4 pairs with undetermined zygosity. The relative frequency of birth weight–discordant twin pairs did not differ significantly between DZ (10.7%) and MZ (15.8%) pairs ($\chi^2=3.68, P=.06$).

In the full sample of same-sex twins ($N=799$), birth weight data were missing in 72 families and conduct problems data were missing in 41 families, which were excluded from the main analyses. A comparison of these families with families with complete data using independent-sample t tests showed that families who had missing birth weight data were not significantly different from families with complete data on twins’ conduct problems ($t=1.29, P=.21$) family income ($t=-0.41, P=.68$), mothers’ religiousness ($t=-1.01, P=.31$), and education level ($t=-0.08, P=.93$). Similarly, families with missing conduct problems data were not different from families with complete data on twins’ birth weight ($t=0.13, P=.89$), family income ($t=-0.38, P=.56$), mothers’ religiousness ($t=-0.13, P=.90$), and education level ($t=-0.53, P=.39$).

**STATISTICAL ANALYSES**

All analyses were performed using SPSS statistical software, version 13 (SPSS Inc., Chicago, Illinois). To check for sex and zygosity effects on birth weight and conduct problems in the whole same-sex sample, a multivariate analysis of variance (MANOVA) test was used. To check for the effect of birth weight on twins’ height and weight at early childhood, Pearson correlations were calculated using the laboratory sample. Differences between the larger and smaller twins in the tendency to be smaller, similar, or larger in physical size compared with other children in their kindergarten class were examined using the McNemar-Bowker test of symmetry in the weight-discordant sample. To examine other medical implications of the twins’ birth weight difference, we conducted paired t tests, comparing 1-minute Apgar scores, length of hospitalization, and NICU stay between the larger and smaller twins in birth weight–discordant dyads. Population-level associations between birth weight and subsequent conduct problems were examined using Pearson correlations. To examine our main hypotheses regarding the effect of birth weight on conduct problems among same-sex, birth weight–discordant twins, we conducted paired t tests, comparing the level of conduct problems of the larger and smaller twins in each twin dyad, once for the whole group (DZ and MZ) and then separately for MZ and DZ twins. We also used a goodness-of-fit $\chi^2$ test to compare the percentage of twin pairs in which the larger twin had more conduct problems, the percentage of twin pairs in which the smaller twin had more conduct problems, and the percentage of twin pairs in which twins had a similar level of conduct problems.

**RESULTS**

In the whole same-sex sample, a MANOVA test with both twins’ birth weight as dependent variables showed no significant effects of sex ($F_{2,799}=2.69, P=.07$), zygosity ($F_{2,799}=0.25, P=.78$), or their interaction ($F_{2,799}=0.41, P=.41$) on the twins’ birth weight. Similarly, a MANOVA test with twins’ conduct problems as dependent variables showed no significant effects of sex ($F_{2,799}=0.99, P=.37$), zygosity ($F_{2,799}=1.56, P=.21$), or their interaction ($F_{2,799}=1.83, P=.16$) on the twins’ conduct problems.

In birth weight–discordant twin pairs, the smaller twins’ mean (SD) birth weight was 2497 (619) g, and the larger twins’ mean (SD) birth weight was 1797 (488) g, and the average weight difference comprising 28.4% of the larger twin’s weight. Growth discrepancy is calculated as subtracting the neonatal weight of the smaller infant from that of the larger and dividing it by the larger twin’s weight. As expected from previous studies on birth weight and subsequent physical size, twins’ weight at birth predicted their physical size 3½ years after birth. In the laboratory subsample, positive correlations were found between birth weight and the child’s height ($r=0.29, P=.002$) and weight ($r=0.26, P=.01$). In addition, the McNemar-Bowker test of symmetry showed significant differences between the larger and smaller twins in the tendency to be smaller, similar, or larger in physical size compared with other children in their kindergarten class ($\chi^2=22.83, P<.001$). Although among the smaller twins (at birth) 41.2% tended to be smaller relative to other children, among the larger twins only 17.6% did. This result was significant for DZ twins ($\chi^2=16.89, P=.001$) and MZ twins ($\chi^2=4.0, P=.046$).

To examine other medical implications of the twins’ birth weight difference, we conducted paired t tests, comparing 1-minute Apgar scores, length of hospitalization, and NICU stay between the larger and smaller twins in birth weight–discordant dyads. No differences were found between the larger and smaller twins in birth weight–discordant dyads. However, the smaller twins remained longer in the NICU (mean [SD], 1.96 [2.95] weeks) compared with the larger twins (mean [SD], 1.17 [2.24]; $t_{799}=-4.21, P<.001$, $D^*=0.28$) and were also hospitalized for a longer time after birth (mean [SD], 19.88 [23.61] days vs 14.14 [17.08] days; $t_{799}=-4.58, P<.001$, $D^*=0.25$).

Population-level associations between birth weight and subsequent conduct problems were investigated by correlating these 2 variables. The correlation between them was not significant ($r=0.035, P=.36$).

Next, we examined our main hypotheses in birth weight–discordant, same-sex twins. A paired t test compared the level of conduct problems of the larger and smaller twins in each twin dyad. Results showed that the larger twins in birth weight–discordant dyads had significantly more conduct problems (mean [SD], 0.60 [0.26]) than their smaller twins (mean [SD], 0.54 [0.27]; $t_{112}=2.57, P=.01$, $D^*=0.25$). Further analyses showed no interaction between zygosity and being the larger or smaller twin in twins’ conduct problems.

In addition, we used a goodness-of-fit $\chi^2$ test to compare the proportion of twin pairs in which the larger twin had more conduct problems, the proportion of pairs in which the smaller twin had more conduct problems, and the proportion of pairs in which twins had a similar level of conduct problems. There were twice as many twin pairs in which the larger twin had more conduct problems (41.1%) than twin pairs in which the smaller twin had more conduct problems (20.5%) ($\chi^2=8.38, n=112, P=.02$). Although this difference was found in MZ and DZ twins, it was smaller in MZ pairs (31.0% vs 24.1%, $\chi^2=1.93, n=29, P=.38$) than in DZ pairs (45.6% vs 20.3%, $\chi^2=7.62, n=79, P=.02$) (Figure).

We examined the effect of birth weight differences on the development of subsequent conduct problems among
Monozygotic

Dizygotic

Same level of conduct problems in both twins

Larger twin has more conduct problems

Smaller twin has more conduct problems

Figure. Proportion of twin pairs in which the larger or smaller twin has more conduct problems compared with his or her co-twin in dizygotic vs monozygotic twins.

3- to 4-year-old twins. Evidence from previous research showed mixed results regarding the possible effects of birth weight on conduct problems. In the present study, population-level analyses did not show an association between conduct problems and birth weight. However, within-family twins' differences in birth weight were associated with their conduct problems. This finding indicates that birth weight differences may operate by affecting children's problems through differentiation processes.

Personal and familial factors can account for the differences in conduct problems between larger and smaller twins. Larger twins' conduct problems, particularly aggressive behavior, may have been enhanced by their having more physical possibilities to behave aggressively compared with their smaller co-twin. In addition, our results showed longer NICU stay and subsequent hospitalization for the smaller compared with the larger twin. The differential health status of newborn, birth weight--discordant twins may lead mothers to invest more time, effort, and emotional resources in the weaker, smaller twin, possibly increasing the larger twin's likelihood for developing conduct problems. However, neonate temperamental differences between the larger and smaller twin are also a compelling possibility.

Although we did not find an interaction between birth weight status (large vs small) and zygosity, the differences in conduct problems tended to be higher in DZ discordant twins than in MZ twins. A previous study, which examined the implications of birth weight differences on conduct problems among MZ twins at the age of 7 years, did not find significant correlations between teacher-reported conduct problems and birth weight. Thus, there is some evidence that the effects of birth weight twin differences are more prominent among DZ twins. This may occur because of their different genetic heritage, which inclines them to seek or create more diverse environments, compared with MZ twins (who share 100% of their DNA sequence) in accordance with processes of evocative and active gene-environment correlations.

In their review of the literature, Plomin and Daniels concluded that the nonshared environment of different children in the same family has a major influence on personality, psychopathological behavior, and cognitive abilities. In the present study, we examined birth weight differences as one potential contributor to this environmental variability. Although birth weight may reflect genetic differences between the twins, it may be affected by environmental factors as well, such as location of the placenta, sex of the other twin, and twin-to-twin transfusion syndrome in MZ, monochorionic twins. Furthermore, transplacental hormonal transfer may also affect behavior of MZ twins, especially in cases of twin-to-twin transfusion syndrome, compared with DZ twins, in whom the circulation systems are separate. The lack of an overall association between conduct problems and birth weight suggests that the larger DZ twin effects are not the result of the same genes being responsible for the differentiation in twins' conduct problems and weight. Indeed, our results single out weight differences as the differentiating factor in terms of conduct problems.

Although the present study has shown interesting findings regarding the effect of birth weight on subsequent conduct problems, further studies are needed to clarify the factors that may mediate this effect. One promising path of research may be to examine, in longitudinal studies, differences in early parenting toward twins with substantially different birth weight and, in case such differences are found, to examine them as mediators of the effect of birth weight on later conduct problems. Although birth weight--discordant twins may grow within the normal weights for twins, it is also possible that 1 or both twins would be intrauterine growth restricted, and the physiologic and behavioral consequences of intrauterine growth restriction are well established. We plan to address these issues in future reports.

In conclusion, this study addressed the effect of birth weight differences in twins on their subsequent development of conduct problems. Larger twins in birth weight--discordant dyads developed more conduct problems compared with the smaller twins. These results may suggest that in addition to considering genetic and environmental influences on conduct problems, future research should investigate the role of twins' birth weight differences.

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