Twin Concordance for Attention Deficit Hyperactivity Disorder: A Comparison of Teachers' and Mothers' Reports

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Objective: *The present study examined probandwise concordance rates for attention deficit hyperactivity disorder (ADHD) in a community sample of 194 monozygotic and 94 dizygotic male twins, ages 11–12 years.* *Method:* *DSM-III and DSM-III-R diagnoses of ADHD were based on rating scale reports from the twins' teachers and structured interview reports obtained from their mothers. Model-fitting analyses were used to estimate genetic and environmental effects on ADHD.* *Results:* *Concordance rates for ADHD were greater for monozygotic than dizygotic twins according to both mothers' and teachers' reports; this finding indicates the importance of genetic factors in the etiology of this syndrome. Fifteen percent of subjects received an ADHD diagnosis by teachers' ratings, compared with 6% by mothers' reports. Three percent of subjects met criteria for ADHD in both school and home settings. Teachers' ratings yielded moderate monozygotic and dizygotic concordance rates, in contrast to mothers' reports, which indicated a high monozygotic and a zero dizygotic concordance for ADHD. A model that included additive genetic and nonshared environmental factors provided the best fit to these ADHD data.* *Conclusions:* *ADHD, as defined by DSM criteria, appears to be a genetically influenced disorder whether diagnoses are based on teachers' or mothers' reports. However, the extent of this genetic influence seems to vary by informant source. These findings suggest that obtaining diagnostic data from either teachers' or mothers' reports alone may provide an incomplete characterization of ADHD.*

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The heterogeneous syndrome of attention deficit hyperactivity disorder (ADHD) occurs in about 5%–10% of school-age children, with greater frequency among boys than girls. Prevalence estimates can vary considerably depending on which of the key symptoms (inattention, impulsivity, and hyperactivity) are emphasized and who reports the occurrence of those behaviors.

Although overlapping evidence from family-genetic, twin, adoption, and segregation analysis studies (1–12) supports an important genetic contribution to the disorder, there have been but a few studies reporting twin concordances for ADHD. While the results of these studies are in general agreement with each other, they remain equivocal because of methodological limitations including small sample size, operational syndrome definitions based on restricted measures, or diagnoses based on symptom reports of a single informant. Probandwise concordance rates in the larger and more methodologically sound of these studies have ranged from 50% to 80% for monozygotic twins and have been approximately 30% for dizygotic twins (7, 12). Even so, only one of the studies (12) used DSM diagnoses, and they were based solely on mothers' reports of ADHD symptom criteria. Moreover, the sample in that study (12) was originally selected for the presence of reading disabilities. In the other large twin investigation (7), concordance rates were reported for categorical hyperactivity, operationalized as a cutoff score for ratings of mothers or teachers or both on a brief hyperactivity rating scale (13, 14).

The present study has the advantage of having employed a large, unselected, twin sample for which information on DSM-III and DSM-III-R criteria were available from two informant sources. Structured interview reports were collected from the twins' mothers and rating scale data from their teachers. Thus, we were able to compare concordance rates for DSM diagnoses of ADHD from the two separate informant sources. In addition, model-fitting analyses provided estimates of genetic and environmental effects on ADHD.

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METHOD

Subjects

The subjects in this study were 576 11- and 12-year-old (mean age=11.8 years), male, reared-together twins (194 monozygotic and 94 dizygotic pairs) who were participants in the longitudinal, population-based Minnesota Twin Family Study. The identification, recruitment, and assessment of the twins are described in more detail elsewhere (15). Briefly, the recruitment pool consisted of twins and their parents identified from a review of all Minnesota birth records covering the 5-year period from 1977 through 1981. Approximately 90% of families from the recruitment pool in which both twins were still living were located by the Minnesota Twin Family Study. From this group, all families still residing in or near Minnesota constituted the pool from which families were drawn. Shortly before the twins' 11th birthday, a semistructured telephone interview, usually with the biological mother of the twins, was carried out to collect demographic and family health history data. Families were excluded from participation if, on the basis of this parental report, it was determined that the twins had severe intellectual or physical disabilities or were adopted.

Recruited families traveled to our university laboratory from around the state and were housed in a hotel if they lived outside of the Minneapolis metropolitan area. Because there were more families in the pool than there was laboratory time available to assess them, only about two-thirds of eligible families participated in the assessment. Subjects received an honorarium for their day-long visit, which included clinical, psychophysiological, and personality assessments of both the twins and their parents. All subjects provided written informed consent or assent, as appropriate.

A parental questionnaire, an experimenter zygosity estimate, and an algorithm diagnosis calculated from ponderal index, cephalic index, and fingerprint ridge count were used to determine zygosity. If there was disagreement among any of these three estimates, it was resolved through a serological analysis procedure that has been shown to have a zygosity classification error rate of less than 0.001 (16).

Measures

The Minnesota Twin Family Study teacher rating form contains items describing the behavior of the twins in the classroom, compared with that of the average child, as well as items reflecting academic progress, personality, and peer group relations. In addition to items adapted from the Conners Teacher Rating Scale (17) and the Rutter Child Scale B (13), items were included in the teacher rating form to provide coverage of all DSM-III criteria for attention deficit disorder with hyperactivity (ADDH) and DSM-III-R criteria for ADHD. One DSM-III hyperactivity item that teachers were unlikely to have first-hand knowledge of, "moves about excessively during sleep," was excluded from the teacher rating form. A 4-point rating scale, with responses ranging from "not at all" to "very much," was used with each teacher rating form item.

Teachers' reports were collected from more than one individual whenever possible, and mean teacher ratings were used to compute diagnoses. A total of 450 subjects (78%) had two or more teacher rating forms completed and returned, and 116 (20%) had one teacher rating form returned; only 10 subjects (2%) had no teacher rating form data available. Teacher ratings were excluded from analyses if responses to seven or more of the form's 49 items were missing. Interteacher agreement for individual rating form behavioral items ranged from 0.26 to 0.56 (mean intraclass correlation=0.44). The average agreement between pairs of teachers for the summed ADHD symptom score was also good (r=0.67).

Mothers' reports of symptoms pertaining to DSM-III ADDH and DSM-III-R ADHD were elicited by administration of the parents' version of the Diagnostic Interview for Children and Adolescents—Revised (18, 19), a structured psychiatric interview. The Minnesota Twin Family Study version of this diagnostic interview also contained some supplementary probes and questions that were added to the interview, after consultation with one of its authors, to ensure complete coverage of these disorders.

The Diagnostic Interview for Children and Adolescents—Revised was administered by interviewers trained by Minnesota Twin Family Study staff clinical psychologists and advanced clinical psychology graduate students. Each diagnostic interview item was coded by the interviewers on a 3-point scale as threshold (definitely present), subthreshold (e.g., in severity, frequency, or pervasiveness), or absent. Subsequently, the coding of each diagnostic interview symptom was reviewed by a consensus team consisting of at least two individuals with advanced clinical training. Audiotaped interviews were listened to as needed to resolve scoring uncertainties. Diagnoses were then generated by computer algorithms through use of symptom counts that were matched to DSM criteria for each disorder. Subjects who either met full criteria for (definite diagnosis) or fell one symptom short of (probable diagnosis) DSM criteria were considered to have ADHD in the present study. It was also required that subjects met age at onset (before 7 years) and duration (at least 6 months) criteria for a diagnosis of ADHD based on the Diagnostic Interview for Children and Adolescents—Revised.

The reliabilities of diagnoses based on the Diagnostic Interview for Children and Adolescents—Revised and arrived at by the consensus process described earlier have been assessed by a second review of interviews and audiotapes with a different consensus team. Kappas for dichotomously assigned diagnoses of ADDH and ADHD were 0.84 and 0.77, respectively.

DSM Diagnoses

Only threshold symptoms on the Diagnostic Interview for Children and Adolescents—Revised and symptoms with ratings of "very much" and "pretty much" on the teacher rating form were counted as present when diagnoses were assigned. Diagnoses of ADDH and ADHD were generated from both the Diagnostic Interview for Children and Adolescents—Revised and the teacher rating form but were ultimately combined because of substantial overlap between the two diagnostic groups.

In a subtyping of all subjects with ADHD, situational and pervasive diagnoses of ADHD were also given. A pervasive diagnosis required a diagnosis in two situations, that is, by both maternal and teacher reports. A school-situational or home-situational diagnosis was given if a diagnosis of ADHD was reported by only the child's teacher or mother, respectively.

Statistical Analyses

Probandwise concordances and tetrachoric correlations were computed for the monozygotic and dizygotic twins. The probandwise rate, calculated here as 2C divided by (2C + D) where C is the number of pairwise concordant and D is the number of discordant twin pairs, directly estimates risk to the co-twin of an affected proband and is thus preferred over other estimates of twin concordance (20). Model-fitting analyses were conducted to estimate genetic and environmental influences on ADHD and determine the best-fitting models for teacher rating form, Diagnostic Interview for Children and Adolescents—Revised, and combined concordance data through use of standard biometrical procedures (21).

RESULTS

Teacher rating forms with complete data for both twins were available for 274 twin pairs. Eighty individuals (14%) had diagnoses of ADDH or ADHD or both on the basis of teacher ratings. Fifty-two of these subjects (65%) had both diagnoses. Eighty-four percent of the children with a DSM-III diagnosis of ADDH also had a DSM-III-R diagnosis. Conversely, 74% of those with a diagnosis of ADHD also received a diagnosis of ADDH.

Data from the Diagnostic Interview for Children and Adolescents—Revised were unavailable for one twin pair.

TABLE 1. Prevalence, Probandwise Concordance, Tetrachoric Correlations, and Model-Fitting Results for ADHD Defined by Mothers' Structured Interview Reports, Teachers' Ratings, and Combined Reports of Mothers and Teachers[a] for Monozygotic and Dizygotic Male Twins

	Monozygotic Subjects[b]					Dizygotic Subjects[c]					Model-Fitting Estimate and Analysis[d]					
			Twin ADHD					Twin ADHD			Estimate			Analysis		
Informant	N	Percent With ADHD	Number of Pairs	Concordance	Correlation (r)	N	Percent With ADHD	Number of Pairs	Concordance	Correlation (r)	A	C	E	χ^2	df	p
Teacher	362	14.6	53	0.53	0.71	186	14.5	27	0.37	0.49	0.73	0	0.27	0.51	4	0.97
Mother	388	7.0	27	0.67	0.90	186	5.4	10	0.0	—[e]	0.89	0	0.11	3.18	4	0.53
Combined	388	17.8	69	0.58	0.74	186	17.2	32	0.31	0.32	0.79	0	0.21	0.20	4	0.98

[a]For combined category, a twin pair was considered concordant if both twins met ADDH/ADHD criteria on the basis of report of mother or teacher.
[b]Teachers' ratings on 181 twin pairs and mothers' ratings on 194 pairs.
[c]Teachers' and mothers' ratings on 93 pairs.
[d]A=additive genetic, C=shared environmental, and E=nonshared environmental proportion of liability variance.
[e]Tetrachoric correlation was not estimated because of an empty cell (i.e., no concordant dizygotic pairs on the basis of mothers' reports).

For the remaining 287 pairs, maternal reports resulted in 37 subjects (6%) with diagnoses of DSM-III ADDH or DSM-III-R ADHD or both. Of these, eight subjects (22%) had a diagnosis of ADDH but not ADHD, while nine (24%) had only a diagnosis of ADHD.

A combined diagnosis was assigned if a subject had a diagnosis of ADDH and/or ADHD by teachers' and/or mothers' reports. Eighteen percent (N=101) of the total group had a combined ADDH/ADHD diagnosis.

Taking full advantage of the available diagnostic information, we used the combined ADDH and ADHD data for evaluating whether symptoms of the disorder occurred in only one setting (situational) or were cross-situational (pervasive). If a child had a diagnosis of ADHD (no more than one symptom short of DSM criteria) based on one informant's report and, by the other informant's report, missed a diagnosis by just one additional symptom, neither a situational nor a pervasive diagnosis was given. Thus, not every subject with a diagnosis of ADHD or ADDH or both was classified by this procedure. Of those who were classified, 18 children (20%) met criteria for pervasive ADHD, 15 (16%) met criteria for ADHD in the home setting, and 58 (64%) met criteria for ADHD in the school setting.

Monozygotic and dizygotic probandwise concordance rates and tetrachoric correlations are shown in table 1. The consistently larger monozygotic than dizygotic concordance rates indicate the importance of genes in the expression of the ADHD syndrome as defined by DSM criteria. Mothers' reports showed a high degree of within-monozygotic pair similarity and complete discordance within dizygotic pairs. By contrast, teacher-based diagnoses showed more modest concordances for both zygosity groups and a smaller, although still important, genetic contribution to the syndrome. Concordances for the combined data were similar to those based on teachers' reports.

Models that included additive genetic (A or the heritability), shared environmental (C), and nonshared environmental (E) effects were fit to teacher rating form, Diagnostic Interview for Children and Adolescents—Revised, and the combined data. Akaike's information criterion (22) (χ^2<2) was used to test the goodness of a model's fit to the data, with the model that minimized Akaike's information criterion selected as the best-fitting one. For both the mothers' and combined reports, models that did not include a genetic effect fit significantly more poorly than models that included the genetic factor. For the teachers' reports, models with A fit better than models without A, although the difference was not statistically significant. Alternatively, in no case was the shared environment factor, C, statistically significant. Consequently, in every case the AE model that included both additive genetic and nonshared environmental effects provided the best fit to the data, and it is the estimates of the factors for this model that are given in table 1. In each case the heritability estimates were substantial, indicating that the vast majority of liability variance was associated with genetic factors.

DISCUSSION

Probandwise concordances found for this unselected twin sample provide evidence for the importance of genes in ADHD as defined by DSM-III and DSM-III-R criteria. A comparison of concordance rates based on teachers' or mothers' reports suggests, however, that the extent of that influence may deviate according to whose report is considered. Concordances calculated from our combined mother and teacher reports of ADHD were nearly identical to those reported by Goodman and Stevenson (7) for combined teachers' and mothers' hyperactivity ratings, despite widely differing operational definitions between their study and ours. On the other hand, we found a dizygotic concordance of zero on the basis of mothers' reports on the Diagnostic Interview for Children and Adolescents—Revised, whereas Gilger and colleagues (12) reported a moderate dizygotic concordance. Although we do not know the reason for this difference, it may reflect nothing more than statistical imprecision due to limited sample size.

Our findings in several other areas largely corroborate those previously reported by others. The relatively

small percentage of subjects with pervasive ADHD found in the present study is consistent with previous prevalence reports (7, 14) indicating a substantially lower rate of ADHD when the expression of symptoms in more than one setting is required. Although the 18% rate of ADHD found in this study of boys is much higher than the general prevalence of 3%–5% indicated in DSM-IV, it is comparable to the 25% reported by Goodman and Stevenson (6) for their sample of boys and girls. However, mothers' reports accounted for the majority of cases in Goodman and Stevenson's study (6), whereas in the present study, they are largely attributable to diagnoses based on teachers' ratings. Methodological differences, including diagnostic criteria used, are probably the most plausible explanation for discrepancies across studies.

A number of factors, including differences in the collection and scoring of the two informants' reports, may account for some of the disparity we found in case identification across informants. It is possible that mothers and teachers are actually rating different phenotypes. For instance, teachers may tend to endorse ADHD symptoms in children with a variety of other behavioral problems. It is also conceivable that mothers, who are not trained in child development and are without benefit of a large reference group to compare their children to, underreport ADHD behavior. Teachers, by contrast, may overreport ADHD symptoms, a factor that could account for the high prevalence of ADHD when the diagnosis is based on their reports.

This study suggests some directions for future genetic studies of ADHD. First, it points out the importance of examining the relative validity of teachers' and mothers' reports. Second, even larger samples would permit genetic contributions to ADHD to be separately evaluated in pervasive and situational subtypes. Finally, a greater reliance on more rigorous and consistent operational definitions of ADHD would facilitate the interpretability of findings across studies.

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