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ARTICLE

# Positive Association Between Attention-Deficit/Hyperactivity Disorder Medication Use and Academic Achievement During Elementary School

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**What's Known on This Subject**

Approximately 4.4 million children in the United States have been diagnosed with ADHD, and ~56% of affected children take prescription medications to treat the disorder. ADHD is strongly linked with low academic achievement.

**What This Study Adds**

This study shows that children who took prescription medication to treat ADHD had higher mathematics and reading test scores during elementary school, comparable with 0.19 and 0.29 school years, respectively, than their unmedicated peers with ADHD.

## ABSTRACT

OBJECTIVE. Approximately 4.4 million (7.8%) children in the United States have been diagnosed with attention-deficit/hyperactivity disorder, and 56% of affected children take prescription medications to treat the disorder. Attention-deficit/hyperactivity disorder is strongly linked with low academic achievement, but the association between medication use and academic achievement in school settings is largely unknown. Our objective was to determine if reported medication use for attention-deficit/hyperactivity disorder is positively associated with academic achievement during elementary school.

METHOD. To estimate the association between reported medication use and standardized mathematics and reading achievement scores for a US sample of 594 children with attention-deficit/hyperactivity disorder, we used 5 survey waves between kindergarten and fifth grade from the nationally representative Early Childhood Longitudinal Study—Kindergarten Class of 1998–1999 to estimate a first-differenced regression model, which controlled for time-invariant confounding variables.

RESULTS. Medicated children had a mean mathematics score that was 2.9 points higher than the mean score of unmedicated peers with attention-deficit/hyperactivity disorder. Children who were medicated for a longer duration (at >2 waves) had a mean reading score that was 5.4 points higher than the mean score of unmedicated peers with attention-deficit/hyperactivity disorder. The medication-reading association was lower for children who had an individualized education program than for those without such educational accommodation.

CONCLUSIONS. The finding of a positive association between medication use and standardized mathematics and reading test scores is important, given the high prevalence of attention-deficit/hyperactivity disorder and its association with low academic achievement. The 2.9-point mathematics and 5.4-point reading score differences are comparable with score gains of 0.19 and 0.29 school years, respectively, but these gains are insufficient to eliminate the test-score gap between children with attention-deficit/hyperactivity disorder and those without the disorder. Long-term trials are needed to better understand the relationship between medication use and academic achievement. *Pediatrics* 2009;123:1273–1279

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**Key Words**
attention-deficit/hyperactivity disorder, prescription medication, children, academic achievement

**Abbreviations**
ADHD—attention-deficit/hyperactivity disorder
ECLS-K—Early Childhood Longitudinal Study-Kindergarten Class of 1998–1999
IEP—individualized education program

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ATTENTION-DEFICIT/HYPERACTIVITY DISORDER (ADHD) is a prevalent childhood mental health condition affecting ~7.8% of the school-aged population.[1] It is characterized by developmentally atypical levels of inattention, activity, and impulsivity.[2] A recent estimate reports that 56% of affected children are treated with prescription medication,[1] which has proven to be efficacious for symptom reduction in a large number of trials.[3]

Affected children also exhibit deficits in academic functioning.[4] Relative to their peers without the condition, children with ADHD earn lower grades[5] and lower mathematics and reading achievement scores[6]; they also experience higher rates of grade retention, special education placement, and school dropout.[4,6,7] A number of well-controlled studies show that stimulant treatment yields acute improvements on a variety of objective tests of accuracy and academic productivity,[8] such as sustained attention[9] and short-term memory[10]; task performance indexed by brief, repeated tests of school material[11]; note-taking quality, quiz scores, rates of homework completion[12]; and the average number of problems attempted and completed in mathematics and/or reading tests.[13–15] On the other hand, medication trials using the outcome of academic achievement, especially over the long run, are far rarer.[8,16] Notably, research regarding medication effects on academic outcomes has not consistently shown gains.[3,17–20]

Methodologic issues related to choice of outcome measures, small sample sizes, and short durations of medication treatment may all be relevant to explaining the inconclusive findings in the literature. Specifically, typically used "broadband," standardized achievement measures may be too insensitive to show gains.[21] The small samples involved in most studies provide limited power to estimate achievement growth, a key issue given the heterogeneity in achievement growth within children with ADHD, some of which is related to initial achievement levels.[22] In addition, the typical stimulant trial spans only a few weeks or months, an inadequate period of time for effects on growth in academic achievement to become evident.

In short, a major gap remains between relatively small-sample, short-term investigations of medication effects on various aspects of cognitive performance versus larger-sample, longer-term studies that estimate the relationship between medication use and academic achievement growth over time. We attempted to bridge that gap by using data from a US sample of 594 children diagnosed with ADHD who took 5 well-calibrated, standardized tests in both mathematics and reading between kindergarten and fifth grade. On the basis of existing findings of short-term symptomatic and cognitive enhancements from medication treatment, we hypothesized that children who were medicated for ADHD would demonstrate higher mathematics and reading achievement relative to their unmedicated peers with ADHD. We also conducted exploratory analyses to examine if the gender of the child or whether he or she received an individualized education program (IEP) would moderate any medication findings.

## METHODS

### Data

We used the Early Childhood Longitudinal Study—Kindergarten Class of 1998–1999 (ECLS-K) data set to test our hypotheses.[23,24] The ECLS-K tracks the academic progress of a large, nationally representative sample of children who attended kindergarten in the United States in 1998 to 1999. Parents also provided extensive information on child and family background characteristics at 5 data-collection waves between kindergarten and fifth grade.

This data set is particularly well suited for estimating the association between medication use and academic achievement: (1) it includes information about whether a child has been diagnosed with ADHD and whether he or she has been taking medication to treat the condition; (2) it collects repeated, standardized, and carefully calibrated measures of academic achievement across the elementary school years; and (3) its longitudinal structure enables us to control for time-invariant confounding variables. These key features present an unprecedented opportunity to supplement previous research generated from small-sample, short-term medication trials that typically use narrow academic achievement measures.

### Key Variables

#### *Mathematics and Reading Achievement*

Mathematics and reading achievement tests were administered to each child at 5 waves: in the fall and spring of kindergarten and in the spring of the first, third, and fifth grades. The achievement tests were developed by ECLS-K staff from a combination of sources including published achievement tests and extensive consultation with educational experts.[25] These tests closely parallel the National Assessment of Educational Progress, a widely recognized national assessment system designed to gauge student progress on early mathematics and reading skills. Specific test items were constructed to capture the range of grade-appropriate and subject matter-specific proficiencies garnered between kindergarten and fifth grade (eg, from number recognition to word problems involving area and volume for mathematics; from letter recognition to textual extrapolation and evaluation for reading). To carefully calibrate student achievement, all children initially completed a "routing" test. On the basis of their individual results, children were then administered a second set of items closely matched to their respective ability levels. ECLS-K achievement tests have undergone extensive psychometric testing and were ultimately calibrated by using an item response theory analytic technique, thus allowing for direct comparison of scores from kindergarten through fifth grade.

#### *ADHD Diagnosis*

Parents were asked whether their child had been diagnosed with ADHD by a professional at 4 waves: the fall of kindergarten and the spring of first, third, and fifth grades. If the parent responded affirmatively at any of these waves, we considered the child to have a diagnosis of ADHD on the basis of evidence that ADHD is quite persistent over time.[5,26,27]

#### *ADHD Medication*

At the fifth-grade-spring wave, parents of diagnosed children were asked whether the child was currently taking prescription medication to treat ADHD, and if so, the total time the child had taken the medication. Table 1 shows our coding of medication status at each wave based on the total time the child had taken medication. For children who were not currently taking medication, we assumed they did not take medication during the study time frame. For children who were currently taking medication (almost 90% of whom were taking a

**TABLE 1 Medication Status of Children Diagnosed With ADHD at Each Survey Wave According to Medication Duration**

| Medication Duration Range | Midpoint of Medication Duration Range, y | *n* | Percent (Weighted) | Medication Status According to Survey Wave | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | K, Fall 1998 | K, Spring 1999 | First Grade, Spring 2000 | Third Grade, Spring 2002 | Fifth Grade, Spring 2004 |
| Not currently taking medication | 0.00 | 191 | 32.3 | 0 | 0 | 0 | 0 | 0 |
| $0 < \text{years} < 0.08$ | 0.04 | 13 | 1.8 | 0 | 0 | 0 | 0 | 1 |
| $0.08 \le y < 1$ | 0.54 | 69 | 10.3 | 0 | 0 | 0 | 0 | 1 |
| $1 \le y < 2.5$ | 1.75 | 118 | 15.5 | 0 | 0 | 0 | 0 | 1 |
| $2.5 \le y < 4.5$ | 3.50 | 131 | 23.7 | 0 | 0 | 0 | 1 | 1 |
| ≥4.5 y | 5.00 | 72 | 16.4 | 0 | 1 | 1 | 1 | 1 |
| Total | | 594 | 100.0 | | | | | |
| No. of years between fifth-grade-spring and survey wave | | | | 5.5 | 5 | 4 | 2 | 0 |

Medication status according to medication indicates whether the child was taking medication at each wave (0, no; 1, yes). Medication status is 1 for a given wave if the midpoint of the medication duration range (see second column) is greater than or equal to the number of years between the fifth-grade-spring and the given wave (see last row). For example, for the $2.5 \le \text{years} < 4.5$ duration row, the midpoint of the duration range is 3.5 years. Therefore, medication status is 0 in first-grade spring because 3.5 years is <4 years (the number of years between fifth-grade spring and first-grade spring), but is 1 in third-grade spring because 3.5 years is >2 years (the number of years between fifth-grade spring and third-grade spring). Medication duration endpoints were based on the endpoints used by ECLS-K interviewers. Note that 0.08 years represents 1 month. *n* indicates number of observations; K, kindergarten.

stimulant), the possible responses for the total time taking medication included duration ranges (eg, 2.5–4.5 years). Therefore, we assumed that the child took medication for a duration equal to the midpoint of the range (eg, 3.5 years for the 2.5- to 4.5-year range) and did not have significant nonadherence gaps. For children who had taken medication for ≥4.5 years, we assumed that they had been taking medication in the spring of kindergarten but had not taken medication in the fall of kindergarten, as the onset of medication typically occurs when the child enters formal schooling.[7] We estimated additional models that varied our medication coding assumptions. The medication rate of 67.7% (95% confidence interval: 61.1%–74.3%) in the spring of fifth grade is consistent with the 62.7% we found for 12-year-old children with ADHD using the 2003 National Survey of Children's Health.[28]

## Model

Our goal was to estimate the association between ADHD medication use and a child's academic achievement using a method that best controls for confounding variables. Because we repeatedly observed the same children, we were able to use a first-differenced regression model.[29] Importantly, this model controls for time-invariant characteristics, which include many potential confounders such as a child's demographic characteristics (eg, gender and race) and intelligence, as well as time-invariant components of parent, teacher, and school educational inputs to the child.

Although a first-differenced model regresses changes in the dependent variable on changes in the independent variables, the parameter estimates are interpreted by using a structural model, which is the model that is first differenced.[30] In the structural model, each child had a maximum of 5 observations; separate models were estimated for mathematics and reading scores. The dependent variable was the child's test score, and the key independent variable was whether the child was medicated. Each model also included the child's test date, a dummy variable for each wave (except the first), the interaction between the test date and each wave, and a dummy variable for each child (except 1). Therefore, the medication parameter represents the mean test score difference between the test scores of children at waves when they were unmedicated and the test scores of children at waves when they were medicated, controlling for the time-varying variables as well as time-invariant characteristics.

To compare children who had been medicated at ≥2 waves with unmedicated children, we estimated additional models that included 2 medication variables: the first indicated at each wave whether the child was first medicated, and the second indicated at each wave whether the child had been medicated at ≥2 waves. The 2 medication parameters, respectively, represent the mean difference between the test scores of children at waves when they were unmedicated and the test scores of children (1) at waves when first medicated and (2) at waves when medicated for ≥2 waves.

All models were estimated by using SUDAAN 9.0.1. (Research Triangle Institute, Research Triangle Park, NC),[31] incorporated the complex survey design of the ECLS-K and allowed for the first-differenced error terms to have an exchangeable correlation structure.

## Sample Size

The ECLS-K included 21 356 eligible children. Totals of 19 684, 20 578, 17 324, 15 305, and 11 820 children responded at the fall of kindergarten, spring of kindergarten, and the spring of the first-, third-, and fifth-grade waves, respectively.[23] Medication information was available for 783 of the 1195 children who had been diagnosed with ADHD; data were missing for the remainder mostly because they did not participate in the fifth-grade-spring wave. Missing weights reduced our analytic sample to 594 children who had at least 2 nonmissing test scores in adjacent waves, resulting in 2258 and 2226 first-differenced mathematics and reading scores, respectively.

**TABLE 2** Descriptive Statistics of Full and Analytic Sample of ADHD-Diagnosed Children

| Variable | Full Sample ($N = 8370$) | ADHD-Diagnosed Sample ($N = 594$) |
|---|---|---|
| Academic achievement tests, mean (SD) | | |
| Mathematics scores | | |
| Kindergarten, fall | 22.7 (8.7) | 19.3 (6.0) |
| Kindergarten, spring | 32.9 (11.4) | 28.1 (8.5) |
| First grade, spring | 57.4 (16.5) | 49.8 (13.1) |
| Third grade, spring | 91.7 (21.6) | 82.3 (19.1) |
| Fifth grade, spring | 112.8 (21.8) | 102.1 (20.9) |
| Reading scores | | |
| Kindergarten, fall | 29.3 (9.9) | 25.4 (5.4) |
| Kindergarten, spring | 40.7 (13.5) | 35.1 (9.0) |
| First grade, spring | 71.5 (22.3) | 60.7 (17.4) |
| Third grade, spring | 117.7 (25.3) | 105.1 (23.3) |
| Fifth grade, spring | 138.4 (23.3) | 126.2 (22.0) |
| Test date, months from earliest test taken | | |
| Kindergarten, fall | 1.7 (0.6) | 1.7 (0.5) |
| Kindergarten, spring | 1.9 (0.5) | 1.9 (0.5) |
| First grade, spring | 1.7 (0.6) | 1.7 (0.5) |
| Third grade, spring | 1.5 (0.6) | 1.6 (0.6) |
| Fifth grade, spring | 1.8 (0.8) | 1.7 (0.7) |
| Demographic characteristics | | |
| Female, % | 48.5 | 25.1 |
| Race, % | | |
| White | 57.7 | 71.6 |
| Black | 16.1 | 12.2 |
| Hispanic | 18.9 | 11.0 |
| Asian/Pacific Islander | 3.5 | 1.4 |
| Other | 3.8 | 3.8 |
| Age (Feb 2004), mean (SD), mo | 143.0 (4.3) | 143.6 (4.4) |
| IEP (at any wave), % | 19.0 | 48.7 |
| IEP (≥3 waves), % | 3.2 | 11.9 |
| Parents married (fifth-grade spring), % | 66.6 | 55.6 |
| Household size (fifth-grade spring), % | | |
| 2 to 3 | 20.6 | 26.1 |
| 4 to 5 | 60.8 | 57.2 |
| ≥6 | 18.5 | 16.7 |
| Household income (fifth-grade spring), % | | |
| ≤\$25 000 | 26.6 | 31.8 |
| \$25 001–50 000 | 29.6 | 30.3 |
| \$50 001–75 000 | 17.6 | 16.9 |
| >\$75 000 | 26.2 | 21.0 |
| Mother's education (fifth-grade spring), % | | |
| Less than high school | 11.2 | 12.4 |
| High school graduate (or equivalent) | 25.9 | 30.6 |
| Some college | 36.7 | 35.8 |
| College graduate | 16.8 | 13.2 |
| Some graduate school | 9.4 | 8.0 |
| ADHD diagnosis, % | 9.4 | |

All statistics incorporate the complex survey design of the ECLS-K. The full sample was reduced from 11 820 children at the fifth-grade-spring wave to 8370 children primarily because of missing (or nonpositive) weights. Percentages may not add to 100 because of rounding.

**TABLE 3** Regression Results for Mathematics and Reading Test Score Models

| Variable | Mathematics | | Reading | |
|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 |
| Medication | 2.9[a] (1.4) | | 2.4 (1.6) | |
| Medication (first wave) | | 2.9[a] (1.3) | | 2.6 (1.5) |
| Medication (second+ wave) | | 2.6 (1.9) | | 5.4[b] (1.9) |
| Test dates | | | | |
| Test date | 1.7[b] (0.7) | 1.7[a] (0.7) | 3.2[c] (0.8) | 3.1[c] (0.8) |
| Test date × wave 2 | 0.8 (0.9) | 0.8 (0.9) | 0.2 (1.2) | 0.2 (1.2) |
| Test date × wave 3 | 2.0 (1.1) | 2.0 (1.1) | 0.3 (1.4) | 0.2 (1.4) |
| Test date × wave 4 | −0.6 (1.2) | −0.6 (1.2) | −1.7 (1.5) | −1.7 (1.5) |
| Test date × wave 5 | −0.4 (1.4) | −0.5 (1.4) | −3.1[a] (1.5) | −2.9 (1.5) |
| Wave dummies | | | | |
| Wave 2 | 6.5[c] (1.7) | 6.5[c] (1.7) | 8.3[c] (2.2) | 8.3[c] (2.2) |
| Wave 3 | 27.1[c] (2.1) | 27.1[c] (2.1) | 34.8[c] (2.4) | 34.5[c] (2.4) |
| Wave 4 | 63.2[c] (2.6) | 63.2[c] (2.7) | 81.6[c] (3.3) | 81.1[c] (3.3) |
| Wave 5 | 82.0[c] (3.8) | 82.1[c] (3.8) | 105.5[c] (2.9) | 103.9[c] (2.9) |
| *n* | 2258 | 2258 | 2226 | 2226 |
| *df* | 426 | 426 | 426 | 426 |
| $R^2$ | 0.41 | 0.41 | 0.46 | 0.46 |
| F statistic | 319[c] | 400[c] | 846[c] | 734[c] |

Each variable in the table includes a parameter estimate followed by its standard error in parentheses. The dummy variables representing each child, which control for time-invariant characteristics, drop out of the first-differenced model and, therefore, are not shown. The model does not include a constant term because of first differencing. Wave 1 (reference wave) is kindergarten fall; wave 2 is kindergarten spring; wave 3 is first-grade spring; wave 4 is third-grade spring; and wave 5 is fifth-grade spring. *n* indicates number of observations; *df*, degrees of freedom. The parameter estimate was based on the following: [a] $P < .05$; [b] $P < .01$; and [c] $P < .001$.

## RESULTS

### ECLS-K Sample Statistics

Table 2 shows the standardized mathematics and reading test scores and the demographic characteristics of the full and ADHD-diagnosed samples. As of the fifth-grade-spring wave, 9.4% (95% confidence interval: 8.2%–10.6%) of all children had been diagnosed with ADHD, consistent with the 9.9% prevalence we found for 12-year-old children using the 2003 National Survey of Children's Health.[28]

### Model-Based Comparison of Diagnosed Children by Medication Status

Related to our hypotheses, Table 3 presents the results for the mathematics and reading regression models. Medicated children's mean mathematics score was 2.9 points higher ($P = .04$) than the mean score of unmedicated child's with the same time-invariant characteristics (see model 1). When medication was coded using 2 variables to indicate the first wave of medication and the second or subsequent wave of medication, respectively, the parameter estimates of 2.9 and 2.6 differed neither practically nor statistically from each other (see model 2). Among all children, the mean gain in mathematics scores between the fall of kindergarten and the spring of fifth grade was 90.2 points; therefore, the 2.9-point difference between medicated and unmedicated children is comparable with gains attained during 0.19 school years over this 6-year period.

For reading, only children medicated at ≥2 waves had a reading score that was significantly different (on average, 5.4 points higher [$P < .01$]) than those of their unmedicated peers (see models 3 and 4; note that the medication parameter estimate in model 3 does not equal the average of the 2 medication parameter estimates in model 4, because the medication variables are correlated with other variables in the model). The 5.4-point mean reading score difference is comparable with ~0.29 school years. When additional time-varying independent variables (parent's marital status, household size, household income, and mother's education) were added to the above models, the statistical significance of the results did not change.

We tested our medication coding assumptions as follows. The above models assumed that children with ADHD who were not taking medication at the fifth-grade-spring wave had never taken medication. When these children were excluded from the models, so that only children who took medication at ≥1 wave remained, the medication parameter estimate in model 1 slightly decreased to 2.8, whereas its standard error slightly increased to 1.6, resulting in a *P* value equal to .08; the reading result from model 4 remained significant. The original models also assumed no significant gaps in medication usage once a child began taking medication, which is often not the case.[32] To address this issue, we reestimated models 1 and 3 by removing a child's observations after the first wave of medication, when adherence may decrease, and the statistical significance of the results did not change.

To examine whether the medication parameter estimates varied among the subgroups of children, we reestimated the models in Table 3 by including the interaction between the medication variables and (1) the child's gender, (2) a variable indicating whether the child had an IEP at any wave, suggesting comorbid conditions or severe ADHD, or (3) a variable indicating whether the child had an IEP at ≥3 waves, indexing the degree of special education supports. In these models, the interaction-term parameters measure whether the association between medication and test scores differs between, for example, boys and girls. Because gender is time-invariant, we cannot estimate the medication association for boys and girls separately.[29] We did not find a significant interaction with gender but did find that the medication parameter estimate indicating ≥2 waves of medication was significantly lower in reading for children who had an IEP and was significantly lower in both mathematics and reading for children who had an IEP at ≥3 waves.

## DISCUSSION

The major finding from our analysis of the ECLS-K longitudinal data set is that medication use during elementary school is associated with higher mathematics test scores and is associated with higher reading test scores after ≥2 waves of medication. Such improvement is notable, as early academic success seems to be critical to later school progress.[33,34] The models controlled for all time-invariant differences between the unmedicated and medicated children. The 2.9-point difference in mathematics scores between medicated versus unmedicated children is comparable with the gains achieved during 0.19 school years; however, this gain does not eliminate the achievement gap between children with and without ADHD. Similarly, the 5.4-point difference in reading scores between children medicated at ≥2 waves versus unmedicated children is comparable with 0.29 school years, but is not sufficient to eliminate the achievement gap during the elementary school years.

The finding that medication was associated with reading scores only for children medicated at ≥2 waves needs additional investigation. The different findings for mathematics versus reading may point to underlying differences in the process of knowledge acquisition as well as dynamics related to strategies of formal instructional input between these 2 subject areas. The finding that the association between ≥2 waves of medication and reading scores was lower for children who had an IEP also needs additional investigation to determine how medication may differentially affect children with comorbid conditions or severe levels of ADHD.

The first-differenced regression model is a powerful design that controls for all time-invariant differences between unmedicated and medicated children. However, the parameter estimates may be biased if test scores influenced which children were medicated (also known as simultaneity) or if omitted variables associated with medication and test scores changed over time. Yet here, simultaneity would seem to understate the medication association with achievement, under the assumption that parents may be more likely to medicate an academically underperforming child. Omitted educational input variables that may change over time, such as parent, teacher, and school inputs, may cause the results to be understated (eg, if a parent substitutes medication for his or her time) or overstated (eg, if a parent complements medication with additional time). Also noteworthy is that improvements in behavior may indirectly lead to test score gains related to receipt of more educational inputs from a teacher.[35] The educational input variables were not included in the models, because they are endogenous (ie, the level of the input may be related to the child's academic achievement); hence, their inclusion may bias the other parameter estimates. Overall, the direction of the potential bias is inconclusive, but the arguments above suggest that any bias may underestimate the true medication-achievement linkage.

Key data limitations included missing or incomplete data from planned and unplanned attrition, other types of nonresponse, missing sampling weights, and imprecision in ADHD diagnostic and medication-duration measures. Overall, we contend that these limitations do not significantly affect the results. Most of the attrition was planned because the ECLS-K sampled only a subset of children who moved. Regression results showed that the sampling weights were statistically higher for children with lower kindergarten-fall test scores, the same children who were more likely to have missing data at subsequent waves. Hence, the weighting scheme did account for nonresponse in this dimension, reducing or eliminating the potential bias.

We note that the ECLS-K provided several sets of design variables (sampling weights, sampling unit identifiers, and strata identifiers) to aid with analysis of the data.[23] The recommended set for our analysis omitted some sampling weights. Therefore, we reestimated each model using the set of design variables provided by the ECLS-K to analyze fifth-grade, cross-sectional data, because this set included weights for all 783 diagnosed children with medication information. The statistical significance of the main results did not change.

Finally, information on both ADHD diagnosis and medication status was determined by parent reports, and the survey did not collect information on potential medication adherence gaps or medication dosage-level information. Although these are critical limitations, the ECLS-K is the best nationally representative data set available to complement small-sample, short-term medication trials that typically use narrow academic performance measures. Moreover, if our medication coding had random errors, including not accounting for medication adherence gaps, this would bias estimated medication-academic achievement associations toward zero, whether medication actually improved or degraded academic achievement.[30]

## CONCLUSIONS

Some 4.4 million children in the United States have been diagnosed with ADHD, a condition that is strongly associated with low academic achievement. We have shown that medicated children with ADHD scored higher on the ECLS-K standardized mathematics and reading achievement tests compared with unmedicated peers; the score differences are comparable with 0.19 and 0.29 school years, respectively, during the primary schooling years. With nearly 60% of diagnosed children taking prescription medications to treat the disorder,[1] at a cost of $2.2 billion in 2003,[36] the current findings have the potential for wide applicability, particularly because diagnostic prevalence and medication rates differ among demographic groups.[37,38] Our research supports the need for long-term trials to better understand the relationship between medication use and academic achievement in children with ADHD.

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## THE ART OF MEDICINE: LORENZO ODONE AND MEDICAL MIRACLES

"There is no question that Lorenzo Odone lived until the age of 30 years because his parents, Augusto and Michaela Odone, defied doctors and developed a mixture of 2 cooking oils as a possible treatment for their son's devastating disease. The 1992 film *Lorenzo's Oil*, which commemorated this heroic effort, became an inspirational saga for other patients and families dealing with incurable conditions. Yet Lorenzo's story tells us as much about the limitations of medical research as it does about its triumphs. Not surprisingly, the movie outraged scientists and families affected by ALD (adrenoleukodystrophy), both of whom believed the film played with people's hopes. But the Odones had the last laugh. When the late Hugo Moser, the world's expert on ALD and one of Lorenzo's physicians, finally published data in 2005, it became clear that although the oil did little for already sick boys, it prevented the onset of ALD in two-thirds of susceptible boys who otherwise would surely have died from the disease. It was a breathtaking scientific achievement spearheaded by 2 laypeople."

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Noted by JFL, MD