1040-5488/16/9305-0459/0 VOL. 93, NO. 5, PP. 459–465
OPTOMETRY AND VISION SCIENCE

FEATURE ARTICLE—PUBLIC ACCESS

ADHD and Vision Problems in the National Survey of Children's Health

Dawn K. DeCarlo*, Mark Swanson*, Gerald McGwin†, Kristina Visscher‡, and Cynthia Owsley§

ABSTRACT

Purpose. To compare the prevalence of attention deficit/hyperactivity disorder (ADHD) in children with normal vision and with vision problems not correctable with glasses or contact lenses (vision problems) as determined by parent report in a nationwide telephone survey.

Methods. This cross-sectional study included 75,171 children without intellectual impairment aged 4 to 17 years participating in the 2011 to 2012 National Survey of Children's Health, conducted by the U.S. Centers for Disease Control and Prevention. Demographic information and information regarding vision and ADHD status were obtained by parent interview. Questions asked whether they had ever been told by a doctor or health care provider that the child had a vision problem not correctable with glasses or contact lenses, ADHD, intellectual impairment, or one of 13 other common chronic conditions of childhood. A follow-up question asked about condition severity. The main outcome measure was current ADHD.

Results. The prevalence of current ADHD was greater ($p < 0.0001$) among children with vision problems (15.6%) compared with those with normal vision (8.3%). The odds of ADHD compared with those of children with normal vision were greatest for those with moderate vision problems (odds ratio [OR], 2.6; 95% confidence interval [95% CI], 1.7 to 4.4) and mild vision problems (OR, 1.8; 95% CI, 1.1 to 2.9). Children with severe vision problems had similar odds of ADHD to those of children with normal vision perhaps because of the small numbers in this group (OR, 1.6; 95% CI, 0.8 to 3.1). In multivariable analysis adjusting for confounding variables, vision problems remained independently associated with current ADHD (OR, 1.8; 95% CI, 1.2 to 2.7).

Conclusions. In this large nationally representative sample, the prevalence of ADHD was greater among children with vision problems not correctable with glasses or contacts. The association between vision problems and ADHD remains even after adjusting for other factors known to be associated with ADHD.

(Optom Vis Sci 2016;93:459–465)

Key Words: ADHD, attention deficit/hyperactivity disorder, National Survey of Children's Health, vision problems, vision impairment

Attention deficit/hyperactivity disorder (ADHD) is one of the most frequently encountered neurodevelopmental disorders of childhood. Among children aged 4 to 15 years in the 1999 to 2002 National Health and Nutrition Examination Survey (NHANES), 8.2% had parent-reported ADHD.[1] The National Survey of Children's Health (NSCH) found that 10.1% of children in the 2007 survey[2] and 11% of children in the 2011 to 2012 survey had parent-reported ADHD.[3] Children with ADHD have difficulty maintaining focus and controlling their behavior; some exhibit hyperactivity. There is no single known cause for ADHD; both genetic and environmental factors are thought to play a role.[4]

Focus groups of parents of children with vision impairment revealed concerns about ADHD.[5] Children with low vision seen in a vision rehabilitation clinic or attending a state school for the blind, both in Alabama, had a 22.9% prevalence of parent-reported diagnosis of ADHD, which is considerably higher than that in the general population.[6] Another study found an increased prevalence of self-reported ADHD among people with vision impairment caused by albinism.[7]

*OD, MSPH, FAAO
†MS, PhD
‡PhD
§MSPH, PhD

Department of Ophthalmology, School of Medicine, University of Alabama at Birmingham, Birmingham, Alabama (DKDeC, GMcG, CO); Department of Optometry, School of Optometry, University of Alabama at Birmingham, Birmingham, Alabama (DKDeC, MS); Department of Epidemiology, School of Public Health, University of Alabama at Birmingham, Birmingham, Alabama (GMcG); and Department of Neurobiology, School of Medicine, University of Alabama at Birmingham, Birmingham, Alabama (KV).

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.optvissci.com).

Several studies have elucidated a link between vision problems and ADHD. Attention deficit/hyperactivity disorder has been found to be associated with astigmatic refractive error.[8,9] Other groups have found an association between convergence insufficiency and ADHD.[10,11] This is a significant finding because convergence insufficiency is a relatively common condition, affecting between 2.25 and 8.3% of elementary schoolchildren.[12,13] In addition, symptoms of convergence insufficiency are closely related to symptoms of ADHD, and those symptoms decreased after vision therapy to improve vergence movements.[14] These symptoms include difficulty completing schoolwork and inattentiveness during reading, among others.[10] The complex relationship of vision to ADHD is further evidenced by the finding of early deficits in visual sensory integration using event-related potentials measured in the visual cortex of children with ADHD[15] as well as deficient blue color perception in adults with ADHD.[16]

The present study sought to use the data set from the NSCH 2011 to 2012 to examine the association between vision problems that are not correctable with glasses or contact lenses and ADHD.[17]

METHODS

NSCH Design

The NSCH is designed to examine factors related to the physical and emotional well-being of children aged 0 to 17 years to provide both state- and national-level estimates of child health.[17] It is a random digit dialed telephone survey conducted in six languages (English, Spanish, Mandarin, Cantonese, Vietnamese, and Korean) by the National Center for Health Statistics and the U.S. Centers for Disease Control and Prevention (CDC) using the CDC's State and Local Area Integrated Telephone System. The NSCH sampling is structured to obtain representative populations of children aged 0 to 17 years in each state, with a goal of at least 1800 children per state. In multichild households, one child was randomly selected to be the subject of the interview. A parent or guardian living in the household who had the most knowledge about the study child's health and health care was interviewed. The 2011 to 2012 NSCH included responses about 95,677 children. Questions were divided into 13 sections: initial demographics, health and functional status, health insurance coverage, health care access and utilization, medical home, early childhood (aged 0 to 5 years), middle childhood and adolescence (aged 6 to 17 years), family functioning, parental health, neighborhood characteristics, additional demographic characteristics, additional health insurance questions, and locating information. Data collection was conducted under contract by the National Opinion Research Center at the University of Chicago and adhered strictly to the confidentiality and privacy regulations of the National Center for Health Statistics. Respondents were informed that participation was voluntary—that they may choose not to answer any questions they do not wish to answer and that their privacy is protected by Federal Law but did not provide written consent. The database is publicly available on the CDC web site at: http://www.cdc.gov/nchs/slaits/nsch.htm and contains no personal identifiers.[17] None of the authors participated in survey design or data collection. Local institutional review board approval was not required for this study.

Study Variables

Questions about a wide range of health conditions and disorders including ADHD and vision problems were asked about all NSCH children aged 2 years and older. Disorder-specific inquiries followed a three-question format. (1) ''Has a doctor or health care provider ever told you your child has [condition] even if they don't have it now?'' (2) ''Does the child currently have the [condition]?'' (3) ''Would you describe [his/her] [condition] as mild, moderate, or severe?'' Definitions of severity were not given during survey administration; responses were based on parent perception. The vision-specific question asks about vision problems that cannot be corrected with standard glasses or contact lenses. Children whose parents responded affirmatively to this question were categorized as nonrefractive vision problems (hereafter referred to as ''vision problems''). The questions are structured similarly for ADHD with accompanying explanatory prompts provided. Within the ADHD series, an additional question asked if the child with current ADHD was taking medication for the condition. Specific wording for survey questions and responses that were analyzed in this study can be found in the Appendix, available at http://links.lww.com/OPX/A233. Children were categorized as having ADHD using parent report of ADHD diagnosed by a doctor or other health care provider. No clinical confirmations of ADHD or vision problems were obtained. A population-level estimate of prevalence and a within-group estimate of severity (mild, moderate, severe) were created from these questions for ADHD and vision problems.

A number of sociodemographic factors have been associated with ADHD and were included as potential confounders. Ages of mother and child were classified by NSCH to the nearest year. Responses to race and ethnicity questions were combined to create four groups: non-Hispanic White, non-Hispanic Black, Hispanic, and Other (composed of all other responses including mixed race). Children with birth weight less than 88 oz (2500 g) were categorized as having low birth weight. Children born more than 3 weeks early were considered premature. The primary language spoken in the household was dichotomized as English or other language. Family household structure was dichotomized as two-parent biological or adoptive households versus other household types. The total number of children younger than 18 years in the family was classified as a categorical variable of one, two, or three or more children. Poverty status (based on income and family size) was categorized into two groups based on income at or above 200% or less than 200% above the federal poverty level. Family member smoking status was dichotomized as at least one smoker in the household or no smokers; highest level of education by either parent or main guardian in the household was dichotomized as high school or less or more than high school. Having health insurance was dichotomized as yes or no. Region of the United States was categorized as North East, South, West, and Midwest per the U.S. Department of Health and Human Services Health Resources and Services Administration. Residence in a metropolitan statistical area is determined by the U.S. Office of Management and Budget. This variable was dichotomized as yes or no.

The current study cohort includes 75,151 children aged 4 to 17 years from the publicly available NSCH 2011 to 2012 data

set for whom the responding adult denied that a doctor or other health care provider ever told them that the child had intellectual disability or mental retardation (see the Appendix, available at http://links.lww.com/OPX/A233, for wording of question). The sample included an unweighted group of 1017 children with vision problems and 74,073 children without vision problems (Fig. 1). Children with intellectual impairment were excluded because the diagnosis of ADHD requires that the behaviors be inappropriate for age, and intellectual impairment could confound the diagnosis.[18] Children younger than 4 years were omitted because the American Academy of Pediatrics Clinical Practice Guideline for ADHD evaluation is only established for children aged 4 to 18 years.[19]

Statistical Analysis

All analyses were conducted accounting for the sample design and weighting by methods suggested by the National Center for Health Statistics[20] using SAS version 9.3 Survey Methods (SAS Institute Inc., Cary, NC). Base weighting accounts for the probability of selection of each phone number from others in the bank of numbers. The base weights are adjusted for nonresolution of telephone lines, nonresponse, subsampling by age eligibility, multiple phone lines, and noncoverage of children in households with no landlines. Next, raking adjustments are used to match each state's weighted survey responses to selected characteristics of the state's population of noninstitutionalized children aged 0 to 17 years. As a consequence, estimates reflect the national population of noninstitutionalized children. We report unweighted sample sizes and percentages as well as weighted percentages and weighted 95% confidence intervals (95% CIs). The χ^2 test and t-test were used as appropriate. Variance estimates used the Taylor linearization method. "Don't know" and missing responses were denoted as missing and not included in the analysis. Univariate and multivariate logistic or ordinal regression was used to calculate p values and odds ratios (ORs) for both dichotomous (vision problems, yes or no) and multilevel (vision problems severity) variables. Weighted t-tests were used in univariate analysis of continuous variables. Adjusted odds ratios were calculated with all statistically significant univariate variables included in the model. Significance was set at $\alpha < 0.05$.

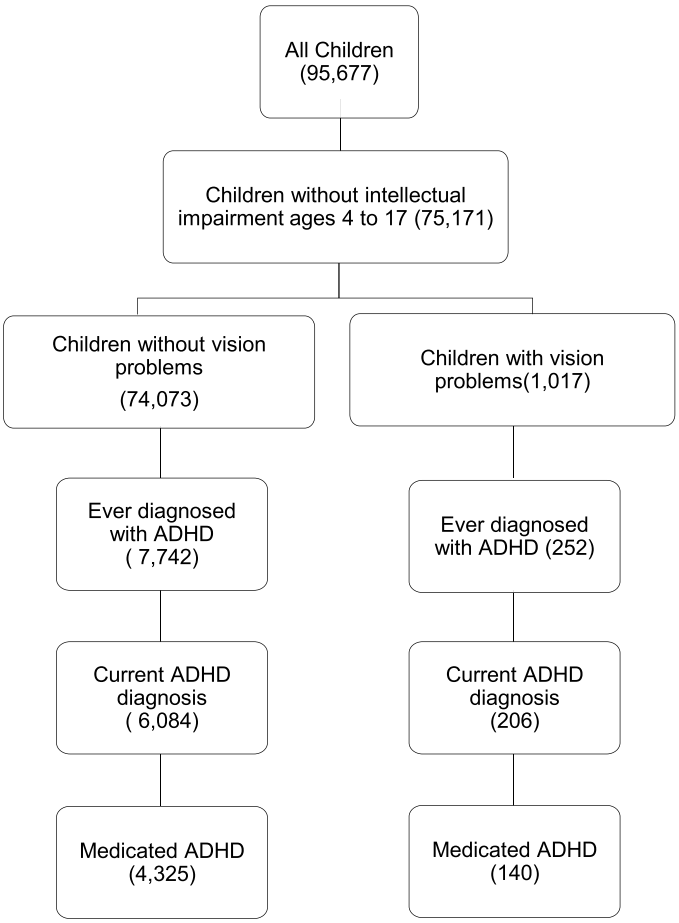

FIGURE 1.
Description of the unweighted sample within the NSCH.

RESULTS

In the weighted analyses of U.S. children without intellectual disability between 4 and 17 years of age, 1.5% was estimated to have parent-reported vision problems not correctable with standard glasses or contact lenses. Among children in this cohort, 8.4% (95% CI, 8.0 to 8.8) were estimated to have a current diagnosis of ADHD. Children with vision problems account for an estimated 2.7% (95% CI, 2.0 to 3.4) of children with current ADHD. Children with vision problems were more likely to have a current diagnosis of ADHD than those without vision problems (15.6 vs. 8.3%; $p < 0.001$). Children with vision problems were also more likely to have ever been diagnosed as having ADHD (18.6% vs. 10.4%; $p < 0.001$). For those with ADHD, children with vision problems were not more or less likely to receive medication for the condition (64.4 vs. 69.0%; $p = 0.46$).

Table 1 shows the descriptive statistics for all children according to vision problem status. The percentage of males was greater in the group with vision problems (58.8 vs. 50.9%; $p = 0.02$). There was no difference in the prevalence of low birth weight between those with or without vision problems; however, those with vision problems were significantly more likely to be born 3 or more weeks prematurely ($p < 0.001$). Families with children who have vision problems appear different in some respects to other U.S. families. Children with vision problems were more likely to have family income less than 200% above the poverty line than children without vision problems ($p = 0.0002$). Children with vision problems were more likely to have a family structure including 2 adoptive or biological parents ($p = 0.003$) and to have at least one smoker in the household ($p = 0.02$). However, they were similar to children without vision problems in many aspects, including race/ethnicity, primary language in the home being English, parental education, and region of the United States where they resided, as well as whether or not they resided in a metropolitan statistical area. In multivariable analysis adjusting for the potential confounding variables in Table 1 (sex, premature birth, family structure, smoker in the family, and poverty level), having a vision problem was independently associated with current ADHD (OR, 1.8; 95% CI, 1.2 to 2.7).

The associations of vision problem severity with current ADHD, the severity of ADHD, and use of medication for ADHD were also evaluated (Table 2). Children with mild and moderate vision

TABLE 1.

Association of ADHD and demographic variables with vision problems not correctable with glasses or contact lenses

Variable	Children with vision problems, N = 1017	Children without vision problems, N = 74,073	Weighted* estimate for children with vision problems, N = 840,922	Weighted* estimate for children without vision problems, N = 56,380,570	Weighted* t-test or χ^2 p value
Mean age (SE), yr	11.3 (0.12)	10.7 (0.02)	11.4 (0.03)	10.5 (0.03)	<0.001
Male, n (%, SE)	598 (58.9)	38,089 (51.5)	493,490 (58.8, 3.4)	28,648,022 (50.9, 0.4)	0.02
Race					
Hispanic, n (%, SE)	135 (13.5)	9,421 (13.0)	227,390 (27.2, 3.9)	12,527,348 (22.8, 0.4)	0.24
Non-Hispanic White, n (%, SE)	663 (66.6)	48,203 (66.6)	412,643 (49.4, 3.6)	29,248,999 (53.3, 0.4)	0.28
Non-Hispanic Black, n (%, SE)	96 (9.6)	6,958 (9.6)	96,056 (11.5, 2.0)	7,635,610 (13.9, 0.3)	0.27
Other, n (%, SE)	110 (11.0)	7,828 (10.8)	99,888 (11.9, 2.8)	5,471,113 (10.0, 0.2)	0.44
Low birth weight, n (%, SE)	219 (21.5)	9,921 (13.4)	164,978 (19.5, 2.5)	8,105,744 (14.4, 0.3)	0.21
Premature birth, n (%, SE)	220 (22.0)	8,035 (11.0)	189,689 (22.8, 2.8)	6,164,764 (11.0. 0.3)	<0.001
Family structure* two adoptive or biological parents	295 (29.6)	17,128 (23.4)	305,791 (36.6, 3.2)	14,749,452 (26.5, 0.4)	0.003
No. children in household					
1, n (%, SE)	431 (42.4)	28,999 (39.2)	207,225 (24.6, 2.9)	11,880,345 (21.1, 0.3)	0.52
2, n (%, SE)	343 (33.7)	28,612 (38.8)	252,285 (30.0, 2.8)	21,846,076 (38.7, 0.4)	0.004
3 or more, n (%, SE)	243 (23.9)	16,462 (22.2)	381,413 (45.4, 3.7)	22,654,149 (40.2, 0.4)	0.16
English primary language in home, n (%, SE)	70 (6.9)	5,328 (7.2)	130,066 (15.5, 2.9)	8,174,954 (14.5, 0.4)	0.74
Mother's age mean, n (mean, SE)	836 (41.4, 0.26)	67,292 (41.1, 0.26)	744,962 (40.6, 0.6)	51,225,788 (39.1)	0.02
Parent attended college or higher, n (%, SE)	503 (52.3)	36,218 (50.9)	460,576 (58.3, 3.5)	29,424,401 (35.2, 0.4)	0.38
Smoker in the family, n (%, SE)	315 (31.3)	17,042 (23.2)	264,490 (31.6, 3.2)	13,593,074 (24.4, 0.4)	0.02
Poverty level <200%, n (%, SE)	500 (49.2)	27,838 (37.6)	509,050 (60.5, 3.3)	26,051,864 (47.6, 0.4)	<0.001
Has health insurance, n (%, SE)	979 (96.4)	70,626 (95.5)	799,863 (95.1, 1.6)	52,920,979 (94.1, 0.2)	0.34
Region of United States					
No East (Regions 1, 2, 3), n (%, SE)	255 (25.1)	20,527 (27.7)	170,910 (20.3, 2.4)	12,423,828 (20.0, 0.2)	0.49
West (Regions 8, 9, 10), n (%, SE)	257 (25.3)	20,034 (27.05)	213,335 (25.4, 3.8)	13,273,622 (23.5, 0.3)	0.62
South (Regions 4, 6)), n (%, SE)	301 (29.6)	18,891 (25.5)	281,258 (33.4, 3.4)	18,579,623 (32.9, 0.3)	0.89
Midwest (Regions 5, 7)), n (%, SE)	204 (20.1)	14,621 (19.7)	175,420 (20.9, 2.4)	12,103,497 (21.5, 0.2)	0.80
Residence in a Metropolitan Statistical Area), n (%, SE)	187 (25.1)	10,887 (21.8)	125,952 (16.3, 2.0)	7,715,728 (15.5, 0.3)	0.68
Ever told has ADHD, n (%, SE)	252 (24.8)	7,742 (10.5)	156,383 (18.6, 2.2)	5,872,289 (10.4, 0.2)	<0.001
Current ADHD, n (%, SE)	206 (20.4)	6,084 (8.2)	130,121 (15.6, 2.0)	4,660,602 (8.3, 0.2)	<0.001
Medicated ADHD, n (% of those with current ADHD, SE)	140 (68.0)	4,325 (71.1)	83,796 (64.4, 6.3)	3,224,641 (69.0, 1.4)	0.46

Vision problems, vision problems not correctable with glasses or contact lenses.

*Weighting methods used were those provided by the National Center for Health Statistics available at http://www.childhealthdata.org.

problems have increased odds of having current ADHD (OR, 1.8; 95% CI, 1.1 to 2.9; and OR, 2.6; 95% CI, 1.6 to 4.1, respectively) compared with children without vision problems. Children with severe vision problems were not at increased risk to have current ADHD (OR, 1.6; 95% CI, 0.8 to 3.1). All levels of vision problems had increased odds of being in a more severe ADHD category (as rated by parent report) compared with children without vision problems. The odds of being in a more severe ADHD category were greatest for those with mild vision problems (OR, 1.9; 95% CI, 1.2 to 3.0) and with moderate vision problems (OR, 2.8; 95% CI, 1.7 to 4.4) compared with their peers with normal vision. Although children with severe vision problems have increased odds of more severe ADHD level, the difference is not statistically different. No significant associations were found between the severity of vision problems and the use of medication for ADHD.

Table 3 examines only those children with ADHD and compares the odds ratios for children with vision problems with those without for many factors thought to be associated with ADHD. Children with vision problems and ADHD were similar to their normally

TABLE 2.

Unadjusted associations between ADHD and vision problem severity

	Mild VP OR (95% CI)	Moderate VP OR (95% CI)	Severe VP OR (95% CI)
Any level ADHD	1.8 (1.1–2.9)	2.6 (1.6–4.1)	1.6 (0.8–3.1)
Severity ADHD*	1.9 (1.2–3.0)	2.8 (1.7–4.4)	1.6 (0.8–3.3)
Medicated ADHD	1.4 (0.6–3.0)	0.5 (0.2–1.2)	1.3 (0.4–3.4)

Reference group: no vision problems.

*Ordinal regression, odds of being in higher ADHD severity category.

VP, vision problems not correctable with glasses or contact lenses.

sighted peers with ADHD with respect to sex, family member smoking status, language spoken at home, health care coverage, and family structure. Children with vision problems and ADHD however were less likely to report Hispanic and more likely to report "other" as their race/ethnicity compared with non-Hispanic Whites. Adjusting for all factors that were significant at the univariate level yielded similar results.

DISCUSSION

Results from this large survey of a nationally representative sample of children suggest an increased risk of ADHD among children with vision problems relative to other children. The prevalence of ADHD among children with vision problems from this national cross-sectional study is similar to that previously reported among children with low vision in a vision rehabilitation clinic in

TABLE 3.
Odds of vision problems among children with current ADHD

Variable	Unadjusted odds ratio (LCL, UCL)	p	Adjusted odds ratio (LCL, UCL)	p
Age	0.97 (0.90, 1.04)	0.41		
Sex				
Female (ref)	1.0			
Male	0.74 (0.43, 1.28)	0.28		
Race/ethnicity				
White (ref)	1.0		1.0	
Hispanic	1.71 (0.80, 3.68)	0.08	0.32 (0.14, 0.77)	0.001
Black	0.32 (0.14, 0.73)	<0.001	1.27 (0.64, 2.48)	0.28
Other	2.04 (0.97, 4.26)	0.02	1.91 (0.87, 4.18)	0.02
Low birth weight				
≥2500 g (ref)	1.0		1.0	
<2500 g	2.50 (1.40, 4.60)	<0.001	1.83 (0.92, 3.63)	0.08
Premature birth				
>37 weeks' gestation (ref)	1.0		1.0	
≤37 weeks' gestation	2.80 (1.60, 5.00)	0.003	2.09 (1.04, 4.20)	0.04
Family structure				
2 parent biological/adoptive/step (ref)	1.0			
Single mother/father/other	0.69 (0.41, 1.18)	0.18		
No. children in household				
1 (ref)	1.0			
2	0.72 (0.39, 1.33)	0.53		
3 or more	0.74 (0.40, 1.37)	0.63		
English primary language at home				
No (ref)	1.0		1.0	
Yes	3.12 (0.96, 10.14)	0.06	1.41 (0.41, 4.85)	0.58
Mother's age	1.01 (0.98, 1.04)	0.71		
Highest education level in household				
High school or less (ref)	1.0			
More than high school	0.74 (0.44, 1.26)	0.27		
Smoker in the family				
No (ref)	1.0			
Yes	1.25 (0.72, 2.13)	0.44		
Family income				
>200% poverty level (ref)	1.0		1.0	
≤200% poverty level	1.64 (0.98, 2.76)	0.6	1.63 (0.96, 2.76)	0.7
Region of United States				
Midwest (regions 5, 6) (ref)	1.0			
North East (regions 1, 2, 3)	1.08 (0.50, 2.35)	0.61		
West (regions 8, 9, 10)	0.68 (0.30, 1.52)	0.24		
South (regions 4, 6)	1.07 (0.59, 1.94)	0.53		
Residence in a metropolitan statistical area				
No (ref)	1.0			
Yes	1.02 (0.56, 1.85)	0.46		
Currently medicated for ADHD				
No (ref)	1.0			
Yes	0.81 (0.47, 1.41)	0.46		

LCL, 95% lower confidence limit; UCL, 95% upper confidence limit; ref, reference group.

Alabama[6] (18.6 vs. 22.9%, respectively). Likewise, the prevalence of ADHD among children without a vision problem is similar to that found in other national studies (8.3% in this study compared with 8.2% in the NHANES). Importantly, diagnosis in the NHANES was based on *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition*, criteria and included clinical examination.

Although there were differences between the participants with vision problems and those without vision problems, none of those differences has been established as a cause of ADHD. The cause of ADHD is still unknown and likely multifactorial, involving both genetic and environmental influences. Many factors have been found to be associated with ADHD such as maternal and paternal smoking during pregnancy, low birth weight, blood lead level, as well as family history of ADHD.[4] Here we provide evidence that vision problems are also independently associated with ADHD. Because the question regarding vision problems was nonspecific, it is likely that parents responded affirmatively for many types of vision problems such as monocular vision loss, color vision deficiency, or strabismus, as well as for conditions resulting in vision impairment, suggesting that many different types of vision problems may be associated with ADHD.

Children with convergence insufficiency have been shown to have an increased prevalence of ADHD.[10,21] Children with ADHD have been shown to have an increased frequency of ametropia and visuoperceptual problems.[8] It is probable that some of the children with vision problems whose parents classified their condition as mild had binocular vision anomalies. The odds of ADHD are lower among those with mild vision problems than among children in the moderate vision problem group. Children with obvious signs of vision problems (such as strabismus or nystagmus) would likely be categorized by their parents as having a more severe vision problem. Because vision plays such an important role in acquiring information, it is easy to see how vision problems might impact attention and how more severe vision problems would have a greater effect.

It is likely that some children with vision problems are incorrectly identified as having ADHD. If children are unable to see something, they may not be able to keep their attention focused on it. Similarly, if they are struggling to see their work, they may have difficulty finishing in a timely manner. These problems may incorrectly be interpreted as ADHD. It is surprising and counterintuitive that the children with the most severe vision problems had increased odds of having ADHD but that the increase was not statistically significant (likely caused by the small number of children in this category).

One intriguing possible explanation relates to utilization of executive function. Each individual has a finite amount of executive functioning (the higher-order cognitive processes that enable people to plan, organize, pay attention, and manage time and space).[22] Impairment of executive functioning is implicated in ADHD.[23] Individuals with a sensory deficit will necessarily need to use more of their executive functioning to compensate for that deficit, leaving less executive function in reserve to change or maintain an attentional state. This theory is supported by the odds of having ADHD as well as the odds of having more severe ADHD, being greatest among those with moderate vision problems. Those with moderate vision problems would likely need to use the largest amount of executive functioning to compensate for their vision impairment, whereas those with mild vision problems would need less. Those with severe vision problems may use other tools in their daily activities such as magnification, Braille, or a white cane for mobility and may use less executive function to compensate for their vision impairment.

This study has several limitations common to survey-based health research. The NSCH is a telephone survey, and although parents were asked to report if a doctor or other health care provider had made a diagnosis of ADHD or vision problems, their report was not validated. In addition, there is no information available on the cause or type of vision problem or about which type of health care provider made the ADHD diagnosis. The PLAY Study (Project to Learn About ADHD in Youth) has shown that case definition has a significant impact when determining ADHD prevalence.[24] Thus, the prevalence found in this study is impacted by the varying criteria used by the doctors or health care providers who reportedly made the diagnosis. To further emphasize the difficulty in assessing ADHD prevalence, the PLAY Study found that less than 40% of children medicated for ADHD in one school district in South Carolina and five school districts in Oklahoma actually met *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition,* criteria for ADHD diagnosis.[25] However, the opposite was found in a study using data from the NHANES. Only 48% of children meeting *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition,* criteria for ADHD according to a structured diagnostic interview had a parent report of an ADHD diagnosis by a health care professional.[26] There are undoubtedly both false-positive and false-negative reports of ADHD and/or vision problems in the data set. The possibility of recall bias or intentional inaccurate reporting also exists.

A strength of this work is that the NSCH is a large national sample that was designed to be representative of noninstitutionalized children in the United States, and thus, the results are generalizable. There is also evidence that parent report of ADHD has convergent validity with medical records and well-defined criteria.[27] Although it would be preferable to have both psychological and optometric evaluations of the children, these data do strongly suggest that there is an association between vision problems and ADHD that merits further investigation.

In conclusion, there is an independent association between parent-reported vision problems not correctable with standard glasses or contact lenses and ADHD even after adjusting for other factors known to be associated with ADHD. This finding suggests that children with vision problems should be monitored for signs and symptoms of ADHD so that this dual impairment of vision and attention can best be addressed. Although eye care providers are not trained to diagnose or treat ADHD, they should be aware that their patients with vision problems are at increased risk of having ADHD. If there is a suspicion of ADHD, the primary care provider and/or a specialist in ADHD should be consulted. Future research should be directed toward longitudinal studies examining associations between type and severity of vision impairment and ADHD, the mechanisms underlying the association, as well as determining the most effective treatment strategies.

ACKNOWLEDGMENTS

Previously presented in part as a poster at the American Academy of Optometry Annual Meeting 2013, Seattle, Washington.

Received May 13, 2015; accepted October 27, 2015.

APPENDIX

The Appendix, specific wording of questions regarding ADHD and vision problems in the 2011 to 2012 NSCH, is available at http://links.lww.com/OPX/A233.

REFERENCES

1. Braun JM, Kahn RS, Froehlich T, Auinger P, Lanphear BP. Exposures to environmental toxicants and attention deficit hyperactivity disorder in U.S. children. Environ Health Perspect 2006;114:1904–9.
2. Lingineni RK, Biswas S, Ahmad N, Jackson BE, Bae S, Singh KP. Factors associated with attention deficit/hyperactivity disorder among U.S. children: results from a national survey. BMC Pediatr 2012;12:5.
3. Visser SN, Danielson ML, Bitsko RH, Holbrook JR, Kogan MD, Ghandour RM, Perou R, Blumberg SJ. Trends in the parent-report of health care provider-diagnosed and medicated attention-deficit/hyperactivity disorder: United States, 2003–2011. J Am Acad Child Adolesc Psychiatry 2014;53:34–46.e2.
4. Thapar A, Cooper M, Eyre O, Langley K. What have we learnt about the causes of ADHD? J Child Psychol Psychiatry 2013;54:3–16.
5. Decarlo DK, McGwin G, Jr., Bixler ML, Wallander J, Owsley C. Impact of pediatric vision impairment on daily life: results of focus groups. Optom Vis Sci 2012;89:1409–16.
6. DeCarlo DK, Bowman E, Monroe C, Kline R, McGwin G, Jr., Owsley C. Prevalence of attention-deficit/hyperactivity disorder among children with vision impairment. J AAPOS 2014;18:10–4.
7. Kutzbach B, Summers CG, Holleschau AM, King RA, MacDonald JT. The prevalence of attention-deficit/hyperactivity disorder among persons with albinism. J Child Neurol 2007;22:1342–7.
8. Grönlund MA, Aring E, Landgren M, Hellström A. Visual function and ocular features in children and adolescents with attention deficit hyperactivity disorder, with and without treatment with stimulants. Eye (Lond) 2007;21:494–502.
9. Fabian ID, Kinori M, Ancri O, Spierer A, Tsinman A, Ben Simon GJ. The possible association of attention deficit hyperactivity disorder with undiagnosed refractive errors. J AAPOS 2013;17:507–11.
10. Rouse M, Borsting E, Mitchell GL, Kulp MT, Scheiman M, Amster D, Coulter R, Fecho G, Gallaway M; CITT Study Group. Academic behaviors in children with convergence insufficiency with and without parent-reported ADHD. Optom Vis Sci 2009;86:1169–77.
11. Borsting E, Rouse M, Chu R. Measuring ADHD behaviors in children with symptomatic accommodative dysfunction or convergence insufficiency: a preliminary study. Optometry 2005;76:588–92.
12. Letourneau JE, Ducic S. Prevalence of convergence insufficiency among elementary school children. Can J Optom 1988;50:194–7.
13. Rouse MW, Borsting E, Hyman L, Hussein M, Cotter SA, Flynn M, Scheiman M, Gallaway M, De Land PN. Frequency of convergence insufficiency among fifth and sixth graders. The Convergence Insufficiency and Reading Study (CIRS) group. Optom Vis Sci 1999;76:643–9.
14. Lee SH, Moon BY, Cho HG. Improvement of vergence movements by vision therapy decreases K-ARS scores of symptomatic ADHD children. J Phys Ther Sci 2014;26:223–7.
15. Nazari MA, Berquin P, Missonnier P, Aarabi A, Debatisse D, De Broca A, Wallois F. Visual sensory processing deficit in the occipital region in children with attention-deficit/hyperactivity disorder as revealed by event-related potentials during cued continuous performance test. Neurophysiol Clin 2010;40:137–49.
16. Kim S, Chen S, Tannock R. Visual function and color vision in adults with attention-deficit/hyperactivity disorder. J Optom 2014;7:22–36.
17. Centers for Disease Control and Prevention. National Survey of Children's Health; 2013. Available at: http://www.cdc.gov/nchs/slaits/nsch. Accessed November 1, 2013.
18. Antshel KM, Phillips MH, Gordon M, Barkley R, Faraone SV. Is ADHD a valid disorder in children with intellectual delays? Clin Psychol Rev 2006;26:555–72.
19. Subcommittee on Attention-Deficit/Hyperactivity Disorder; Steering Committee on Quality Improvement and Management, Wolraich M, Brown L, Brown RT, DuPaul G, Earls M, Feldman HM, Ganiats TG, Kaplanek B, Meyer B, Perrin J, Pierce K, Reiff M, Stein MT, Visser S. ADHD: clinical practice guideline for the diagnosis, evaluation, and treatment of attention-deficit/hyperactivity disorder in children and adolescents. Pediatrics 2011;128:1007–22.
20. 2011–2012 National Survey of Children's Health. SAS Code for Data Users: Child Health Indicator and Subgroups; Version 1.0. Sponsored by the Maternal and Child Health Bureau; 2013. Available at: http://www.nschdata.org/docs/nsch-docs/sas-codebook_-2011-2012-nsch-v1_05-10-13.pdf?sfvrsn=1. Accessed November 1, 2013.
21. Granet DB, Gomi CF, Ventura R, Miller-Scholte A. The relationship between convergence insufficiency and ADHD. Strabismus 2005;13:163–8.
22. Baddeley A. Exploring the central executive. Q J Exp Psychol (A) 1996;49:5–28.
23. Rapport MD, Orban SA, Kofler MJ, Friedman LM. Do programs designed to train working memory, other executive functions, and attention benefit children with ADHD? A meta-analytic review of cognitive, academic, and behavioral outcomes. Clin Psychol Rev 2013;33:1237–52.
24. McKeown RE, Holbrook JR, Danielson ML, Cuffe SP, Wolraich ML, Visser SN. The impact of case definition on attention-deficit/hyperactivity disorder prevalence estimates in community-based samples of school-aged children. J Am Acad Child Adolesc Psychiatry 2015;54:53–61.
25. Wolraich ML, McKeown RE, Visser SN, Bard D, Cuffe S, Neas B, Geryk LL, Doffing M, Bottai M, Abramowitz AJ, Beck L, Holbrook JR, Danielson M. The prevalence of ADHD: its diagnosis and treatment in four school districts across two states. J Atten Disord 2014;18:563–75.
26. Froehlich TE, Lanphear BP, Epstein JN, Barbaresi WJ, Katusic SK, Kahn RS. Prevalence, recognition, and treatment of attention-deficit/hyperactivity disorder in a national sample of U.S. children. Arch Pediatr Adolesc Med 2007;161:857–64.
27. Visser SN, Danielson ML, Bitsko RH, Perou R, Blumberg SJ. Convergent validity of parent-reported attention-deficit/hyperactivity disorder diagnosis: a cross-study comparison. JAMA Pediatr 2013;167:674–5.

Dawn K. DeCarlo
UAB Department of Ophthalmology
CEFH 405; 700 18th St South
Birmingham, AL 35233
e-mail: ddecarlo@uab.edu