ATTENTION DEFICIT/HYPERACTIVITY DISORDER, SCREEN TIME, PHYSICAL ACTIVITY, AND DIET QUALITY

A Dissertation Presented

By

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ABSTRACT

Background. Emerging evidence suggests that youth with attention deficit/hyperactivity disorder (ADHD) may engage in sub-optimal health behaviors including high levels of screen time, low physical activity participation, and consumption of poor diets. These are independent risk factors for adverse health outcomes, and health-related behavior patterns established in childhood can track into adulthood. Thus, identifying and addressing dietary and physical activity habits in sub-populations of youth have important implications for health over the lifespan. The specific aims of this dissertation were to: (1) compare screen time between youth with and without ADHD and to assess its relationship to ADHD symptomatology; (2) compare participation in physical activity (PA) between adolescents with and without ADHD and to assess the relationship of PA participation to ADHD symptomatology; and (3) evaluate the association of diet quality and dietary patterns to ADHD symptomatology among youth ages 8-15 years.

Methods. The aforementioned outcomes of interest were analyzed using data from the continuous National Health and Nutrition Examination Survey (NHANES) 2001-2004. These waves of NHANES included a structured DSM-IV-based interview administered to parents that identified youth with ADHD and also yielded symptom counts for hyperactivity/impulsivity and inattention. Screen time and physical activity data were obtained from questionnaires that queried the amount of time spent watching television, playing videos, or using the computer outside of school time, and also surveyed the types, frequency, and duration of PA in which youth participated. Diet quality and dietary patterns, which included consumption of sugar-sweetened beverages (SSBs), total calorie intake, and eating frequency, were obtained by a 24-hour dietary recall using the Automated Multiple Pass Method of interviewing. Linear and logistic regression models adjusted for sociodemographic factors and anxiety/depression were employed to address the specific aims.

Results. The findings suggest that youth with ADHD are at the same, if not higher, risk for engaging in suboptimal health behaviors. Overall, youth participating in NHANES engaged in excessive amounts of screen time, failed to acquire sufficient physical activity, and consumed diets of poor quality. However, our findings suggest that ADHD symptomatology places youth at higher risk for sedentary behavior and poor diet quality. Relative to screen time, youth with ADHD showed a trend toward increased screen time, as did youth who took medication. ADHD symptoms were also associated with over two hours of daily TV viewing and overall increased screen time, and this was particularly true for children ages 8-11 years. Relative to physical activity, the outcomes did not differ between youth with and without ADHD, but the majority of youth did not meet the recommended guidelines of 60 minutes or more of moderate-to-vigorous PA each day. Diet quality was poor across the population of youth who participated in NHANES, and hyperactive/impulsive symptoms were associated with an even greater decrease in diet quality in both children and adolescents. In males, the presence of hyperactive/impulsive symptoms was associated with a decrease in diet quality, whereas in females, inattentive symptoms accounted for a decrease in diet quality. No differences

in the other dietary patterns (i.e., SSB consumption, total energy intake, and eating frequency) were observed.

Conclusions. The diagnosis of ADHD and/or its symptoms are associated with less-than-recommended levels of screen time and poor diet quality, though youth in general were found to be engaging in suboptimal sedentary, physical activity, and dietary behaviors. The mechanisms for why youth with ADHD may have increased vulnerability to poorer health behaviors are not yet well understood. The findings from this dissertation support the need for ongoing efforts to address lifestyle factors among the nation's youth generally, but may also stimulate new hypotheses about the needs of youth with ADHD from both public health and clinical perspectives, and encourage research on the implications of ADHD symptomatology on health-related behaviors and lifestyle factors.

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LIST OF ABBREVIATIONS

ADHD	Attention Deficit/Hyperactivity Disorder
AMPM	Automated Multiple Pass Method
CDC	Centers for Disease Control
DGA	Dietary Guidelines for Americans
DISC-IV	Diagnostic Interview Schedule for Children (version IV)
FFQ	food frequency questionnaire
FNDDS	Food and Nutrient Database for Dietary Studies
HEI	Healthy Eating Index
MEC	Mobile Examination Center
NCHS	National Center for Health Statistics
NHANES	National Health and Nutrition Examination Survey
PA	physical activity
PIR	poverty-to-income ratio
RDC	Research Data Center
SE	standard error
SoFAAS	solid fats, alcoholic beverages, and added sugars
SSB	sugar-sweetened beverage

CHAPTER I

INTRODUCTION

Attention Deficit/Hyperactivity Disorder and Lifestyle Factors

Emerging evidence suggests that youth with attention deficit/hyperactivity disorder (ADHD) have higher levels of sedentary behavior, engage in lower amounts of physical activity,[1] and have poorer diets[2,3] than their non-ADHD peers. There is also growing evidence that youth with ADHD are at higher risk for obesity than their non-ADHD counterparts.[4-9] Excess time spent in sedentary behavior, low levels of physical activity, and poor eating habits are independent risk factors for adverse health outcomes. Cardiovascular risk factors in adults can originate in childhood; for example, dietary patterns established in childhood and adolescence have been shown to track into adulthood,[10] and diet quality frequently declines over time.[11] Low intake of dairy in childhood has been associated with adult osteoporosis,[12] and low intake of fruits and vegetables has been associated with coronary heart disease[13] and the development of some cancers.[14-16] Physical inactivity and excess sedentary behavior have also been independently associated with cardiovascular disease.[17,18] Thus, identifying and addressing dietary and physical activity habits in youth has important implications for health over the lifespan.

ADHD is one of the most common neurodevelopmental disorders of childhood; prevalence estimates vary widely, from 3-18% in school-age children, which is a function of the methods of diagnosis, case ascertainment, and broadening criteria over time.[19-21] Core features of ADHD include developmentally inappropriate levels of inattention, impulsivity, distractibility, and motoric over-activity. These behaviors cause functional impairment and occur across settings such as school, home, and social situations.[22] The inattentive symptoms of ADHD manifest themselves as difficulty maintaining attention in tasks or play, difficulties paying close attention to details in school work or other activities, a propensity to lose things, high levels of distractibility, and difficulties with organizing time, belongings, and activities. Hyperactive/impulsive symptoms are associated with motoric over-activity, difficulty sitting still and/or playing quietly, and excessive talking. Impulsivity often manifests in such behaviors as difficulty taking turns and interrupting others.[23] Youth with ADHD may experience some unique risk factors that predispose them to suboptimal health behaviors, which may be associated with the neurobiology and core features of the disorder itself or with the concomitant psychosocial challenges that this population of youth face.

With regard to the neurobiology and core features of ADHD, inattention and impulsivity have been shown to affect the regulation of food intake, which may be related to the role of dopamine dysfunction in eating behavior.[24] Dopamine systems in the brain are involved in the pathogenesis of ADHD,[25,26] and dopamine is also central to appetite regulation and partially mediates natural reinforcers such as food, alcohol, drugs, and sexual activity. Some research has also shown that dysfunction of dopamine receptor genes gives rise to "reward deficiency syndrome" wherein the individual is unable to derive reward from normal everyday activities, does not experience satiety at normal levels, and thus engages in elevated levels of pleasure-seeking behavior.[27,28] As an example, children with ADHD have been shown to demonstrate greater preference for small, immediate rewards over larger delayed rewards compared to youth without ADHD.[29] Because palatable, energy-dense food is known to activate dopamine pathways, some have also suggested that overeating among individuals with ADHD may be an attempt at self-medication.[30,31] A propensity for self-medication with alcohol and psychoactive substances has been documented in patients with ADHD.[32,33] Regarding physical activity and sedentary behavior, problems with under-arousal and hypoactivity seen in some persons with ADHD may contribute to reduced energy expenditure and sedentary behavior.[34]

The psychological and social challenges that youth with ADHD experience may also increase their vulnerability to less-than-ideal health behaviors. In youth generally, physical activity and sedentary behavior have been linked to academic and psychological adjustment. For example, perceived academic rank has been correlated with physical activity and sedentary behavior; youth who perceive themselves as being more advanced academically than peers who engage in more physical activity and less sedentary behavior.[35] Higher participation in physical activity and lower levels of sedentary behavior in youth have been also been linked to positive health indicators including health status, self-image, and quality of life, and inversely associated with health complaints and alcohol/substance use.[36] High TV/video use has been associated with other risky health behaviors (e.g., cigarette smoking, delinquency, truancy, etc.) in adolescents.[37] Poor academic and educational outcomes in youth with ADHD have been well documented,[38] as have negative psychological and psychosocial outcomes in both youth[39] and young adults with ADHD.[40] It has also been suggested that because individuals with ADHD do not tend to take the future implications or consequences of their behavior into account, they may be at higher risk for diminished engagement in health-conscious behaviors, such as exercise and maintaining a healthy diet.[41] Finally, youth with ADHD have also been reported to participate less and experience less enjoyment in sports and leisure activities.[42,43]

In light of the extant evidence that the neurobiological and psychosocial underpinnings associated with ADHD may also be associated with sub-optimal health behaviors, it seems plausible that youth with ADHD could be more vulnerable to increased sedentary behavior, lower levels of physical activity, and consuming poorer diets than their peers without ADHD. If this is the case, then standard approaches to obesity prevention, weight loss, and general health promotion may be inadequate because those efforts fail to address the influence of underlying ADHD symptomatology.

In an effort to shed light on whether youth with ADHD have higher levels of sedentary behavior, engage in less physical activity, and have more suboptimal dietary behaviors than their peers without ADHD, this dissertation focuses on children with ADHD ages 8-15 years using data from the National Health and Nutrition Examination Survey (NHANES) 2001-2004. To date, only a handful of studies have examined these outcomes with regard to ADHD or its symptoms in youth. The strength of this dissertation is that it uses a nationally representative dataset to explore the outcomes of interest. In contrast to other similar studies on US youth that rely on parent report via phone,[3,44] youth who participated in NHANES were interviewed in person about their health-related behaviors. Additionally, NHANES utilizes robust methodologies for examining dietary factors [45] and is one of the few nationally representative surveys that collects in-depth information on food consumption. NHANES has also developed more structured methods for collecting self-report data on physical activity compared to other surveys, which rely on single, open-ended questions about youths' participation. Accordingly, the specific aims of this dissertation were as follows:

Specific Aim 1. To compare sedentary behavior between children with and without ADHD. The goal of this aim was to determine whether youth with ADHD spend more time in sedentary behavior (screen time) than children without ADHD. The relationship of inattentive and/or hyperactive/impulsive symptoms to screen time was also explored.

Specific Aim 2. To compare participation in physical activity between children with and without ADHD. In this aim, time spent in moderate and vigorous physical activity was compared between children with and without ADHD. Specifically, the number of physical activities youth participated in, the intensity level of their participation, and the likelihood of their meeting national guidelines for physical activity participation (i.e., engaging in at least 60 minutes of moderate-to-vigorous physical activity each day of the week) were compared between youth with and without ADHD. The relationship of inattentive or hyperactive/impulsive symptoms to these outcomes was also assessed.

Specific Aim 3. To evaluate the association of ADHD symptomatology and diet quality and dietary patterns. The goal of this aim was to determine whether diet quality as measured by the 2005 Healthy Eating Index was associated with ADHD symptomatology. We also evaluated whether eating frequency, as defined by number of eating occasions, was associated with symptomatology. Eating occasions have been associated with increased caloric intake in the general population. Finally, we determined whether overall calorie intake and consumption of sugar-sweetened beverages (SSBs) were associated with ADHD symptoms. SSB consumption has been identified by the CDC as an "actionable" target for health promotion and obesity reduction in youth generally.[46]

Data Source: The National Health and Nutrition Examination Surveys (NHANES) 2001-2004

Data from the National Health and Nutrition Examination Surveys (NHANES) 2001-2004 were used to explore the specific aims described above. NHANES grew out of the National Health Survey Act of 1956, which authorized a continuing survey to capture data on illness and disability in the United States. The National Center for Health Statistics (NCHS) oversees data collection efforts authorized by the Act. Earlier surveys, called the National Health Examination Survey (NHES), focused on adult chronic disease and child growth and development. In 1970, the NHES took on a new emphasis by focusing on nutrition and health status, and the Department of Health, Education, and Welfare established the National Nutrition Surveillance System, whose purpose was to evaluate the nutritional status of the United States population and monitor changes over time. The National Nutrition Surveillance System was ultimately combined with the National Health Examination Survey to form NHANES. Earlier versions of NHANES were conducted during discrete time periods; however, since 1999, NHANES has been a continuous survey. Approximately 5,000 randomly selected residents across the United States are selected to participate in NHANES and undergo interviews, complete questionnaires, and take part in standardized physical examinations. The data provided by NHANES constitute a nationally representative, objective assessment of the health status of people living in the United States.[47]

NHANES uses a stratified, multistage, probability cluster sample, with oversampling of some population groups. Probability sampling weights are applied so that the interviewed sample is representative of the civilian non-institutionalized US population. In the first study visit, randomly selected participants are interviewed in their homes, where demographic, socioeconomic, and some health-related information is obtained via survey. In a subsequent study visit conducted in a Mobile Examination Center (MEC), participants' weight and height are measured using a standard protocol and additional medical, psychiatric, behavioral, dietary, and biological specimens are collected. In 2001-2004, the response rates to NHANES were well over 80% for youth ages 6-17 years.[48]

In NHANES 2001-2004, in-depth mental health assessments of youth were conducted using the Diagnostic Interview Schedule for Children (version IV) (DISC-IV), a structured psychiatric interview based on the DSM-IV and ICD-10.[49] Diagnostic modules for generalized anxiety disorder and panic disorder, eating disorders, elimination disorders, major depression/dysthymic disorder, ADHD, and conduct disorder were included in these waves of NHANES. The DISC-IV can be administered by lay interviewers, with established validity and reliability.[49]

NHANES restricts access to data on the mental health status of youth to researchers who receive prior approval and conduct analyses via a secure system administered by the National Center for Health Statistics (NCHS) via portals or onsite visits to specified Research Data Centers (RDC). Data analyses for this dissertation were conducted on-site at the National Bureau of Economic Research in Cambridge, MA, which has an RDC in collaboration with NCHS and the US Census Bureau. Data collection for NHANES was approved by the NCHS Research Ethics Review Board. This study was also reviewed and deemed exempt by the Institutional Review Board at the University of Massachusetts Medical School.

Study Population: Diagnostic Categorizations and Symptom Counts

In this dissertation, youth with ADHD were classified by combining information available from the DISC-IV interview, which queried the presence of past-year symptoms consistent with DSM-IV diagnostic criteria for ADHD, and from parent report. The DISC-IV was administered to parents by telephone following the youth's visit to the MEC. Youth were considered to have ADHD if they met DSM-IV diagnostic criteria based on the algorithm developed by the DISC Group at Columbia University.[50] The DISC-IV focuses on current and past-year symptoms, but because stimulant medication reduces ADHD symptoms, treated youth may fail to fulfill full diagnostic criteria.[51] Additionally, we were also interested in lifetime diagnoses of ADHD, so youth were also considered to be positive for ADHD if parents responded affirmatively to the following question, *"Has a doctor or health professional ever told you that [sample person] had attention deficit disorder?"*

Participants with ADHD were classified further according to whether or not they had taken medication for ADHD in the past year. During the DISC-IV interview, respondents were asked a single question, *"In the past year, has [the sample person] taken medication for being overactive, being hyperactive, or having trouble paying attention?"* We classified participants with self-report and/or DISC-IV derived diagnosis as ADHD-Medicated or ADHD-Not Medicated. Ascertaining medication status was important for determining whether medication had an effect on the outcomes of interest, since previous research has demonstrated that non-medicated youth with ADHD are at increased risk for obesity,[5,9] and have also been shown to be less physically active and more sedentary than non-ADHD youth.[1]

In determining the diagnosis of ADHD, the DISC-IV interview consisted of querying parents about the presence of ADHD symptoms. Symptom counts, which included 11 inattentive symptoms and 12 hyperactive/impulsive symptoms, were made available for the population as a whole. This permitted an examination of ADHD symptomatology on a continuum, which both genetic studies[52-54] and latent class analyses[55-57] have suggested may be a viable way to conceptualize ADHD; i.e., as existing on the extreme end of a continuous trait. By examining symptom counts, we were able to determine whether hyperactive/impulsive or inattentive symptoms were associated with our outcomes of interest, and to assess the relationship of these on a population-wide basis. Symptom counts also provide more statistical power, an important advantage given the relatively small sample sizes of youth with ADHD who were included in NHANES. The individual symptoms derived from the DISC-IV in NHANES are listed in Table 1.1 below.

Implications for Study Findings

The results from this dissertation may have implications for health-related anticipatory guidance of youth with ADHD and/or ADHD-related symptomatology by healthcare providers. ADHD is the most common disorder of childhood second only to childhood asthma, and thus the findings may also be of interest to policy makers. As noted, several studies have documented an association between ADHD and obesity in both children and adults, but for the most part the extant literature does not provide clear insights into the modifiable risk factors associated with obesity and ADHD. As a cross-sectional study, the temporal relationships among the associations identified in this dissertation cannot be determined, but the findings can serve to generate hypotheses for future research. Addressing lifestyle factors in children and youth with ADHD have important implications for subsequent health outcomes.

Finally, it should be noted that the findings and conclusions in this dissertation are those of the author and do not necessarily represent the views of the Research Data Center, the National Center for Health Statistics, or the Centers for Disease Control and Prevention.

Table 1.1. DISC-IV derived ADHD symptoms in NHANES.

Inattentive Symptoms	Hyperactive/Impulsive Symptoms
In the past year ...	
• Trouble keeping mind on tasks for more than a short period of time • Often tried to avoid doing things that required paying attention • Often disliked doing things that required paying attention • Couldn't keep mind on one thing when other things were going on • Disorganized • Trouble finishing homework • Forgot what they were supposed to do • Often lost things • Often made a lot of mistakes because it's hard for him/her to do things carefully • Often didn't listen when people were speaking to them • Started activities without finishing them	• Been on the go, more active than usual, as if driven by a motor • Fidgety/restless • Left seat (as in school, movie, restaurant) often when wasn't supposed to • Often climbed on things/ran around when they weren't supposed to • Always restless (wanted to kick feet or run around) • Often talked a lot more than other children their age • Often made much more noise while playing/having fun than other children of the same age • Often interrupted others while they were busy • Often butted in on what others were doing • Blurted out answers before hearing the whole question • Often had trouble waiting for turns (as in standing on line) • Was in a dangerous situation in the past year because he/she wasn't thinking

CHAPTER II

COMPARING SCREEN TIME IN YOUTH WITH AND WITHOUT ATTENTION DEFICIT/HYPERACTIVITY DISORDER

Abstract

Objective. To compare screen time in youth ages 8-15 years with and without attention deficit/hyperactivity disorder (ADHD).

Study design. Screen time in youth with and without ADHD was estimated using data from the continuous National Health and Nutrition Examination Survey (NHANES) 2001-2004. These waves of NHANES included a DSM-IV-based interview to identify youth with ADHD and also yielded symptom counts for inattention and hyperactivity/impulsivity. We included 2,918 youth who had data on ADHD and key outcomes and covariates. Two questions queried the amount of time spent watching television, playing videos, or using the computer outside of school time. These were combined to calculate overall screen time. Logistic regression models adjusted for sociodemographic factors were used to determine whether youth with ADHD were more likely to exceed recommendations for TV viewing, computer use, and overall screen time.

Results. Over half of all youth exceeded recommended guidelines for screen time, which call for no more than 2 hours per day. Youth with ADHD overall as well as youth with ADHD who had taken medication in the past year showed a trend for engaging in more than 2 hours a day of screen time, though after adjustment for age, race/ethnicity, poverty status, and anxiety/depression, these associations were not statistically significant. Hyperactive/impulsive symptoms were associated with more than 2 hours of TV viewing (OR 1.05 (95%CI 1.00-1.09), p=0.04) and more than 2 hours of screen time (OR 1.06 (95%CI 1.01-1.11), p=0.03), after adjusting for covariates. A

significant interaction with age was detected, such that hyperactive/impulsive symptoms were associated with a higher likelihood of spending more than 2 hours in screen time only among children ages 8-11 years (OR 1.08 (95%CI 1.00-1.16), p=0.04).

Conclusion. The findings suggest that hyperactivity/impulsivity are associated with levels of TV viewing and screen time that exceed recommendations. In children ages 8-11 years, hyperactive/impulsive symptoms appear to increase the risk for exceeding screen time guidelines.

Introduction

Engagement in physical activity is a key component to good health; however, evidence is also emerging that sedentary behavior, i.e., behavior that involves mainly sitting and inactivity, is an independent risk factor for negative health outcomes.[58] This concern also applies to children and youth, particularly the time they spend watching television, playing video games, and using computers (collectively referred to as "screen time"). Healthy People 2020 and the American Academy of Pediatrics have recommended that screen time be limited to no more than 2 hours per day.[59,60] However, data suggest that most children do not meet these guidelines, and that boys and adolescents are less likely to meet them compared to girls and younger children.[61,62] Moreover, some evidence suggests that children with neurodevelopmental and neurobehavioral disorders, including those with attention deficit/hyperactivity disorder (ADHD),[1,3] may be at higher risk for inactivity than children generally.[63,64]

Youth with ADHD may experience some unique risk factors that predispose them to suboptimal health-related behaviors. ADHD is one of the most common neurodevelopmental disorders of childhood; current estimates indicate that 5-10% of school-age children have ADHD.[19,20] Core features include developmentally inappropriate levels of inattention, impulsivity, distractibility, and motoric over-activity. These behaviors cause functional impairment and occur across settings such as school, home, and in social situations.[22] Factors such as under-arousal and hypoactivity associated with ADHD may contribute to reduced energy expenditure[34] and thus increased time spent in sedentary behavior. Some research on the correlates of sedentary behavior among youth generally have found that those who pursue more academic and productive pursuits are less likely to engage in sedentary behavior and more likely to have higher levels of physical activity.[65] Adolescents with high TV/video use have also been found to engage in other risky behaviors (e.g., cigarette smoking, delinquency, truancy, etc.).[37] Given that youth with ADHD can experience academic difficulties as well as adverse behavioral health and risky health behaviors,[38,66] it seems plausible that these youth might be more likely to engage in sedentary behavior. In children without clearly diagnosed ADHD, symptoms may also be associated with sedentary behavior. Thus, if the presence of ADHD or its symptoms leads to a greater likelihood to engage in sedentary behavior, general health promotion efforts may be inadequate because they fail to address the influence of underlying symptomatology.

The present study focused on children ages 8-15 years with and without ADHD using data from the National Health and Nutrition Examination Survey (NHANES) 2001-2004, with the goal of determining whether youth with ADHD spent more time in TV watching, non-school related computer use, and overall screen time than their non-ADHD counterparts. We also tested the hypothesis that symptoms of ADHD (hyperactivity/impulsivity and inattention) outside the context of a formal ADHD diagnosis would be associated with screen time in the general population. The present study uses a nationally representative dataset to explore the outcomes of interest, and in contrast to other studies of US youth which interview parents by phone,[1,44] youth who participated in NHANES were interviewed in person about their behavior.

Methods

Screen time was assessed using data combined from the 2001-2002 and 2003-2004 waves from NHANES. NHANES collects data every two years from a representative sample of the US population from infancy through old age. In the 2001-2004 waves of NHANES, the mental health of youth was assessed using a structured diagnostic interview.[49] NHANES uses a stratified, multistage, probability cluster sample, with oversampling of some population groups including Mexican-Americans, blacks, adolescents ages 12-19, and those living under 130% poverty.[67] Probability sampling weights are used to allow the sample to be representative of the civilian non-institutionalized US population. Randomly selected participants are first surveyed in their homes, where demographic, socioeconomic, and some health-related information is collected. A subsequent study visit is conducted in a Mobile Examination Center (MEC), where additional medical, psychiatric, behavioral, dietary, and other data are collected.

NHANES data on the mental health status of youth are restricted and only available to researchers who submit a proposal and conduct analyses via a secure system administered by the National Center for Health Statistics (NCHS) Research Data Center (RDC). Analysis of de-identified data from the survey is exempt from the federal regulations for the protection of human research participants. Use of restricted data through the NCHS RDC is approved by the NCHS Research Ethics Review Board. The study was also reviewed and deemed exempt by the University of Massachusetts Medical School Institutional Review Board.

Measures

Main predictor: attention deficit/hyperactivity disorder. Participants with ADHD were classified by combining information available from the structured diagnostic interview administered by NHANES personnel and parent report. NHANES used the National Institute of Mental Health (NIMH) Diagnostic Interview Schedule for Children (version IV) (DISC-IV)[49] to assess the presence of past-year symptoms consistent with DSM-IV diagnostic criteria for mental disorders in children and adolescents. The DISC-IV was administered to parents by telephone, and youth were considered to have ADHD if they met DSM-IV diagnostic criteria based on the algorithm developed by the DISC Group at Columbia University.[50] The DISC-IV focuses on current and past-year symptoms, but because stimulant medication reduces ADHD symptoms, treated youth may fail to fulfill full diagnostic criteria.[51]Additionally, we were also interested in lifetime diagnoses of ADHD, so youth were also considered to be positive for ADHD if parents responded affirmatively to the following question, *"Has a doctor or health professional ever told you that [the sample person] had attention deficit disorder?"*

Participants with ADHD were classified further according to medication status. During the DISC-IV interview, respondents were asked a single question, *"In the past year, has [the sample person] taken medication for being overactive, being hyperactive, or having trouble paying attention?"* We classified participants with self-report and/or DISC-IV derived diagnosis as ADHD-Medicated or ADHD-Not Medicated.

To arrive at a diagnosis of ADHD, the DISC-IV interview consisted of querying parents about the presence of ADHD symptoms. Symptom counts, which included 11 inattentive symptoms and 12 hyperactive/impulsive symptoms, were also available for the population as a whole. This permitted an examination of ADHD symptomatology on a continuum, an approach supported by genetic studies[52-54] and latent class analyses[55-57] that suggest that ADHD exists on the extreme end of a continuous trait.

Primary outcome: screen time. Two questions were used to assess screen time: *"Over the past 30 days, on average how many hours per day did [the sample person] sit and watch TV or videos?"*, and *"Over the past 30 days, on average about how many hours per day did [the sample person] use a computer or play computer games [outside of work or school]?"* Response categories include: none, less than an hour, and hour-long increments up to 5 or more hours. TV and computer time were assessed separately and also combined to create a total sedentary time outcome variable. This approach has been used in prior research using NHANES data to estimate sedentary time in youth.[61] We also created a binary variable (yes/no) to categorize youth who exceeded recommended amounts of screen time, which the American Academy of Pediatrics has suggested be no more than 2 hours per day.[60]

Covariates. Sociodemographic characteristics and potentially confounding variables were included in the analyses. These included age, sex, race/ethnicity, and poverty-to-income ratio (PIR). Age was calculated from birth date and interview date. Race/ethnicity was based on self-report and was categorized as non-Hispanic white, non-Hispanic black, and Hispanic/other race. The PIR was used to classify the poverty status of participants. The PIR is the ratio of reported income to the poverty threshold appropriate for household size; those who were at or below 130 percent of the poverty threshold (PIR ≤ 1.3) were classified as being low income, and those above 130 percent (PIR > 1.3) were considered above low income. A PIR of 1.3 is the threshold for qualifying for the Supplemental Nutrition Assistance Program.[68] Data on depression and anxiety were also available from the DISC-IV interview and were combined as one variable (depression/anxiety) because the frequency was low for each, and because these conditions frequently co-occur in ADHD.[69,70] Medication status (yes/no) was also included as a covariate in the symptom count models.

Statistical Analysis

The present study compares hours of TV viewing, computer use, and total screen time as well as the likelihood of exceeding guidelines which specify that youth should engage in no more than 2 hours of screen time per day. We examined these outcomes by making the following comparisons: (1) between youth with and without ADHD; (2) between youth without ADHD and those with ADHD who took medication in the past year and those who did not take medication; and (3) an assessment of the associations between hyperactive/impulsive or inattentive symptoms and screen time.

Data from the 2001-2002 and 2003-2004 waves of NHANES were combined according to NCHS guidelines.[71] Analyses were restricted to youth aged 8 to 15 years who had data available on ADHD, key outcomes, and covariates. Sample weights were applied to ensure that estimates would be representative of U.S. youth ages 8 to 15 years in 2001-2004. We tabulated associations between descriptive characteristics, ADHD status (Any ADHD, ADHD-Medicated, ADHD-Not Medicated, No ADHD) as well as symptom counts and key outcomes using design-corrected chi-square and t-tests to assess statistical significance of differences. Multivariable logistic regression models were used to estimate the odds (95% confidence interval [CI]) of engagement in screen time beyond recommended amounts (i.e., >2 hours time spent watching TV, using the computer, and overall screen time) for youth with ADHD who were medicated and for youth with ADHD who were not medicated, each compared to youth without ADHD. We also examined these associations using hyperactive/impulsive and inattentive symptom counts. Unadjusted odds ratios (ORs) and ORs adjusted for age (as a continuous variable), race/ethnicity, PIR, and depression/anxiety are presented. Regression models that assessed associations with symptom counts also included medication status as a covariate.

Because prior research has identified differences among boys and girls and also younger versus older children with respect to sedentary behavior in the general population, interaction terms for sex (male/female) and for age (ages 8-11 or 12-15 years) were evaluated. Where interaction terms were significant, stratified results are presented separately. All analyses were conducted using Stata statistical software, version 12.0 (College Station, TX) on-site at the Boston Research Data Center located at the National Bureau of Economic Research in Cambridge, MA.

Results

Sample Characteristics

As shown in Figure 2.1, of the 3,907 youth aged 8-15 years who participated in NHANES 2001-2004, 78.5% had data on ADHD status (n=3,069). Of these, less than 1% (n=3) were missing data on sedentary behavior, 3.8% (n=117) were missing data on poverty, and 1% of the remaining sample (n=31) was missing data on depression/anxiety. This yielded a final sample of 2,918 participants, which represents 26,038,898 of the population of youth ages 8-15 years living in the United States at the time. Participants missing data on ADHD were more likely to be younger than those who had data on ADHD (11.3 years vs. 11.6 years, p=0.03), were more likely to have a PIR ≤ 1.3 (39% vs. 29%; p=0.007), and also differed by race/ethnicity (p=0.007). There were no differences by missing data status for sex (p=0.37) or depression/anxiety (p=0.95).

As shown in Table 2.1, the overall prevalence of ADHD was 13% (n=375); of these, 32% (n=121) were diagnosed by the DISC-IV alone, 43% (n=162) according only to self-report, and 25% (n=92) were diagnosed by both the DISC-IV and self-report. The remaining 2,543 participants in the cohort were classified as not having ADHD ("No ADHD"). Of the 375 youth with ADHD, 58% (n=216) had not received medication in the prior year for problems with attention or hyperactivity. Youth with ADHD were more likely to be male, and were more likely to have depression or anxiety. ADHD status differed by race/ethnicity, but there were no differences overall relative to poverty status (poverty-to-income ratio [PIR]) in youth with ADHD compared to youth without ADHD. Youth with PIR ≤ 1.3 were less likely to receive medication.

Relative to symptom counts, the mean(SE) of hyperactive/impulsive symptoms was 1.8(0.10) for youth ages 8-11 years and 1.4(0.07) for youth ages 12-15 years (p=0.002). The mean(SE) of inattentive symptoms was 2.5(0.11) for youth ages 8-11 years and 2.3(0.11) for youth ages 12-15 years (p=0.14). Compared to females, males were more likely to have hyperactive/impulsive symptoms (mean(SE) 1.9(0.09) vs.

1.3(0.05); p<0.001) as well as more inattentive symptoms (2.9(0.012) vs. 1.9(0.11); p<0.001). Hyperactive/impulsive symptoms varied by race/ethnicity (p=0.001), and this was also true for inattentive symptoms (p=0.12). Low income youth (PIR ≤ 1.3) had more hyperactive/impulsive symptoms (mean(SE) 2.2(0.11)) compared to youth above low income (mean(SE) 1.4(0.05); p=0.001). A similar pattern was observed with inattentive symptoms (mean(SE) 2.3(0.11) for PIR > 1.3 vs. 2.7(0.14) for PIR ≤ 1.3; p=0.001). Finally, youth with depression/anxiety had more hyperactive/impulsive symptoms than did youth without depression/anxiety (mean(SE) 3.6(0.39) vs. 1.6(0.06); p<0.001), with a similar pattern for inattentive symptoms (mean(SE) 6.1(0.38) vs. 2.3(0.09); p<0.001).

Screen Time and ADHD Diagnosis

The NHANES population had an average of a little over two hours per day of TV viewing, an hour or less of computer time, and slightly over three hours per day of total screen time. Notably, over half (57%) of youth without ADHD exceeded screen time recommendations, and 63% of youth with ADHD overall exceeded guidelines. Similar rates were observed for youth who had not taken medication in the prior year (62%) and those who had taken medication (65.5%). Overall, mean screen time did not differ between youth with and without ADHD (Table 2.2).

In logistic regression analyses that explored whether youth with ADHD were more likely to exceed recommendations for 2 hours spent on screen time, youth with ADHD generally were 31% more likely to exceed these recommendations compared to youth without ADHD (OR 1.31 (95% CI 1.03-1.66), p=0.03). However, after adjusting for sex, age, race, poverty status, and depression/anxiety, this association was attenuated to a 26% greater likelihood and was no longer statistically significant (OR 1.26 (95% CI 0.99-1.61), p=0.06) (Table 2.2). Medicated youth were 42% more likely to engage in more than 2 hours of screen time compared to youth without ADHD (OR 1.42 (95% CI 1.05-1.93); p=0.03), but after adjustment with the aforementioned covariates, this difference was no longer statistically significant (OR 1.33(95% CI 0.99-1.81); p=0.06). There were no significant interactions found for sex or age for any of the outcomes (Table 2.2).

Screen Time and ADHD Symptomatology

In examining the association between hyperactive/impulsive or inattentive symptoms with screen time, hyperactive/impulsive symptoms were associated with over two hours of daily TV viewing after adjusting for covariates (OR 1.05 (95% CI 1.0-1.09), p=0.04). Each increase in hyperactive/impulsive symptoms was associated with a 5% higher likelihood of over two hours of TV viewing per day. Likewise, hyperactive symptoms were also associated with overall increased screen time (OR 1.06 (95% CI 1.00-1.11); p=0.03); each unit increase in hyperactive symptoms increased the likelihood of spending more than 2 hours of screen time per day by 6% (Table 2.3). No statistically significant relationships were found for screen time and inattentive symptoms.

There was a significant interaction by age (p=0.02) but not by sex (p=0.63) for spending more than 2 hours in screen time. In children ages 8-11 years, each additional hyperactive/impulsive symptom was associated with an 8% higher likelihood of spending more than 2 hours per day in screen time (OR 1.08 (95% CI 1.00-1.16), p=0.04). In adolescents (ages 12-15 years), hyperactive/impulsive symptoms were not associated with increased screen time (OR 1.01(95% CI 0.94-1.09), p=0.80).

Discussion

The findings presented here suggest that overall, youth with and without ADHD spent roughly equivalent amounts of time in TV viewing or computer use. At a population level, the presence of hyperactive/inattentive symptoms, irrespective of diagnostic thresholds, was associated with increased TV viewing and total daily screen time.

When assessing the categorical diagnoses, there was a trend for youth with ADHD to engage in more screen time, but this association was attenuated by adjustment for potential confounders, suggesting that much of the impact was accounted for by sociodemographic factors. The sample size may have also accounted for the borderline significance (p=0.06) observed for this association. In a much larger study of 66,707 children ages 6-17 years enrolled in the 2003 National Survey of Children's Health (NSCH), Kim et al.[1] found that compared to youth without ADHD, un-medicated girls with ADHD had increased odds for more than two hours of screen time (OR=1.60, 95% CI=1.20-2.13). In a later wave of the NSCH in 2007, Cook et al.[44] found no differences in sedentary behavior between youth with and without ADHD, irrespective of medication status. However, the authors did not conduct separate analyses of sedentary behavior between boys and girls with ADHD.

In our study, we found no differences between girls and boys, and that having taken medication in the past year appeared to increase screen time, though again, these findings were of borderline significance. The reasons for this finding, given the limitations of the available data, are not clear. The medicated youth in this sample had higher levels of both TV watching and computer use than did the other youth in the sample, thus yielding higher amounts of overall screen time. Medications are frequently given to help children with ADHD focus on school and other goal-directed behaviors, so it is possible that pharmacotherapy might also have an unintended consequence of facilitating engagement in higher levels of screen time. However, it is also possible that youth who receive medication have more severe symptomatology or other concomitant behavior problems,[72] and thus engagement in screen time reflects an ADHD effect rather than a medication effect per se. Assessing symptom severity and the presence of behavior problems was not possible with the data provided by NHANES, but this is an area for future research.

Our findings are consistent with some evidence that has been previously reported. Egmond-Fröhlich et al.[3] found that ADHD symptoms in youth ages 11-16 years in Germany were associated with television viewing, as did Ebenegger and colleagues[73] in their study of 450 pre-school children in Switzerland. Our analysis of the associations between symptom counts and screen time provides an opportunity to assess these relationships on a population level. The statistically significant association between increased TV and total screen time and hyperactive/impulsive symptoms suggests that increased sedentary behavior is correlated with fidgetiness and impulsivity. The NHANES is a cross-sectional study, which does not permit conclusions to be drawn about the temporality or causality of the observed associations. Therefore, it is unclear if the observations made in these data indicate that hyperactivity and impulsivity are the cause or consequence of sedentary behavior, as some have suggested for television viewing and internet/gaming.[74]

Although evidence from studies conducted with youth generally have suggested that sedentary behavior increases with age,[61,75] our study suggests that ADHD symptoms had less of an impact for adolescents than for younger children. It is possible that younger children have more dysregulated symptomatology and thus have fewer opportunities to engage in other activities, rendering them more likely to engage in higher levels of screen time. However, the present analysis did not permit an examination of symptom severity or the extent to which children's symptoms were under control; thus, the reasons why hyperactive/impulsive symptomatology exclusively was associated with screen time for younger children remains unknown. Nevertheless, these results suggest that younger children with hyperactive/impulsive symptoms may have an elevated risk, and thus their vulnerability for engaging in excessive amounts of screen time should be a focus of anticipatory guidance and clinical concern for health care providers, school personnel, and parents.

The findings presented here should be considered in light of the limitations of this study. NHANES collected data about children with ADHD only between 2001 and 2004, thus limiting the sample size and precluding any analysis of secular trends in ADHD prevalence or in media use. Sedentary behavior was estimated by only two close-ended questions about TV and computer use, and thus it was not possible to ascertain whether screen time differed between weekdays and weekends, or the types of TV viewing or computer use in which participants engaged. The single question about past-year medication use limits the ability to understand whether youth who were continuously medicated were different from those who use medication episodically or who had used medication in the past year but discontinued it. The outcomes were based on parent or self-report, which may introduce some reporting bias; research has shown that youth tend to under-estimate their sedentary behavior.[76] If so, it is possible that the findings here represent conservative estimates of sedentary time.

In spite of these limitations, the data presented here suggest that hyperactivity and impulsivity are associated with suboptimal levels of TV viewing and screen time. However, the question remains whether ADHD-related symptoms increase the risk for screen time or whether increased screen time contributes to symptomatology. Longitudinal studies to elucidate this relationship are warranted, especially in light of our society's changing and increasingly pervasive media usage.

Figure 2.1. Flow chart of missing data for youth ages 8-15 years participating in NHANES interviews about sedentary behavior.

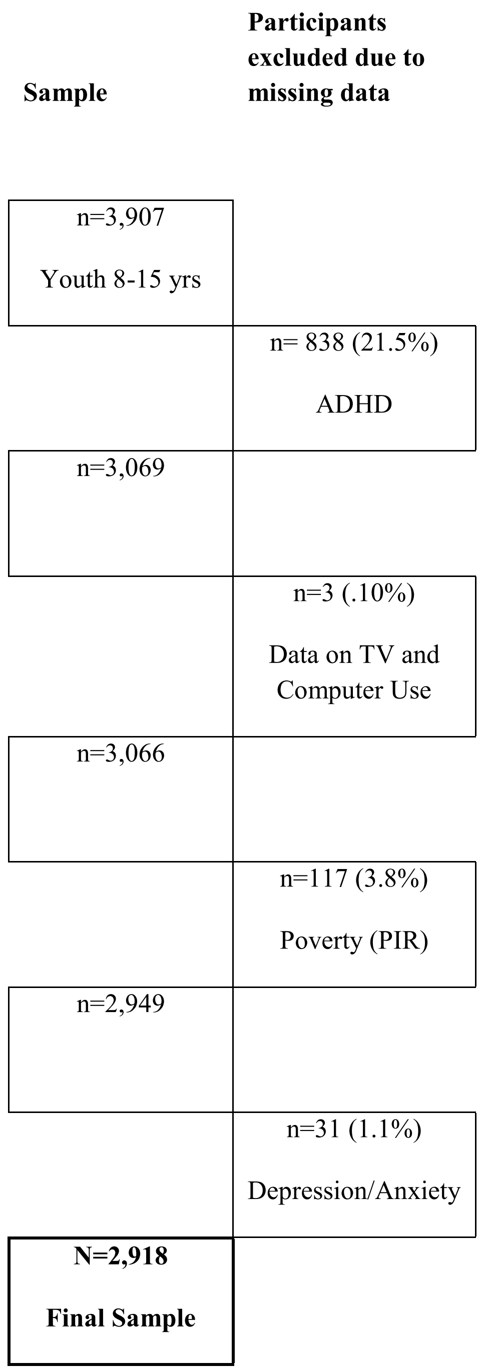

Table 2.1. Demographic characteristics by diagnostic category and medication status.

Weighted N = 26,038,898 youth ages 8-15 years Characteristic:		No ADHD n = 2543[a]	Any ADHD n = 375[a]	p-value*	ADHD-Not Medicated n = 216[a]	ADHD-Medicated n = 159[a]	p-value**
Age: mean(SE)[b]		11.61(0.06)	11.27(0.23)	0.16	11.04(0.27)	11.55(0.24)	0.10
Sex: n[a](%)[b]	Male	1172(48.43)	256(69.43)	<0.001	135(64.32)	121(75.81)	<0.001
	Female	1371(51.57)	119(30.57)		81(35.68)	38(24.19)	
Race: n[a](%)[b]	Non-Hispanic White	738(62.56)	138(69.70)	0.03	74(70.58)	64(68.61)	0.09
	Non-Hispanic Black	831(14.42)	142(15.27)		85(16.83)	57(13.32)	
	Hispanic/Other Race	974(23.02)	95(15.03)		57(12.59)	38(18.07)	
Poverty Status: n[a](%)[b]	>1.3PIR	1549(71.54)	220(67.50)	0.22	115(61.13)	105(75.44)	0.016
	≤1.3 PIR	994(28.46)	155(32.50)		101(38.87)	54(24.56)	

	No ADHD	Any ADHD	p-value*	ADHD-Not Medicated	ADHD-Medicated	p-value**
Depression/anxiety: n[a](%)[b]	51(1.73)	29(5.39)	<0.001	20(6.93)	9(3.47)	<0.001
Hours per day TV viewing: mean(SE)[b]	2.24(0.05)	2.33(0.10)	0.37	2.28(0.11)	2.40(0.14)	0.52
Hours per day of computer use: mean(SE)[b]	0.92(0.04)	0.89(0.10)	0.74	0.78(0.10)	1.02(0.16)	0.30
Hours per day total screen time: mean(SE)[b]	3.16(0.07)	3.22(0.16)	0.70	3.06(0.16)	3.42(0.21)	0.22
Number(%) who exceed screen time guidelines[b,c]	1512(57.1)	246(63.4)	0.03	142(62.0)	104(65.5)	0.04

[a] Unweighted n's
[b] Weighted mean/SE & percentages (%)
[c] Screen time guidelines are no more than 2 hrs/day of screen time
* Any ADHD vs. No ADHD
** ADHD-Not Medicated or ADHD-Medicated vs. No ADHD

Table 2.2. Associations between ADHD and screen time, by diagnosis and medication status.[1]

Outcomes	No ADHD		Any ADHD OR (95% CI)[2]	Any ADHD p-value*	ADHD-Not Medicated OR (95% CI)[2]	ADHD-Not Medicated p-value*	ADHD-Medicated OR (95% CI)[2]	ADHD-Medicated p-value**
>2 hours per day TV viewing	Ref	Unadjusted	1.3(0.95-1.72)	0.11	1.1(0.78-1.65)	0.50	1.5(0.99-2.20)	0.05
		Adjusted[3]	1.2(0.88-1.66)	0.24	1.1(0.72-1.56)	0.76	1.4(0.92-2.15)	0.11
>2 hours per day computer use	Ref	Unadjusted	0.9(0.55-1.45)	0.64	0.70(0.40-1.21)	0.19	1.2(0.57-2.36)	0.68
		Adjusted[3]	0.8(0.47-1.25)	0.28	0.60(0.34-1.07)	0.08	0.97(0.48-1.97)	0.93
>2 hours per day total screen time	Ref	Unadjusted	1.3(1.03-1.66)	0.03	1.2(0.90-1.66)	0.18	1.4(1.05-1.93)	0.03
		Adjusted[3]	1.3(0.99-1.61)	0.06	1.2(0.89-1.65)	0.22	1.3(0.99-1.81)	0.06

[1] Logistic regression
[2] Odds ratios and 95% confidence intervals
[3] Models adjusted for age, sex, race/ethnicity, PIR, and depression/anxiety
* Any ADHD vs. No ADHD
** ADHD-Not Medicated or ADHD-Medicated vs. No ADHD

Table 2.3. Associations between ADHD symptomatology and screen time.[1]

		Hyperactive/Impulsive Symptoms		**Inattentive Symptoms**	
Outcomes		OR (95% CI)[2]	p-value	OR (95% CI)[2]	p-value
>2 hours per day TV viewing	Unadjusted	1.05(1.01-1.10)	0.03	1.04(1.00-1.09)	0.05
	Adjusted[3]	1.05(1.00-1.09)	0.04	1.04(0.99-1.10)	0.08
>2 hours per day computer use	Unadjusted	1.05(0.96-1.14)	0.27	1.04(0.98-1.10)	0.22
	Adjusted[3]	1.07(0.97-1.17)	0.16	1.01(0.95-1.09)	0.68
>2 hours per day total screen time	Unadjusted	1.05(1.00-1.11)	0.05	1.03(0.98-1.07)	0.22
	Adjusted[3]	1.06(1.01-1.11)	0.03	1.02(0.98-1.06)	0.32

[1] Logistic regression
[2] Odds ratios and 95% confidence intervals
[3] Adjusted for age, sex, race/ethnicity, PIR, depression/anxiety, and medication use

CHAPTER III

PHYSICAL ACTIVITY PARTICIPATION IN ADOLESCENTS WITH AND WITHOUT ATTENTION DEFICIT/HYPERACTIVITY DISORDER

Abstract

Objective. To compare physical activity (PA) participation between adolescents with and without attention deficit/hyperactivity disorder (ADHD).

Study design. We included 1,689 adolescents ages 12-15 years who participated in the National Health and Nutrition Examination Survey (NHANES) 2001-2004, which included a DSM-IV-based interview to identify youth with ADHD and also captured symptom counts for hyperactivity/impulsivity and inattention. Youth reported physical activities they had participated in over the past month, and the frequency and duration of their participation. We examined the number of activities, the duration of PA on average, and the intensity in metabolic equivalents (METs) among youth.

Results. The majority of youth did not meet recommended guidelines for PA participation. Less than half of all youth, irrespective of ADHD status, acquired 60 minutes or more of PA per day; 36% of youth without ADHD met guidelines compared to 41% of youth with ADHD (p=0.30). There were no differences in guideline attainment for non-medicated youth or medicated youth compared to youth without ADHD (36% and 46%, respectively; p=0.28). Youth with and without ADHD were similar relative to the number of PA activities, duration, and intensity. The presence of ADHD symptomatology was also not associated with PA participation.

Conclusion. The results from this study show that while there are no differences between youth with and without ADHD, PA participation is low for all adolescents. Public health efforts to support increased PA participation among all youth are urgently needed.

Introduction

Attention deficit/hyperactivity disorder (ADHD) is one of the most common neurodevelopmental disorders of childhood; current estimates indicate a prevalence of ADHD in up to 18% of school-age children.[19-21] Core features of ADHD include developmentally inappropriate levels of inattention, impulsivity, distractibility, and motoric over-activity. These behaviors cause functional impairment and occur across settings such as school, home, and in social situations.[22] Participation in regular physical activity (PA) is key to promoting good health and well-being for all youth,[77,78] but some evidence suggests that youth with ADHD have equally low or even lower levels of PA than youth generally.[1,44] The extent to which the features of ADHD impact health behaviors such as PA is not well understood. Some evidence has suggested that youth with ADHD participate less and experience less enjoyment in sports and leisure activities.[42,43,79] Under-arousal and hypo-activity associated with inattentive features of ADHD may also contribute to reduced energy expenditure.[34]

The goal of this study was to compare participation in PA between adolescents with and without ADHD by assessing time spent in moderate and vigorous physical activity, the average number of physical activities they reported engaging in, and the metabolic equivalents (METs) they acquired, the latter of which allowed us to evaluate PA intensity. Finally, we assessed whether youth with ADHD were less likely to meet recommended guidelines of participating in PA 60 minutes per day on most days of the week.[80] We hypothesized that youth with ADHD would engage in fewer physical activities, would engage in physical activity for less time, and would be less likely to meet national guidelines than their non-ADHD counterparts. We examined whether there would be differences between youth based on medication status, since stimulant medications often quell ADHD symptomatology.[81] We also examined these outcomes by examining their associations with ADHD-related symptomatology, i.e., hyperactive/impulsive or inattentive symptoms.

To our knowledge, this is the first study to examine these outcomes using data from the National Health and Nutrition Examination Survey (NHANES), a nationally representative dataset that evaluates the health of the population of the United States. Although other nationally representative surveys have investigated the physical activity of youth with ADHD, they have either been studies conducted outside of the United States or have used other U.S. national datasets such as the National Survey of Children's Health (NSCH),[1,44] which collects data via phone interviews with parents rather than the youth themselves, and uses a single question to estimate participation in physical activity (i.e., *"During the past week, on how many days did [selected child] exercise, play a sport, or participate in physical activity for at least 20 minutes that made [him/her] sweat and breathe hard?"*). NHANES uses a more detailed structured interview to query youth about their physical activity participation, and enables youth to report on their own activities rather than rely on proxy reporting by parents. The NHANES interview provides an opportunity to evaluate the number of physical activities youth participated in, the amount of time they spent in physical activity, and the intensity of their participation.

Methods

Data Source

Data from NHANES 2001-2002 and 2003-2004 were combined. These are the most recent waves in which the mental health of youth, including ADHD, was assessed using a structured diagnostic interview. Since 1999, NHANES has been collected every two years from a representative sample of the US population of all ages (infancy through old age). NHANES uses a stratified, multistage, probability cluster sample, with oversampling of some populations, including Mexican-Americans, blacks, adolescents ages 12-19, and those living under 130% poverty.[67] Probability sampling weights permit the sample to be representative of the civilian non-institutionalized US population. In the first study visit, randomly selected participants are interviewed in their homes, where demographic, socioeconomic, and some health-related information are obtained via survey. For participants who are children or adolescents, an identified adult in the household answers questions about demographic and family economic status. In a subsequent study visit conducted in a Mobile Examination Center (MEC), additional medical, psychiatric, behavioral, dietary, and other data are collected. For this study, we included youth ages 12 to 15 years who had data available on ADHD, physical activity, and the aforementioned covariates (n=1,689).

NHANES restricts access to data on the mental health status of youth to researchers who submit a proposal and conduct analyses via a secure system administered by the National Center for Health Statistics (NCHS) Research Data Center (RDC). Analysis of de-identified data from the survey is exempt from the federal regulations for the protection of human research participants. Analysis of restricted data through the NCHS RDC was approved by the NCHS Research Ethics Review Board. The study was also reviewed and deemed exempt by the University of Massachusetts Medical School Institutional Review Board.

Measures

Main predictor: attention deficit/hyperactivity disorder. Classification of participants with ADHD was achieved by combining information available from the structured diagnostic interview administered by NHANES personnel and parent self-report. NHANES used the National Institute of Mental Health Diagnostic Interview Schedule for Children (version IV) (DISC-IV), a diagnostic interview that assesses the presence of past-year symptoms consistent with DSM-IV and ICD-10 diagnostic criteria for mental disorders in children and adolescents, with established reliability and validity.[49] In NHANES, the DISC-IV was administered to parents by telephone. Youth were considered to have ADHD if they met DSM-IV diagnostic criteria based on the algorithm developed by the DISC development group at Columbia University.[49,50] The DISC-IV focuses on current and past-year symptoms, but because stimulant medication reduces ADHD symptoms, treated youth may fail to fulfill full diagnostic criteria.[51] Additionally, we were interested in lifetime diagnoses of ADHD beyond its presence over the previous year. Thus, we also classified youth with ADHD if their parents responded positively to the following question: *"Has a doctor or health professional ever told you that [the sample person] had attention deficit disorder?"*

We also classified youth with ADHD based on whether they had taken medication for ADHD in the previous year. During the DISC-IV interview, respondents were asked a single question, *"In the past year, has [the sample person] taken medication for being overactive, being hyperactive, or having trouble paying attention?"* Participants with self-report and/or DISC-IV derived diagnosis were classified as ADHD-Medicated or ADHD-Not Medicated.

Finally, all participants were assessed with the DISC-IV interview, which yielded ADHD symptom counts. We used the symptom count (18 DSM-IV symptoms and five additional symptoms, resulting in 11 inattentive symptoms and 12 hyperactive symptoms) to assess the relationship between key outcomes and symptomatology. Some genetic studies[52-54] and latent class analyses[55-57] have suggested that examining symptom counts is a viable method for research on ADHD, arguing that the diagnosis ADHD is the extreme end of a continuous trait.

Outcomes.

Time spent in PA. Youth ages 12-15 who participated in NHANES completed a physical activity questionnaire within the MEC where they indicated whether or not they had participated in any moderate or vigorous activities over the previous 30 days. Moderate activity was defined as engaging in activities that "caused light sweating or a slight to moderate increase in breathing or heart rate," and vigorous intensity was defined as activities that "caused heavy sweating or large increases in breathing or heart rate." Participants who did not report 10 or more minutes of moderate or vigorous activities were assigned a value of "0" (zero) for their time spent in PA. Participants who endorsed moderate or vigorous participation for more than 10 minutes were asked to indicate both the frequency and duration of their participation in PA during the past month from a list of 47 different activities, with an opportunity to indicate any activities not on the list. These questions were only asked of adolescents ages 12-15 years, thus precluding younger children in the present analysis. Listed activities included sports such as baseball, football, skating, skiing, and soccer, other activities such as dance, hiking, yoga, walking, and swimming, and exercises such as weight lifting, treadmill, sit-ups, and pushups. Participants reported on the frequency (times per day, week, or month) and the average duration per session (minutes or hours per day) for each activity. Time spent in each physical activity was converted to minutes by NHANES; these values were summed for each participant to obtain estimates of total time spent in PA in minutes over 30 days, which was divided by 4.3 to obtain weekly PA estimates in minutes. For each participant, if the reported time for any individual activity exceeded 12 hour or more hours per day, it was set to missing by NHANES. Additional visual inspection of individual cases for values exceeding ten hours per day for total participation were examined to assess the potential for miscoding or implausible values (none were found).

Intensity of PA participation. For each activity, a metabolic equivalent score (MET) was provided by NHANES according to established guidelines.[82] The metabolic equivalent of task (MET) is a method for expressing the energy cost of physical activities, and provides an assessment of intensity. One (1) MET is the energy equivalent expended by an individual while seated at rest. For example, an activity with a MET value of 6 indicates that 6 times the energy is expended than the energy expended at rest. MET minutes are the time engaged in an activity with consideration to the number of

METs. For example, 120 minutes of a moderate activity such as walking (3 METs) is equal to 360 MET minutes. However, half as much time (60 minutes) spent on a 6-MET activity such as running results in an equivalent MET-minute score.[83] We calculated MET minutes by multiplying the number of activities and the time spent in each by the MET value provided by NHANES.[84]

Number of activities. The number of activities participants engaged in were calculated by summing the activities that youth reported they had taken part in over the previous month.

Meeting recommended guidelines for PA participation. We created a binary variable (yes/no) for determining whether youth met the physical activity guidelines of 60 minutes of PA per day.[80] Youth acquiring 1,806 or more minutes per month (equivalent to an average of 60 minutes per day of PA) were coded as "1" (Yes), indicating that they were in alignment with recommended guidelines. Youth with less than 1,806 minutes per month were coded as "0" (No) and were considered not to meet recommended guidelines.

Covariates. Socio-demographic characteristics and potentially confounding variables were included in the analyses. These included age, sex, race/ethnicity, and poverty-to-income ratio (PIR). Age was calculated from birth date and interview date and was included as a continuous variable in statistical models. Race/ethnicity was categorized as non-Hispanic white, non-Hispanic black, or Hispanic/other race. PIR is the ratio of reported income to the poverty threshold appropriate for household size. We categorized PIR as ≤ 1.3 to signify low income, which is the threshold for qualifying for the Supplemental Nutrition Assistance Program.[68] PIR scores > 1.3 indicate non-low income status. Data on depression and anxiety were available from the DISC-IV interview and were combined as one variable (depression/anxiety) because the frequency was low for each and depression and anxiety frequently co-occur in ADHD.[69,70] Medication status is also included as a covariate in the models for symptom counts (yes/no).

Statistical Analysis

All analyses were conducted using Stata statistical software, version 12.0 (College Station, TX) on site at the Boston Research Data Center (RDC) located at the National Bureau of Economic Research in Cambridge, MA. We combined data from the 2001-02 and 2003-04 waves of NHANES according to NCHS guidelines.[71] Our analyses were restricted to youth ages 12 to 15 years who had data available on ADHD, key outcomes, and covariates. Sample weights were applied to ensure estimates would be representative of U.S. youth ages 12 to 15 years in 2001-2004. Outcome variables were assessed for implausible outliers and collinearity, with none found. Variables that did not follow a normal distribution (i.e., minutes spent in PA, MET minutes) were log-transformed. For the count of physical activities, both linear regression and Poisson regression were employed to assess its relationship with the aforementioned predictors. As there were no differences in the results for log-transformed variables or for those assessed by Poisson vs. linear regression, untransformed means and/or linear regression beta coefficients are presented for ease of interpretability and correspondence across models.

Associations between the aforementioned outcomes, predictors, and covariates were assessed using design-corrected chi-square tests, t-tests, or Pearson correlations to assess statistical significance of differences. Linear regression models were used to estimate the associations between youth with and without ADHD and to evaluate whether medication status (medicated or not medicated) differed from youth without ADHD. Logistic regression was used to compare the likelihood of youth with ADHD meeting PA guidelines compared to youth without ADHD. Linear regression models were also used to assess whether PA outcomes were associated with ADHD symptom counts. All models were adjusted for age (as a continuous variable), race/ethnicity, PIR, and depression/anxiety. Statistical models that evaluated the relationship of symptom counts to PA outcomes were also adjusted for medication use.

Results

Demographic Characteristics

Of the 2,395 youth aged 12-15 years who participated in NHANES 2001-2004, 80% (n=1,917) had data on ADHD status. Of these, 8% (n=145) were missing data on physical activity, slightly less than 4% (n=65) were missing data on poverty status (PIR), and 1% (n=18) were missing data on depression/anxiety. This yielded a final sample of 1,689 youth, which represents 12,554,392 youth ages 12-15 living in the United States (see Figure 3.1). The amount of missing data did not differ between youth with and without ADHD. Those who were missing data on ADHD did not differ on sex (p=0.43), age (p=0.15), race/ethnicity (p=0.11), or depression/anxiety (p=0.48), but were more likely to be classified as low income (PIR $\leq$ 1.3) (p=0.003).

The prevalence of ADHD was 12% (n=199), with 21% (n=43) diagnosed on the DISC-IV alone, 54% (n=109) by parent self-report, and 24% (n=47) meeting criteria both on the DISC-IV and self-report. Of the 199 youth with ADHD, 45% had taken ADHD medication in the prior year. Youth with ADHD were more likely to be male, and were more likely to have depression/anxiety than youth without ADHD.

Relative to symptom counts, the mean(SE) of hyperactive/inattention symptoms was 1.4(0.07) across the cohort, and the interquartile range was 3 symptoms. The mean(SE) and interquartile range of inattentive symptoms was 2.3(0.11) and 4 symptoms, respectively. Hyperactive/impulsive symptoms varied by race/ethnicity ($p=0.007$), but this was not the case for inattentive symptoms ($p=0.21$). Low income youth (PIR $\leq$ 1.3) had more hyperactive/impulsive symptoms (mean(SE) 1.8(0.14)) compared to non-low-income youth (mean(SE) 1.3(0.09); $p=0.008$). There was no difference between the income groups on inattentive symptoms (mean(SE) 2.3(0.15) for PIR > 1.3 vs. 2.3(0.17) for PIR $\leq$ 1.3, $p=0.71$). Finally, youth with depression/anxiety had more hyperactive/impulsive symptoms than did youth without depression/anxiety (mean(SE) 3.9(0.58) vs. 1.3(0.06); $p<0.001$), with a similar pattern for inattentive symptoms (mean(SE) 6.0(0.05) vs. 2.2(0.11); $p<0.001$).

Physical Activity Outcomes

As shown in Table 3.1, the number of activities, average minutes spent in PA per week, and intensity (as assessed by MET minutes) did not differ between youth with and without ADHD. Although the mean number of minutes spent in PA per week was between 455 and 515, which is equivalent to between 65 and 73 minutes per day, the median for minutes of PA participation was 289 minutes per week, or about 41 minutes per day. Consequently, less than half the adolescents in all groups met the PA guidelines of 60 minutes or more of moderate-to-vigorous PA each day. Thirty-six percent (36%) of youth without ADHD met PA guidelines compared to 41% of youth with ADHD (p=0.30). Among youth with ADHD, 36% of non-medicated youth and 46% of youth who had been on medication during the prior year met PA guidelines, and these rates were not different in comparison to youth without ADHD (p=0.28). All youth, regardless of diagnosed ADHD, medication status, or symptom counts, participated in approximately 3 different activities on average over the past month.

In multivariable regression models that were adjusted for sex, age, race/ethnicity, poverty status, and depression/anxiety, the lack of significant differences for all PA outcomes persisted between youth with and without ADHD. The PA outcomes also did not differ by medication status or ADHD symptomatology. With regard to the likelihood of exceeding recommendations for participation in PA, there were no differences among any of the groups or by ADHD symptomatology.

Discussion

We found that less than half of all youth in the cohort as a whole met physical activity recommendations for engagement in PA, which is consistent with other reports that suggest PA participation is low among the nation's youth.[85-87] Contrary to our hypotheses, youth with ADHD were not less physically active than those without ADHD; no differences in the number of activities, time spent, or intensity of PA were observed among any of the groups assessed. Neither hyperactive/impulsive nor inattentive symptoms were associated with PA.

Most prior research conducted on youth with ADHD with respect to PA participation has largely focused on efforts to describe hyperactivity or the impact of exercise on the amelioration of symptoms rather than participation in moderate/vigorous physical activity from a health promotion perspective.[88-91] Of the studies that have attempted to examine physical activity levels in youth, the findings are mixed. In a study of 1,172 Western Australian youth, Howard et al.[2] found that youth with ADHD were less likely than their non-ADHD counterparts to exercise 2-6 times per week. Likewise, in a longitudinal study of 8,106 of children over 8 years of follow-up, Khalife et al.[92] found that ADHD identified in childhood predicted lower levels of physical activity in adolescents. Kim et al.[1] used data from 66,707 children ages 6-17 years enrolled in the 2003 National Survey of Children's Health and found that compared to controls, youth with ADHD had elevated odds for low physical activity (i.e., participation in moderate-vigorous PA less than 3 days/week), and odds were greatest for girls not receiving medication. In all of these studies, PA participation was ascertained by asking youth a single question about the amount of time they spent in PA during the week.

In contrast, other studies have found that ADHD symptomatology or youth diagnosed with ADHD are more likely to be physically active than their counterparts without ADHD. Van Egmond-Fröhlich et al.[3] examined 11,676 German children using self-report data on leisure time from youth ages 11-16 who were asked to report the hours per week they engaged in physical activity that made them sweat or get out of breath. They found that ADHD symptomatology was significantly and positively associated with medium-to-high physical activity. In a small study of 20 school-aged boys with ADHD and matched controls using accelerometry to assess PA levels, Lin et al.[93] found that youth with ADHD had higher levels of PA and spent more time in moderate-to-vigorous PA than controls. Likewise, a study using a community sample of 450 children ages 4-6 in Switzerland found that higher scores of hyperactive/inattention were associated with higher levels of physical activity as measured by accelerometry.[73] Although the latter two studies are small and one of the studies includes younger children than those that were included in our NHANES analysis, their use of accelerometry provides an objective measure of PA. The results of these studies suggest that children with ADHD have higher PA levels than their non-ADHD counterparts. It is possible that accelerometers detect purposeful physical activity as well as hyperactivity, which could account for higher levels of PA. Whether hyperactive behavior that is not necessarily goal-directed confers the same health benefits as engagement in purposeful PA is a question to be answered, and could have important implications for youth with ADHD.

The findings of the present study sit in the middle of these disparate findings, offering evidence that while PA participation is low among youth generally, youth with ADHD are not differentially affected, though self-report data on PA is not highly reliable or valid.[94] Regardless, the results do suggest that efforts to increase PA participation among the nation's youth must continue.[95]

The strengths of this study include the use of NHANES, a nationally representative sample of youth. The advantage of NHANES over other national datasets in the U.S. that provide data about youth with ADHD is that ADHD was ascertained via a structured interview based on DSM-IV criteria, which allowed us to identify youth who had not previously received an ADHD diagnosis (n=23). The DISC-IV interview also generated hyperactive/impulsive and inattentive symptom counts, allowing for an analysis of the impact of ADHD symptomatology on a population basis. Regardless, these findings should be considered in light of several limitations. PA in this study was based on self-report, and as noted, the use of questionnaires to assess physical activity is known to have limitations.[94] Self-report methods for PA participation are particularly subject to several sources of error or bias, including inaccurate recall and intentional misreporting, which can include social desirability bias.[96] In general, individuals tend to over-estimate their engagement in PA.[97] In contrast to self-reported PA levels, a study that used NHANES 2003-2004 to assess adherence to guidelines based on accelerometry data, which found that only about 8% of adolescents ages 12-19 years participated in 60 minutes or more of PA per day.[86] Accelerometry was not used in NHANES in 2001-2002, which precluded its use in this dissertation.

It is not possible to determine from the available data whether youth with ADHD would have been more or less likely to report inflated PA levels, although previous literature suggests that youth with ADHD may be more likely to engage in “positive illusory bias” wherein they over-estimate and/or over-report their competence or skills.[98,99] If this were the case for the present study, it could suggest that youth with ADHD may engage in lower levels of PA than they reported during their NHANES interviews.

Future research on PA in adolescents with ADHD should make use of objective measures, such as accelerometry. Studies in younger children using this methodology suggest higher levels of PA in youth with ADHD than in their non-ADHD peers, but whether this association persists into adolescence remains unknown. Differentiating between purposeful engagement PA and the hyperactivity associated with ADHD would also merit further investigation, including whether movement associated with hyperactivity itself confers health benefits.

Figure 3.1. Flow chart of missing data for youth ages 12-15 years participating in NHANES interviews about physical activity participation.

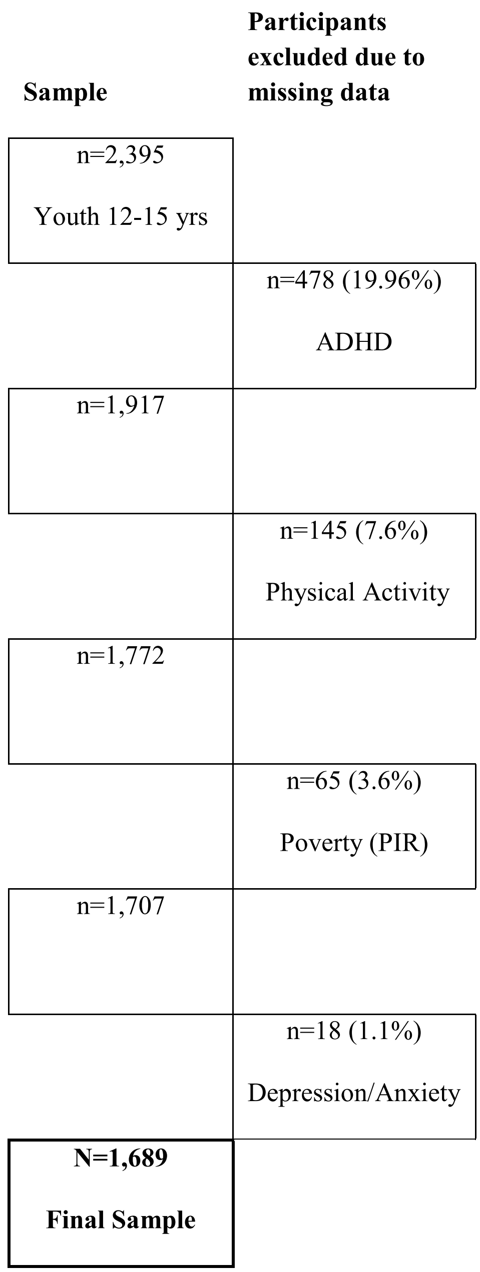

Table 3.1. Demographic characteristics by diagnostic category and medication status.

Weighted N=12,554,392 youth ages 12-15 yrs		No ADHD	Any ADHD		ADHD Not Medicated	ADHD Medicated	
Characteristic/Outcome:		**n = 1490[1]**	**n = 199[1]**	**p-value***	**n = 109[1]**	**n = 90[1]**	**p-value***
Age (years): mean(SE)[2]		13.5(0.03)	13.3(0.09)	0.09	13.5(0.13)	13.2(0.12)	0.08
Sex: n(%)[2]	Male	692(47.7)	142(68.5)	0.001	71(59.7)	71(77.6)	<0.002
	Female	798(52.3)	57(31.5)		38(40.3)	19(22.4)	
Race: n(%)[2]	Non-Hispanic white	433(64.2)	80(71.8)	0.22	40(72.0)	40(71.5)	0.42
	Non-Hispanic black	467(14.0)	65(11.6)		37(12.8)	28(10.3)	
	Hispanic/Other race	590(21.8)	54(16.7)		32(15.9)	22(18.2)	
Poverty Status: n(%)[2]	>1.3PIR	952(75.3)	130(75.6)	0.93	63(69.5)	67(81.9)	0.20
	≤1.3 PIR	538(24.7)	69(24.4)		46(30.5)	23(18.1)	

Depression/Anxiety: n(%)	42(2.6)	19(6.7)	0.01	11(7.1)	8(6.3)	0.03
Number of physical activities per week[2]	3.2(0.10)	3.3(0.14)	0.69	3.3(0.22)	3.3(0.26)	0.87
Number of minutes of PA per week[2]	437.6(15.7)	446.6(53.3)	0.86	415.0(67.1)	479(70.8)	0.77
Number of MET minutes per week[2,a]	2864.0(101.2)	2966.1(363.6)	0.77	2654.7(410.2)	3288.0(496.4)	0.54
Number (%) meeting PA guidelines[2,b]	475(35.6)	76(41.2)	0.30	40(36.0)	36(46.4)	0.28

[1] Unweighted n's
[2] Weighted means(SE) and percentages
* Compared to youth without ADHD
[a] Metabolic equivalent of a task (MET) minutes per week
[b] Guidelines are 60+ mins of PA per day

Table 3.2. Associations between ADHD and physical activity outcomes, including by medication status.

Outcome variables		Any ADHD		ADHD-Not Medicated		ADHD-Medicated	
		β(SE)	p-value*	β(SE)	p-value*	β(SE)	p-value*
Number of physical activities per week[1]	Crude	0.06(0.15)	0.69	0.11(0.20)	0.61	0.02(0.28)	0.95
	Adjusted[3]	-0.08(0.17)	0.63	0.01(0.20)	0.95	-0.19(0.32)	0.56
Number of minutes of PA per week[1]	Crude	8.9(51.3)	0.86	-22.7(64.1)	0.73	41.8(70.9)	0.56
	Adjusted[3]	-34.1(56.9)	0.56	-28.5(59.4)	0.63	-39.4(80.8)	0.63
Number of MET minutes per week[1]	Crude	102.1(351.3)	0.77	-209.3(386.0)	0.60	424.9(498.8)	0.40
	Adjusted[3]	201.0(386.0)	0.61	-248.3(356.2)	0.49	149.1(560.7)	0.79
Likelihood of meeting PA guidelines[2]	Crude	1.3(0.80-2.0)	0.30	1.02(0.57-1.8)	0.98	1.6(0.86-2.9)	0.17
	Adjusted[3]	1.2(0.70-2.0)	0.53	0.97(0.55-1.72)	0.94	1.4(0.70-2.8)	0.33

[1] Linear regression
[2] Logistic regression; odds ratio (OR) (95% CI)
[3] Adjusted for age, sex, race/ethnicity, PIR, and depression/anxiety
* Compared to youth without ADHD

Table 3.3. Associations between hyperactive/impulsive and inattentive symptom counts and physical activity outcomes.

		Hyperactive/Impulsive Symptoms		Inattentive Symptoms	
Outcome variables		**β(SE)**	**p-value**	**β(SE)**	**p-value**
Number of physical activities per week[1]	Crude	-0.01(0.03)	0.68	0.02(0.03)	0.64
	Adjusted[3]	0.007(0.03)	0.84	0.01(0.04)	0.80
Number of minutes of PA per week[1]	Crude	4.5(6.2)	0.47	1.04(6.7)	0.87
	Adjusted[3]	12.9(7.6)	0.10	-2.3(7.7)	0.77
Number of MET minutes per week[1]	Crude	56.5(37.1)	0.14	25.0(36.4)	0.50
	Adjusted[3]	105.3(47.7)	0.37	-37.7(44.2)	0.40
Likelihood of meeting PA guidelines[2]	Crude	1.1(1.0-1.2)	0.01	0.99(0.96-1.0)	0.61
	Adjusted[3]	1.0(0.94-1.1)	0.74	0.98(0.94-1.0)	0.58

[1] Linear regression
[2] Logistic regression; odds ratio (OR) (95% CI)
[3] Adjusted for age, sex, race/ethnicity, PIR, and depression/anxiety

CHAPTER IV

ADHD SYMPTOMATOLOGY, DIET QUALITY, AND EATING PATTERNS IN CHILDREN AND YOUTH

Abstract

Objective. To assess the relationship of ADHD symptomatology with diet quality, consumption of sugar-sweetened beverages, total caloric intake, and eating frequency among youth ages 8-15 years.

Method. We included 2,854 children and adolescents ages 8-15 years who participated in the National Health and Nutrition Examination Survey (NHANES) 2001-2004. These waves included a DSM-IV-based interview to identify youth with ADHD and captured symptom counts for hyperactivity/impulsivity and inattention across the interviewed sample. Dietary intake patterns including diet quality, as measured by the Healthy Eating Index 2005 (HEI-2005), total energy intake, sugar-sweetened beverage (SSB) consumption, and eating frequency as determined by the number of eating occasions, were obtained from a single 24-hour diet recall. The association of these intake patterns with ADHD-related symptomatology was assessed via multiple linear regression.

Results. Diet quality was universally poor among all youth, independent of ADHD symptomatology; the average total HEI-2005 score was 48.6 (out of a total 100). The relationships of hyperactivity/impulsivity and inattentive symptoms with total HEI-2005 scores were modified by age group and sex. In children ages 8-11 years, each unit increase in hyperactive/impulsive symptoms decreased the overall HEI-2005 score by an average of 0.48 points (p=0.03). In adolescents ages 12-15 years, each unit increase in hyperactive/impulsive symptoms was associated with a decrease in the total HEI score by

0.58 points on average (p=0.03). A similar finding was also observed for inattentive symptoms, but only in adolescents (p=0.02). In males, the presence of hyperactive/impulsive symptoms was associated with a decrease in diet quality (p=0.01), whereas in females, inattentive symptoms were associated with a decrease in diet quality (p=0.05). ADHD symptomatology was not associated with total energy intake, SSB consumption, or eating frequency.

Conclusion. To our knowledge, this is the first study using nationally representative data to examine diet quality and eating patterns and ADHD symptomatology among youth in the United States. Diet quality was poor for all youth, and ADHD symptomatology was associated with even poorer diet quality across the population. Efforts to address healthy eating should be a focus for all children, and youth with ADHD and ADHD symptomatology should be included in anticipatory guidance efforts.

Introduction

Attention deficit/hyperactivity disorder (ADHD) is one of the most common neurodevelopmental disorders of childhood; the prevalence of ADHD has been estimated to be as high as 18% of the population.[19-21] Core features include developmentally inappropriate levels of inattention, impulsivity, distractibility, and motoric over-activity or hyperactivity.[100] Youth with ADHD experience elevated rates of academic, behavioral, and psychiatric disorders compared to youth generally.[101] There is growing interest in dietary intake and eating patterns among children, especially in light of the current obesity epidemic. Irrespective of weight status, poor diet confers negative health risks; research shows that dietary patterns established in childhood have implications for adult health status, including osteoporosis,[12] several cancers,[14-16] and coronary heart disease.[13] Emerging research suggests that ADHD and/or its symptomatology may increase the risk for poor diet and subsequent obesity.[4-9,102-105] Specifically, both inattention and impulsivity affect the regulation of food intake, which may be related to the role of dopamine dysfunction in eating behavior.[24] Research also shows that dysfunction of the dopamine receptor genes gives rise to "reward deficiency syndrome" wherein an individual is unable to derive reward from normal everyday activities, does not experience satiety at normal levels, and thus engages in elevated levels of pleasure-seeking behavior.[27,28] This may extend to the consumption of highly palatable but low-nutrient dense foods.

There is limited research on the association between ADHD symptomatology and eating patterns in youth, and to our knowledge, no studies have been conducted in the

United States. A handful of studies conducted in youth from Germany,[3] Australia,[2] and Korea[106,107] suggest that youth with ADHD or ADHD-related symptoms consume less healthy diets overall and have diets characterized by higher intakes of fat, sugar, sodium, and sugar-sweetened beverages (SSBs). Some evidence also suggests that adolescents and adults diagnosed with ADHD may be more likely to snack often, eat between meals, and consume larger volumes of food than their non-ADHD counterparts.[108,109] Increased eating frequency and portion sizes are associated with increased energy intake among the general population.[110]

If ADHD symptomatology is associated with poor diet quality, then standard approaches to health promotion may be inadequate because they fail to address the influence of underlying symptomatology. The present study focuses on children ages 8-15 years using data from National Health and Nutrition Examination Survey (NHANES) 2001-2004; to our knowledge, this is the first study to use nationally representative data on children living in the US to examine the association of ADHD symptomatology to dietary behaviors. We hypothesized that ADHD symptomatology would be associated with a lower quality diet, greater energy intake, greater sugar-sweetened beverage consumption, and increased eating frequency.

Methods

Data from the 2001-2002 and 2003-2004 waves of the National Health and Nutrition Examination Surveys (NHANES) were combined to examine the outcomes of interest. These are the most recent waves in which the mental health of youth was assessed using a structured diagnostic interview. Since 1999, NHANES has been collected continuously using a stratified, multistage, probability sampling design that provides a nationally representative sample of the civilian, non-institutionalized US population. In these two waves, NHANES oversampled Mexican-Americans, blacks, adolescents ages 12-19, and those living under 130% poverty.[67] Data for NHANES are collected during an at-home visit, in which demographic, socioeconomic, and health-related information are obtained via survey. In a subsequent study visit in a Mobile Examination Center (MEC), medical, psychiatric, behavioral, and dietary intake data are collected. For participants who are minors, a parent or guardian provides consent, the child or adolescent provides assent, and an identified adult provides demographic and family income information.

NHANES restricts access to data on the mental health status of youth to researchers who submit a proposal and conduct analyses via a secure system administered by the National Center for Health Statistics (NCHS) Research Data Center (RDC). Analysis of de-identified data from the survey is exempt from the federal regulations for the protection of human research participants. Analysis of restricted data through the NCHS RDC is approved by the NCHS Research Ethics Review Board. The study was also reviewed and deemed exempt by the Institutional Review Board at the University of Massachusetts Medical School.

Measures

Main predictor: ADHD symptomatology. NHANES used the National Institute of Mental Health (NIMH) Diagnostic Interview Schedule for Children (version IV) (DISC-IV), a diagnostic interview that assesses the presence of past-year symptoms consistent with DSM-IV diagnostic criteria for mental disorders in children and adolescents, with established reliability and validity. [49] In NHANES 2001-2004, ADHD was one of the conditions assessed using the DISC-IV, which was administered to parents by telephone. We used ADHD symptom count variables, which included 11 inattentive symptoms and 12 hyperactive/impulsive symptoms for the present analysis, which allowed for an examination of ADHD symptomatology on a continuum. Genetic studies[52-54] and latent class analyses[55-57] have suggested that conceptualizing ADHD as existing on a continuum may provide an alternative to classifying it solely on a categorical basis. In other words, ADHD exists at the extreme end of a continuous trait.

Outcomes: dietary intake patterns. During the MEC exam, participants completed a 24-hour dietary recall, in which an interviewer asked them to recall everything they had to eat and drink on the prior day using the Automated Multiple Pass Method (AMPM), a standardized, multi-pass dietary interview. Youth 12 years and older completed the recall on their own, and proxy-assisted interviews by parents were conducted with children 6-11 years of age. Previous research has shown that the AMPM is valid for assessing dietary intakes in children.[111] In the 2001-2002 waves of NHANES, only one dietary recall was obtained, thus the current study includes only one recall for all participants. Whereas multiple recalls are ideal for measuring usual dietary intake, a single recall is valid for estimating dietary intake for populations.[45]

Diet quality. The HEI-2005 was used to measure diet quality. The HEI-2005 is based on the *Dietary Guidelines for Americans 2005* (DGA), which underlies U.S. nutrition policy and guidance. Dietary adequacy is assessed by comparing intakes with guideline recommendations for foods including (but not limited to) fruit, vegetables, legumes, grains, milk, meat, beans, eggs, fish, and oils. Three additional components, for which moderation is recommended, are saturated fat, sodium, and calories from solid fats, alcohol, and added sugars (SoFAAS). For these three additional components, higher scores are indicative of intakes closer to the recommended ranges and thus better diet quality, whereas lower scores indicate intakes that are less in compliance with the recommended intakes. The total HEI-2005 score is the sum of 12 dietary components, each of which is weighted equally, generating a maximum total HEI-2005 score of 100. With the exception of energy from SoFAAS, the HEI-2005 uses a density approach (per 1,000 calories) to reflect the 2005 DGA recommendation to meet food group and nutrient needs while maintaining energy balance.[112] The HEI-2005 scoring system has very high concordance with other exemplar menus including the Harvard Healthy Eating Pyramid and the NHLBI DASH Eating Plan.[112] Total and component HEI-2005 scores were determined for each participant using the MyPyramid Equivalents Database,[113] the 2003-2004 addendum,[114] and SAS code made publicly available by the USDA.[115] For monitoring diet quality of populations, using the overall diet quality score is the most useful approach.[112] A cut-point score of 50 or below has been suggested for classifying for overall diet quality as “poor.”[112,116]

Sugar-sweetened beverages. SSB consumption was computed using the classification system of the Food and Nutrient Database for Dietary Studies (FNDDS) which categorizes soft drinks, juices, juice drinks, energy drinks, flavored milks, powdered beverages, sweet tea, coffee drinks, smoothies, and fast-food milkshake/icecream drinks as SSBs. The FNDDS database provides the nutrient values for foods and beverages reported in the dietary intake component of NHANES.[117]

Energy intake. Total energy intake (calorie consumption) was determined for each participant using the Total Nutrients File for the 24-hour diet recall.

Eating frequency. We defined eating frequency as the number of eating occasions reported over the 24-hour recall period. The AMPM uses probes to collect detailed information on the name and timing of each eating occasion. We defined an eating occasion as any distinct time when a participant reported consuming at least one food or beverage item, excluding water.

Covariates. Socio-demographic characteristics and potentially confounding variables were included in the analyses. These included age, sex, race/ethnicity, and poverty-to-income ratio (PIR). Age was calculated from birth date and interview date. Race/ethnicity was based on self-report by participants and was categorized as non-Hispanic white, non-Hispanic black, and Hispanic/other race. Poverty-income-ratio (PIR), the ratio of reported income to the poverty threshold appropriate for household size, was categorized as ≤ 1.3 to signify low income, and is the threshold for qualifying for the Supplemental Nutrition Assistance Program.[68] Data on depression and anxiety were available from the DISC-IV interview and were combined as one variable (depression/anxiety) because the frequency was low for each, and these conditions frequently co-occur in ADHD.[69,70] Because some youth in the sample were treated with ADHD medication (n=179), medication status was also included as a covariate. This was determined by parental response to a question that asked if their child had taken medication in the past year for being overactive, hyperactive, or having trouble paying attention. This variable was coded as “1” for yes and “0” for no.

Statistical Analysis

Data from the 2001-02 and 2003-04 waves of NHANES were combined according to NCHS guidelines.[71] Our analyses were restricted to youth aged 8 to 15 years who had data available on ADHD symptomatology, dietary intake patterns, and covariates. All analyses were conducted using SAS 9.4 (SAS, Cary, NC) and Stata statistical software, version 12.0 (College Station, Texas). Sample weights were applied to ensure estimates would be representative of U.S. youth ages 8 to 15 years in 2001-04.

Dietary intake pattern variables were assessed for implausible outliers, with none being identified. Predictors were checked for multi-collinearity via variance inflation factor which yielded no collinear variables. We assessed associations between predictors, covariates, and outcomes using design-corrected chi-square or t-tests to assess statistical significance of differences. Linear regression models were employed to estimate associations between dietary intake patterns and hyperactive/impulsive and inattentive symptoms. All models were adjusted for age (as a continuous variable), race/ethnicity, PIR, depression/anxiety, and medication use. Height and weight were also considered for inclusion in the model assessing total calorie intake and symptomatology in order to account for body size, but were not retained in the final model, as the relationship was not significant after adjustment by the aforementioned sociodemographic covariates. For count variables (i.e., SSB intake and eating occasions), both linear regression and Poisson regression were employed to assess the relationship between these outcomes and ADHD symptomatology. As there were no differences in results, means and/or linear regression beta coefficients are reported for ease of interpretability and correspondence across models.

Because prior research has identified differences among boys and girls and also younger versus older children with respect to diet quality, interaction terms for sex (male/female) and for age (ages 8-11 or 12-15 years) were evaluated. Where interaction terms were significant, stratified results are presented separately.

Results

Of the 3,907 youth aged 8-15 years who participated in NHANES 2001-2004, 3,620 children and adolescents (92.7%) participated in the dietary interview at the MEC. Of these, 623 (17.2 %) were missing data on ADHD symptomatology. Approximately 3.7% (n=111) of these youth were missing data on poverty, and 1.1% (n=32) were missing data on depression/anxiety. This yielded a final sample of 2,854 participants, representing 26,478,107 youth ages 8-15 years living in the United States (Figure 4.1). Participants with missing data on symptomatology were more likely to be younger than those who had data on symptomatology (11.3 years vs. 11.6 years, p=0.03), more likely to have a PIR ≤ 1.3 (39% vs. 29%; p=0.007), and also differed by race/ethnicity (p=0.007). There were no differences by missing data status for sex (p=0.37) or depression/anxiety (p=0.95).

As shown on Table 4.1, the mean (SE) of symptom counts across the population of youth ages 8-15 years was 1.7(2.5) for hyperactive/impulsive symptoms, and 2.4(2.9) for inattentive symptoms. The median of symptom counts was one (1) symptom for both types of symptoms. The interquartile range for hyperactive/impulsive symptoms was 3 symptoms and 4 symptoms for inattentive symptoms. Males had more hyperactive/impulsive and inattentive symptoms than females. There were no racial/ethnic differences for hyperactive/impulsive or inattentive symptoms. Youth with a poverty-to-income ratio (PIR) of 1.3 or below had more hyperactive/impulsive and inattentive symptoms than those who had a PIR > 1.3. Likewise, youth with anxiety and depression had more inattentive and hyperactive/impulsive symptoms than did youth without depression or anxiety.

Diet Quality

Total HEI-2005 scores suggest that diet quality is poor across all youth; the mean(SE) HEI 2005 score across the population was 48.6(0.71) (out of a total 100) (Table 4.2). As shown in Table 4.3, when examining the relationship between overall diet quality and hyperactive/impulsive symptoms, we found a statistically significant effect modification by age group (p=0.02). Specifically, in younger children, for every symptom unit increase in hyperactive/impulsive symptoms, diet quality decreased by an average 0.49 points (β(SE)= -0.49(0.21); p=0.03); in adolescents, each unit increase in hyperactive/impulsive symptoms was associated with a decrease in diet quality by 0.58 points on average (β(SE)= -0.58(0.23); p=0.03). The relationship between inattentive symptoms and diet quality was also significantly modified by age group; however, when stratified, the relationship was only statistically significant in adolescents (β(SE)= -0.40(0.17); p=0.02). The relationships of diet quality with hyperactive/impulsive symptoms and inattentive symptoms, respectively, were both modified by sex as well (p=0.17 and p=0.03, respectively). In males, the presence of hyperactive/impulsive symptoms was associated with a decrease in diet quality (β(SE)= -0.55(0.20), p=0.01), whereas in females, inattentive symptoms accounted for a decrease in diet quality (β(SE)= -0.34(0.17), p=0.05). The relationships between the individual HEI-2005 component scores, hyperactive/impulsive symptoms, inattentive symptoms, and interaction terms can be found in the Ancillary Table 4.5.

Sugar-Sweetened Beverage Consumption, Total Energy Intake, and Eating Frequency

Table 4.2 shows the population means for these dietary patterns. On average, youth consumed a little over 2½ servings of SSBs (mean(SE) 2.7(0.07)), and took in a mean(SE) of 2162(31.6) calories in the previous 24 hours. Youth also reported a mean(SE) of 5.0(0.05) eating occasions. We observed no statistically significant relationships of hyperactive/impulsive or inattentive symptoms with total energy intake or SSB consumption, and age group and sex did not significantly modify the relationships with ADHD symptomatology. Hyperactive/impulsive symptoms were associated with a small but statistically significant increase in eating frequency; for every one unit increase in hyperactive/impulsive symptoms, there was a 0.07 increase in eating occasions (β(SE)=0.07(.02); p<0.002), but this was not significantly associated with increased energy intake. Eating frequency was not associated with inattentive symptoms.

Discussion

Diet quality was generally poor as evidenced by an overall HEI-2005 score of 48.6 points across the population. This is consistent with previous reports.[118] We found that lower diet quality was associated with hyperactive/impulsive symptoms overall. Hyperactive/impulsive symptoms were associated with lower diet quality in boys and inattentive symptoms accounted for lower diet quality in girls. However, we found no evidence of statistically significant relationships between ADHD symptomatology and SSB consumption, total energy intake, or eating frequency.

Our findings on diet quality are consistent with four other, non-U.S. studies that examined dietary patterns and diet quality in youth with ADHD or ADHD symptomatology. In Korea, Park et al.[106] examined the diets of 986 community-dwelling youth, 186 of whom had ADHD or probable ADHD based on the DISC-IV. Using a mini-dietary assessment consisting of 10 items based on dietary guidelines and the food pyramid for Koreans, the authors calculated an overall healthy dietary score. They found that ADHD symptomatology was negatively associated with a balanced diet. A case-control study by Woo et al.[107] studied 192 children ages 7-12 years seen in university hospitals in Busan, Korea, half of whom (n=96) had ADHD ascertained via clinical records. The authors used three non-consecutive 24-hour recalls to assess dietary intake, and classified children's diets into "traditional," "seaweed-egg," "traditional-healthy," and "snack" patterns, to reflect the dietary patterns of that country. The "traditional-healthy" dietary pattern, which represented diets composed of high intakes of kimchi, grains, bonefish, and low intake of fast-foods and beverages, was associated with lower odds of having ADHD.

Two large population-based studies in Australia[2] and Germany[3] reported similar findings to the current study. Howard et al. examined the relationship between dietary patterns and ADHD in a population-based cohort of adolescents in Australia using the Western Australian Pregnancy Cohort Study.[2] The authors conducted a 14-year follow-up of 2,688 children and families in this cohort that included a food frequency questionnaire (FFQ) and questionnaires on demographic and lifestyle factors. ADHD status was classified by parental report on whether a qualified health professional had ever diagnosed their adolescent with ADHD. Data from FFQs were labeled as "Healthy" or "Western," the latter being characterized by higher intakes of total fat, saturated fat, refined sugar, and sodium, and lower intakes of omega-3 fatty acids, fiber, and folate. The "Healthy" dietary pattern was classified in the reverse, i.e., lower intakes of the aforementioned food components and higher intakes of omega-3 fatty acids, fiber, and folate. Each participant received a score for both dietary patterns and were dichotomized as "high" or "low." The authors found that adolescents with a high score for the "Western" dietary pattern were more than twice as likely to have received an ADHD diagnosis. ADHD was not associated with a high score for the "Healthy" dietary pattern. The authors also examined specific foods that contributed to dietary patterns and found that ADHD was associated with a greater likelihood of consuming take-away foods, red meat, processed meat, high-fat dairy, and soft drinks.

In Germany, van Egmond-Fröhlich et al.[3] used data on 11,967 children ages 6-17 years from the German Health Interview & Examination Survey for Children & Adolescents, a nationally representative cross-sectional dataset of children living in Germany. Parents completed the Strengths and Difficulties Questionnaire which included a Hyperactivity/Inattention subscale of 5 items that tapped symptoms. Dietary assessment was accomplished via a FFQ that contained 9 beverages and 36 food items querying usual intake over the last few weeks, and was used to calculate the ratio between food intake and age- and sex-specific dietary recommendations. They found that youth with ADHD symptomatology had lower nutritional quality scores and also higher beverage volume and energy density. They also found that girls with ADHD symptomatology had stronger associations with these variables compared to boys.

Our findings, in conjunction with the others summarized here, suggest that ADHD symptomatology increases risk for poorer diet quality in children and adolescents, though as noted, poor diet quality is problematic for the population of children and youth as a whole. In contrast to expectations, we did not find any significant relationships among ADHD symptomatology and total energy intake or SSB consumption. Aside from cultural differences that may account for consumption patterns, the different dietary assessment methods used may have yielded different findings than ours relative to SSB consumption. Studies using semi-quantitative food frequency questionnaires typically assess usual intake over a longer period of time (i.e., past month or past year). In contrast, a 24-hour dietary recall represents what a participant ate over the course of one day but in more detail (e.g., portion sizes and food preparation) than an FFQ.

As a cross-sectional study, the temporality of the observed associations between ADHD symptoms and dietary intake patterns cannot be determined. Although evidence has largely invalidated the myth that sugar contributes to or is causal of hyperactivity,[119] it is nevertheless possible that poor diet quality could contribute to poorer cognition and academic achievement.[120] However, it is also possible that ADHD symptomatology influences dietary intake patterns and eating behaviors. Inattentiveness has been shown to be associated with reduced awareness of internal hunger and satiety cues, especially when the individual is engaged in other activities.[105,121] Impulsivity has been shown to be associated with overeating and weight gain[122-124] and also eating pathology.[125,126] Lowe[127] opined that impulsivity may lead to difficulty inhibiting the consumption of high energy-dense palatable foods, especially in response to stress and other cues. Our finding that hyperactive/impulsive symptoms were associated with lower diet quality lends some support to this hypothesis, though the circumstances under which adolescents in NHANES consumed foods was not possible to determine.

The sex differences we observed are of interest; in males, hyperactive/impulsive symptoms were found to be associated with lower diet quality (β(SE)= -0.55(0.20), p=0.01), whereas in females, inattentive symptoms were associated with lower diet quality scores (β(SE)= -0.34(0.17), p=0.05). In youth diagnosed with ADHD, hyperactive/impulsive symptoms are more common in males, and females are more likely to have inattentive symptoms.[128] Further, overall symptomatology severity is often higher in males.[129] An area worthy of future research would be to determine whether different symptom typologies are predictive of dietary intake patterns in males and females.

The strengths of the present study include the use of a nationally representative dataset and the use of DSM-IV criteria to ascertain the presence of ADHD symptomatology. A rigorous method for conducting the in-person diet recall, i.e., the Automated Multiple Pass Method, was employed to assess food intake over the previous 24 hours. However, several limitations are worth noting. Only one 24-hour recall was used in the present study. While this has been shown to be valid for assessing population intakes,[45] multiple recalls typically yield data that reflect a more accurate picture of usual intake. The ecological validity of this study also warrants mention, since the youth participated in the NHANES 2001-2004 waves over a decade ago. The U.S. food environment and food supply have continued to change over time,[130] as have dietary guidelines,[131] so caution must be taken when drawing conclusions about present-day youth based on data collected in the past.

The results presented in this study suggest that diet quality is poor for youth overall, and that ADHD symptomatology is associated with even poorer diet quality. Dietary adequacy is a focus of Healthy People 2020, which calls for increased fruit and vegetable consumption, increased intake of whole grains, and decreased consumption of solid fats, sugars, and sodium.[132] Pediatric providers, educators, and parents should be aware that children and adolescents with ADHD-related symptoms may be even more vulnerable to sub-optimal eating habits than their non-affected peers, and thus should provide guidance early on to help shape healthy eating patterns.

Figure 4.1. Flow chart of missing data for youth ages 8-15 years participating in NHANES 24-hour dietary recall.

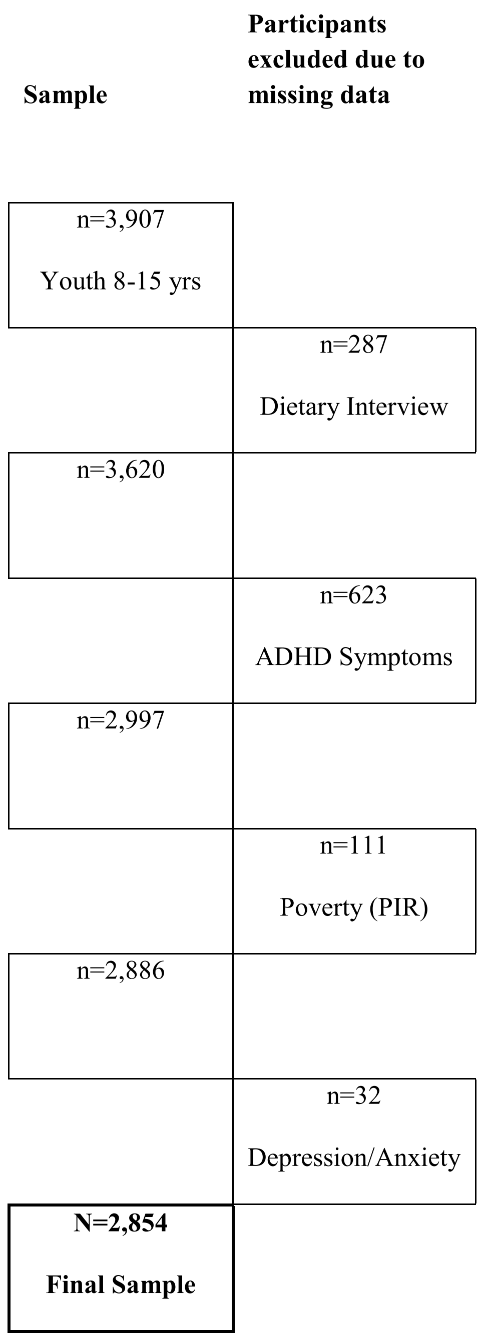

Table 4.1. Demographic characteristics and symptom counts for youth ages 8-15 years in NHANES 2001-2004.

Weighted N=26,478,107 youth ages 8-15 yrs			Hyperactive/ Impulsive Symptoms	Inattentive Symptoms
Characteristic:		**n[1]**	**Mean(SE)[2]**	**Mean(SE)[2]**
Overall		2854	1.7(0.04)	2.4(0.05)
Age	8-11 years	1,059	1.8(0.13)	2.5(0.15)
	12-15 years	1795	1.4(0.11)	2.2(0.12)
Sex	Male	1393	1.9(0.10)*	2.8(0.12)*
	Female	1461	1.2(0.08)	1.8(0.10)
Race/Ethnicity	Non-Hispanic White	864	1.47(0.11)	2.33(0.14)
	Non-Hispanic Black	945	2.18(0.14)	2.65(0.15)
	Hispanic/Other	1045	1.62(0.13)	2.13(0.19)
Poverty Status	>1.3 PIR	1733	1.3(0.08)*	2.1(0.11)*

	≤1.3 PIR	1121	2.3(0.15)	2.8(0.15)
Depression/Anxiety		78	3.61(0.44)*	5.90(0.10)*

[1] Unweighted n
[2] Weighted means and percentages
* $p<0.001$

Table 4.2. Diet quality and dietary pattern scores for youth ages 8-15 years in NHANES 2001-2004.

Healthy Eating Index (HEI-2005)	Maximum Score	Mean(SE)[1]
TOTAL HEI-2005 SCORE	100	48.6(0.71)
○ Total Fruit (HEI-1)	5	2.1(0.08)
○ Whole Fruit (HEI-2)	5	1.6(0.09)
○ Total Vegetables (HEI-3)	5	2.2(0.06)
○ Dark Green & Orange Vegetables (HEI-4)	5	0.5(0.06)
○ Total Grains (HEI-5)	5	4.5(0.04)
○ Whole Grains (HEI-6)	5	0.8(0.06)
○ Milk (HEI-7)	10	6.7(0.16)
○ Meat & Beans (HEI-8)	10	7.0(0.15)
○ Oils (HEI-9)	10	5.5(0.13)
○ Saturated Fat (HEI-10)*	10	5.6(0.15)
○ Sodium (HEI-11)*	10	4.5(0.10)
○ Calories from SoFAAS (HEI-12)*	20	7.8(0.28)

Servings of Sugar Sweetened Beverages (SSBs)	2.7(0.07)
Total Calories Consumed	2,162(31.6)
Number of Eating Occasions	5.0(0.05)

[1]Weighted mean(SE)
* Lower scores signify lower compliance with recommended guidelines

Table 4.3. Association between symptom counts and overall Healthy Eating Index (HEI-2005) score.[1,2]

	Overall HEI-2005 Score		Overall HEI-2005 Score by Age				Overall HEI-2005 Score by Sex			
	HEI 2005 Score	**p-value**	**8-11 years**	**p-value**	**12-15 years**	**p-value**	**Boys**	**p-value**	**Girls**	**p-value**
Hyperactive/ Impulsive Symptoms	-0.46(0.16)	0.008	-0.48(0.21)	0.03	-0.58(0.23)	0.02	-0.55(1.0)	0.01	-0.37(0.24)	0.14
Inattentive Symptoms	0.01(0.21)	0.95	0.43(0.30)	0.16	-0.40(0.17)	0.02	0.27(0.29)	0.36	-0.34(0.17)	0.05

[1] Linear regression
[2] Adjusted for age, sex, race, PIR, depression/anxiety, medication status

Table 4.4. Associations between symptom counts and other dietary outcomes.[1,2]

Predictor:	Number of Servings of Sugar-Sweetened Beverages[a]	p-value	Total Calories Consumed Mean(SE)	p-value	Number of Eating Occasions	p-value
Hyperactive/ Impulsive Symptoms	0.03(0.04)	0.50	14.8(12.1)	0.23	0.07(0.02)	0.002
Inattentive Symptoms	0.003(0.04)	0.94	-0.10(13.99)	0.99	-0.01(0.03)	0.70

[1] Linear regression
[2] Adjusted for age, sex, race, poverty status, depression/anxiety, and medication
[a] n = 2424

Ancillary Table

Table 4.5. Associations between Healthy Eating Index component scores and ADHD symptomatology, including by-age and by-sex interactions.

	Hyperactive-Impulsive Symptoms[1]		Inattentive Symptoms[1]			Age[1]						Sex[2]					
	β (SE)	p-value	β (SE)	p-value		Interaction Term β (SE)	p-value	8-11 yr β (SE)	p-value	12-15 yr β (SE)	p-value	Interaction Term β (SE)	p-value	Boys β (SE)	p-value	Girls β (SE)	p-value
Total HEI-2005 Score	-.46 (.16)	.008	.01 (.21)	.95	*Hyp/ Imp*	-.72 (.30)	.02	-.48 (.21)	.03	-.58 (.23)	.02	-.37 (.26)	.17	-.55 (.20)	.01	-.37 (.24)	.14
					Int	-.86 (.29)	.006	.43 (.30)	.15	-.40 (.17)	.02	-.62 (.27)	.03	.28 (.29)	.36	-.34 (.17)	.05
Total Fruit (HEI1)	-.04 (.03)	.25	0.19 (.02)	.44	*Hyp/ Imp*	-.10 (.03)	.006	-.02 (.05)	.70	-.05 (.04)	.17	-.07 (.04)	.09	-.01 (.04)	.76	-.07 (.04)	.09
					Int	-.12 (.03)	<.001	.08 (.04)	.04	.05 (.03)	.13	-.06 (.04)	.16	.03 (.04)	.39	-.003 (.03)	.94
Whole Fruit (HEI2)	-.02 (.03)	.57	-.004 (.03)	.90	*Hyp/ Imp*	-.06 (.03)	.11	-.03 (.05)	.59	-.03 (.04)	.43	-.05 (.04)	.16	-.01 (.05)	.81	-.03 (.04)	.44
					Int	-.08 (.03)	.02	.05 (.04)	.21	-.06 (.03)	.04	-.05 (.04)	.23	.002 (.04)	.95	-.009 (.03)	.78

	Hyperactive -Impulsive Symptoms[1]		Inattentive Symptoms[1]			Age[1]						Sex[2]					
	β (SE)	p-value	β (SE)	p-value		Interaction Term β (SE)	p-value	8-11 yr β (SE)	p-value	12-15 yr β (SE)	p-value	Interaction Term β (SE)	p-value	Boys β (SE)	p-value	Girls β (SE)	p-value
Total Vegs (HEI3)	.02 (.02)	.47	-.03 (.19)	.10	*Hyp/ Imp*	.04 (.04)	.25	.006 (.04)	.87	.04 (.03)	.18	-.03 (.03)	.38	.04 (.03)	.19	-.03 (.03)	.28
					Int	.04 (.02)	.09	-.05 (.03)	.05	-.01 (.03)	.71	.01 (.02)	.46	-.05 (.02)	.05	-.02 (.03)	.47
Drk grn & orng veg (HEI4)	- .003 (.01)	.86	.005 (.02)	.81	*Hyp/ Imp*	-.02 (.03)	.49	-.02 (.03)	.43	.002 (.02)	.93	-.003 (.02)	.86	-.01 (.02)	.60	-.005 (.03)	.84
					Int	-.04 (.03)	.26	.03 (.04)	.53	-.01 (.02)	.54	-.007 (.03)	.78	.02 (.03)	.54	-.01 (.03)	.75
Total grains (HEI5)	-.01 (.01)	.53	-.03 (.01)	.03	*Hyp/ Imp*	.004 (.02)	.84	-.02 (.03)	.48	.0006 (.02)	.97	.02 (.02)	.17	-.03 (.02)	.09	.02 (.02)	.22
					Int	-.01 (.02)	.44	-.01 (.02)	.50	-.04 (.02)	.03	-.01 (.02)	.56	-.02 (.01)	.38	-.04 (.02)	.03
Whole grains (HEI6)	- .000 4 (.02)	.98	-.02 (.02)	.33	*Hyp/ Imp*	-.004 (.04)	.89	.001 (.03)	.97	-.01 (.02)	.69	.03 (.03)	.43	-.02 (.02)	.36	.03 (.02)	.22
					Int	.0004 (.03)	.86	-.02 (.02)	.37	-.01 (.02)	.65	-.003 (.03)	.90	-.007 (.02)	.69	-.03 (.02)	.25

	Hyperactive -Impulsive Symptoms[1]		Inattentive Symptoms[1]			Age[1]						Sex[2]					
	β (SE)	p-value	β (SE)	p-value		Interaction Term β (SE)	p-value	8-11 yr β (SE)	p-value	12-15 yr β (SE)	p-value	Interaction Term β (SE)	p-value	Boys β (SE)	p-value	Girls β (SE)	p-value
Milk (HEI7)	-.07 (.04)	.11	.05 (.05)	.25	*Hyp/ Imp*	-.27 (.10)	.008	.01 (.07)	.87	-.19 (.07)	.02	-.001 (.08)	.99	-.05 (.05)	.30	-.09 (10)	.38
					Int	-.18 (.06)	.006	.09 (.06)	.10	.02 (.06)	.77	.03 (.06)	.70	.04 (.06)	.46	.06 (.07)	.31
Meat & Beans (HEI8)	-.05 (.06)	.43	.003 (.04)	.92	*Hyp/ Imp*	.01 (.07)	.85	-.11 (.10)	.06	.003 (.09)	.98	.11 (.06)	.06	-.11 (.07)	.15	.05 (.07)	.46
					Int	-.09 (.06)	.16	.10 (.05)	.07	-.08 (.05)	.14	.003 (.07)	.96	.04 (.05)	.44	-.05 (.08)	.56
Oils (HEI9)	.03 (.05)	.55	-.04 (.06)	.50	*Hyp/ Imp*	-.19 (.08)	.03	.12 (.09)	.20	-.07 (.07)	.37	.02 (.09)	.82	-.03 (.07)	.68	.13 (.10)	.19
					Int	-.09 (.08)	.30	-.07 (.09)	.44	-.01 (.07)	.84	-.08 (.09)	.39	.007 (.08)	.92	-.10 (.06)	.15
Saturated Fat (HEI10)*	-.03 (.07)	.61	-.05 (.05)	.40	*Hyp/ Imp*	.15 (.08)	.08	-.16 (.03)	.14	.08 (.08)	.32	-.11 (.08)	.18	-.04 (.09)	.68	-.05 (.09)	.61
					Int	-.01 (.06)	.86	.03 (.07)	.73	-.12 (.06)	.06	-.13 (.08)	.12	-.006 (.07)	.93	-.10 (.09)	.26

	Hyperactive -Impulsive Symptoms[1]		Inattentive Symptoms[1]			Age[1]						Sex[2]					
	β (SE)	p-value	β (SE)	p-value		Interaction Term β (SE)	p-value	8-11 yr β (SE)	p-value	12-15 yr β (SE)	p-value	Interaction Term β (SE)	p-value	Boys β (SE)	p-value	Girls β (SE)	p-value
Sodium (HEI11)*	-.02 (.05)	.62	.06 (.04)	.10	*Hyp/ Imp*	-.09 (.07)	.19	-.005 (.07)	.95	-.05 (.05)	.32	-.05 (.05)	.24	-.02 (.07)	.79	-.05 (.05)	.36
					Int	-.08 (.05)	.17	.08 (.07)	.25	.04 (.04)	.26	-.02 (.06)	.78	.06 (.05)	.25	.07 (.05)	.14
Calories from SOFAAS (HEI12)*	-.26 (.11)	.02	.03 (.09)	.74	*Hyp/ Imp*	-.21 (.15)	.19	-.25 (.14)	.08	-.30 (.13)	.03	-.23 (.11)	.05	-.26 (.15)	.09	-.27 (.11)	.02
					Int	-.22 (13)	.09	.13 (.13)	.31	-.07 (08)	.38	-.31 (.13)	.03	.15 (.14)	.29	-.13 (.06)	.02

[1] Statistical models adjusted for age, sex, race, PIR, depression/anxiety, and medication
[2] Statistical models adjusted for age, race, PIR, depression/anxiety, and medication
* Lower scores signify lower compliance with recommended guidelines

CHAPTER V

DISCUSSION AND CONCLUSIONS

The goal of this dissertation was to compare screen time, engagement in physical activity, and diet quality and other dietary behaviors between youth with and without ADHD. We also evaluated whether these outcomes were associated with hyperactive/impulsive or inattentive symptoms. The analyses were performed using nationally representative data from the National Health and Nutrition Examination Survey (NHANES) conducted in 2001-2004, the most recent waves when diagnostic information on the mental health of children and youth was collected.

Taken together, our findings suggest that youth in the United States as a whole are engaging in excessive amounts of screen time, failing to acquire sufficient physical activity, and are consuming diets of poor quality. Our data also suggest that youth with ADHD are at the same, if not at higher risk, for engaging in these suboptimal health behaviors, and likewise, the symptoms of ADHD place youth at higher risk for sedentary behavior and poor diet quality.

Relative to screen time, we found that youth with ADHD showed a trend toward increased screen time, and a trend for youth who took medication sometime in the past year to engage in higher amounts of screen time. ADHD symptoms were also associated with over two hours of daily TV viewing and overall increased screen time, and this was particularly true for children ages 8-11 years. The correlates of screen time in relation to ADHD and/or ADHD symptomatology are not yet well understood. The matter of whether attention difficulties are the cause or the consequence of television viewing has received considerable research attention. Habitual non-educational TV viewing has been hypothesized to contribute to poor educational attainment and reduced cognitive functioning because it is thought to displace reading, homework completion, and also requires little intellectual engagement on the part of the viewer. Alternatively, some have hypothesized that youth with intellectual and cognitive challenges are more likely to engage in excessive TV viewing.[133] A prospective study found that adolescents who watched one or more hours of TV per day were at increased risk for attention difficulties and had elevated rates of poor homework completion, dislike of school, and academic failure, and that those watching more than 3 hours of TV per day had the highest risk for these outcomes.[133] Notably, the researchers classified youth as having "frequent" attention difficulties if they had only one ADHD symptom, which comprised over 20% of their sample. Additional research to shed light on the nature and direction of this association is warranted.

In our analyses that examined time spent in and intensity of physical activity (PA) among youth, we found that while these outcomes did not differ between youth with and without ADHD, the majority of youth were not meeting the recommended guidelines of 60 minutes or more of moderate-to-vigorous PA each day.[80] Most of the research on youth with ADHD and PA has focused on the salutary effects of PA on the cognitive and behavioral symptoms associated with the diagnosis. Although limited, the extant literature supports the findings that PA has a positive impact children's behavior at school and ameliorates the behavioral and cognitive performance of children with ADHD.[89] Given that PA levels were suboptimal in the overall sample of youth that participated in NHANES, including those with ADHD, and evidence that suggests that the functioning of youth with ADHD may be enhanced by engagement in PA, efforts to increase this subpopulation's engagement in PA seems doubly important.

The dietary outcomes we assessed included overall diet quality as measured by the Healthy Eating Index-2005 (HEI-2005), sugar-sweetened beverage (SSB) consumption, total caloric intake, and eating frequency. As with our findings relative to screen time and physical activity, youth overall are not faring well with respect to diet quality, which we found to be poor across the population of youth who participated in NHANES. However, hyperactive/impulsive symptoms were associated with an even greater decrease in diet quality in both children and adolescents. In males, the presence of hyperactive/impulsive symptoms was associated with a decrease in diet quality, whereas in females, inattentive symptoms accounted for a decrease in diet quality. We observed no differences in the other dietary patterns that we assessed (i.e., SSB consumption, total energy intake, and eating frequency). However, youth consumed a little over 2½ servings of SSBs in the previous 24 hours overall, which likely increased their excess sugar intake beyond recommended levels.[134-136]

The underlying reasons that ADHD symptomatology may be related to poorer diet and/or eating habits is not well understood. Evidence suggests that impulsivity is associated with overeating, weight gain, and obesity.[123,124,137] Davis et al.[30] tested a path model that proposed that ADHD is linked to eating pathology, which in turn is linked to body size. They found that ADHD symptomatology was related to various measures of eating pathology including eating in response to negative moods, eating in response to external cues, and binge eating. Whether these factors are also associated with diet quality remains unknown; further research in this area would shed light on this question, which may lead to clinical and/or public health solutions.

Although the effect sizes we detected for differences in youth with ADHD and ADHD-related symptomatology and the key outcomes were modest from a population perspective, the findings are noteworthy. ADHD is one of the most common conditions of childhood, second only to asthma, and thus if ADHD-related symptomatology is associated with suboptimal levels of screen time, physical activity, and dietary patterns, then the population health implications are significant. As noted, the mechanisms for why this subgroup of youth may have increased vulnerability to poorer lifestyle factors is as yet unknown, though it is possible that they are more vulnerable to our current environment, which has become increasingly conducive to overeating and sedentary behavior. In their review of the obesity epidemic, Mitchell et al.[138] write:

> Our environment arose as an unintended consequence of our societal progress. In fact, our environment was likely shaped in large part because of our biological preferences for high energy foods and lack of biological preference to be physically active. The environment we have created is one to which our ancestors aspired, and includes a consistent supply of good-tasting, inexpensive, available food and the ability to not have to work hard to secure food, shelter and transportation. [138(p.5)]

Whether those with ADHD are more vulnerable to environmental cues for poor dietary habits and/or sedentary behavior is an area for future investigation. The tendency toward susceptibility to environmental cues has been found in persons with prefrontal cortex dysfunction,[139] which may extend to those with ADHD. Thus, the current obesogenic environment may be particularly challenging for people with low inhibitory control, given the ubiquity of food cues.[140] For example, impulsivity has been shown to be associated with greater food consumption in an environment with high food variety in contrast to an environment characterized by monotonous foods.[141] Nonetheless, given that the majority of youth who participated in NHANES showed less-than-desirable levels of screen time, physical activity, and diet quality, the population as a whole is susceptible to the toxicities of our current environment. The field of behavioral economics and choice architecture has illustrated human beings' vulnerability to choice-making as being largely rooted in environmental arrangements of cues and prompts.[142]

The suboptimal health behaviors identified here among the population of youth call for broad, public health-based approaches to prompt healthful behaviors for the population as a whole. Such approaches include increasing time spent in physical education during the school day, building in PA breaks in schools, and creating opportunities for youth to travel to school via active transport (e.g., walking, biking). Other efforts to address barriers to PA participation in the built environment and in communities must also be ongoing.[95] Taxing SSBs,[143] addressing the role that the food industry plays in promoting unhealthful eating habits,[144] and revising food subsidy policies[145] have also been suggested. The implications of such policies for the population as a whole as well as subgroups such as youth with ADHD warrant further investigation.

The findings presented in this dissertation should be considered in light of their limitations. NHANES collected data about children with ADHD only between 2001 and 2004, thus limiting the sample size and precluding any analyses of secular trends in ADHD prevalence and the outcomes of interest. As a cross-sectional study, the causal associations between ADHD and/or symptomatology and outcomes cannot be determined. The NHANES survey relied on self-report, which is known for its limitations in reporting and/or recall bias. In spite of these limitations, however, this dissertation also has some strengths, which include the use of a nationally representative sample of youth. Unlike other national datasets in the U.S. that have provided data about youth with ADHD, NHANES used a structured interview based on DSM-IV criteria to identify youth with ADHD, which also generated hyperactive/impulsive and inattentive symptom counts allowing for an analysis of the impact of ADHD symptomatology on a population basis. This study is the first of its kind in the United States to examine the association between ADHD and/or its symptoms and dietary quality and dietary patterns in youth ages 8-15 years, using a rigorous method to collect dietary data.

The findings from this dissertation can be used to generate new hypotheses about the needs of this subpopulation of youth from both public health and clinical perspectives, and to inspire future research on the implications of ADHD-related symptomatology on health-related behaviors and key lifestyle factors.

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