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# Association between Attention-Deficit/Hyperactivity Disorder (ADHD) symptoms and obesity and hypertension in early adulthood: A population-based study

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## Abstract

**Objective—**To examine associations between attention-deficit/hyperactivity disorder (ADHD) symptoms, obesity and hypertension in young adults in a large population-based cohort.

**Design, Setting, and Participants—**The study population consisted of 15,197 respondents from the National Longitudinal Study of Adolescent Health, a nationally representative sample of adolescents followed from 1995 – 2009 in the United States. Multinomial logistic and logistic models examined the odds of overweight, obesity, and hypertension in adulthood in relation to retrospectively reported ADHD symptoms. Latent curve modeling was used to assess the association between symptoms and naturally occurring changes in body mass index (BMI) from adolescence to adulthood.

**Results—**Linear association was identified between the number of inattentive (IN) and hyperactive/impulsive (HI) symptoms and waist-circumference, BMI, diastolic blood pressure, and systolic blood pressure (all ps for trend < .05). Controlling for demographic variables, physical activity, alcohol use, smoking, and depressive symptoms, those with 3 or more HI or IN symptoms had the highest odds of obesity (HI 3+ OR, 1.50; 95% CI, 1.22-2.83; IN 3+ OR, 1.21; 95% CI, 1.02-1.44) compared to those with no HI or IN symptoms. HI symptoms at the 3+ level were significantly associated with a higher OR of hypertension (HI 3+ OR, 1.24; 95% CI 1.01-1.51; HI continuous OR, 1.04; 95% CI 1.00-1.09), but associations were non-significant

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**Conflict of interest**

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when models were adjusted for BMI. Latent growth modeling results indicated that compared to those reporting no HI or IN symptoms, those reporting more 3 or symptoms had higher initial levels of BMI during adolescence. Only HI symptoms were associated with change in BMI.

**Conclusion—**Self-reported ADHD symptoms were associated with adult BMI and change in BMI from adolescence to adulthood, providing further evidence of a link between ADHD symptoms and obesity.

### Keywords

attention-deficit/hyperactivity disorder; obesity; hypertension; young adult; risk factors

## Introduction

Globally, it is estimated that 1.6 billion adults are overweight and 400 million are obese. [1] What was once a public health concern for high income countries is now also a concern among middle- and even low income countries. The causes of obesity range from biological susceptibility to socioenvironmental influence and the interaction among these factors.[2] Understanding both proximal and distal risk factors for obesity are essential to developing targeted interventions.

There is evidence for increased comorbidity of non-eating-related psychiatric disorders and obesity in children and adults.[3] Psychiatric conditions such as depression and post-traumatic stress disorder have been associated with obesity and related chronic diseases, such as hypertension.[4]-[6] Additionally, an increasing number of studies suggest a link between attention-deficit/hyperactivity disorder (ADHD) and obesity.[7] Studies of obese children and adults in clinical settings have documented a higher than expected prevalence of ADHD.[8]-[11] Similarly, a marginally higher prevalence of obesity has been observed among patients with ADHD;[12]-[15] however, this finding is not consistent among all studies.[16], [17]

In addition to these clinic-based studies, a small set of population-based studies have investigated the link between ADHD and obesity. One study using data from the National Survey of Children's Health (NSCH), a telephone survey conducted with parents, found that childhood ADHD was associated with an increased odds (1.5) of obesity in these children.[18] Another study using the Collaborative Psychiatric Epidemiology dataset, combining three population based surveys from the US, found that childhood ADHD persisting into adulthood was associated with an increased likelihood of overweight and obesity (1.58 and 1.81, respectively), even after controlling for depression.[19]

Individuals in the population who exhibit high levels of ADHD symptoms, independent of their clinical diagnosis, are at higher risk for problematic health behaviors including smoking.[20], [21] Studies to date have not examined specifically how sub-threshold ADHD symptoms contribute to risk for obesity. However, a small but growing body of literature has demonstrated that certain characteristics commonly seen among individuals with ADHD (e.g., inability to delay gratification, sensitivity to reward, and inability to inhibit motor responses) are more prevalent among obese children and prospectively predict childhood obesity risk.[22]-[27] These findings support the notion that ADHD symptoms assessed on a dimensional scale, not necessarily a categorical diagnosis, are relevant to the association with obesity.

The purpose of the present study was to examine associations between ADHD symptoms, obesity and hypertension in young adults in a large population-based cohort from the US. This study extends previous research on ADHD clinical status and obesity by 1) examining the influence of sub-clinical ADHD *symptoms* and by 2) investigating the specific role of inattentive and hyperactive-impulsive symptoms alone and in combination. Given that psychosocial and psychiatric factors have also been implicated as risk factors for hypertension,[28, 29] we also examined the association between ADHD symptoms and hypertension.

## Method

### Data Source and Study Sample

The study population consisted of 20,745 adolescents from the National Longitudinal Study of Adolescent Health (Add Health), a nationally representative study of adolescents. This longitudinal cohort includes 12,288 respondents who completed in-home surveys on four separate occasions (April to December, 1995; April to August, 1996; August 2001 to August 2002; and January 2008 to February 2009). The mean age of the participants in the four waves of data collection was 15.65 (SD = 1.75) years, 16.22 (SD = 1.64) years, 22.96 (SD = 1.77) years, and 28.9 (SD = 1.76) years, respectively. By design, the Add Health survey was stratified by region, urban versus rural residence, school type, ethnic mix, and size to garner a nationally representative sample. The design and data collection have been described in detail elsewhere.[30, 31]

The study sample included participants from Wave IV who had also completed one or more of the previous waves. Women who were pregnant at Wave IV were excluded from the analyses (n = 433) leaving a final analysis sample of n = 11,666.

### Measures

**Anthropometrics—**Measured height and weight were ascertained by Add Health study personnel at Waves II, III, and IV using a digital scale and was self-reported at Wave I. BMI ($kg/m^2$),[32] was calculated and categorized into 3 groups (normal BMI <= 25; overweight BMI = 25 - 29; and obese BMI >= 30). At Wave IV, waist circumference to the nearest .5cm at the superior border of the iliac crest was also measured by study personnel using a SECA 200 metric-increment circumference tape measure. This measure was not collected at earlier waves.

**Blood Pressure and hypertension—**Blood pressure (systolic [SBP] and diastolic [DBP]) was measured at Wave IV by field interviewers using a Micorolife blood pleasure monitor. Participants were instructed to remain seated for at least 5 minutes prior to the readings. Three separate readings at 30 second intervals were conducted with participants in a seated position with both feet on the floor and legs uncrossed. The average of the 2$^{nd}$ and 3$^{rd}$ readings were used as the SBP and DBP values unless the 2$^{nd}$ and 3$^{rd}$ values were missing, in which case the 1$^{st}$ reading was used. Stage II hypertension was defined in accordance with the 7th report of the Joint National Committee on Prevention Detection, Evaluation, and Treatment of High Blood Pressure: SBP ≥ 160 mm Hg and DBP ≥ 100.[33]

**ADHD symptoms—**At Wave III, participants were asked to retrospectively report ADHD symptoms experienced between the ages of 5 and 12 years. Specifically, they were asked to report the frequency of each symptom using a 4-point Likert scale: never or rarely, sometimes, often, very often. One item ("You were spiteful or vindictive") is not a Diagnostic and Statistical Manual–IV *(DSM-IV)* ADHD symptom and was excluded from analyses; one *DSM-IV* hyperactive/impulsive symptom ("Often interrupts or intrudes on others") was not included in the retrospective ADHD section. Thus, our analyses included responses to 9 inattentive (IN) and 8 hyperactive/impulsive (HI) symptoms.

A symptom was considered present if it was experienced "often" or "very often." This approach to dichotomizing symptoms has been used in other community-based studies of ADHD symptomatology, is considered clinical convention[34] and was also used in previous studies on the relation between ADHD and smoking outcomes.[20, 35] We examined the dimensions of ADHD as the total number of symptoms reported in each domain (0–9 for IN; 0–8 for HI) or as two categorical classifications. Two categorical classifications were also utilized: (1) To examine the incremental effect of increasing symptoms relative to having no symptoms we created an ordinal variable with a 4 categories (0=no symptoms, 1=1 symptom, 2=2 symptoms, and 3=3 or more symptoms); (2) To examine clinically-relevant categories based on the number of reported symptoms, symptoms were classified into one of four clinically relevant categories: (a) IN subtype: ≥6 IN symptoms, <6 HI symptoms (n = 302, 2.8%); (b) HI subtype: ≥6 HI symptoms, <6 IN symptoms (n = 337, 3.1%); (c) Combined subtype: ≥6 IN symptoms AND ≥6 HI symptoms (n = 262, n = 2.6%); and (d) Control subtype: <6 HI AND <6 IN symptoms (n=10,753, 91.5%). The six-symptom cutoff is consistent with DSM-IV ADHD criteria requiring the presence of six or more symptoms from either the IN or HI symptom domains, but does not represent a proxy for the diagnosis of ADHD. Clinical diagnoses of ADHD were not available in this population-based sample.

The use of retrospective report is common in clinical practice when working with adults with ADHD and previous studies support the reliability and validity of these self-reports.[36–40] We have previously demonstrated adequate reliability and validity of this approach by demonstrating good internal consistency of the items ($\alpha$ = .86), and we also showed that parents of adolescents reporting six or more symptoms on either or both HI and IN scales were more likely to indicate learning or behavioral problems in their adolescent children at Wave 1. These adolescents were also more likely to report taking medications for ADHD at Wave III.[35]

**Other variables—**A number of potential covariates believed to be related to obesity or hypertension were included in statistical models. These variables were constructed from Wave IV data. *Physical activity* was assessed by a set of 3 questions regarding leisure-based activities that approximated moderate-to-vigorous physical activity (played a strenuous team sport, played an individual sport, or engaged in the following: roller blade, roller skate, downhill ski, snow board, racquet sports, or aerobics). Participants were asked to indicate the number of times they engaged in each activity in the last 7 days (ranging from 0 to 7 or more times). For analyses, scores were dichothomized (0 = no moderate-vigorous physical activity of the above type or 1 = participation at least once in the past 7 days). *Current or past depression* was a derived variable based on participants' response to whether or not they had ever been diagnosed with depression and were currently (within the past 7 days) feeling depressed. *Alcohol consumption* was assessed by whether or not participants reported consuming alcohol in the past 30 days and, if they had drank alcohol, the number of drinks they usually had each time. Responses were categorized as 0 (no alcohol consumption in the past 30 days), 1 (alcohol consumption in the past 30 days; 1-4 drinks per occasion), and 2 (alcohol consumption in the past 30 days; about 5 or more drinks per occasion). An indicator of *daily smoking* (0 not daily and 1 daily) was also included. Sociodemographic variables included age, gender, and educational attainment (high school or less, vocational or some college, or college or greater) at Wave IV.

**Statistical Analysis—**Associations between reported ADHD symptoms and obesity and hypertension at Wave IV were assessed using SAS-callable SUDAAN (version 10.0.1) statistical software.[41] SUDAAN controls for survey design effects of individuals clustered within sampling unit (school), and stratification of geographic region. In addition, post-stratification weights were applied to make the results generalizable to young adults in the U.S. First, means for continuous covariates and percentages for categorical covariates were tabulated for each of the three BMI categories (normal, overweight, and obese), and chi-square tests and t-tests were used to evaluate statistical differences among these categories. Similar comparisons were made between those with and without stage II hypertension. Second, we compared the prevalences of overweight and obese and stage II hypertension among the ADHD symptom categories. Similarly, we compared the mean waist circumference, BMI, DBP, and SBP among the ADHD symptom categories.

The adjusted associations between ADHD symptoms and the 3 categories of BMI were examined using multinomial logistic regression models. Similarly, logistic regression models were used to assess the adjusted relationship between ADHD symptoms and stage II hypertension. These models examined the relative odds of overweight, obesity, and hypertension in relation to ADHD symptoms with the three different specifications (i.e., clinically-consistent categories; the ordered category of 0, 1, 2, or 3+ HI/IN symptoms; or HI/IN on a continuous scale). To examine which symptom domain had the stronger relationship with the outcome, a final model included both continuous HI and IN symptoms simultaneously. To examine the contribution of ADHD symptoms to hypertension, both directly and as mediated through the height adjusted weight status, the results with and without control for BMI at Wave IV are presented.

To explore whether ADHD symptoms were related to naturally occurring changes in BMI during the developmental period from adolescence to adulthood, we developed a set of latent curve models (also known as random-effects, random-coefficients, or mixed models outside of the structural equation modeling framework). We initially tested a series of unadjusted models comparing linear and quadratic change functions with either user-set heteroscedastic and homoscedastic residual errors to evaluate which model best fit the data, in terms of chi-square and other modeling fit statistics [good model data fit is implied when Root Mean Square Error of Approximation (RMSEA) is .05 or less with a 90% CI around the RMSEA containing .05, and the Tucker Luis Index (TLI) and the Comparative Fit Index (CFI) are .95 or greater].[42], [43] Factor loadings for the linear model were fixed equal to 0, 1, 6, and 12 representing the unequal time intervals (for the quadratic factor loadings were set to 0, 1, 36, 144). The parameter estimate representing the intercept reflects BMI at mean age at Wave I and parameter estimate representing the slope (change) reflects growth in BMI for 1 year intervals. The second stage involved entering the effect of the main time invariant covariates (sex, age at Wave 1, and race) and ADHD symptoms. This allowed for examining the effect of ADHD symptoms on initial BMI status at Wave I (intercept), the change in BMI over the four time points (slope), and the change in BMI over the four time points (curve), while controlling for race, sex, and age at Wave I. Latent growth curve modeling was conducted using Mplus version 5.2,[44] which accounts for survey design effects and incorporates sampling weights. Missing values were treated with the inherent maximum likelihood estimation in the program.

## Results

### Sample characteristics by BMI categories and hypertension status

The mean age at Wave IV was 28.9 years. Individuals in the obese BMI category were more likely to be older, female, black or Hispanic, have a lower educational attainment, no physical activity in the last week, have current or past depression, consume either larger amounts of alcohol or abstain completely, and smoke daily (Table 1). Individuals with stage II hypertension were more likely to be older black males, have a higher BMI, have a lower educational attainment, no physical activity in the past week, have current or past depression, and consume either larger amounts of alcohol or abstain completely.

### ADHD symptoms by BMI categories and hypertension status

The percent obese was slightly higher among those in the ADHD clinically relevant categories, but this was not statistically significant (Table 2). Considering the symptoms domains separately, the proportion obese and the proportion with hypertension were greater among those with 3 or more HI or IN symptoms (Table 2). A slight, gradual increase in the prevalence of obesity and stage II hypertension was present with increasing HI and IN symptoms (Figure 1a, b).

### Mean values for Waist circumference, BMI, DBP, and SBP by ADHD symptoms

Mean waist circumference was higher among those in the ADHD clinically relevant categories compared to those with subclinical ADHD symptoms (Table 2). Mean DBP and SBP were higher, but not statistically significantly higher among those in the ADHD clinically relevant categories compared to those with subclinical ADHD symptoms. In general, means for waist circumference, BMI, DBP, and SBP increased with increasing HI and IN symptoms.

### Multivariate-adjusted oddsof overweight, obesity, and hypertension

Table 3 presents the odds ratio (OR) and 95% confidence intervals (CI) from the multinomial logistic and logistic regression analyses. Compared to those in the subclinical ADHD category (< 6 HI and <6 IN symptoms), those in the hyperactive-impulsive only category had the highest odds of obesity (OR, 1.63; 95% CI, 1.11-2.39). The relative odds of hypertension among those in clinically relevant categories (IN only, HI only, or Combined) were not significantly higher than among those in the subclinical ADHD category.

Compared to those with no HI or IN symptoms, those with 3 or more had the highest odds of obesity (HI 3+ OR, 1.50; 95% CI, 1.22-2.83; IN 3+ OR, 1.21; 95% CI, 1.02-1.44). In models which included the continuous variable of HI and IN (0 to 8 HI symptoms and 0 to 9 IN symptoms), one additional HI symptom was associated with a 5% increase in the odds of overweight and a 9% increase in the odds of obesity (OR overweight, 1.05; 95% CI, 1.01 – 1.09; OR obese, 1.09; 95% CI, 1.04 – 1.14). IN symptoms, when measured on a continuous scale, were not statistically significantly associated with overweight or obesity (OR overweight, 1.00; 95% CI, 0.97 – 1.04; OR obese, 1.03; 95% CI, 0.99 – 1.07) (data not shown).

Additionally, HI symptoms at the 3+ level or measured on a continuous scale were significantly associated with higher relative odds for hypertension (HI 3+ OR, 1.24; 95% CI 1.01-1.51; HI continuous OR, 1.04; 95% CI 1.00-1.09). These associations were attenuated so that no significant associations were observed when models were adjusted for BMI (HI 3+ OR, 1.16; 95% CI 0.92 - 1.45; HI continuous OR, 1.03; 95% CI 0.98 - 1.07). IN symptoms, when measured on a continuous scale, were not statistically significantly associated with hypertension regardless of whether BMI was included in the models (OR Hypertension, 1.03; 95% CI, 0.99 - 1.07; OR Hypertension adjusted for BMI 1.02; 95% CI 0.98-1.07) (data not shown).

When both the HI and IN continuous symptoms were entered together in a model, the OR were attenuated for IN symptoms, but not for HI symptoms (OR overweight for HI, 1.08; 95% CI, 1.03 – 1.13; OR overweight for IN, .96; 95% CI, .91 – 1.00 and OR obese for HI, 1.11; 95% CI, 1.06 – 1.17; OR obese for IN, .96; 95% CI, .93 – 1.01) (data not shown). There was no association between HI or IN symptoms and hypertension when both symptoms were entered into these models simultaneously.

## Longitudinal associations between ADHD symptoms and BMI

The change in BMI was best described by a quadratic growth function with a homoscedastic residual structure [df = 4; $X^2$ = 87.4, p <.001; RMSEA (90% CI) = .04 (0.04-0.05); CFI = .98; TLI = .97]. Group level means indicated that, on average, there was a significant variation in initial BMI at Wave I ($\alpha_{intercept}$ = 22.6, s.e. = .11, p < .0001), linear yearly increase in BMI ($\alpha_{slope}$ = .87, s.e. = .02, p < .0001), and a slowing of yearly increase in BMI from Wave I to Wave IV ($\alpha_{quadratic}$ = -.027, s.e. = .001, p <.0001). There was a significant positive correlation between the intercept and slope (estimate = .76, p <.0001) indicating that higher initial BMI is associated with a greater yearly increase in BMI and a significant negative correlation between intercept and quadratic ($\phi$ = -.02, p < .05) indicating that higher initial BMI is associated with less downward curvature (or leveling-off) in the slope over time. The significant negative correlation between the slope and quadratic ($\phi$ = -.05, p < .0001) indicated that those with greater yearly increases in BMI also showed less leveling-off over time (data not shown).

Results of the longitudinal analyses assessing the influence of ADHD symptoms on BMI growth curves, controlling for age, sex, and race can be seen in Table 4. For all models tested there were no significant model-fit statistic decrements beyond the unadjusted model. In most cases, model-fit was improved (data not shown). Models included the quadratic function, but none of the ADHD variables were related to the curvature, thus the data is not shown. There were no statistically significant associations between the clinically-relevant ADHD categories and overall BMI intercept or slope. HI symptoms assessed as either a categorical variable or on a continuous scale were associated with BMI intercept and slope. Compared to having no HI symptoms, having 3+ HI symptoms was associated with a .36 unit higher initial BMI above the age/sex/race adjusted mean intercept of 22.32 (i.e., 22.68). From Wave I to Wave IV the slope in BMI among those with 3+ HI symptoms was .12 units higher compared to those with no HI symptoms (.85 vs. the age/sex/race adjusted mean slope of .73). A similar effect was observed for the continuous 0 to 8 HI variable with higher HI symptoms associated with a higher initial BMI and steeper slope over time ($\gamma_{intercept}$ = .08, s.e. = .04, $p < .05$; $\gamma_{slope}$ = .02, s.e. = .01, $p < .05$) (data not shown).

Compared to the effect of the HI symptoms, IN symptoms had a slightly different effect on the BMI intercept and slope. IN symptoms were significantly associated with the intercept, but not the slope. Compared to having no IN symptoms, having 3+ IN symptoms was associated with a significantly higher mean BMI intercept of about half a unit ($\alpha_{intercept\ IN\ 3+}$ = 22.73 vs. $\alpha_{intercept\ IN\ 0}$ = 22.29, $p < .01$). Increasing IN symptoms (either assessed with the 4-categorical indicator or on the continuous 0 to 9 scale) were not associated with increasing slope in BMI over time (ps > .05). A graphic depiction of the effect of four category HI and IN symptoms on BMI intercept and slope can be viewed in Figure 2a, b.

When both IN and HI were entered in the model together, increasing IN symptoms were significantly associated with initial BMI intercept, but not slope ($\gamma_{intercept}$ = .08, s.e. =.04, $p < .05$ and $\gamma_{slope}$ = .00, s.e. = .01, p = .84, respectively) (data not shown). Conversely, increasing HI symptoms was not statistically associated with initial BMI intercept, but was with increasing slope in BMI ($\gamma_{intercept}$ = .02, s.e. =.05, p =.60 and $\gamma_{slope}$ = .02, s.e. = .01, $p < .05$, respectively) (data not shown).

## Discussion

In the present study, we found significant associations between the number of reported childhood ADHD symptoms and risk for overweight and obesity in adulthood controlling for demographic variables, depression, and other lifestyle factors. These relationships among ADHD symptoms and obesity were largely linear with more symptoms associated with a higher prevalence of obesity. The longitudinal analyses also indicated that ADHD symptoms, especially HI symptoms, are associated with increasing BMI over the course of adolescence into early adulthood. HI symptoms were also related to risk of hypertension during adulthood, but accounting for BMI during adulthood in the analyses attenuated this association, indicating that adult BMI is a stronger predictor of hypertension than HI symptoms.

The present findings are consistent with previous reports linking clinically diagnosed ADHD with higher prevalence of obesity.[12-15] To our knowledge, only one other population based study has found that a diagnosis of ADHD persisting into adulthood is associated with a higher risk for obesity.[19] However, the database used for that study only included a history of ADHD diagnosis, not specific ADHD symptoms, and only had categorical self-reported indicators of weight rather than measured height and weight and BMI measured in a continuous fashion. Thus, this is the first population-based study to examine the association between ADHD symptoms, both the IN and HI dimensions, as predictors of adult BMI, changes in BMI over time, and risk of adult obesity and hypertension. Studies in clinical or local samples are often the first reports of new associations. However, the degree to which these findings generalize to the larger population remains unknown. Larger, population-based studies of non-clinical samples, such as this one, are important for extending these initials reports as well as identifying the degree to which individual differences, as reflected by inattention and hyperactive-impulsive symptoms, may have on the development of obesity and related health outcomes. Further, examining the different domains of HI and IN dimensionally is important because this better accounts for the variability among people with these symptoms. Also, there may be partially dissociable genetic and phenotypic pathways that give rise to HI and IN symptom domains.[45] As such, identifying associations separately for each symptom domain can generate hypotheses about possible pathways to non-homeostatic eating and risk for obesity.

In general, our findings highlight that HI and IN ADHD symptom domains have differential effects on risk for obesity as they relate to naturally occurring changes in BMI from adolescence to adulthood. IN symptoms, which are related to deficits in ability to sustain attention and/or exert persistent effort were related to higher BMI during adolescence, but did not have an impact on the changes in BMI over time; whereas HI symptoms, which are related to deficits in behavioral inhibitory control, did not affect BMI during adolescence but were associated with increasing BMI over time. Although further work is needed to more precisely characterize the nature of the relationship between ADHD symptoms and obesity, our findings highlight that both symptom domains affect risk for obesity, but have more or less impact during different developmental periods.

The behavioral mechanisms that underlie ADHD symptom-obesity outcomes are yet to be fully elucidated. Laboratory studies have shown that habituation to food cues is disrupted during activities when attention allocation is required (e.g., television viewing), resulting in increased energy consumption[46] with highly inattentive individuals tending to consume more energy during television viewing.[47] As such, children with deficits in ability to sustain attention may be less likely to habituate to food cues and consume more calories when engaged by distracting stimuli, like watching television or playing video games. Later, during adolescence, when parental regulation and control over food choices wanes, individuals with inability to inhibit behavioral responses may be disadvantaged when attempting to regulate their own food choices.

The link between ADHD symptoms and obesity is biologically plausible. Several investigators have hypothesized that ADHD and non-homeostatic eating leading to obesity may share common underlying neurological substrates, especially those related to the production and re-uptake of the neurotransmitter dopamine.[7, 48] Genetic association studies have found that ADHD and obesity are both associated with genes regulating dopamine availability.[49] Further, in two separate studies using Positron Emission Tomography (PET) with [$^{11}$C]raclopride, Volkow and colleagues have shown that individuals with ADHD[50] and those who are obese[51] both show lower than normal dopamine (D2) receptor availability. This lower dopamine receptor availability could reflect the common dispositions in both ADHD and obesity.[22-27, 52-55]

In the present analysis, HI symptoms were associated with an increased risk of hypertension. However, this association was reduced after adjusting for current BMI. Studies of psychosocial risk factors for hypertension have found that trait impulsivity, hostility, and time urgency/impatience are related to greater risk for hypertension.[29, 56] These traits may be overrepresented among those with high levels of HI symptoms.[57] Further study is warranted investigating the degree to which HI symptoms relate to cardiovascular pathology, as well as the mechanisms that may underlie these potential associations. At this point, we can only conclude that the ADHD-hypertension association may be best explained by differences in health behaviors, such as healthy dietary intake and physical activity which may be easier to sustain with decreasing ADHD symptoms.

## Strengths and limitations

In this large population-based sample, clinical assessments were not undertaken. Thus, we are not able to determine the association between a clinical *diagnosis* of ADHD and obesity and/or hypertension. Further, the database only includes ADHD symptoms as recalled from the past. The approach to quantifying ADHD symptoms via retrospective self-report has been shown to be reliable and valid;[34, 35] however, prospective designs should be used to replicate our findings. Our constructed measure of "clinically-relevant" symptoms should not be construed as clinical diagnostic categories, but rather an approximation of ADHD subtypes. The strength of the association that we found between "HI-only" and adult obesity (OR = 1.6) is similar to those reported by others who have examined the association between diagnostic classification of ADHD and adult obesity (OR = 1.8).[19] Thus, it may be that the association reported between our "clinically-relevant" categories and risk for obesity and hypertension is an underestimate of the relationship between clinical ADHD and obesity and hypertension. Nevertheless, the purpose of this study was not to only to examine the association between clinical levels of ADHD and obesity, but rather the relationships between dimensional levels of symptoms and risk for obesity and hypertension for the reasons stated above. The findings highlight that there may be variability unaccounted for by sole use of clinical categories that is important in the relation between ADHD symptoms and obesity, and this deserves further investigation. A strength of the study is that we were able to examine how ADHD symptoms related to naturally occurring changes in BMI over the course of adolescence into adulthood, something which has not heretofore been investigated. In future studies, however, it will be important to confirm these findings with prospectively collected data on ADHD symptoms or ADHD phenotypes (e.g., behavioral inhibition), preferably combined with clinical diagnosis of ADHD. The lack of data on multiple measures of blood pressure or ambulatory blood pressure monitoring prevented us from determining the association that ADHD symptoms had on changes in hypertension susceptibility over time. Finally, although we did include a number of covariates that were related to risk for obesity and hypertension, many of these were based on self-report. There is the possibility of potential residual confounding of both measured as well unmeasured variables.

## Conclusions

Evidence from smaller community based samples and at least one other population based representative sample have found an association between ADHD and adult obesity. Our findings show a dose response increase in risk of obesity associated with increasing ADHD symptoms, especially HI symptoms. Indicators of hypertension also increased with increasing HI symptoms; however, this relationship was attenuated when accounting for BMI. If our findings are confirmed in other samples, they could have relevant clinical implications both for the treatment of ADHD as well as obesity. As has been suggested, it may be clinically relevant to screen patients with ADHD who are at risk for obesity to develop appropriate treatment strategies. [7, 58, 59] Medications for ADHD often suppress appetite and in children decelerated growth velocity has typically been a concern. It may become necessary for clinicians to monitor weight more carefully among their child and adolescent patients with ADHD, especially when they come off medications or in developmental transitions where weight gain is common. Treatment for obesity may also be affected among individuals with ADHD symptoms. Treatment effectiveness may be diminished and relapse may be greater among those with more ADHD symptoms.[27] Given the mounting evidence, effort directed at developing and defining strategies for assessing and treating obese patients with co-occurring ADHD symptoms and for monitoring ADHD patients for unhealthy weight gain appears warranted.

There has been increasing interest in the response inhibition hypothesis of obesity and ADHD.[23, 60-64] Our findings reflecting significant associations between HI symptoms and risk for obesity synchronize with this line of study. Examining the associations between ADHD symptoms or ADHD symptom-like phenotypes on obesity outcomes could be a fruitful venue of research on both the etiology of obesity, as well as a means for improving tailored treatment and prevention strategies.

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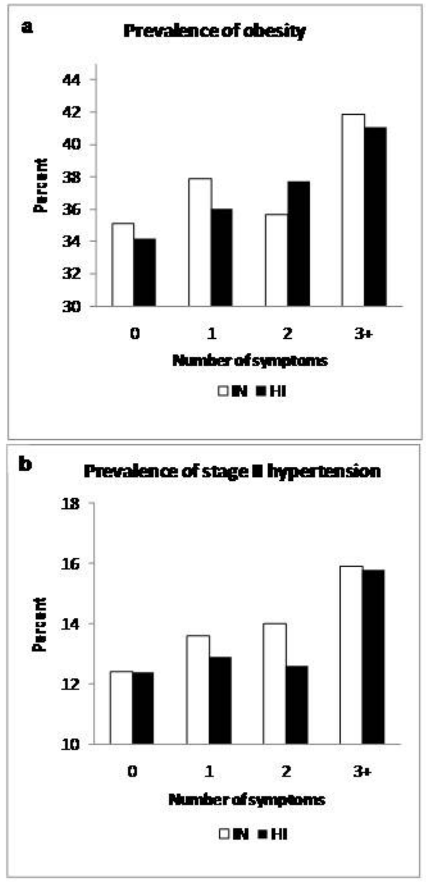


**Figure 1.**
a, b. Prevalence of obesity (a) and stage II hypertension (b) by HI and IN symptom level

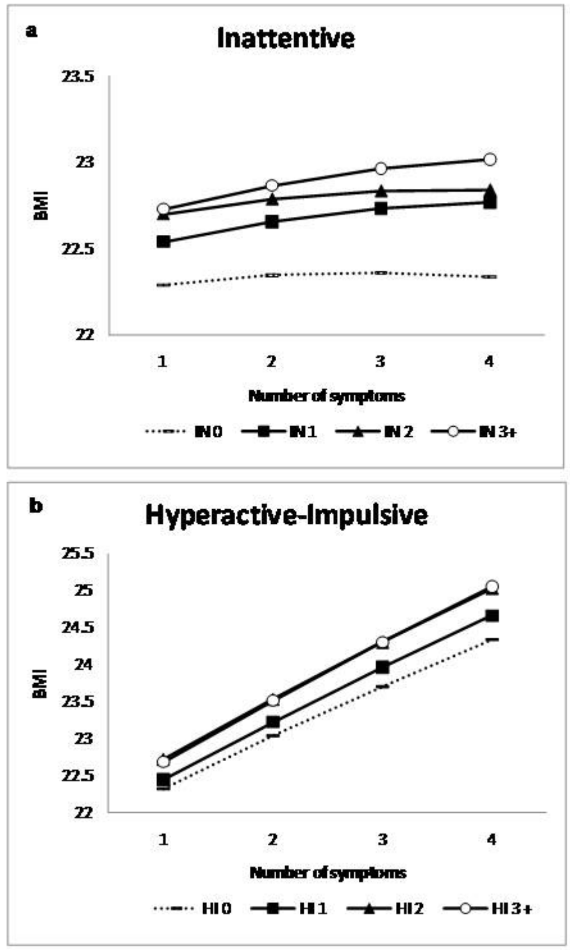


**Figure 2.**
a, b. BMI by IN (a) and HI (b) symptom level

## Table 1

Characteristics of the sample (percentages or means and standard errors)

| | | BMI categories | | | Hypertension (stage II) | |
|---|---|---|---|---|---|---|
| | **Total (n = 11,666)** | **normal (n = 3,849)** | **overweight (n = 3,464)** | **obese (n = 4,343)** | **no (n = 10,198)** | **yes (n = 1,468)** |
| Age (years) | 28.8 (.12) | 28.6 (.12) | 28.8 (.12) ‡ | 28.9 (.12) ‡ | 28.7 (.12) | 29.0 (.14) ‡ |
| BMI | 29.1 (.15) | 22.0 (.04) | 27.4 (.03) ‡ | 36.9 (.15) ‡ | 28.4 (.13) | 33.5 (.34) ‡ |
| Gender | | | | | | |
| male | 51.0 | 45.3 | 59.0 | 49.9 | 49.5 | 60.2 |
| female | 49.0 | 54.7 | 41.0 | 50.1 § | 50.5 | 39.8 § |
| Race/ethnicity | | | | | | |
| Hispanic | 11.6 | 8.3 | 13.4 | 13.4 | 11.7 | 11.0 |
| black | 15.3 | 11.9 | 14.7 | 18.8 | 14.8 | 18.8 |
| other | 6.7 | 7.9 | 6.7 | 5.8 | 6.8 | 6.4 |
| white | 66.3 | 71.9 | 65.3 | 62.0 § | 66.7 | 63.8 § |
| Education | | | | | | |
| High school or less | 25.9 | 22.0 | 26.3 | 29.1 | 25.3 | 29.6 |
| Vocational or some college | 42.9 | 39.1 | 39.8 | 48.8 | 42.6 | 44.8 |
| college degree or higher | 31.2 | 38.9 | 33.9 | 22.1 § | 32.1 | 25.6 § |
| Physical activity | | | | | | |
| None | 57.4 | 53.3 | 54.6 | 63.4 | 56.5 | 64.0 |
| Once in last week | 42.6 | 46.7 | 45.4 | 36.6 § | 43.6 | 36.0 § |
| Past or current depression | | | | | | |
| No history and no current | 79.9 | 79.5 | 81.8 | 78.6 | 80.6 | 75.0 |
| past and/or current | 20.2 | 20.5 | 18.2 | 21.4 § | 19.4 | 25.0 § |
| Alcohol consumption | | | | | | |
| Abstinent | 37.5 | 33.3 | 34.1 | 44.0 | 36.7 | 42.8 |
| Moderate | 45.7 | 51.7 | 47.7 | 38.7 | 47.0 | 37.5 |
| Heavy | 16.8 | 15.0 | 18.2 | 17.3 § | 16.3 | 19.8 § |
| Current daily smoker | | | | | | |

| | Total | BMI categories | | | Hypertension (stage II) | |
|---|---|---|---|---|---|---|
| | (n = 11,666) | normal (n = 3,849) | overweight (n = 3,464) | obese (n = 4,343) | no (n = 10,198) | yes (n = 1,468) |
| Not daily | 74.7 | 72.2 | 76.6 | 75.3 | 74.8 | 73.9 |
| daily | 25.4 | 27.8 | 23.4 | 24.7 § | 25.2 | 26.1 |

‡ $p < .01$ for t tests from mean comparisons (normal vs overweight; normal vs obese; no hypertension vs hypertension)

§ $p \leq .01$ for comparison from $X^2$ test (categorical variables)

## Table 2

Prevalence of overweight, obesity, and hypertension and means and standard errors for waist circumference, BMI, DBP, and SBP for clinically-relevant ADHD symptoms and categorical HI and IN symptoms

| | BMI categories | | Hypertension | Waist | | BMI | | DBP | | SBP | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | overweight | obese | (stage II) | | | | | | | | |
| | % | % | % | mean | s.e. | mean | s.e. | mean | s.e. | mean | s.e. |
| Categories of ADHD symptoms | | | | | | | | | | | |
| Subclinical ADHD | 29.3 | 36.3 | 17.2 | 97.9 | (.36) | 29.0 | (.15) | 79.5 | (.17) | 125.2 | (.22) |
| IN only | 25.3 | 45.0 | 17.2 | 101.0 | (1.30) ‡ | 30.0 | (.60) | 80.1 | (.69) | 126.9 | (1.03) |
| HI only | 28.2 | 44.1 | 16.2 | 100.9 | (1.46) ‡ | 30.2 | (.66) | 80.5 | (.88) | 127.4 | (1.30) |
| Combined | 27.3 | 41.5 | 17.5 | 101.2 | (1.59) ‡ | 29.5 | (.63) | 80.9 | (.74) | 125.6 | (1.27) |
| Hyperactive-Impulsive | | | | | | | | | | | |
| None | 29.1 | 34.2 | 12.4 | 96.6 | (.50) | 28.6 | (.22) | 79.2 | (.23) | 124.8 | (.30) |
| 1 symptom | 28.4 | 36.0 | 12.9 | 97.7 | (.46) | 29.0 | (.21) | 79.3 | (.26) | 124.7 | (.39) |
| 2 symptoms | 29.4 | 37.7 | 12.6 | 98.9 | (.69) ‡ | 29.3 | (.31) ‡ | 79.4 | (.34) | 125.0 | (.50) |
| 3 + symptoms | 29.5 | 41.1 § | 15.8 § | 100.3 | (.58) ‡* | 29.7 | (.24) ‡* | 80.3 | (.29) ‡* | 126.6 | (.35) ‡* |
| Inattentive | | | | | | | | | | | |
| None | 29.4 | 35.1 | 12.4 | 97.0 | (.40) | 28.7 | (.17) | 79.2 | (.21) | 124.6 | (.28) |
| 1 symptom | 27.9 | 37.9 | 13.6 | 98.6 | (.61) ‡ | 29.3 | (.28) | 79.7 | (.34) | 125.1 | (.43) |
| 2 symptoms | 31.4 | 35.7 | 14.0 | 99.0 | (.82) ‡ | 29.1 | (.35) | 79.7 | (.43) | 125.7 | (.60) |
| 3 + symptoms | 28.2 | 41.9 § | 15.9 | 100.8 | (.65) ‡* | 29.8 | (.28) ‡* | 80.4 | (.31) ‡* | 127.0 | (.41) ‡* |

‡ $p < .05$ for t tests from mean comparisons (subclinical ADHD, HI-none, and IN-none as referent)

* p for trend < .01

§ $p < .05$ for comparison from $X^2$ test (categorical variables)

## Table 3

Adjusted odd ratio and 95% confidence intervals for multivariate multilogistic and logistic models

| Model | Overweight OR (95% CI) | Obesity OR (95% CI) | Hypertension (Stage II) OR (95% CI) | Hypertension (Stage II) adjusted for BMI OR (95% CI) |
|---|---|---|---|---|
| Categories of ADHD symptoms | | | | |
| Subclinical ADHD | --- | --- | --- | --- |
| IN only | 0.91 (0.59 - 1.43) | 1.23 (0.81 - 1.88) | 1.12 (0.72 - 1.74) | 1.09 (0.70 - 1.71) |
| HI only | 1.21 (0.85 - 1.72) | 1.63 (1.11 - 2.39) | 1.17 (0.76 - 1.80) | 1.04 (0.66 - 1.63) |
| Combined | 1.05 (0.72 - 1.52) | 1.21 (0.76 - 1.92) | 1.15 (0.75 - 1.76) | 1.12 (0.73 - 1.74) |
| Hyperactive-Impulsive | | | | |
| None | --- | --- | --- | --- |
| 1 symptom | 1.02 (0.85 - 1.23) | 1.11 (0.93 - 1.33) | 1.05 (0.83 - 1.34) | 1.07 (0.83 - 1.39) |
| 2 symptoms | 1.16 (0.94 - 1.43) | 1.26 (1.03 - 1.55) | 1.02 (0.81 - 1.29) | 0.97 (0.74 - 1.27) |
| 3 + symptoms | 1.24 (1.04 - 1.48) | 1.50 (1.22 - 1.83) | 1.24 (1.01 - 1.51) | 1.16 (0.92 - 1.45) |
| p for trend | 0.01 | 0.00 | 0.04 | 0.26 |
| Inattentive | | | | |
| None | --- | --- | --- | --- |
| 1 symptom | 0.91 (0.75 - 1.10) | 0.98 (0.81 - 1.18) | 0.99 (0.79 - 1.26) | 0.98 (0.78 - 1.23) |
| 2 symptoms | 1.05 (0.85 - 1.30) | 0.98 (0.78 - 1.23) | 1.02 (0.76 - 1.36) | 1.00 (0.74 - 1.35) |
| 3 + symptoms | 1.02 (0.86 - 1.22) | 1.21 (1.02 - 1.44) | 1.09 (0.87 - 1.36) | 1.03 (0.82 - 1.31) |
| p for trend | 0.73 | 0.07 | 0.47 | 0.81 |

All models include age, sex, race/ethnicity, education achieved, past or current depression, alcohol use, current smoking, and current physical activity

## Table 4

Standardized regression coefficients, standard errors, and p-values for effect of ADHD symptoms on BMI intercept and Slope adjusted for age, sex, and race

| | Intercept | | | slope | | |
|---|---|---|---|---|---|---|
| **Model** | **estimate** | **se** | **p-value** | **estimate** | **se** | **p-value** |
| Categories of ADHD symptoms | *22.47* [a] | *19.39* [b] | | *0.80* [c] | *1.04* [d] | |
| Subclinical ADHD | | | | | | |
| IN only | 0.75 | (.35) | 0.03 | -0.05 | (.12) | 0.68 |
| HI only | 0.25 | (.35) | 0.48 | 0.09 | (.08) | 0.27 |
| Combined | 0.46 | (.34) | 0.18 | 0.11 | (.11) | 0.34 |
| Hyperactive-Impulsive | *22.32* [a] | *19.38* [b] | | *0.73* [c] | *1.03* [d] | |
| None | | | | | | |
| 1 symptom | 0.12 | (.16) | 0.44 | 0.07 | (.04) | 0.10 |
| 2 symptoms | 0.40 | (.19) | 0.04 | 0.10 | (.05) | 0.05 |
| 3 + symptoms | 0.36 | (.17) | 0.03 | 0.12 | (.05) | 0.01 |
| Inattentive | *22.29* [a] | *19.38* [b] | | *0.76* [c] | *1.04* [d] | |
| None | | | | | | |
| 1 symptom | 0.25 | (.19) | 0.19 | 0.06 | (.05) | 0.27 |
| 2 symptoms | 0.41 | (.23) | 0.07 | 0.03 | (.06) | 0.58 |
| 3 + symptoms | 0.44 | (.16) | 0.01 | 0.08 | (.06) | 0.16 |

Note:

[a] mean intercept;

[b] standard error of intercept;

[c] mean slope;

[d] standard error of slope;

Models included the quadratic function (curve), but none of the variables were related to the curvature. Thus, data not shown