Economic burden of attention-deficit/hyperactivity disorder among children and adolescents in the United States: a societal perspective

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\textbf{ORIGINAL RESEARCH}

\textbf{ABSTRACT}

\textbf{Objective:} To provide a comprehensive evaluation of the economic burden associated with attention-deficit/hyperactivity disorder (ADHD) among children and adolescents from a US societal perspective.

\textbf{Materials and methods:} Direct healthcare costs of children (5–11 years) and adolescents (12–17 years) with ADHD were obtained using claims data from the IBM MarketScan Research Databases (01/01/2017–12/31/2018). Direct non-healthcare and indirect costs were estimated based on literature and government publications. Each cost component was estimated using a prevalence-based approach, with per-patient costs extrapolated to the national level.

\textbf{Results:} The total annual societal excess costs associated with ADHD were estimated at $19.4 billion among children ($6,799 per child) and $13.8 billion among adolescents ($8,349 per adolescent). Education costs contributed to approximately half of the total excess costs in both populations ($11.6 billion [59.9%] in children; $6.7 billion [48.8%] in adolescents). Other major contributors to the overall burden were direct healthcare costs ($5.0 billion [25.9%] in children; $4.0 billion [29.0%] in adolescents) and caregiving costs ($2.7 billion [14.1%] in children; $1.6 billion [11.5%] in adolescents).

\textbf{Limitations:} Cost estimates were calculated based on available literature and/or governmental publications due to the absence of a single data source for all costs associated with ADHD. Thus, the quality of cost estimates is limited by the accuracy of available data as well as the study populations and methodologies used by different studies.

\textbf{Conclusion:} ADHD in children and adolescents is associated with a substantial economic burden that is largely driven by education costs, followed by direct healthcare costs and caregiver costs. Improved intervention strategies and policies may reduce the clinical and economic burden of ADHD in these populations.

\textbf{Introduction}

Attention-deficit/hyperactivity disorder (ADHD) is one of the most common neurobehavioral disorders of childhood, characterized by levels of inattention, impulsivity, and hyperactivity that are inappropriate for the child’s developmental stage\textsuperscript{1,2}. ADHD is most frequently diagnosed among gradeschool children, but it may occur at any stage of life\textsuperscript{3}. The prevalence of ADHD among children and adolescents in the United States (US) is estimated at 10.0% and 6.5%, respectively\textsuperscript{4,5}, compared with 4.4% among adults\textsuperscript{6}.

ADHD symptoms vary depending on disease presentation and may be linked to reduced executive functioning, including loss of the ability to prioritize thoughts and actions as well as being forgetful\textsuperscript{2}. Consequently, individuals with ADHD may display a multitude of functional and psycho-social impairments in the academic and/or occupational settings\textsuperscript{2,7–9}. While ADHD imposes a direct healthcare burden with regard to healthcare resource utilization (HRU), it also poses other challenges in children’s lives, such as educational difficulties\textsuperscript{7,10–12}. Additionally, the burden of ADHD borne by children and adolescents commonly extends to their caregivers\textsuperscript{13–15}. For instance, parents of children with ADHD may incur expenses for medical costs, special education, and/or require additional care services for their children, as well as the additional burden of indirect income loss due to missed workdays to provide additional care for their children. Given these additional expenses, it has been found that raising a child with ADHD to adolescence incurs five times higher economic burden compared to raising a child without ADHD, with the excess burden largely being driven by indirect income loss of caregivers due to missed workdays or losing their jobs\textsuperscript{15}. The burden may be particularly high for parents of children with ADHD who may also have the condition...
themselves. ADHD among parents may hinder their ability to tender their child’s needs, including their child’s ADHD management (e.g., ensuring treatment adherence, providing routines), due to their own difficulties with executive functioning. For these families, it may be especially important to also manage the parental ADHD to allow for optimal management of their child’s ADHD, given the important role that many parents play in the treatment of their children.16,17

Meanwhile, difficulties faced by children with ADHD are likely to continue into adolescence if their symptoms are not properly identified and well managed early on.18,19 As adolescents with ADHD are generally faced with increasing academic, occupational, and social demands, further burdens of ADHD may be encountered, including higher risks of substance use and road traffic accidents.20–23 Furthermore, ADHD is known to be a chronic condition for some patients that can affect patients’ entire lifespan,24,25 with 35%–78% of children and adolescents with ADHD maintaining symptoms through adulthood26,27, and a recent report on the longitudinal remission patterns of ADHD in the Multimodal Treatment Study of ADHD (MTA) finding that 91% of children with ADHD continued to experience residual symptoms (i.e., only 9% of children with ADHD had sustained remission) into adulthood.28 Thus, adolescents with ADHD are also at risk of experiencing a wide range of adverse outcomes associated with ADHD while transitioning to adulthood (e.g., increased unemployment, productivity loss).29 The observation that a sizeable segment of childhood ADHD progresses into adulthood undoubtedly contributes to the large economic burden of ADHD in adults—a burden that exceeds that within children and adolescents.11

Given that the manifestation of ADHD among children and adolescents often has direct implications on how patients interact with society (e.g., with the education system or labor force), it is imperative to look beyond the patient and payer perspectives and consider the total societal costs associated with the condition to understand the true economic burden from a societal perspective. However, despite the extensive body of research conducted in children and adolescents with ADHD, the previous studies that sought to quantify the economic impact mostly have been from the payer perspective, assessing direct healthcare costs only, or have focused on a single or only a few components of ADHD,30–33 without fully contextualizing the multifaceted nature of the disease burden. Previous literature has rarely attempted to monetize the burden comprehensively at a societal level across these multiple components (e.g., direct healthcare costs, education, caregiving, substance use, road traffic accidents, unemployment, productivity loss, premature mortality).11,34–36 Gupte-Singh et al. estimated that the annual total incremental cost of ADHD among patients aged 0–17 years was $3.92 billion in 2011. However, the only indirect cost component assessed was the costs of parents’ loss of productivity; other components that could be substantially costly in this patient population (e.g., costs of education) were not included.34 A systematic review conducted by Doshi et al. found that the national annual incremental costs attributable to ADHD among children/adolescents in the US ranged from $32 to $72 billion; however, the study components were all derived from previously published literature dating back to 1999 and the study did not stratify cost components by the child and adolescent populations.11 Notably, the burden associated with ADHD may differ between children and adolescents as the manifestation of the disease as well as one’s social role may change as patients develop throughout the life course, and hence it would be noteworthy to stratify results by child and adolescent populations to allow for the comparison of the relative importance of cost components using a common methodology.11,35,36

To build upon existing literature and highlight the various stakeholders involved in the economic burden of ADHD, this study aimed to provide a comprehensive evaluation of the economic burden of ADHD among children and adolescents, separately, in the US from a societal perspective. The research sought to identify the major cost components contributing to the societal economic burden associated with ADHD in children and adolescents, which may help drive new clinical (e.g., patient management) and social (e.g., education, disability) policies to mitigate the impact of ADHD on patients and society at large.

Methods

This study applied a prevalence-based approach, primarily with a bottom-up method, to estimate the excess costs incurred by an individual with ADHD compared to an individual without ADHD in the US in 2018. In this approach, the average per-patient excess costs were scaled up to the national level by multiplying the per-patient costs by the number of individuals with ADHD, estimated from the prevalence rate of ADHD and census population data. A top-down method was used for cost components in which data on the total costs associated with ADHD were available (e.g., research funding). Details of data sources and calculations are described below.

Data sources

Direct healthcare costs of children (aged 5–11 years) and adolescents (aged 12–17 years) with ADHD were obtained from health insurance claims data based on the IBM MarketScan Commercial and Medicaid Subsets from 01/01/2017 to 12/31/2018. Patients with ADHD were identified based on two diagnosis claims of ADHD (International Classification of Diseases, 9th Revision, Clinical Modification [ICD-9-CM] codes: 314.0x; International Classification of Diseases, 10th Revision, Clinical Modification [ICD-10-CM] codes: F90.x) on distinct dates. The index date was defined as the most recent calendar date that was followed by 12 months of continuous health plan coverage. The study period was defined as the 12-month period following the index date. The respective direct non-healthcare costs and indirect costs of children and adolescents with ADHD were estimated based on a review of academic literature and government agency publications. A targeted literature review
was conducted to identify each of the potential cost inputs and the final decision for inclusion in the study was based on clinical input and discussion with experts to identify credible and accurate estimates that were relevant to the current study.

**Estimation of ADHD prevalence**

The prevalence of ADHD among children and adolescents in the US was obtained from the US National Survey of Children’s Health (NSCH)\(^4\) and the National Comorbidity Survey Replication (NCS-R), respectively\(^6,37\). The NSCH is a nationwide survey on the physical and emotional health of American children, including an indicator specific for ADHD. Households were randomly sampled across all US states and one child was randomly selected among each household to be the subject of the survey, which was completed by a parent or guardian who was familiar with the child’s health. Survey results were weighted to represent the population of non-institutionalized children in the US\(^4\). The NCS-R estimated the number of adolescent residents with ADHD in US households based on a nationwide household survey of the prevalence and correlates of mental disorders plus the number of adolescent students sampled from a nationally representative sample of schools in the US\(^37\). The total number of children and adolescents with ADHD was estimated, separately, by multiplying the prevalence rate and the total population of children and adolescents in the US in 2018 based on data from the US Census Bureau\(^38\).

**Excess costs of ADHD among children and adolescents**

The total excess all-cause costs incurred by children and adolescents with ADHD in the US in 2018 were calculated as the sum of the excess direct healthcare costs, the excess direct non-healthcare costs, and the excess indirect costs attributable to ADHD. Specifically, direct healthcare costs were defined as all amounts reimbursed by payers and patients’ out-of-pocket costs observed in the claims database, as well as uncompensated healthcare costs covered by the federal, state, and local institutions as well as by the private sector for uninsured individuals. Direct non-healthcare costs were defined as costs identified in published academic and governmental literature that were actual expenses billed or paid, and indirect costs were defined as opportunity costs to society that were not directly observable. Excess costs associated with ADHD were estimated through a prevalence-based approach using the average cost differences between an individual with ADHD and an individual without ADHD or the general population (if data on individuals without ADHD was unavailable). The estimated prevalence rate from nationally representative surveys was then applied to extrapolate per-patient cost to a national level, using census population data, to derive a cost estimate for the total population for one year. Each cost component was estimated to be specific to children and adolescents (i.e. two mutually exclusive populations). Multiple data sources were leveraged to measure each cost component (Table 1), and each estimated cost component was weighted by the distribution of the relevant patient characteristics in the US population in 2018 (e.g. the proportion of individuals with each type of health plan coverage and the proportion without a health plan coverage [uninsured]). Given that some literature-derived parameters were collected before 2018, costs were inflated using the Consumer Price Index and population growth was accounted for using the growth factor relative to 2018, derived from population estimates.

Sensitivity analyses were also conducted by varying the prevalence, excess total direct healthcare costs of an uninsured patient, discount rate, and proportion of patients with ADHD who seek treatment\(^39,40\).

**Estimation of direct healthcare costs**

Direct healthcare costs for Medicaid or commercially insured children and adolescents were calculated as the sum of the primary payer’s paid amount and patient out-of-pocket expenses. The costs comprised all-cause pharmacy costs and medical service costs, and the latter included outpatient (e.g. office visit, home care, ambulatory surgery center), inpatient, emergency room, and durable medical equipment costs. Patients were grouped based on their respective health plan coverage, and each group was divided into the ADHD cohort and the non-ADHD cohort based on recorded diagnoses of ADHD. Patients in the ADHD cohort were matched exactly to those in the non-ADHD cohort up to a 1:3 ratio based on characteristics including age, gender, region of residence, race, health plan, and year of the index date. The excess costs of insured patients with ADHD were expressed as the difference between the average all-cause costs incurred by patients with ADHD and those without ADHD over the 12-month study period, weighted by the ADHD population size in the respective plan type and apportioned to account for the proportion of patients who seek medical services in the ADHD population.

The excess direct healthcare costs of uninsured children and adolescents with ADHD were included in the weighted average calculation as uncompensated healthcare costs, which were based on a prior estimate in the literature for the overall US population\(^41\) and adjusted using data from the current Medicaid population to account for the higher excess costs of uninsured individuals with ADHD.

**Estimation of direct non-healthcare costs**

Direct non-healthcare costs associated with ADHD in children and adolescents included the following components: education, research, and training (i.e. funding allocated by the National Institute of Health [NIH]\(^42\)), substance use (adolescents only), and road traffic accidents (adolescents of driving age [aged 16–17 years] only).

Specifically, excess education costs were calculated as the excess number of days per year devoted to ADHD-related special education in children or adolescents with ADHD (i.e. 3.5 years\(^43\)) multiplied by the cost of one year of special education\(^44\); the excess number of days per year of grade
| Method of estimation | Excess due to ADHD based on data \(^a\) | Number of individuals | Unit cost | Total excess costs due to ADHD (% of total societal costs) | Total excess costs per individual | References |
|----------------------|------------------------------------------|-----------------------|-----------|----------------------------------------------------------|----------------------------------|-----------|
| **Total societal costs** | | | | | | |
| Sum of all mutually exclusive cost components | | | | | | |
| Children | – | 2,856,780 | – | – | $19,423,935,825 (100%) | $6,799 |
| Adolescents | – | 1,655,303 | – | – | $13,819,588,815 (100%) | $8,349 |
| **Direct healthcare** | | | | | | |
| Bottom-up Average excess costs of a patient with ADHD compared to a matched patient without ADHD, applied to the population of individuals with ADHD by insurance type and adjusted for the proportion of patients who seek treatment | Children | $2,801 | 1,793,577 | – | $5,024,322,947 (25.9%) | $1,759 |
| Adolescents | $3,718 | 1,079,082 | – | – | $4,011,650,834 (29.0%) | $2,424 |
| **Direct non-healthcare** | | | | | | |
| Education | Bottom-up Estimated average cost of education \(^b\) for an individual with ADHD compared to an individual without ADHD applied to the population of individuals with ADHD | Children | $4,076 | 2,747,064 | – | $11,643,338,245 (59.9%) | $4,076 |
| Adolescents | $4,076 | 1,594,532 | – | – | $6,746,495,259 (48.8%) | $4,076 |
| Research and training | Top-down: Existing data on funding allocated to ADHD by the National Institute of Health and proportionally adjusted for the proportion of the individuals with ADHD in the US who were children/adolescents | Children | $12,515,637 | – | – | $12,515,637 (0.1%) | $4 |
| Adolescents | $7,251,931 | – | – | – | $7,251,931 (0.1%) | $4 |
| Substance use disorder | Top-down: Existing data on costs of alcohol and drug use to derive costs per person with substance use disorder in the US applied to the estimated number of individuals with ADHD with substance use disorder | Adolescents | – | – | – | $4,434,107 (3.2%) | $268 |
| Alcohol use disorder | 5.4% | 89,021 | $273 | $64,386,280 (5.5%) | – | |
| Drug use disorder | 8.8% | 145,667 | $2,602 | $379,077,796 (2.7%) | – | |
| **Road traffic accidents** | Bottom-up Estimated costs per road traffic accident multiplied by the total number of road traffic accidents, proportionally adjusted by the rate ratio of road traffic accidents among individuals with ADHD compared to those without ADHD | Adolescents | 1.27 times the accident rate | 4,946 excess road traffic accidents | $39,539/accident | $195,557,697 (1.4%) | $118 |
| **Indirect** | | | | | | |
| Caregiving | Bottom-up Estimated number of excess hours devoted to ADHD-related caregiving proportionally adjusted by the proportion of individuals with ADHD who require a caregiver and multiplied by the median hourly earnings in the US adult population | Children | $960/year | 2,856,780 | – | $2,743,758,996 (14.1%) | $960 |
| Adolescents | $960/year | 1,655,303 | $1,589,815,281 (11.5%) | $960 |
| Unemployment | Bottom-up Estimated excess unemployment to population ratio due to ADHD multiplied by the population of individuals with ADHD and the median annual earnings in the US by gender | Adolescents | Male: 3.3% Female: 1.0% | 4,760 | – | $79,743,577 (0.6%) | $48 |
| Productivity loss at work | Bottom-up Estimated excess days lost due to ADHD-related absenteeism and presenteeism multiplied by the population of individuals with ADHD and the median annual earnings in the US by gender | Adolescents | Absenteeism: 13.6 days/year | 210,059 | – | $436,556,019 (3.2%) | $264 |
| | Presenteeism: 21.6 days/year | 210,059 | – | $397,886,648 (1.9%) | – |
| Premature mortality | Bottom-up Estimated number of excess all-cause deaths among adolescents with ADHD, applied to the average annual earnings and adjusted for the employment to population ratio per age group with a 3.0% discount rate | Adolescents | 1.5 times the mortality rate | 280 | $14,713 | $309,054,141 (2.2%) | $187 |

Abbreviations. ADHD, attention-deficit/hyperactivity disorder; US, United States.

\(^{a}\)Calculated by the average cost differences between an individual with ADHD and an individual without ADHD or the general population (if data on individuals without ADHD was unavailable). Data for direct healthcare costs were obtained from IBM MarketScan Commercial and Medicaid Subsets from 01/01/2017 to 12/31/2018. Data for direct non-healthcare and indirect costs were estimated based on literature inputs.

\(^{b}\)Calculated as the excess number of days per year devoted to ADHD-related special education in children or adolescents with ADHD multiplied by the cost of one year of special education; the excess number of days per year of grade retention in children or adolescents with ADHD multiplied by the cost of one year of regular education in the US; and the cost of one year of ADHD-related disciplinary events in children or adolescents with ADHD.
retention in children or adolescents with ADHD (i.e. 0.3 years)\textsuperscript{45} multiplied by the cost of one year of regular education in the US\textsuperscript{45}; and the cost of one year of ADHD-related disciplinary events in children or adolescents with ADHD\textsuperscript{43}.

Research and training costs were calculated with the assumption that the proportion of funding allotted to the research on children/adolescents with ADHD (i.e. $58.0 million in 2018\textsuperscript{42}) was equal to the proportion of children/adolescents with ADHD in the overall ADHD population in the US.

Substance use costs were calculated as the excess number of adolescents with alcohol or drug abuse disorder due to ADHD (i.e. 5.4% with alcohol use disorder and 8.8%, with drug use disorder\textsuperscript{22,46}) multiplied by the average cost of alcohol or drug abuse disorder in the US (i.e. costs to the criminal justice system, property and personal costs incurred by crime victims, costs associated with loss of productivity for incarcerated individuals, and prevention and research costs associated with alcohol use disorder and drug use disorder\textsuperscript{47–49}).

Road traffic accident costs were calculated as the excess number of road traffic accidents due to ADHD (i.e. the total number of road traffic accidents in the US adolescent population\textsuperscript{50} and accounting for 27.0% higher risk of US adolescents with ADHD of driving age being involved in a road traffic accident\textsuperscript{21}) multiplied by the average cost of a road traffic accident in the US (i.e. insurance, legal, congestion, and property damage\textsuperscript{51}).

**Estimation of indirect costs**

Excess indirect costs associated with ADHD in children and adolescents were estimated using a human capital approach in which costs were derived based on paid work compensation rates (i.e. an individual’s productivity was valued at their expected market earnings)\textsuperscript{52}. Cost components in this category included costs associated with caregiving, unemployment (adolescents of working age [aged 16–17 years] only), productivity loss at work (adolescents of working age [aged 16–17 years] only), and premature mortality (adolescents only).

Specifically, caregiving costs were calculated as the number of children or adolescents with ADHD multiplied by the estimated annual cost of ADHD-related caregiving per child or adolescent with ADHD (i.e. excess number of hours per year devoted to ADHD-related caregiving per individual with ADHD multiplied by the median hourly earnings of adults) in the US. Based on inputs from the literature, the costs associated with raising a child with ADHD over the course of the child’s development include monetized direct costs related to the child’s behavior (e.g. legal involvement, accident/injury, and damaged property) and indirect costs related to caregiver strain (e.g. income loss due to getting fired, changed responsibilities, or missing work, parental mental health services, and additional childcare)\textsuperscript{15}.

Given known differences in labor force participation and income by gender, cost estimates for unemployment and productivity loss were first stratified by gender, and the sum of the excess costs by gender was presented as an aggregate estimate.

Unemployment costs were calculated as the excess number of unemployed male or female adolescents with ADHD multiplied by the median annual earnings of male or female employees in the US\textsuperscript{53–55}. Based on the literature, adolescent males and females of working age with ADHD in the labor force are reported to be 2.1 times and 1.3 times more likely to be unemployed, respectively, compared with their respective counterparts without ADHD\textsuperscript{29}. The aggregated excess costs of unemployment were the sum of that of males and females.

The costs of productivity loss at work among adolescents were calculated as the excess number of days per year lost due to ADHD-related absenteeism (i.e. missed workdays) or presenteeism (i.e. low performance while physically at work) multiplied by the median daily earnings of male or female employees multiplied by the number of employed male or female adolescents with ADHD in the US\textsuperscript{53–55}. Based on inputs from the literature, the excess number of workdays lost per year due to ADHD-related absenteeism and presenteeism in the US is 13.6 and 21.6, respectively\textsuperscript{56}.

Premature mortality costs were calculated based on the number of excess all-cause deaths among adolescents with ADHD (i.e. 1.5 times higher than that among adolescents without ADHD\textsuperscript{57,58}), average annual earnings, the employment to population ratio per age group\textsuperscript{54,55}, and a 3.0% discount rate to estimate the excess productivity loss from all-cause deaths.

**Results**

According to the most recent estimates at the time of study, the prevalence of ADHD among children (aged 5–11 years) and adolescents (aged 12–17 years) was 10.0% and 6.5%, respectively\textsuperscript{45}, which corresponds to an estimated 2,856,780 children and 1,655,303 adolescents living with ADHD in the US. As shown in Figure 1, ADHD in children and adolescents was estimated to comprise about one-third of the total ADHD prevalence in the US population after accounting for the respective population size of children, adolescents, and adults in the US\textsuperscript{4–6,38}.

**Figure 1.** Overall ADHD population in the US in 2018. Abbreviations: ADHD, attention-deficit/hyperactivity disorder; US, United States.
The total excess costs and the constituent cost components associated with ADHD in children and adolescents are summarized in Table 1 and Figure 2. Based on the prevalence estimates, the total societal excess costs associated with ADHD were estimated at $19.4 billion in children, or $6,799 per child with ADHD (Figures 2(A), 3), and $13.8 billion in adolescents, or $8,349 per adolescent with ADHD (Figures 2(B), 3). Based on the sensitivity analyses, the total excess costs ranged from $14.8 billion to $20.6 billion for children with ADHD (i.e. $5,166–$7,197 per child) and $13.6 billion to $29.7 billion for adolescents with ADHD (i.e. $8,191–$17,932 per adolescent).

**Direct healthcare costs**

Among children in the US, the excess direct healthcare costs attributable to ADHD based on claims data were estimated at $2,801 per child with ADHD in 2018 (Table 1). The estimated costs were similar across children with different health plan types and ranged from $2,712 to $2,857 per child with ADHD (Figure 4). The estimated costs were apportioned to the US child population with ADHD who received any form of healthcare services (estimated at 62.8%)\(^4\), resulting in excess direct healthcare costs of $1.759 billion. Hence, the total excess direct healthcare costs were estimated at $5.0 billion among children with ADHD in 2018, which accounted for 25.9% of the total societal excess costs associated with ADHD in children (Figure 2(A)).

Among adolescents in the US, the excess direct healthcare costs attributable to ADHD based on claims data were estimated at $3,718 per adolescent with ADHD in 2018 (Table 1). When stratified by health plan type, the average excess direct healthcare costs associated with ADHD were found to be similar and ranged from $3,509 to $3,922 per adolescent with ADHD (Figure 4). After apportioning the estimated costs to the US adolescent population with ADHD who received any form of healthcare services (estimated at 65.2%)\(^4\), the excess direct healthcare costs were estimated at $2,424 per adolescent with ADHD. Hence, the total excess direct healthcare costs were estimated at $4.0 billion among adolescents with ADHD in 2018, which accounted for 29.0% of the total societal excess costs associated with ADHD in adolescents (Figure 2(B)).

**Direct non-healthcare costs**

**Education**

The total excess costs of education among children with ADHD were estimated at $11.6 billion in 2018. Overall, excess education costs accounted for 99.9% of the total excess non-healthcare costs and 59.9% of the total societal excess costs associated with ADHD among children in the US (Table 1; Figure 2(A)). Among adolescents with ADHD, the total excess costs of education were estimated at $6.7 billion. Overall, excess education costs accounted for 91.3% of the total excess non-healthcare costs and 48.8% of the total societal...
excess costs associated with ADHD among adolescents in the US (Table 1; Figure 2(B)).

**Research and training**
The excess research and training costs on ADHD incurred were estimated at $12.5 million for children and $7.3 million for adolescents with ADHD in 2018 (Table 1).

**Substance use disorder**
The excess costs of substance use disorders due to ADHD among adolescents in the US were estimated at $443.5 million (Table 1).

**Road traffic accidents**
The excess costs of road traffic accidents due to ADHD in the US adolescent population were estimated at $195.6 million (Table 1).

**Indirect costs**

**Caregiving**
The annual excess costs of caregiving incurred by raising a child with ADHD were estimated at $2.7 billion and costs incurred by raising an adolescent with ADHD were estimated at $1.6 billion. Overall, the excess costs of caregiving accounted for 14.1% and 11.5% of the total societal excess costs in children and adolescents with ADHD, respectively (Table 1; Figure 2).

**Unemployment**
The estimated combined excess costs of unemployment due to ADHD in the US adolescent population were $79.7 million (Figure 2(B); Table 1).

**Productivity loss at work**
The estimated excess costs of productivity loss at work due to ADHD in the US adolescent population were estimated at $436.6 million (Figure 2(B); Table 1).

**Premature mortality**
The excess costs of productivity loss due to premature mortality associated with ADHD in the US adolescent population were estimated at $309.1 million (Figure 2(B); Table 1).

**Discussion**
This comprehensive societal analysis of the excess economic burden of ADHD among children and adolescents found the total societal costs associated with ADHD in the US in 2018 to be approximately $19.4 billion among children and $13.8 billion among adolescents with ADHD. These findings demonstrate the substantial economic burden of ADHD in children and adolescents in the US and highlight the current unmet need in these populations. Specifically, costs due to education contributed to roughly half of the total burden of ADHD in both populations, which were estimated at $11.6 billion (59.9% of total excess costs) in children and $6.7 billion (48.8% of total excess costs) in adolescents. The main driver of education costs was the costs associated with special education, which, based on the literature inputs, constituted an additional 97 days per year spent on education for children and adolescents with ADHD and could be associated with costs attributable to tutoring, employing special education teachers/service providers/administrators, and spending on non-personnel items (e.g. materials, supplies, technological supports). Other major contributors to the overall burden of ADHD among children and adolescents were direct healthcare costs ($5.0 billion in children [25.9%]; $4.0 billion in adolescents [29.0%]) and caregiving costs ($2.7 billion in children [14.1%]; $1.6 billion in adolescents [11.5%]). The excess costs in children and adolescents were estimated to constitute...
about one-fifth of the total societal excess costs associated with ADHD in the US population, with an additional $122.8 billion being attributable to the adult population with ADHD. Overall, ADHD was associated with a substantial economic burden, which appeared to be higher than anxiety and depression on a population level. The observation that a large proportion of the total economic burden of ADHD among children and adolescents is attributable to education costs, a direct non-healthcare cost, distinguishes it from many other medical conditions, where costs are largely associated with direct medical costs (e.g. hospitalizations). Additionally, the observed relative importance of direct non-healthcare costs in children and adolescents differs from previous findings among adults with ADHD, in which the largest cost drivers reported were indirect costs (e.g. productivity loss). The significant costs of education associated with ADHD align with the findings of a recent systematic literature review on the economic impact on the education sector of various mental and neurodevelopmental disorders (e.g. ADHD, anxiety, depression, autism). The review highlights that ADHD is among the top conditions associated with the highest proportion of education costs, only behind intellectual disability disorder and autism. The excess education costs were mainly driven by special education, such as tutoring and counseling services. A survey showed that children with a parent-reported diagnosis of ADHD were five times more likely to receive special education services compared with those without a reported diagnosis; this adds significant monetary costs to the education system and puts extra strain on education staff. Additionally, due to the age and general lack of independence of children and adolescents, the impact of ADHD on academic outcomes may also be associated with a burden borne by families or caregivers who may bear the direct monetary costs and may also incur indirect costs from their own occupational and socio-emotional...
consequences, such as job loss, missed leisure activities, and need for mental health support. 

Currently available treatments for children and adolescents with ADHD are associated with improvements in certain academic and emotional outcomes. However, despite the various pharmacologic and non-pharmacologic treatments available, barriers to treatment uptake exist as many children and adolescents with ADHD remain undiagnosed or untreated. Indeed, a study based on the 2016 NSCH revealed that among US children and adolescents aged 2–17 years with parent-reported ADHD, ~23% have never received pharmacologic or non-pharmacologic treatments, and among those who do initiate treatment, adherence and persistence tend to be poor. Evidence suggests that adherence and persistence to stimulant medication among children and adolescents with ADHD are relatively low in both clinical trials and real-world settings, and tend to decrease over time, with treatment discontinuation rates found to be around 20% within the first 12 months of treatment and increasing to 40% after 24 months in a medical record–based longitudinal cohort study. The reasoning for poor treatment uptake and low adherence and persistence is likely multifaceted and may differ depending on the patient’s life stage. For instance, parents may be reluctant for their young children to use medication even though most research evidence suggests a strong immediate effect of medication on alleviating ADHD core symptoms. In addition, children who do initiate ADHD medication may have poor adherence due to difficulties swallowing the medication or inadequate monitoring by parents, while poor adherence in adolescents may be more likely due to social peer pressure and greater autonomy in their own decision-making. Poor adherence may also be partly attributable to the symptoms of ADHD that impair executive functioning and render the patients forgetting to take medications, which can be increasingly problematic in adolescents who may prefer to manage their own treatment schedules. Meanwhile, adverse effects of medication, which may include insomnia and appetite loss, are one of the most common reasons for discontinuation. Other reasons for poor adherence and persistence in these populations may include dosing inconveniences and suboptimal response of existing treatments, parents’ decisions to discontinue treatment, delays in prescription fills (e.g. due to regulations of controlled substances such as stimulants that lead to shortages in pharmacies), and social stigma to ADHD medications. Collectively, low rates of treatment uptake, combined with low rates of adherence and persistence, may limit the potential management of ADHD-related symptoms, and ultimately lessen the beneficial impact of treatment on reducing the burden of ADHD in these populations. The current unmet need among patients with ADHD highlights the importance of developing improved treatments with simpler dosing schedules and improved tolerability profiles that may help increase rates of adherence and persistence. Additionally, shedding light on the reasons behind ADHD treatment barriers, such as reasons for treatment changes, may help clinicians tailor treatment management strategies to patients with ADHD in various life stages, which may improve the quality of care and lead to better clinical outcomes.

The substantial burden of ADHD in children and adolescents observed in the current study suggests that additional efforts are needed to address the unmet needs in these populations, and the stratified results for each cost component may inform policy decision-makers on key focus areas. For instance, educational difficulties (e.g. poor academic outcomes) and other school-related issues (e.g. conduct and social problems), which may be exacerbated by unmanaged ADHD symptoms, such as hyperactivity and inattention, and comorbid conditions, such as oppositional defiant disorder (ODD) and conduct disorder (CD), are the major burdens faced by children and adolescents with ADHD. In this regard, along with developing improved treatment strategies, school policies that encourage classroom accommodations, and increased collaboration among school professionals to tailor management for individual students with ADHD may help alleviate certain academic and social challenges. For instance, it has been shown that collaborative consultation between the school psychologist and classroom teachers as well as consultations including the family of children with ADHD may result in improved academic metrics (e.g. reading/math skills, homework performance) for these children. Meanwhile, a recent review on prospective follow-up studies of children with ADHD found that the high rates of persistence of ADHD symptoms among children may result in downstream negative outcomes in adulthood, including impacts on education, occupation, and social, physical, and mental health; therefore, early educational interventions that address conduct and behavioral issues of children and adolescents with ADHD may have long term benefits and improve outcomes in adulthood.

Additionally, it has been suggested that access to disability services, including accommodation programs and continued care, is becoming increasingly challenging for an individual with ADHD as they age (e.g. for adolescents and young adults). Typically, a formal diagnosis and documents that demonstrate that the individual’s ADHD symptoms result in substantial impairment of functioning compared to the general population are required to deem the patient eligible for disability services. However, diagnosing ADHD and determining the level of functioning of adolescents and adults may be more difficult than for children as the diagnostic criteria for ADHD symptoms in the Diagnostic and Statistical Manual of Mental Disorders are child-centric, highlighting the importance of inclusive diagnostic scales to aid clinicians in diagnosing ADHD across the life course. Ensuring that clinicians are well equipped to identify and diagnose ADHD among older patients, increasing awareness of requirements stipulated by disability service providers, and subsidizing these types of required assessments may help to improve access to important services for patients with ADHD.

In addition, raising public awareness of ADHD may help reduce social stigma and lessen the peer pressure faced by children and adolescents with ADHD, which may in turn
increase medication adherence and persistence and hence treatment effectiveness. Improved public education on the condition may also allow employers to be more understanding towards employees with family members who have ADHD, which may lead to higher job stability and better career prospects among these employees, thereby mitigating some of the caregiver burdens. Empathy from employers may also alleviate the burden of adolescents or young adults entering the workforce. Additionally, as ADHD may be a chronic condition for some patients, with symptoms persisting into adulthood\(^{26,27}\), better management of symptoms in children and adolescents may also help alleviate the long-term burden by placing them in a more favorable position as they transition into adulthood (e.g. educational achievement, employment opportunity)\(^{11,49}\). Taken together, the development of improved intervention strategies as well as policies and awareness around ADHD are needed to overcome treatment barriers, improve adherence and persistence, alleviate educational difficulties, and minimize stigmatization, which has the potential to improve various aspects of the patient’s life across life stages and reduce the economic burden from a societal perspective.

The findings of this study should be interpreted in light of certain limitations. Costs were estimated using a prevalence-based approach to capture the economic burden of ADHD in a given year for a representative population of children and adolescents with ADHD. As such, the total economic burden of ADHD per individual should be interpreted as the potential cost savings if ADHD were to be removed from society, and thus should not be interpreted as the potential cost savings from averting a case of ADHD (i.e. if an incident-based approach were to have been applied) or curing a case of ADHD at a given point in their disease trajectory (i.e. accounting for lifetime ADHD effects on human capital formation). The excess direct healthcare costs for insured individuals were estimated based on data from a claims database, which includes diagnosis information collected for administration purposes and may not fully reflect all direct healthcare costs incurred by patients with ADHD. Additionally, as patients were identified based on documented diagnoses of ADHD, individuals with undiagnosed ADHD were not captured, which may lead to an under-estimation of the total excess direct healthcare costs attributable to ADHD in the population. For the estimation of excess direct healthcare costs for those who are uninsured with ADHD, as well as excess direct non-healthcare costs and indirect costs, the estimates were calculated based on available literature and/or governmental publications due to the absence of a single data source for all costs associated with ADHD. As such, the point estimates provided had inherent uncertainty with variation based on each input. Furthermore, the quality of cost estimates is limited by the accuracy of available data as well as the study populations and methodologies used by different studies and may not always be generalizable to the entire population of patients with ADHD. Nonetheless, sensitivity analyses based on several variables were conducted to provide the lower and upper bound estimates for the total excess costs in each studied population. Lastly, cost components were set to be mutually exclusive to avoid overlapping of cost-counting across categories, which may lead to the true burden of a given cost component being under- or over-estimated if an associated cost had already been covered in another category. For example, to keep cost components mutually exclusive, the costs of road traffic accidents (for the adolescent population) included only property damage costs and not medical costs, because medical costs associated with road traffic accidents were captured as direct healthcare costs. Therefore, the estimated costs associated with road traffic accidents were likely an under-estimation.

**Conclusion**

Childhood ADHD is associated with numerous negative outcomes, such as poor academic performance, increased healthcare costs, and caregiver burdens. The impact of ADHD may lead to further negative consequences among children and adolescents with ADHD, such as challenges with social relationships and low self-esteem. Given that childhood ADHD often persists into adulthood, these negative outcomes may continue and manifest in similar ways, such as poor performance at work and difficulties with social relationships. The current findings demonstrate that the economic burden of ADHD among children and adolescents in the US is substantial and mainly driven by education costs. Despite available treatment options, an important unmet need remains. Thus, the development of more effective, safe, convenient, and accessible intervention strategies and accompanying policies may reduce the clinical and economic burden of ADHD in children and adolescents. At the same time, improved management of ADHD symptoms in these patients may also help alleviate the long-term implications of ADHD and ultimately reduce the economic burden across the life course.

**Transparency**

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JS is an employee of Otsuka Pharmaceutical Development & Commercialization, Inc.

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Author contributions

JS, LAA, AC, PGS, MD, FK, MC, AG, and PL contributed to the design of the study and interpretation of the data. PGS, MD, FK, MC, AG, and PL contributed to the data collection and data analysis. All authors critically revised the draft manuscript and approved the final content.

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