Social and Economic Costs of Attention-Deficit/Hyperactivity Disorder Across the Lifespan

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Abstract

Objective: To determine the financial and non-financial costs of Attention-Deficit/Hyperactivity Disorder (ADHD) across the lifespan. **Method:** The population costs of ADHD in Australia were estimated for the financial year 2018 to 2019 using a prevalence approach to cost estimation across all ages. Financial (healthcare, productivity, education and justice systems, and deadweight losses) and non-financial costs were measured (Disability Adjusted Life Years (DALYs)). **Results:** The total social and economic cost of ADHD in 2018 to 2019 were US$12.76 billion (range US$8.40 billion to US$17.44 billion, with per person costs of US$15,664 per year). Productivity costs made up 81% of the total financial costs, followed by deadweight losses (11%), and health system costs (4%). Loss in terms of wellbeing was significant (US$5.31 billion). **Conclusion:** There is a need to raise public awareness of the considerable socioeconomic impact and burden of ADHD in order to drive investment and policy decisions that improve identification and treatment of ADHD. *(J. of Att. Dis. XXXX; XX(X) XX-XX)*

Keywords

ADHD, economic, costs, health care, education, justice, wellbeing

Attention-Deficit/Hyperactivity Disorder (ADHD) is a common neurodevelopmental mental health disorder defined by inappropriate levels of inattention, hyperactivity and/or impulsivity. ADHD is a risk factor for a wide range of negative outcomes including exclusion from school and educational under-achievement, difficulties with employment and relationships, criminality and increased mortality (Dalsgaard et al., 2015; Faraone et al., 2015; Shaw et al., 2012; Willoughby, 2003). Although more prevalent in childhood there is increasing acknowledgement of the persistence of symptoms and impairment into adulthood in the majority of cases (Bonvicini et al., 2016). Mental health and developmental comorbidities are common across the lifespan with about half of those with ADHD meeting criteria for at least one other condition (Capusan et al., 2019; Chen et al., 2018; Faraone et al., 2015; Lawrence et al., 2015; Sciberras et al., 2014). Despite the broad impact and high prevalence and global burden of ADHD, few international studies have comprehensively mapped the social and economic costs of ADHD across multiple domains. Yet documenting these costs has the potential to act as a powerful policy lever to effect the societal change needed to improve the lives of individuals with ADHD. This study uses Australia as an exemplar and comprehensively documents the social and economic costs of ADHD.

Previous studies have highlighted the significant costs associated with ADHD. Most have focused on the increased healthcare attendances and medication and are based on data from insurance databases (Doshi et al., 2012). Less is known about total societal costs across multiple areas including education, justice and productivity

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and few studies have accounted for comorbidities within their cost estimates (Daley et al., 2019). Despite the lifelong nature of ADHD most published studies have focused on children (Le et al., 2014; Quintero et al., 2018; Schlander et al., 2010; Sciberras et al., 2017) or adults (D'Amico et al., 2014) separately and have not been able to provide a comprehensive estimate of costs across the lifespan. Furthermore, few studies have comprehensively considered both the financial and non-financial costs of ADHD (Hong et al., 2019). Disability Adjusted Life Years (DALYs) reflect important non-financial costs associated with time lost due to ill health. Although the Global Burden of Disease (GBD) study reported that ADHD is associated with 491,500 DALYs globally, per year (Erskine et al., 2014) methodological limitations of the GBD studies almost certainly mean that this is an underestimate. For example, accidents are coded as such and it is not possible to identify those that are attributable to ADHD so that they can be included within cost estimates for ADHD (Erskine et al., 2014). Additionally, as the GBD studies only consider non-financial costs they cannot comment on the financial costs.

Global policy changes are needed in the recognition of the burdens associated with ADHD and the changes in services and funding required to reduce these impacts. While medication can reduce the symptoms of ADHD, the mental health and broader outcomes remain poorer than for individuals without ADHD (Fazel, 2015; Langberg & Becker 2012; Storebø et al., 2015). To advocate for policy changes, including advancement in treatments, we urgently need comprehensive data about both the financial and non-financial costs that are presented in metrics commonly employed by politicians and other policy makers. These include detailing costs of existing services (e.g., health, educational and justice), impact on productivity and broader indices such as DALYs. To the best of our knowledge, no published study has examined the financial and non-financial costs of ADHD across the lifespan. Understanding the costs and burdens associated with ADHD across the lifespan, is essential in informing, planning and justifying policies and interventions for youth and older people affected by the disorder.

This study aimed to undertake an investigation into the social and economic costs of ADHD, using Australia as an exemplar, for the 2018 to 2019 financial year. We examined both financial (health, productivity, education, justice, deadweight) and non-financial costs (DALYs) associated with the condition in both children and adults.

Method

This study used a prevalence approach to cost estimation to determine the costs associated with ADHD in Australia in the 2018 to 2019 financial year. Figure 1 outlines the methodology used in this project. We conducted a targeted literature review to calculate the prevalence of ADHD and to estimate financial and non-financial costs incurred across the relevant categories related to ADHD for the given year (Appendix A). A bottom-up approach was predominantly used to estimate costs across most domains given the availability of data. This involves estimating the number of cases incurring each cost item, and multiplying the number of cases by the average cost per item. We used a top-down approach in the rarer instances were data were available for example, pharmaceutical costs. A top-down approach accesses the total costs of a program element using availability data (e.g., accessing existing data to estimate the costs of ADHD medications). Table 1 details the approach used to estimate costs across the various domains of interest in this study, except for the loss of wellbeing costs, which we describe below.

Prevalence of ADHD

Bottom-up cost estimates require accurate estimates of overall ADHD prevalence. Due to the well-recognized changes in ADHD prevalence across the lifespan these were calculated separately for children and youth/adults.

Prevalence Estimates in Childhood (0 to 14 years)

We conducted a targeted literature review to identify epidemiological population prevalence of ADHD in Australia. This prevalence estimate was then used to model the number of people with ADHD in Australia in 2019. The main source used to estimate prevalence in this study was the Global Burden of Disease study (Erskine et al., 2014). We selected this study as it pools prevalence from a range of studies, controls for study quality and ensures the representativeness of each study of the general population (Erskine et al., 2014). Using these data the prevalence estimate for ADHD in Australia is 4.1% in children aged 0 to 14 years (Supplementary Table 1).

Prevalence Estimates in Youth and Adulthood and Persistence (≥15 years)

To determine the number of youth and adults with ADHD in 2019, we used data from the Australian Twin Registry (Ebejer et al., 2012). In this study the persistence of ADHD was calculated from the age of 14 according to whether 1) full Diagnostic and Statistical Manual of Mental Disorders IV (DSM-IV) criteria were met (55.3% persistence from childhood); 2) full DSM-IV criteria were met other than the age of onset criterion (50.3% persistence); and 3) the participant experienced difficulties due to ADHD symptoms (40.2% persistence). For the current analyses we use the average persistence across these definitions for each age and by sex. The average decline in prevalence with a one unit increase in age was calculated and then extrapolated to estimate further

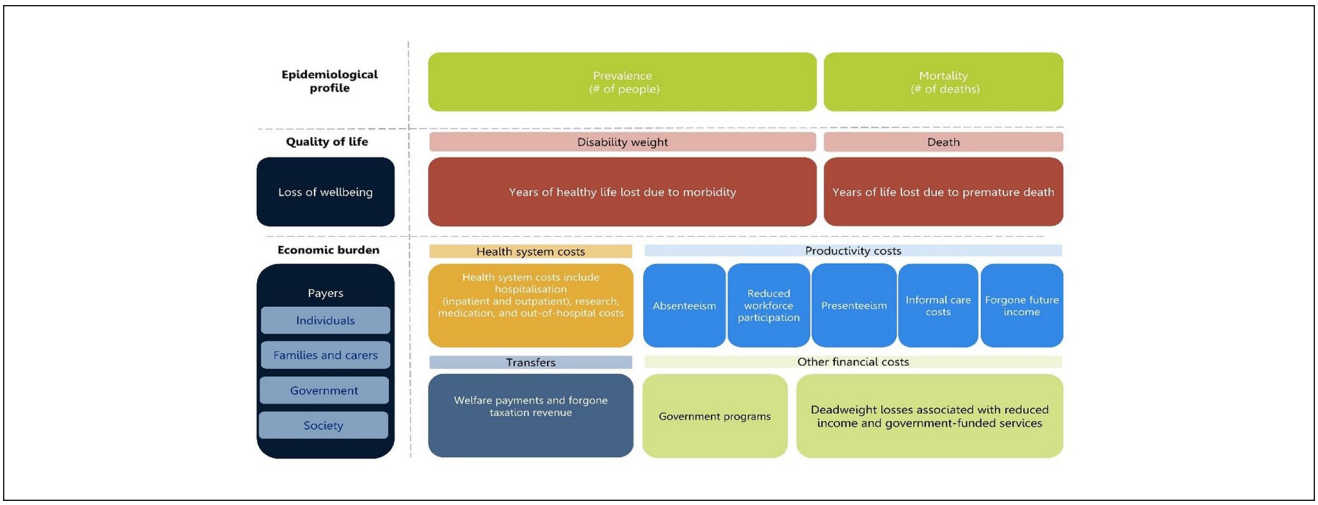

Figure 1. Study methodology framework.

decline in prevalence for older age groups (see Supplementary Table 1). These persistence rates were then applied to prevalence at age 14 from the GBD study (Erskine et al., 2014) to estimate the decline in prevalence rates with age.

Estimating Mortality Associated with ADHD

In order to estimate mortality associated with ADHD, in the absence of available Australian data, we used data from a prospective cohort study of 1.92 million Norwegian individuals, including 32,061 with ADHD (Dalsgaard et al., 2015). This study found that those with an ADHD diagnosis had a two-fold increased mortality rate ratio (MRR) with an all-cause mortality rate of 5.85 per 10,000 person-years compared with 2.21 per 10,000 person-years in controls (Dalsgaard et al., 2015). The MRR was higher in women (3.01:1) than in men (1.93:1). When adjusting for potential confounding factors (e.g., age, calendar year, sex, parental history of psychiatric disorders, parent age, parent education, parent employment status. comorbid conditions such as conduct disorder), the MRR for ADHD remained significant at 1.5:1 (Dalsgaard et al., 2015). We applied the more conservative MRR of 1.5:1 to general population mortality rates in Australia to estimate the mortality due to ADHD. As the Dalsgaard et al. (2015) only considers the risk of mortality from ADHD until 30 years of age, it was conservatively assumed that there is no increased risk of mortality for adults who are older than this.

Estimating the Financial and Non-Financial Costs of ADHD in Australia

Health system costs. Costs of hospitalizations, visits to general practitioners and specialists (out-of-hospital costs), medications and health research expenditure due to ADHD were estimated (Table 1). Other out-of-hospital services, such as allied health (e.g., psychologist or social worker visits, etc) and other related health system costs were unable to be estimated due to lack of robust evidence. Hospital costs and out of hospital costs were estimated by multiplying the unit cost of the service by the incremental service use between people with and without ADHD, which was then multiplied by prevalence. We took a conservative approach and assumed hospital and out of hospital costs only apply to 50.7% of people with ADHD based on Australian health service use data (Johnson et al., 2016). A top-down approach was used to estimate medication costs and health research expenditure. Health system costs in Australia are primarily paid for by governments, with the remainder paid for by individuals through out-of-pocket costs and private-health insurance. Most of the health system costs reported in this paper relate to government expenditure due to the availability of such data.

Productivity costs. Productivity costs included workforce participation (may occur through disadvantages in job-seeking or self-selection out of the labor force), temporary absenteeism (worker may take time off work due to their ADHD but remain in the workforce), presenteeism or reduced productivity at work (worker produces less due to lower capacity to work), premature mortality (loss of future earnings due to premature mortality) and the value of informal care (lost income of carers of children with ADHD). A human capital approach was adopted to estimate the productivity losses due to ADHD in Australia, which involves calculating the difference in employment or production between people with ADHD and that of the general population, multiplied by average weekly earnings (AWE) (Table 1).

Other costs. Other costs comprised costs of government services, including education and the justice system, loss of future income due to premature mortality (the future

Table 1. Approach to Bottom-Up and Top Down Estimation Across Health, Productivity and Other Cost Domains.

Cost domain	Method of estimation	Prevalence reference data	Cost reference data
Health system costs[a,b]			
Hospital costs	Bottom-up: Average number of hospital visits attributed to ADHD was multiplied by the average costs per visit. This estimate was then multiplied by ADHD prevalence estimates.	Children with ADHD had a difference of 0.07 additional emergency room visits compared to children without ADHD (Chan et al., 2002). Adults with ADHD have a difference of 0.23 in emergency room admissions compared to adults with ADHD (Secnik et al., 2005). Assumed costs only apply to 50.7% of people with ADHD based on health-service use data in Australia (Johnson et al., 2016).	Average cost per hospital visit was calculated using a weighted average of the total actual cost for AR-Diagnosis Related Group (DRGs) X60A (injuries with catastrophic or severe complications), X62A (poisoning/toxic effects of drugs and other substances with catastrophic or severe complications) and X64A (other injury, poisoning and toxic effect diagnosis with catastrophic or severe complications), weighted according to the number of separations. The 2014 to 2015 cost values were updated to 2019 dollars using Australian Institute of Health and Welfare (AIHW) health expenditure inflation, so that each hospital admission costs an estimated US$1,775 per, on average (Independent Hospital Pricing Authority, 2018).
Out of hospital costs	Bottom-up: The average number of annual out-of-hospital visits attributed to ADHD was multiplied by the average cost per visit. The average annual cost per patient was then multiplied by ADHD prevalence estimates.	Over the first five years following diagnosis, children had 4.2 more primary care appointments and 2.2 more specialist attendances per year on average, while adults with ADHD had 8.1 more primary care appointments and 2.4 more specialist attendances per year on average (Holden et al., 2013). Assumed costs only apply to 50.7% of people with ADHD based on health-service use data in Australia (Johnson et al., 2016).	Average General Practitioner (GP) visit cost per consultation was estimated to be US$38.80 (Annual Medicare Statistics, 2018). Given that patients may present to GPs with more than one problem, the average cost (US$38.80) was divided by the average number of presenting problems (1.55) based on a report into General Practice Activity in Australia (Britt et al., 2016). Thus the average cost of GP services specifically for ADHD in this study was calculated to be US$25.0. The average cost of a specialist attendance was estimated using the Medicare Benefits Schedule fee for general specialist attendances (US$60.7) (MBS online).
Pharmacotherapy	Top-down: Access of existing data to estimate the costs of ADHD medications.	NA	Data were directly accessed from the Pharmaceutical Benefits Schedule (PBS) data, which is a measure of total expenditure (Pharmaceutical Benefits Schedule).
Health research expenditure	Top-down: Access of existing data to estimate costs of health research expenditure on ADHD.	NA	Data were directly accessed from the National Health and Medical Research Council (NHMRC), Australia's major grant funded database (National Health and Medical Research Council [NHMRC], 2017). The database outlines all NHMRC research grant funding between 2000 and 2015 and for this study we took the average across these periods to determine funding allocated to ADHD research in 2019. We followed the same approach for grants awarded by the Australian Research Council, which have also been included. We have not estimated funding from other sources due to a lack of available data.

(continued)

Table 1. (continued)

Cost domain	Method of estimation	Prevalence reference data	Cost reference data
Productivity costs			
Workplace absenteeism	Bottom-up: Average additional days absent from work was estimated for adults with ADHD compared to the general population, multiplied by average weekly earnings. Additional costs were also included for management time associated with the absence from work and the overtime premium to maintain work output.	People with ADHD have on average an additional 13.6 days absent from work each year (Kessler et al., 2005); a conservative estimate of days missed from work using a measure of self-reported symptom-based childhood ADHD. The study also controlled for sociodemographic factors including age, sex, ethnicity, education and occupation.	To estimate the costs of absenteeism associated with ADHD, the average additional days absent from work was applied to Australian general population employment rates and average weekly earnings by age and sex (Australian Bureau of Statistics [ABS], 2018a). The total cost of manager time was estimated by assuming that a manager would require 2.5 hr to manage the absence for each individual (Risk Solutions, 2011), which was combined with average weekly earnings for a manager (ABS, 2018a). Overtime premiums associated with absences were estimated by applying a premium of 40% (Safe Work Australia, 2015) to wages and on costs in Australia (ABS, 2018a).
Presenteeism	Bottom-up: Average additional reduction in productivity while at work for adults with ADHD compared to the general population was applied to Australian general population employment rates and average weekly earnings by age and sex.	People with ADHD have on average a 10% reduction in work output each year compared to general population (Kessler et al., 2005); a conservative estimate of the reduction in productivity for people with ADHD while at work using a measure of self-reported symptom-based childhood ADHD. The study also controlled for sociodemographic factors including age, sex, ethnicity, education and occupation.	The percent of work time lost due to absence in productivity was converted to an average number of days lost each year based on the average yearly supply of work hours in the Australian general population (Australian Bureau of Statistics [ABS], 2019b).
Reduced workforce participation	Bottom-up: Estimated percentage of ADHD population that are unemployed.	Adults with ADHD are 10% less likely to be employed than a population comparison group accounting for key potential confounding variables (e.g., age, sex, high school test scores, co-occurring illnesses and health behaviors such as asthma, depression, childhood mistreatment, tobacco and alcohol use, obesity, etc, and whether the individual completed school, along with family and occupation fixed effects (employment, earnings and individual's occupation)) (Fletcher, 2014).	The relative reduction in employment was applied to Australian general population employment rates (Australian Bureau of Statistics [ABS], 2018b) and average weekly earnings (ABS, 2018a) by age and sex.

(continued)

Table 1. (continued)

Cost domain	Method of estimation	Prevalence reference data	Cost reference data
Premature mortality	Bottom-up: Estimated by multiplying the number of deaths due to ADHD for each age and sex group by their expected future earnings.	The Mortality Ratio Rate of 1.5:1 was used to estimate the number of deaths due to ADHD by age and sex (see Supplementary Table 2).	Expected future earnings for each age and sex group were based on current general population employment rates (ABS, 2018b) and average weekly earnings (ABS, 2018a). Average weekly earnings were held constant in real terms (a conservative approach). All lifetime earnings were estimated in discounted net present value terms using a discount rate of 2.0%.
Informal carer costs	Bottom-up: Estimated the proportion of people with ADHD receiving support from an informal carer and the additional hours of care that are provided.	One Australian study showed that 63% of children aged 6 to 8 years received health services and this estimate as taken as the proportion that would have received informal care from a caregiver (Efron et al., 2016). We assumed conservatively that no adults received support from an informal carer. Flood et al (2016) found that carers of children and adolescents aged 6 to 17 with medicated ADHD reported missing an average of 3.8 hr of work every four weeks, attributed to their child's ADHD (Flood et al., 2016).	The opportunity cost of an informal carer's time was based on Australian general population employment rates (ABS, 2018b) and average weekly earnings (ABS, 2018a) by age and sex.
Other costs			
Education	Bottom-up: Estimated educational service costs taking into account prevalence of ADHD in childhood.	One Australian study was identified finding that that 22% of students with ADHD had an Individual Education Plan and 18% had a Student Support Group; midpoint of 20% service use was taken for this study (Zendarski et al., 2018).	The Australian Nationally Consistent Collection of Data on School Students with Disability (NCCD) was used to estimate the costs for supplementary (low level) classroom adjustments (US$3,287) (Department of Education and Training). To account for comorbid conditions, the average funding was divided by the average number of comorbid conditions, in the absence of better data (i.e., assuming that each condition contributes equally to the need for additional supports). Around 33% of children with ADHD have one comorbid disorder, 15% have two, 18% have three and the remaining 33% are estimated to have only ADHD (Larson et al., 2011). Using these data, it was assumed that the cost of providing supplementary adjustments to students with ADHD was approximately US$1,977 per annum due to ADHD alone.

(continued)

Table 1. (continued)

Cost domain	Method of estimation	Prevalence reference data	Cost reference data
Crime & justice	Top-down: Population attributable fraction (PAF) approach was used to estimate the additional crime and justice system taking into account the prevalence of ADHD in Australia.	Data from Erskine et al. (2016) was used to estimate the increased odds of people with ADHD engaging in a variety of criminal activities (Erskine et al., 2016); see Supplementary Table 3.	Australian Bureau of Statistics data on the prevalence rate of offences and convictions in Australia in 2018 was used as an input to estimate the PAFs (Australian Bureau of Statistics [ABS], 2019a). Average costs of criminal acts and convictions were taken from the Australian Institute of Criminology (Morgan, 2018; Smith et al., 2015).
Deadweight losses	Bottom-up: To estimate the deadweight loss, the reduced income of carers and those with ADHD, and increased government expenditure due to ADHD was used. Lost taxation revenue was estimated by applying an average personal income tax rate and average indirect taxation rate to lost earnings. The efficiency loss of raising taxation and the administrative loss which covers the expenses of administering taxation was calculated by assuming tax revenue is maintained by taxing individuals and companies more as needed, to replace the lost tax, and to raise funds to cover the additional spending.	NA	The average rates of taxation in Australia were derived by dividing net income tax and net indirect tax by the taxable income. This method was also used to derive the average Australian company tax rate, which was then applied to lost company earnings (through reduced output). The respective tax rates used in the calculation of deadweight losses were: • 23.4% average personal income tax rate, and 12.6% average indirect tax rate; and • 22.9% average company tax rate. Analyses have reported the marginal burden of various government taxes (Cao et al., 2015; KPMG Econtech, 2010). The additional tax revenue to maintain a budget neutral position is raised in the same proportions from the sources of tax from which it is currently being raised. Thus, weighted by the source of tax revenue: • reduced income for individuals results in a 25% efficiency loss. • reduced income for employers' results in a 51% efficiency loss. • welfare payments, health and other Commonwealth Government expenditure results in a 30% efficiency loss. • state and territory government expenditure results in a 48% efficiency loss. All rates of efficiency loss include a 0.8% administrative loss which covers expenses of administering taxation (Australian Taxation Office [ATO], 2016).

[a]Includes government and private costs of funding hospitals, primary, specialist and allied health care.
[b]Although we aimed to estimate costs for other allied health providers there was no suitable bottom-up data available to enable this.

income stream is discounted to current dollars) and deadweight losses, or reduced economic efficiency, due to the reduced income of carers and those with ADHD which is associated with the need to raise additional taxation to fund provision of government services (Table 1).

Loss of wellbeing. In terms of non-financial costs, we examined the costs associated with reduced quality of life and impaired functioning, and premature death that result from ADHD. Wellbeing costs are measured in terms of the years of life, or healthy life, lost using the burden of disease methodology. DALYs include both years of life lost due to premature death (YLLs) and years of healthy life lost due to disability (YLDs) (GBD 2017 Disease and Injury Incidence and Prevalence Collaborators, 2018). One DALY equals one year of healthy life lost. We used the disability weight from the Global Burden of Disease study (0.045) (Erskine et al., 2014) and applied this to the population of those with ADHD. The YLLs were calculated through analysis of the mortality rate of people with ADHD and comparing it to their expected lifespan in the absence of ADHD.

Sensitivity Analysis

A one-way sensitivity analysis, where a single model parameter is varied and all other parameters are held constant, was conducted to help characterize and explain the uncertainty surrounding the expected costs of ADHD in Australia. One-way sensitivity analyses were conducted on prevalence, the value of a statistical life year, the disability weight, estimated productivity losses, justice and crime costs, and the mortality rate ratio used to estimate the number of deaths associated with ADHD. An upper and lower bound for each parameter was based on the 95% confidence intervals available in the underlying literature.

Currency Standardization

All costs are expressed in 2018 to 2019 US dollars. Costs were converted from 2018 to 209 Australian dollars using the 2019 Organisation for Economic Cooperation and Development purchasing power parity of 1.43 Australian dollars per US dollar in 2017 (Organisation for Economic Cooperation and Development. Purchasing power parities for GDP and related indicators, 2019).

Results

Overall Prevalence of ADHD and Estimated Mortality

The overall prevalence in 2019 across all ages was estimated to be 3.2% (4.9% males, 1.5% females), representing 814,500 Australians (620,900 males, 193,600 females); see Supplementary Table 1. In 2019, ADHD contributed to an estimated 64 premature deaths. Approximately 85% of these deaths would have been in males, and most would have occurred between the ages of 15 to 29 (see Supplementary Table 2).

Financial Costs of ADHD

Health system. The total health system costs due to ADHD in 2019 were estimated to be US$321.1 million, or US$394 per individual with ADHD. Most health system costs were incurred within hospitals (US$128.0 million) or in out-of-hospital care (US$128.5 million), which represents 80% of all costs to the system (see Table 2). The in hospital costs are defined as excess hospital visits compared to the general population by individuals with ADHD. Table 3 includes estimated pharmaceutical costs for 2019: US$63.4 million (20% of total health system costs). The estimated annual funding allocated to ADHD research in 2019 was US$1.1 million (0.3% of total health system costs).

Productivity costs. Total productivity costs were estimated to be US$6.0 billion in 2019 or US$7.424 per Australian with ADHD (see Table 4 for a breakdown of productivity costs). Absenteeism associated with ADHD was estimated to cost US$1.7 billion in 2019, which is US$2,087 per Australian living with ADHD. Presenteeism associated with ADHD that is, reduction in productivity while at work was estimated to cost US$1.9 billion in 2019, which is US$2,389 per Australian living with ADHD. Reduced employment associated with ADHD was estimated to cost US$2.16 billion in 2019, or US$2,654 per Australian with ADHD.

Other costs. Total other costs were estimated to be US$1.08 billion. This comprised US$74.1 million in educational costs (over 37,000 supplementary adjustments), $215.0 million in costs of crime and to the justice system (see Supplementary Table 3 for a breakdown of criminal justice outcomes attributed to ADHD) and US$790.9 million in deadweight losses from government expenditure of services and programs and reduced taxation revenue (see Supplementary Table 4).

Non-Financial costs of ADHD

Loss of wellbeing. Overall, it was estimated that there are 36,653 YLDs, and 4,236 YLLs (without discounting, consistent with current GDP methodology) (Erskine et al., 2014) that were due to ADHD. Thus, there were an estimated 40,890 DALYs due to ADHD in 2019. DALYs were converted to a US dollar estimate using the Value of a Statistical Life Year (VSLY), which is the value society places on reducing the risk of premature death, expressed in terms

Table 2. Health Care Costs Attributable to ADHD in 2019.

Cost type	Average cost per visit or consultation (US$)	Average number of annual visits	Average annual cost per person with ADHD (US$)	Prevalence (cases)	Estimated annual cost (US$m)
Hospital costs					Total: **128.0**
Admissions (child)	1,775	0.07	124.5	142,562	17.7
Admissions (adult)	1,775	0.23	407.7	270,398	110.3
Out of Hospital costs					Total: **128.5**
GP (child)	25.0	4.2	104.9	142,562	15.0
GP (adult)	25.0	8.1	202.8	270,398	54.9
Specialist (child)	60.7	2.2	133.6	142,562	19.0
Specialist (child)	60.7	2.4	145.4	270,398	39.4

Table 3. Core ADHD Medications Costs for 2019.

Drug type[a]	Government expenditure by drug type (US$m)	Patient contribution (US$m)	Total cost (US$m)	Cost per script (US$)
Methylphenidate	17.7	9.6	27.4	35.0
Dexamphetamine	2.8	4.2	7.0	23.1
Atomoxetine	4.7	0.7	5.4	91.6
Lisdexamfetamine	19.7	4.1	23.7	81.8
Total annual cost	44.9	18.5	63.4	

[a]Extended release Guanfacine (e.g., Intuniv) was excluded as it was only listed on the Australian Pharmaceuticals Benefits Scheme in September 2018 for the treatment of ADHD.

Table 4. Total Costs Associated with ADHD in Australia, 2019.

Category	Total cost (US$bn)	Per person with ADHD (US$)	Proportion of total (%)
Health system	0.32	394	2.5
Productivity costs			
Absenteeism	1.70	2,087	13.3
Presenteeism	1.95	2,389	15.3
Reduced employment	2.16	2,654	16.9
Premature mortality (including search, hiring and training costs)	0.09	113	0.7
Informal care	0.15	181	1.2
Education	0.07	91	0.6
Crime and justice system	0.22	264	1.7
Deadweight loss	0.79	971	6.2
Total financial costs	7.45	9,144	58.4
Loss of wellbeing (non-financial)	5.31	6,520	41.6
Total costs	12.76	15,664	100.0

of saving a statistical life year. The VSLY is based on willingness to pay to reduce the risk of premature death. The future value of life lost was discounted at 3% per annum). The total cost associated with the loss of wellbeing was estimated to be US$5.31 billion in 2019. DALYs were estimated to be higher in males than in females, peaking at 10 to 14 years, reflecting the greater prevalence in males, and in children and adolescents. See Supplementary Figure 1 for an age and sex break down of costs to loss of wellbeing associated with ADHD.

Total costs. The total financial costs associated with ADHD were estimated to be US$7.45 billion and the total loss of wellbeing US$5.31 billion, which equates to a total cost of US$12.76 billion in 2019 (see Table 4). A substantial proportion of the costs were attributable to adult ADHD (US$10.9 billion).

Sensitivity analysis. The results of the sensitivity analysis are illustrated in Figure 2 and Table 5. They indicate that the total cost of ADHD was most sensitive to changes in the

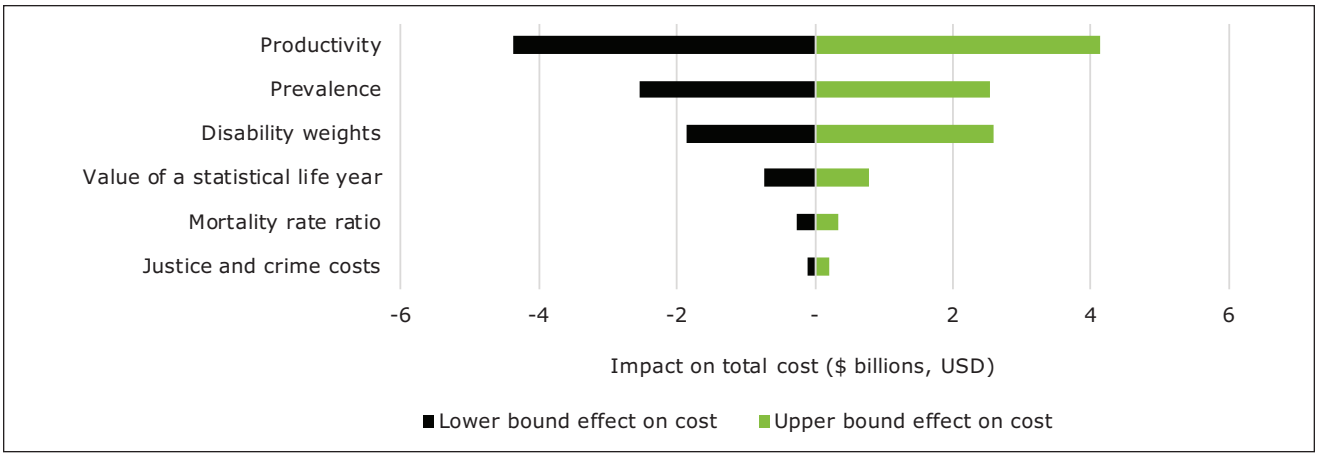

Figure 2. Sensitivity analysis (tornado diagram) of the impact on total cost of ADHD of variations in parameter values.
Note: The tornado diagram helps convey the relative importance of parameters in the modelling, and the impact of uncertainty surrounding these estimates. For example, in Table 5, ADHD prevalence was varied by 20% reflecting the 95% confidence interval around prevalence estimates. When considering the upper bound effect on prevalence (+20%), the costs increase by $2.5 billion compared to the base case assumptions in the model.

Table 5. Results of One-Way Sensitivity Analyses.

Scenario	Variation from base case assumption	Health system (US$B)	Productivity and informal care (US$B)	Education (US$B)	Crime and justice system costs (US$B)	Deadweight losses (US$B)	Loss of wellbeing (US$B)	Total (US$B)
Base case		0.32	6.05	0.07	0.22	0.79	5.31	12.76
ADHD prevalence								
Lower	−20%	0.27	4.84	0.06	0.17	0.64	4.25	10.22
Upper	20%	0.37	7.26	0.09	0.26	0.95	6.37	15.29
DSM scenario[a]	37%	0.42	8.28	0.10	0.29	1.08	7.27	17.44
VSLY								
Lower	−14%	0.32	6.05	0.07	0.22	0.79	4.56	12.01
Upper	15%	0.32	6.05	0.07	0.22	0.79	6.09	13.53
Disability weights								
Lower	−37%	0.32	6.05	0.07	0.22	0.79	3.45	10.90
Upper	51%	0.32	6.05	0.07	0.22	0.79	7.89	15.34
Productivity impacts								
Lower	−69%	0.32	2.09	0.07	0.22	0.38	5.31	8.40
Upper	69%	0.32	9.80	0.07	0.22	1.17	5.31	16.89
Justice and crime costs								
Lower	−41%	0.32	6.05	0.07	0.13	0.76	5.31	12.64
Upper	71%	0.32	6.05	0.07	0.37	0.84	5.31	12.96
Mortality rate ratio								
Lower	−26%	0.32	5.97	0.07	0.22	0.78	5.11	12.48
Upper	32%	0.32	6.14	0.07	0.22	0.80	5.55	13.10

[a]Studies have shown that the prevalence of ADHD is 27% to 47% higher when using DSM-5 compared to DSM-IV criteria (Matte et al., 2015; Vande Voort et al., 2014). The average of these bounds (a 37% increase in prevalence) was used in sensitivity testing.

productivity impacts (reduced employment, absenteeism and presenteeism) and the overall prevalence rate. The total cost of ADHD was estimated to range from US$8.40 billion to US$17.44 billion in 2019 (Table 5).

Discussion

This study comprehensively examined the costs associated with ADHD across multiple domains. We advanced the international literature on the costs of ADHD by using a lifespan approach to cost estimates and by considering both the financial and non-financial costs associated with the disorder. We found that ADHD is associated with substantial societal costs across the lifespan equating to US$15,664 per person and approximately US$12.76 billion in 2019 alone. Costs were incurred across multiple domains with the largest proportion of financial costs in productivity (absenteeism, presenteeism, reduced employment). The costs to loss of

wellbeing were substantial equating to 42% of the costs attributable to ADHD. Similar economic modelling exercises have been conducted in Australia. For example, the total national costs attributable to asthma in 2015 were higher at approximately US$20.8 billion (in 2019 dollars) likely due to the higher prevalence of asthma (Deloitte Access Economics, 2015). However, notably the per person costs associated with ADHD was higher (~US$13,000) compared with the per person costs associated with asthma (~US$8,700).

Several other international studies have also estimated the economic burden of ADHD. As described below, these have, however, largely focused on the health care costs, with cost per person higher than our estimate of healthcare costs (US$394 per person) likely due to the conservative approach used in our study. Matza and colleagues estimated the economic burden of ADHD in children and adults in the US using data from 22 studies (Matza et al., 2005). Results of the medical cost studies consistently indicated that children with ADHD had higher annual medical costs than either matched controls (ranged from $503 to $1,343 per year) or non-matched controls (ranged from $207 to $1,560 per year) without ADHD (results in 2004 US dollars) (Matza et al., 2005). Studies of adults suggest significantly higher annual medical costs among adults with ADHD (ranging from $4,929 to $5,651 per year) than among matched controls (ranging from $1,473 to $2,771) (results in 2004 US dollars) (Matza et al., 2005). A more recent US study found that children and adolescents with ADHD had an estimated 58% higher medical expenditure than the non-ADHD cohort, with an estimated annual incremental cost of ADHD of $949 (2011 US dollars) (Gupte-Singh et al., 2017).

Relatively few studies have considered the broader financial costs associated with ADHD, outside of healthcare costs. In their 2007 study of US children and adolescents, Pelham et al. estimated the economic impact of ADHD including the costs of ADHD treatment-related and other health care costs, education, parental work loss and juvenile justice (Pelham et al., 2007). The study estimated an annual cost of illness of ADHD in children and adolescents of $14,576 per person (2005 US dollars). A 2014 economic impact study of ADHD in children and adolescents in Europe found the average total ADHD related costs ranged from €9,860 to €14,483 per patient (2012 Euros) (Le et al., 2014). These costs included healthcare, education, social services, and productivity losses of family members. One recent study estimated the cost of raising a child with ADHD, using a longitudinal sample from the US (Zhao et al., 2019). This study reported that the total economic burden over the course of a child's life to families was five times higher in children with ADHD, at US$15,036, compared to US$2,848 for children without ADHD (Zhao et al., 2019). This extra burden on the family was largely due to parents being more likely to change jobs, and having lower productivity.

To the best of our knowledge, this study represents the first attempt to comprehensively document both the financial and non-financial costs associated with ADHD using a lifespan approach. There are some limitations to consider when interpreting our findings. Although ADHD is a global disorder with a similar prevalence across the world much of our understanding of the impact of ADHD on individuals and society comes from Westernized societies and relatively little is known about the impact in other societies (Polanczyk et al., 2007). Furthermore, studies have shown that the prevalence of ADHD is 27% to 47% higher when using DSM-5 compared to DSM-IV criteria (Matte et al., 2015; Vande Voort et al., 2014). The implications for our cost estimates could be substantial, with costs increasing to US$17.4 billion using the average of these bounds (a 37% increase in prevalence). As the sensitivity analysis showed, prevalence is a key driver of the model results. Our study also focused on Australia, which is a relatively prosperous country. Although our findings are likely to generalize across similarly well-developed countries it is not clear how well they can be applied to low and middle income countries. Future studies are urgently required to improve our understanding of the impact of ADHD across a range of low and middle income settings.

Our estimates would be improved with access to data that links health, education, employment, welfare and justice, similar to that available in Scandinavia and Hong-Kong. We used top-down approaches where data were available but mostly relied on bottom-up approaches. As a consequence the total costs derived in this study are likely to be underestimated as it was only possible to estimate healthcare costs for a subset of all health expenditures due to data limitations (e.g., lack of reference data for allied health services). It is also not always possible to determine whether or not the estimated costs are due to ADHD per se or are a function, at least in part, of associated comorbidities. This can become a somewhat circular argument as a proportion of comorbid disorders would themselves not have been present were it not for the ADHD. Where possible we have adjusted estimates based on estimation of comorbid conditions, for example, education, mortality rates, and GP costs.

It is imperative that we increase our understanding of the effectiveness and cost-effectiveness of, prevention and early intervention, as well as improving the implementation and effectiveness of interventions and management strategies that can improve long-term outcomes for ADHD (Caye et al., 2019; Coghill, 2019). This study points to the importance of identifying preventive approaches aimed at reducing the costs and burdens associated with ADHD in adulthood. This should include a focus on improving screening approaches that can identify those at risk for ADHD early in life accurately but without high levels of false positives. As more "big"

longitudinal datasets become available the application of artificial intelligence approaches using causal inference and the various machine learning paradigms present the field with new opportunities and more sophisticated approaches to prediction.

Irrespective of these new opportunities, it is pressing that we start to tackle the many structural challenges facing services for ADHD. One particular barrier to care facing young people with ADHD is the high risk of discontinuity of treatment when transitioning from pediatric to youth and/or adult services (Appleton et al., 2019; Eke et al., 2019; Ford, 2020). The reasons for this are complex but include poor transition planning, lack of available services and trained professionals in the area, other life transitions occurring at the same time, and the shift towards less parental involvement (Hollis, 2018).

Directly comparing the estimated total population costs associated with ADHD across the present study and that of Daley et al. (2019) is challenging given the different approaches used to estimate prevalence of ADHD in the two studies. However, similar to Daley et al. (2019), the bulk of the costs in this study were associated with ADHD in adulthood and arise due to estimated impacts on presenteeism, absenteeism and reduced employment. This points to the need for better identification, treatment and support to help individuals with ADHD in the workplace. Medication is likely to result in multiple functional benefits (Advokat, 2010) and additionally adjustments in the workplace can be considered, however, empirical research is needed to demonstrate the real world effectiveness and cost-effectiveness of such approaches.

In conclusion, ADHD imposes significant economic and wellbeing costs, and it can have lifelong impacts on individuals, including on educational achievement, occupational under attainment, and the increased likelihood of interaction with the criminal justice system. These impacts place significant pressure on society and its institutions. There is a continued need to raise public awareness of the socioeconomic burden of ADHD and educate and inform key stakeholders so as to drive investment in research and services that can reduce the burden and lifelong impact of ADHD. These data point to the considerable public health significance of ADHD and the need for expansion of clinical services for the condition, as well as increased research investment.

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Author Contributions

A/Prof Sciberras contributed to the conception and design of the study, drafted the initial manuscript and reviewed and revised the manuscript prior to submission. Mr Streatfeild, Mr Ceccato and Ms Pezzullo contributed to the conception and design of the study, conducted literature reviews, conducted analyses, reviewed and revised the manuscript, and provided critical input. Prof Scott, Prof Bellgrove and Prof Coghill contributed to the conception and design of the study, reviewed and revised the manuscript, and provided critical input. Prof Middeldorp, Dr Hutchins and Dr Paterson reviewed and revised the manuscript, and provided critical input.

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Supplemental Material

Supplemental material for this article is available online.

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