ARTICLE

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Incidence, prevalence, and global burden of ADHD from 1990 to 2019 across 204 countries: data, with critical re-analysis, from the Global Burden of Disease study

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Data on incidence, prevalence and burden of ADHD are crucial for clinicians, patients, and stakeholders. We present the incidence, prevalence, and burden of ADHD globally and across countries from 1990 to 2019 from the Global Burden of Disease (GBD) study. We also: (1) calculated the ADHD prevalence based on data actually collected as opposed to the prevalence estimated by the GBD with data imputation for countries without prevalence data; (2) discussed the GBD estimated ADHD burden in the light of recent meta-analytic evidence on ADHD-related mortality. In 2019, GBD estimated global age-standardized incidence and prevalence of ADHD across the lifespan at 0.061% (95%UI = 0.040–0.087) and 1.13% (95%UI = 0.831–1.494), respectively. ADHD accounted for 0.8% of the global mental disorder DALYs, with mortality set at zero by the GBD. From 1990 to 2019 there was a decrease of −8.75% in the global age-standardized prevalence and of −4.77% in the global age-standardized incidence. The largest increase in incidence, prevalence, and burden from 1990 to 2019 was observed in the USA; the largest decrease occurred in Finland. Incidence, prevalence, and DALYs remained approximately 2.5 times higher in males than females from 1990 to 2019. Incidence peaked at age 5–9 years, and prevalence and DALYs at age 10–14 years. Our re-analysis of data prior to 2013 showed a prevalence in children/adolescents two-fold higher (5.41%, 95% CI: 4.67–6.15%) compared to the corresponding GBD estimated prevalence (2.68%, 1.83–3.72%), with no significant differences between low- and middle- and high-income countries. We also found meta-analytic evidence of significantly increased ADHD-related mortality due to unnatural causes. While it provides the most detailed evidence on temporal trends, as well as on geographic and sex variations in incidence, prevalence, and burden of ADHD, the GBD may have underestimated the ADHD prevalence and burden. Given the influence of the GBD on research and policies, methodological issues should be addressed in its future editions.

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INTRODUCTION

Attention-Deficit/Hyperactivity Disorder (ADHD) is one of the most common diagnoses in child and adolescent mental health services in many countries [1]. Impairing symptoms of the disorder persist in adulthood in up to 70% of individuals with a childhood diagnosis [2]. The global prevalence, incidence, and burden of ADHD have been estimated in the 2010 [3, 4] and 2019 [5] versions of the Global Burden of Disease (GBD) study. GBD estimates disease burden by summing up the estimated *years of life lived with a disability* (YLDs), as a measure of nonfatal burden, and the *years of life lost* (YLLs), related to mortality [6]. The sum of YLDs and YLLs is referred to as *disability-adjusted life years* (DALYs), with one DALY equaling the loss of one healthy year of life [6].

In the most recent report of the 2019 GBD including ADHD, published in 2022 [5], the global age-standardized prevalence of ADHD was estimated to be at 1.24% in 1990 and 1.13% in 2019, with higher figures in males (1990: 1.77%; 2019: 1.61%) compared to females (1990: 0.7%; 2019: 0.63%). The 2019 age-standardized prevalence varied across regions, with the highest and lowest figures in Australasia (3.24%) and Eastern sub-Saharan Africa (0.57%), respectively. ADHD accounted for 0.8% of the global mental disorder DALYs across ages.

The GBD report [5] provided important information on the epidemiology and overall burden of ADHD. However, given its overarching nature covering all the main mental disorders, it could not provide a more fine-grained overview of the prevalence, incidence and burden of ADHD in individual countries, which is needed to inform national policies on ADHD. Additionally, the GBD report [5] did not provide data by sex, which is of interest in the light of the different pattern of symptom expression and comorbidities of ADHD in males and females, respectively [7]. Furthermore, the report [5] did not present data on trends in the prevalence, incidence and burden of ADHD between 1990 and 2019. As diagnostic criteria for ADHD changed in the period 1990–2019, a detailed year-by-year assessment is needed to estimate the impact of diagnostic classifications on the prevalence, incidence and burden of ADHD. This is particularly relevant given concerns on possible overdiagnosis of ADHD over the years [8]. To fill these gaps, the first aim of the present study was to present the incidence, prevalence, and burden of ADHD by country/region and sex across each year in the period 1990–2019 as estimated by the GBD.

Additionally, even though the GBD provides data that are influential on research and policies, some of its methodological aspects have been criticized [9, 10]. In relation to ADHD, the GBD methodology might have led to inaccurate estimates of the prevalence and burden of ADHD. GBD estimated statistics for locations where high-quality raw epidemiological data were unavailable by using the modeled output from surrounding locations. This might have biased the estimate of the global prevalence of ADHD. As for burden, GBD estimated YLL at zero, given insufficient evidence, at the time the GBD 2019 team conducted the literature search, of increased risk of mortality directly accounted for by ADHD. As there is growing evidence of increased mortality due to ADHD [11], the burden of ADHD may have been underestimated by the GBD. Therefore, the second aim of the present study was to assess and critically discuss to what extent the 2019 GBD may have miscalculated the prevalence and burden of ADHD.

METHODS

GBD data

Source. The GBD 2019 Results Database, available from the GBD Collaborative Network website (http://ghdx.healthdata.org), includes data from 204 countries and territories [12]. The GBD 2019 group retrieved data on incidence and prevalence of the diseases via a systematic review in PsycINFO, Embase, and PubMed up to 10th October 2018 (see details in Supplementary Methods 1). The sources included were surveys using probability sampling to obtain a representative sample of the general population. Surveys based on non-probabilistic sampling or reporting on population subgroups were excluded. Acceptable definitions of ADHD were those based on the Diagnostic and Statistical Manual of Mental Disorders (DSM, from III to 5th edition) or the corresponding category (Hyperkinetic Syndrome) in the International Classification of Diseases (ICD, 9–10) criteria.

Measures. Prevalence was estimated in the GBD 2019 by including data on past-year prevalence. Lifetime prevalence was not considered given the possible risks related to recall bias. YLDs was defined as the number of incident cases of ADHD in the population multiplied by a "disability" weight for that specific condition and the average duration of the case until remission or death (see additional details in Supplementary Methods 2). The GBD group set YLL, defined as number of deaths due to a condition multiplied by standard life expectancy at the age of death, at zero for ADHD. Indeed, among the mental health conditions, the GBD 2019 calculated deaths and YLLs only for anorexia nervosa and bulimia nervosa, as these were deemed the only mental disorders directly causing death. By contrast, if premature mortality in individuals with mental disorders, such as ADHD, was accounted for by another disease or injury, it was not counted as a contributing factor to the YLL for that particular mental condition.

Statistical analyses. GBD 2019 analyzed the data obtained from the systematic review in two steps. In step one, biases [e.g., related to the type of recall (point or 12-month), instrument used in the survey (diagnostic or symptom scale), and type of interviewer (lay or clinician)] were identified and adjusted for. Estimates with these biases were considered "alternative" estimates to "gold-standard" estimates and adjusted using, as adjustment factor, the pooled ratio between gold-standard estimates and these alternative estimates. However, unlike the GBD 2017, the GBD 2019 did not include: (1) an adjustment of bias from small community samples towards the level of nationally representative samples and (2) two covariates adjusting for estimates which did not require agreement between survey informants (e.g., parent and child), and/or did not require impairment for diagnosis. The rationale for this lack of adjustment was that, following consultation with experts, it was unclear whether there was systematic bias between these types of survey methodologies.

The gold-standard and adjusted estimates were modeled using DisMod-MR 2.1 [13], a Bayesian meta-regression tool developed for the GBD that generates estimates for locations where high-quality raw epidemiological data were unavailable. Since GBD attributes burden attributable to each cause separately, a simulation method was used to adjust for the burden related to comorbidities. Additional information on the GBD methodology is available in Supplementary Methods 2.

Critical re-analysis of GBD data

Prevalence of ADHD. To gain insight into possible inaccurate estimation of the prevalence of ADHD by the GBD, from the GBD website (http://ghdx.healthdata.org) we selected studies in children/adolescents ≤ (18 years old) only from countries for which actual data on prevalence were available. We calculated the pooled prevalence of ADHD from these studies using random-effects models weighted by the inverse of the variance. We only included studies that were conducted prior to 2013, to ensure that our analyses would be comparable to two previous systematic reviews and meta-analyses including studies up to 2006 [14] and 2013 [15], respectively, that, like the GBD, included studies based on DSM or ICD criteria, as opposed to other meta-analyses focusing on DSM only (e.g., [16]). We also estimated the pooled prevalence in low- and middle-income countries (LMIC) (defined from https://www.iapb.org/learn/vision-atlas/about/definitions-and-regions/) and high income countries, respectively, and performed a meta-regression to assess the impact of socio-economic status - estimated by a GBD socio-demographic index (SDI) accounting for income per capita, educational attainment, and total fertility rate in women <25 years old [12] - on the prevalence of ADHD (Supplementary Methods 3).

Mortality. To gather evidence on mortality related to ADHD, we conducted a meta-review of available meta-analyses on the risk of mortality in individuals with ADHD. Details of the methods are reported in Supplementary Methods 4.

Table 1. Prevalence, Incidence, and DALYs attributable to attention-deficit/hyperactivity disorder, by 5-year (age-standardized rate per 100,000).

	Prevalence	Incidence	DALYs
1990	1240.47 (909.6, 1647.06)	64.73 (43.1, 91.65)	15.09 (8.6, 25.38)
1995	1262.49 (921.37, 1682.25)	67.37 (44.75, 95.19)	15.36 (8.6, 26.21)
2000	1247.99 (916.54, 1653.68)	65.46 (43.89, 92.25)	15.19 (8.65, 25.68)
2005	1207.39 (889.71, 1587.03)	63.25 (42.59, 89.14)	14.7 (8.35, 24.97)
2010	1179.12 (867.68, 1569.5)	62.4 (41.88, 87.56)	14.36 (8.15, 24.29)
2015	1150.77 (843.36, 1533.79)	61.71 (40.9, 86.65)	14.01 (7.92, 23.81)
2019	1131.87 (831.74, 1494.54)	61.65 (40.74, 87.16)	13.78 (7.87, 23.45)
Percent change between 1990 and 2019	−8.75 (−10.91, −6.46)	−4.77 (−7.5, −2.23)	−8.67 (−10.99, −6.27)

Data in parentheses are 95% uncertainty intervals.
DALYs disability-adjusted life-years.

RESULTS

GBD data

Incidence, prevalence and DALYs and their temporal trends. Table 1 reports the age-standardized incidence, prevalence and DALYs for ADHD from 1990 to 2019 (every five years). Since YLL was considered zero in ADHD, YLDs and DALYs values are identical. Raw and age-standardized estimates for each year from 1990 to 2019 are reported in Supplementary Table 1. GBD 2019 estimated that, in 2019, over 84 million people were affected by ADHD globally, which yields an age-standardized prevalence of 1.13% (95%UI = 0.83–1.49). Incident cases were almost 4.2 million globally, yielding an age-standardized incidence of 0.061% (95% UI = 0.04–0.087). In terms of change from 1990 to 2019, the raw prevalence of ADHD increased from 72.4 million (95% UI = 52.9–96.4) to over 84 million (95%UI = 62.5–111.3), corresponding to a relative increase of 16.9% (Supplementary Table 1). However, the age-standardized prevalence changed in the opposite direction, with a decrease of −8.75%. Incidence estimates followed the same pattern, with an increase of 5.14% in raw incidence (which is of limited value as it is not corrected for the increase in the population), and a decrease of −4.77% in age-standardized estimates.

In 2019, ADHD was associated with 1,030,485 DALYs globally, corresponding to an age-standardized estimate of 13.78 DALYs per 100,000 (95%UI = 7.87–23.45). As for prevalence and incidence, raw DALYs increased by 16.93%, while age-standardized DALYs decreased by −8.67% from 1990 to 2019 (Supplementary Table 1).

Geographic differences. ADHD was associated with different prevalence, incidence and disability figures across different countries (Fig. 1 and Supplementary Fig. 1, and Supplementary Table 2), and GBD regions (Supplementary Tables 3–4, Supplementary Figs. 2–4).

Across countries (Fig. 1 and Supplementary Fig. 1, Supplementary Table 2), the largest increase in prevalence, incidence, and burden from 1990 to 2019 was in the United States of America, and the largest decrease occurred in Finland.

Across GBD regions (Supplementary Table 3, Supplementary Figs. 2–4), the largest prevalence and DALY increase occurred in North America (11.76, 95%UI = 2.68–20.95, and 11.61, 95% UI = 2.62–21.40, respectively), while the highest age-adjusted prevalence and DALY were in Australasia (3248.79 per 100,000, 95%UI = 2476.1–4108.93, 39.41 per 100,000, 95%UI = 23.26–64.78, respectively). The largest increase in incidence occurred in East Asia (23.84, 95%UI = 12.35– 35.38), and the largest age-adjusted incidence was in Australasia (181.06 per 100,000, 95% UI = 129.71–239.05).

Sex differences. The prevalence, incidence, and DALYs were between 2.5 and 2.6 times higher in males than females in 2019 (Supplementary Table 4) and during the last 30 years (Fig. 2, Supplementary Figs. 5–6). Incidence, prevalence and DALY figures by sex for each year from 1990 to 2019 are reported in Supplementary Table 5.

Incidence, prevalence and DALYs across age groups for males and females separately in 2019 are available in Fig. 3a and Supplementary Table 6; incidence peaked at age 5–9 years, and prevalence (total and age- adjusted) and DALY between age 10–14 years, in both sexes, with larger figures for males. Raw numbers and age-adjusted male to female ratio of ADHD prevalence (Fig. 3b), incidence (Supplementary Fig. 7) and DALYs (Supplementary Fig. 8) significantly decreased with age.

Re-analysis of prevalence

When all studies up to 2013 ($n = 136$), for which data on prevalence were actually available, were included in the analyses, the pooled-prevalence of ADHD was 5.41% (95% CI: 4.67%, 6.15%, $p < 0.0001$), with evidence of considerable heterogeneity (I^2 100%, τ 4.3%). Fifteen (11.3%) of these studies were based on ICD, the rest on DSM criteria. This prevalence estimate was two-fold compared to the GBD 2019 estimate for 2013, that is 2.68% (95% CI: 1.83%, 3.72%) and close to the prevalence estimated in a meta-analysis [15] including studies up to 2013 (around 6%).

When only studies conducted prior to 2006 were included ($n = 94$), their meta-analysis indicated a pooled-prevalence estimate of 4.85% (95% CI: 3.97%, 5.72%, $p < 0.0001$), with considerable heterogeneity (I^2 100%, τ 4.2%). This prevalence estimate was 1.74 times that from GBD 2019 for 2006, that is 2.79% (95% CI: 1.93%, 3.88%), and in line with the one estimated by Polanczyk et al. [14] (around 5.3%). We did not find significant differences in the prevalence of ADHD between LMICs (5.65%) and high-income (5.47%) countries and SDI did not significantly impact on ADHD prevalence in the meta-regression model (see Supplementary Results for details).

Meta-review on the risk of mortality

The only meta-analysis [17] that we found showed that, in individuals with ADHD, deaths from natural causes were not significantly increased (RR: 1.62; 95% CI, 0.89–2.96), whereas deaths from unnatural causes were significantly higher than expected (RR: 2.81; 95% CI, 1.73–4.55).

DISCUSSION

To our knowledge, this is the most comprehensive and detailed report on the incidence, prevalence and burden of ADHD, based on the GBD 2019 data. GBD 2019 estimates for ADHD represent a substantial advance over earlier GBD estimates, with the inclusion of new data from 18 locations (Argentina, Australia, Austria, Brazil, China, Colombia, Cyprus, Finland, United Kingdom, India, Iran, Lebanon, Nigeria, Saudi Arabia, South Korea, Spain, Taiwan, and

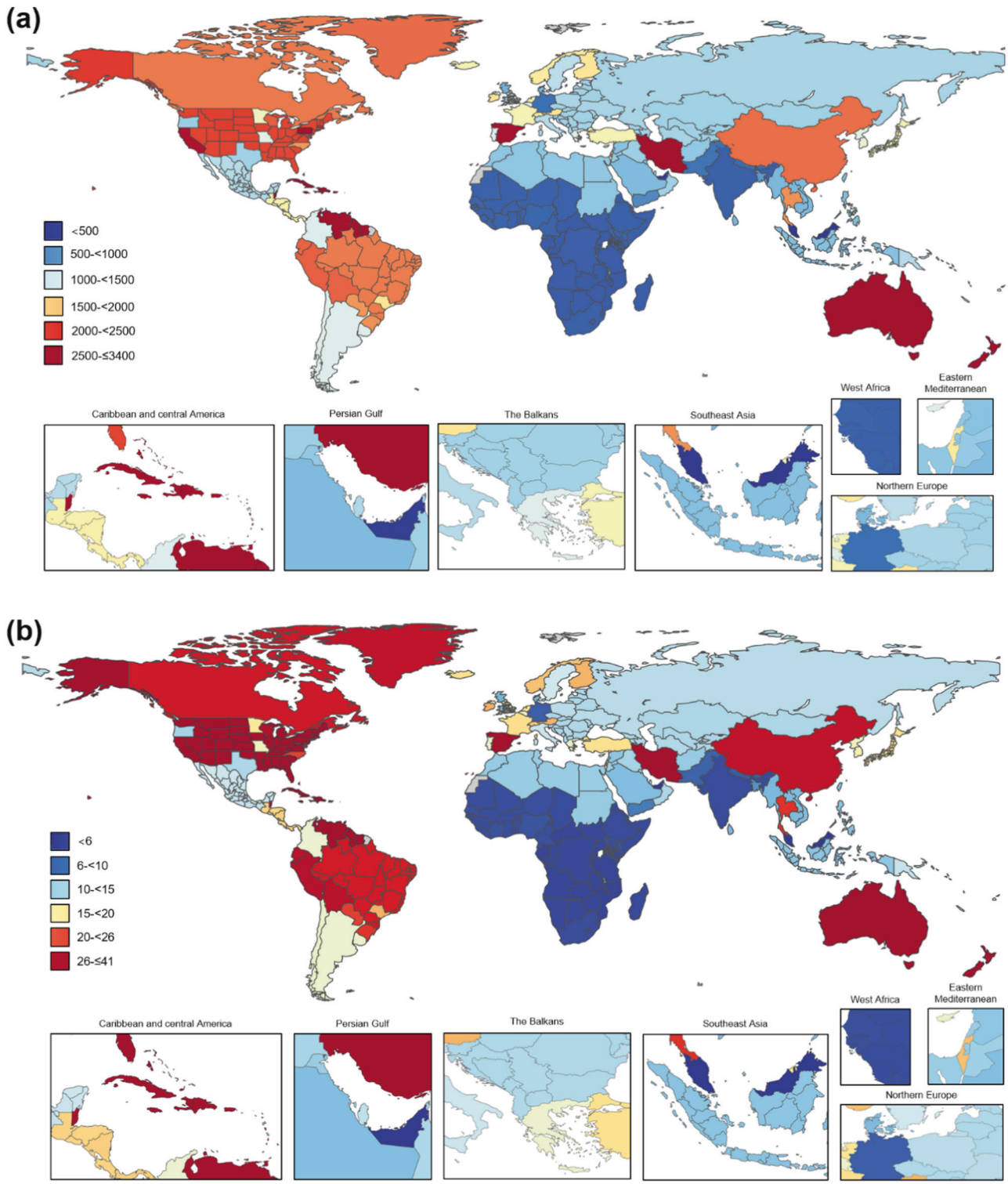

Fig. 1 Age standardized prevalence and DALY rates. Age-standardized **a** prevalence **b** DALY rates (per 100 000) by location, both sexes combined, 2019. DALY disability-adjusted life years.

United States). When GBD imputed missing data, the global age-adjusted prevalence of ADHD based on studies published up to 2018 was 1.13% (2.87% in children aged 10–14; 0.66% in adults aged 40–44). These figures are substantially lower than the prevalence reported in previous meta-analyses of epidemiological studies, i.e., ~5% [14] and ~7% [16] in children/adolescents, and ~2.5% in in adults [18]. As GBD 2019 did not adjust for bias due to discrepancy between informants or lack of related impairment, one would rather expect an overestimation of prevalence rates. However, when limiting to studies included in the GBD 2019 for which data were actually available (in children), the pooled prevalence in our re-analysis was in line with what has been reported in previous meta-analyses. The prevalence of ADHD is influenced, among other factors, by the type of diagnostic system used for the diagnosis. ICD-

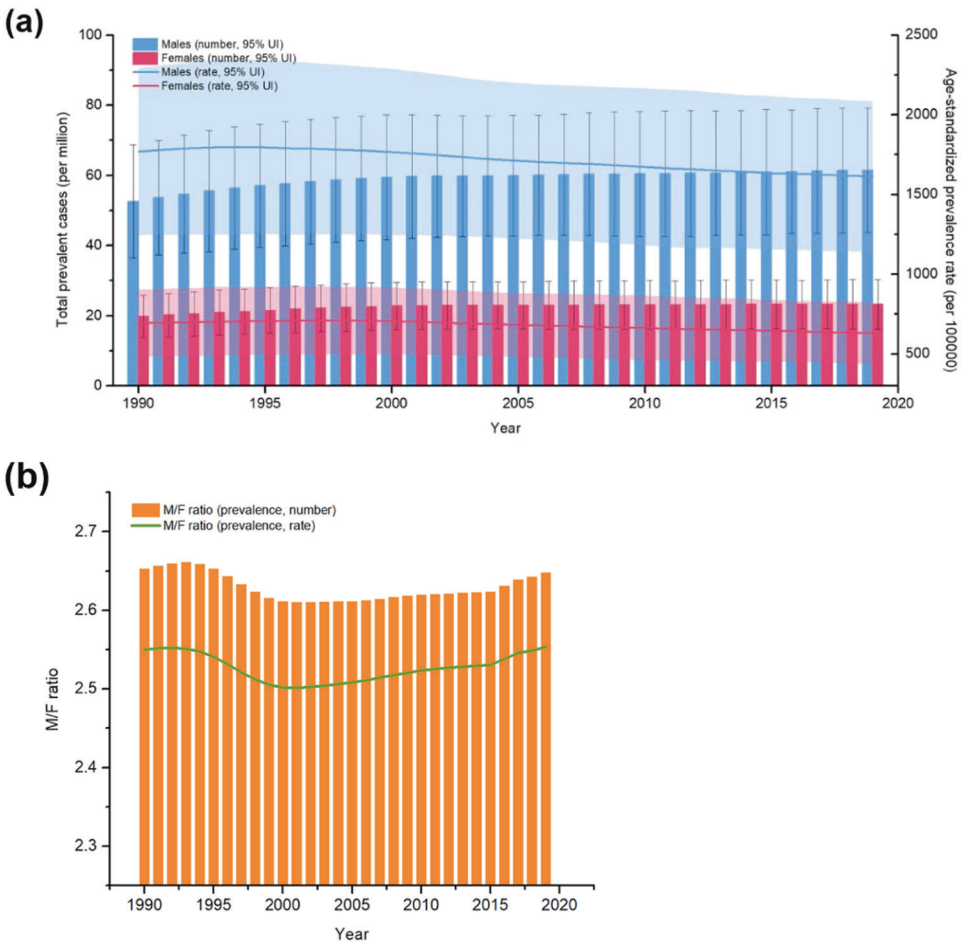

Fig. 2 Temporal trends. Trends from 1990 to 2019 **a** in number and age-standardized prevalence rates and **b** in male to female (M/F) prevalence ratio of ADHD at the global level. Error bars indicate the 95% uncertainty level (UI) for prevalent cases; shading indicates the 95% UI for the age-standardized prevalence rate. ADHD attention deficit and hyperactivity disorders.

9 and 10 included a category, referred to as "Hyperkinetic syndrome", which describes a more restricted and severe group of individuals compared with the definition of ADHD in the DSM-IV(TR) and DSM-5 [19]. As such, studies based on the ICD should lead to more conservative estimates of the prevalence of ADHD. This is a very important factor to consider when interpreting the GBD estimates. Indeed, for instance, in the National Comorbidity Survey Replication (NCS-R), the prevalence of adult ADHD in the USA estimated based on DSM-IV criteria was 4.4%, substantially higher than the GBD estimated prevalence in adults [20]. Notably, the rate of studies using the ICD among those with actual data included in the GBD up to 2013 (11.3%) was very similar to that reported by a meta-analysis that included studies up to 2013 (11.0%) [14]. It could be argued that lower estimates of the prevalence of ADHD from the GBD reflect lower prevalence - imputed - of ADHD in LMICs where data tend to be less available. However, in our re-analysis, we did not find any evidence of significant differences in prevalence between LMICs and high-income countries. Therefore, we conclude that the global prevalence of ADHD was underestimated mainly due to the imputation by the GBD group.

However, it would be expected that this issue would not affect the estimation of the temporal trends, as well as geographic and sex variations, in the incidence, prevalence, and burden of ADHD, as the biased estimate would equally affect numerator and denominator; this should be formally tested in future research. Regarding temporal trends, from 1990 to 2019, the overall age-adjusted prevalence peaked in 1994–1995 and then declined, albeit mildly. Indeed, the ICD-10, with its more stringent criteria, started being used in 1994, which may have contributed to this slight decline. Therefore, the temporal trends that emerge for the GBD in terms of prevalence show that the epidemic of ADHD often portrayed in some media outlets [20] is not supported by empirical evidence.

Whereas ADHD has been and is still viewed by some as an "American" condition [21], Australasia was the region with the highest age-adjusted prevalence in the most recent estimate of the GBD 2019, even though the USA had one of the highest prevalence worldwide and the largest increase in incidence, prevalence, and burden from 1990 to 2019. As the GBD did not adjust estimates for which there was no agreement between survey informants (e.g., parent and child), the extent to which differences in prevalence/incidence across countries reflect actual difference or are driven by methodological issues remains unclear.

Male and female prevalence data contribute to our understanding of sex differences in the presentation of ADHD. There is evidence that males, at least in childhood-adolescence, are over-represented in clinical services, as they tend to be referred more promptly due to their more disruptive presentation compared to females [22]. As the GBD included population-based representative samples, our data show that there is a material difference in prevalence/incidence also in non-clinical samples, in line with other population-based studies [7]. However, it is possible that, due to cultural expectations, at least in some geographic settings, women may report their ADHD symptoms less frequently or as less disabling than men, thus not meeting the diagnostic criteria [23].

While the GBD addresses a crucial aspect, i.e., the burden of mental disorder, the burden of ADHD may have been underestimated. First,

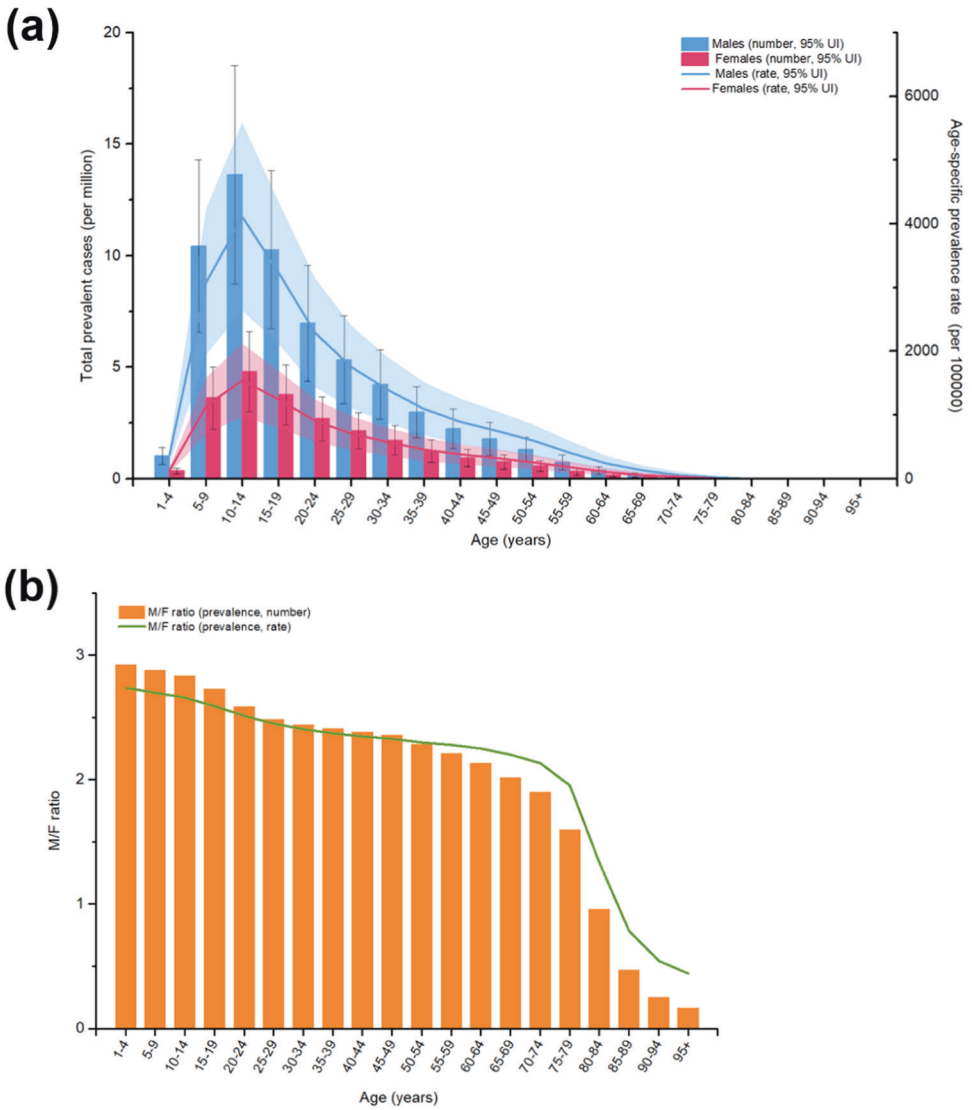

Fig. 3 Age patterns. Age patterns by sex in 2019 of **a** the total prevalent cases and age-specific prevalence rate **b** male to female (M/F) prevalence ratio of ADHD at the global level. ADHD attention deficit and hyperactivity disorders.

the phrasing of the questions used in the survey to derive the weights may have narrowed the attention to the core symptoms of ADHD, decreasing the importance of other dimensions, such as emotional dysregulation [24, 25], that affect a sizeable portion of individuals with ADHD. Moreover, the breakdown of severity for the proportion of time spent symptomatic versus asymptomatic was based on a study now more than 20 years old [26]. Recent evidence suggests that the symptoms of ADHD fluctuate [27], so that remission may be only transitory. Moreover, after remission below the diagnostic threshold, considerable impairment often persists [28–30]. We found meta-analytic evidence that ADHD is associated with increased mortality [31], mainly due to unintentional injuries [17] but likely also to physical comorbidities [32], regardless of psychiatric comorbidities. The approach followed by the GBD 2019 to include mortality in the calculation of DALYs only for eating disorders, on the ground that these are the only disorders directly related to mortality, is questionable. Indeed, one would argue that mortality in these disorders is still mediated by physical events, just as it would be in the case of suicide [33] and unintentional injuries [17] in ADHD.

Two other limitations of the GBD 2019 should be highlighted. First, the GBD definition of disability was based on health but not on welfare loss, thereby failing to capture the broad psychosocial impact of mental disorders. Second, the estimated burden did not include the burden of comorbidities, which is the rule rather than the exception in ADHD [34]. The impact of comorbidities cannot be easily disentangled from the impact of ADHD per se.

In conclusion, the present work provides evidence on the prevalence and burden of ADHD locally and globally. Moreover, this work indicates that the GBD 2019 may have underestimated the prevalence and burden of ADHD. Given the influence of the GBD in informing research and policies, the limitations highlighted here should be addressed in its future editions.

Data sharing

Data are publicly available at the Institute for Health Metrics and Evaluation (IHME) website (http://www.ghdx.healthdata.org/gbd-results-tool).

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AUTHOR CONTRIBUTIONS

All authors contributed and approved the study's protocol. SC created the first draft of the manuscript. MS, LCF, DKY, SWL, MSK, SP, JWO, SL, and KAC extracted and analysed data. SC, MS, and JIS provided overall guidance. Finally, all authors read, edited, and approved the final version of the manuscript.

COMPETING INTERESTS

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ETHICS APPROVAL

We followed the standard procedure recommended to register additional publication from GBD2019 project after publication of capstone paper. Our study was also approved by the Institutional Review Board at Yonsei University Health System for the data use.

ADDITIONAL INFORMATION

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s41380-023-02228-3.

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