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Risky behaviours and injuries amongst Catalan children with ADHD: does pharmacological treatment improve outcomes?

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Abstract

Background Attention-Deficit/Hyperactivity Disorder (ADHD) prevalence rates are around 5–10% of school-aged children. We test whether medication use for ADHD decreases the likelihood of risky behaviour (sexual behaviour, alcohol, tobacco, and drug consumption) and injuries amongst children aged 6–18.

Methods We use a large administrative dataset for the whole population of Catalan children in Spain who were born between 1998 and 2012. We apply a scale that contains alternative definitions of ADHD so that over-diagnosis is also identified and estimate a count data model to explain the number of visits whilst accounting for confounding. Our identification strategy relies on instrumenting medication using an average indicator of the probability of prescribing medication for each most visited healthcare centre provider.

Results Our results suggest that medication use significantly reduced the number of visits of children diagnosed with ADHD for injuries but not risky behaviour. This finding is robust irrespective of the considered span or the grace period after including ADHD-related comorbidities as controls.

Conclusion In line with previous literature, medication use amongst children with ADHD reduces the prevalence of injuries but not risky behaviours.

Keywords Risky behaviour, Injuries, Pharmacological treatment, ADHD, Diagnosis, Health outcomes

JEL classification D91, I12, I18

Background

Attention-Deficit/Hyperactivity Disorder (ADHD) constitutes the most common mental health disorder for young children [1]. The disease is characterised by two behavioural problems: attention deficiencies and hyperactivity or impulsiveness. The former may mean that children with ADHD have a short attention span, are unable to stick to tasks, have difficulty carrying out instructions and make careless mistakes. In contrast, the latter may mean they are unable to sit still, are unable to concentrate on tasks and may act without thinking, with little or no sense of danger. The causes of ADHD are not well understood; it is considered a neurodevelopmental

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disorder [2, 3] where genetics may play a significant role [4], and there is a strong association between ADHD and lower socioeconomic status [5] and adversity [4]. The neurotransmitter dopamine, responsible for regulating emotional responses such as feelings of pleasure and reward, may also contribute to ADHD [6]. Children with ADHD may be more prone to risky or impulsive behaviours because these activities increase pleasure-enhancing brain chemicals like dopamine. Children and adolescents with ADHD may, therefore, be more likely to engage in dangerous driving, gambling [7], substance misuse [8], and risky sexual behaviours [9, 10]. This may result in the occurrence of more injuries and adverse outcomes, including a higher probability of being involved in a car accident and being at fault [11], a greater likelihood of experiencing teen pregnancy, and sexually transmitted diseases (STDs) [12].

Behavioural economic models can be used to explain the mental processes that might account for risk-taking in ADHD, where risk-taking may be seen as the interplay between the perceived benefits and risks of alternatives. Studies have sought to distinguish between the perceptions of risk and benefit and attitudes towards these perceptions and show that people with ADHD tend to engage in risky behaviours because of the perceived benefits associated with such behaviours [13, 14]. ADHD, therefore, likely involves some disruption in the perception of the choice outcomes, which may lead to non-optimal choices [15].

Prevalence rates for ADHD are between 5 and 10% of school-age children [16]. However, clinical guidelines for diagnosing ADHD have increased the age range in which appropriate diagnosis can include preschool-aged children and adolescents, likely resulting in more significant numbers being diagnosed [17]. Given the risks of untreated ADHD, its lifetime morbidity and heritability, the clinical benefits of diagnosing and treating ADHD often outweigh the risks. However, there is an ongoing debate about the existence of over-diagnosis of ADHD across developed countries [18, 19].

In this study, we examine the effect of ADHD treatment through medication use on the prevalence of risky behaviours and injury, and we account for potential overdiagnosis, which has typically not been adequately accounted for in this literature.

Prior literature on the association between ADHD and risky behaviours and injuries and the role of medication use

Evidence on the association between ADHD and the risk of injuries is somewhat mixed. In a study following over 700,000 Danish children [20] using the Danish Psychiatric Central Research Register, children with ADHD were more likely to sustain an injury at ages 10 and 12 years than children without ADHD. The same association was found in 6-to 17-year-old ADHD children using data from 18,416 children in Sweden [21, 22]. A German study [23] of over 350,000 participants found an association between ADHD diagnosis and the risk of accidents. Finally, a population-based survey across European countries with over 4,000 participants found similar results [24]. In contrast, a population-based Canadian prospective study including over 2 million children aged 4 to 11 years did not find a relationship between ADHD and injuries when comorbidity was accounted for [25].

The role of medication in the relationship between ADHD and risky behaviour/injuries in many of these studies provides a further complicated picture. A systematic review by Shaw et al. [26] found that without treatment, people with ADHD had poorer long-term outcomes in all categories compared with people without ADHD, where the outcomes included driving and drug use/addictive behaviour.

Ruiz-Goikoetxea et al. [27] performed a meta-analysis of the relationship between ADHD and unintentional injuries and the role of medication in preventing it. Results showed that ADHD is significantly associated with an increased risk of accidental injuries, and ADHD medications have a protective effect, at least in the short term.

Dalsgaard et al. [20] also focused on the modifying effect of pharmacological treatment on the risk of injuries in children with ADHD. The authors used a difference-in-difference design examining the change in prevalence rates of injuries and emergency ward visits before and after medication with matched unmedicated children as controls. While they found that compared to children without ADHD, those with ADHD had a higher risk of injuries, the prevalence of injuries in those medicated decreased from 19 to 14% compared with a prevalence of 17% in non-medicated children with ADHD. Their findings suggest that treatment with ADHD drugs reduced the risk of injuries by up to 43% and emergency ward visits by up to 45% in children with ADHD. Lange et al. [23], in the German study, on the other hand, found no mediating influence of medication on the occurrence of accidents. Finally, Chorniy and Kitashima [10] investigated the effect of ADHD drugs on the probability of risky sexual behaviours (pregnancy and sexually transmitted diseases - STDs), substance use and abuse disorders, and injuries. The analysis was instrumented using physicians' preferences to prescribe medication to solve endogeneity issues. Their findings suggest that pharmacological treatment reduces the probability of every negative health outcome they identify in their data. The probability of contracting an STD decreases by 3.6% points, by 7.3% points for having a substance abuse disorder, and by 2.3% points per year for injuries. The probability of teenage

pregnancy decreased by 2.3% points, though the effect was not statistically significant.

While the preponderance of the evidence, therefore, seems to suggest that the prevalence of ADHD increases risky behaviour and unintentional injuries, the findings are not always consistent. Moreover, the role of medication use within this relationship is also not entirely clear. This is mainly due to methodological issues in the reported studies, the selection criteria of samples, and the inability to control for comorbidities adequately.

In this paper, we test whether a diagnosis of ADHD plus medication use decreases the likelihood of risky behaviour (sexual behaviour, alcohol, tobacco, and drug consumption) or injuries by reducing the number of healthcare visits to all types of healthcare providers for risky behaviour and injuries, amongst children aged 6–18 in Catalonia (Spain). Our objective is to explore whether the diagnosis of ADHD and subsequent pharmacological treatment could alter children's behavioural choices, which could arguably reduce the prevalence of injuries or risky conduct.

We address some of the limitations in the previous studies and contribute to the literature in several ways. First, we are one of the few studies to use instrumental variables to seek to address the relationship between medication use and outcomes causally. Since we have access to a novel dataset of the whole population of children, we consider all healthcare providers and overall visits. We exploit all universal public coverage over five years compared to Chorniy and Kitashima [10], who used only the first occurrence of each negative health outcome. We also consider the appropriate time zero span or baseline period from when we consider follow-up in our observational data, as done by Dalsgaard et al. [28], to account for possible delays in initiating medication. Second, most previous studies do not adequately account for comorbidities, especially mental health ones. We do this by considering a complete list of mental health comorbidities related to ADHD. Third, we contribute to understanding the role of overdiagnosis in ADHD by using a scale that contains different definitions of ADHD in which overdiagnosis can be identified. This is a significant complicating factor and omission in the current literature. Finally, our approach also considers a broad definition of risky behaviours, including all diagnoses related to STDs, alcohol, tobacco, and substance use.

Methods

Data sources and linkage

We use a large administrative dataset from the Agency for Health Quality and Assessment of Catalonia (AQuAS) that includes information from several providers, although for different periods, for the whole population of Catalan children that were born between 1998 and 2012 (1,225,406 individuals), including those diagnosed with ADHD and those not. Note that Catalonia (Spain) has a universal public coverage health system. We focussed on cohorts of children over six years old because they typically do not receive an ADHD diagnosis before this age.

This database contains information on primary care (2012–2017), hospitalisations (2010–2017), emergency care (2014–2017), mental health hospitalisations (2010–2017) and community mental health care (2010–2017). The data contain the individual identifier, the visit date (and length of stay in the case of hospitalisations), age and all diagnoses and procedures administered (ICD-9). Based on dates and diagnoses amongst the different providers, we identified spells (visits to the same provider related to the same diagnosis within a month).

Additional files provide information about dispensed drugs at the ATC3 level (2010–2017), specific medications related to the disease at the ATC7 level (2010–2017), as well as information related to specific laboratory tests (including blood tests) that may be asked by physicians when diagnosing ADHD (2010–2017). Files also include relevant information that doctors or nurses include in patients' clinical history: BMI (2010–2017) and alcoholism risk level (2010–2017). Specifically, regarding pharmacological consumption for treating ADHD, we obtained registers related to methylphenidate, atomoxetine and lisdexamfetamine, as well as all possible combinations. Guanfacine was approved in 2017. These four drugs allowed us to examine patterns of medications. Pharmacological treatment for ADHD is prescribed by a doctor in Spain, usually a psychiatrist or paediatrician. Specifically, methylphenidate and atomoxetine are recommended as first-line drugs for behavioural problems in children and adolescents. Furthermore, guanfacine and lisdexamfetamine must be prescribed by a child-adolescent psychiatrist.

Via unique personal identifiers, the data files are linked between all providers and to some demographic information: gender, age, and drug co-payment level (a proxy for the parent's socioeconomic status), municipality of residence, individual nationality, date of death, and the sanitary health region they belong to. We excluded from our analysis those children with ADHD who died during the period and those with extreme values for the Elixhauser and Charlson comorbidity indexes (74 individuals).

We calculated children's age based on data provided on their age in years as of December 31st, 2017, and their quarter of birth.

Construction of ICD-9 relevant variables

We constructed two additional variables from ICD-9 codes: visits for injuries and any side effects. We identified injury-related diagnostic codes through ICD-9 (733,

800–897, 900–959, besides all injury prevention visits). Given concerns around medication adherence, we also considered the presence of any side effects from medication. Experiencing side effects might affect adherence to ADHD medication. For this reason, we looked for conditions (through ICD-9 codes) that the literature has related to consuming medication to alleviate the effects of ADHD: (i) sleep-related problems; (ii) loss of appetite; (iii) weight loss; (iv) increased blood pressure; (v) dizziness; (vi) headache or stomach-ache; (vii) low mood and irritability; (viii) nervousness, and (ix) retardation of body growth. In our dataset of ADHD children, only 4.97% have experienced fewer visits related to these side-effect conditions, and 82.11% had no variation after initiating ADHD medication. On the contrary, 12.92% experienced more visits related to these side-effect conditions compared to the period before ADHD medication.

Finally, we established several definitions of children diagnosed with ADHD (highly likely ADHD diagnosis, potentially likely ADHD diagnosis and not very likely ADHD diagnosis) following previous literature [30]. Additionally, we constructed three periods for everyone, considering the condition of diagnosis and medication use. That is, we defined a non-diagnosed period and a diagnosed period, further disentangling those medicated from those not medicated. Then, we examined adherence patterns to ADHD medication once they are medicated. 37% of children ever medicated quit medication at some point during the period. Notwithstanding, not everyone who stopped using medication remained in that category, and a significant percentage of individuals (80.4%) were moving in and out of the medication use category.

Econometric methodology

Our main goal is to estimate the impact of medication on the number of visits related to injuries and risky behaviours for children diagnosed with ADHD. We focus on children who are diagnosed and medicated, comparing them to those who are diagnosed but not medicated and to those who have never been diagnosed. To address the potential endogeneity of medication use (i.e., the fact that the decision to medicate could be correlated with unobserved factors that also affect health outcomes), we use an instrumental variables (IV) approach.

The treatment variable is medication, which we define as the percentage of time that a child was prescribed ADHD medication after the diagnosis. This variable captures the effect of medication adherence on the number of healthcare visits related to injuries and risky behaviours. To isolate the causal effect of medication, we use the propensity to prescribe medication at the healthcare centre level as our instrument. This instrument is based on the variation in prescribing patterns across different healthcare providers, reflecting systemic differences in the likelihood of prescribing medication independent of individual patient characteristics. The assumption is that the propensity to prescribe medication is correlated with the likelihood of receiving ADHD medication but not directly with injury or risky behaviour outcomes.

The key assumption for the validity of this IV strategy is the exclusion restriction, which states that the instrument (propensity to prescribe) affects the outcome (number of visits related to injuries or risky behaviours) only through its effect on medication. In other words, the instrument must not directly influence the number of visits to healthcare facilities. We argue that this exclusion restriction holds conditional on covariates such as comorbidities and demographic factors because the propensity to prescribe is determined by provider characteristics, not by factors related to injury or risky behaviour. However, we acknowledge that there could be concerns regarding this assumption, especially if unobserved factors affecting both prescribing practices and the frequency of healthcare visits exist. This follows the method described by Dalsgaard et al. [20], who used a similar instrument to examine the effects of medication on injury risks in children with ADHD.

In Eq. (2), we estimate the causal effect of medication on the outcome variables by using the predicted values from the first stage (the propensity to prescribe) to instrument for the medication variable. This approach allows us to estimate the impact of medication on the number of visits related to injuries and risky behaviours while accounting for potential endogeneity in the treatment assignment. We evaluate the strength of our instrument through the first-stage F-statistic and perform robustness checks to assess the validity of the exclusion restriction in our models, including testing for the potential effects of overdiagnosis and varying the span and grace periods of medication adherence.

Given the nature of the endogenous variable, the number of visits, we use a count data model to estimate the effects of ADHD medical treatment (the treatment) on the incidence of injuries and risky behaviour, as shown in Eq. (1) below.:

$$Y_i = X_i\beta + med_i\gamma_1 + abs_i + \epsilon_i \quad (1)$$

where Y_i indicates the number of visits related to injuries and risky behaviour by individual i to any health care centre provider (primary, hospitalisations, emergency care, mental health hospitalisations and community mental health care) during the five years considered as a pooled cross-section whereas X_i is a set of observable characteristics (gender, age, nationality, quarter of birth, co-payment rates and out-of-pocket limits per person) and comorbidities at year level such as the existence of visits because of: overweight condition, asthma, learning

disability, depression and anxiety. med_i is the percentage of months an individual i is being medicated during the pharmacological treatment period (diagnosed and medicated).

$$\widehat{med}_i = prop_i + X_i\delta + u_i \quad (2)$$

Following [10, 20], our identification strategy relies on instrumenting medication (Eq. 2) using the average of a time-varying indicator of the probability of prescribing medication for each most visited health care centre provider based on the individual monthly visits to each provider in which that visit was related to ADHD and medication was prescribed to that child ($prop_i$) as shown in Eq. (2). Our identification, following [10], relies on the fact that two equally sick children have a different medication because they saw physicians with a dissimilar propensity to prescribe, which provides exogenous variation necessary to evaluate the causal effect of treatment. Compared to previous research [20], we include all provider units in Catalonia instead of only hospital units. Given the presence of peaks in new incidences, we smoothed these prescription figures using moving averages accounting for six backward months, two onwards, plus the current month. The latter will allow us to consider those switching to other healthcare providers for drugs - what [10] called treatment shopping.

We considered fixed effects that might affect prescribing behaviour: basic health areas for health sectors (abs_i) or sanitary health regions (aggregated basic health areas). All models considered error terms (ε_i). Given that our dependent variable is a count of visits, we estimated Eq. (1) by negative binomial regression and clustered standard errors at the *abs* level, given that medical decisions on prescribing may be shared at this aggregated level. Equation (2) was estimated using a generalised linear model, given that it is a percentage.

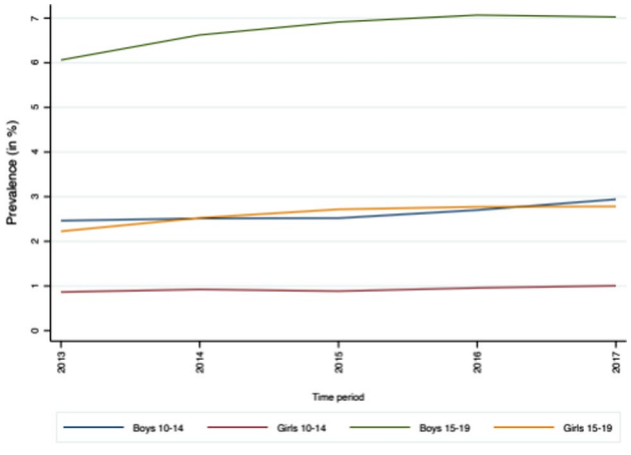

Fig. 1 Prevalence rates by gender and age cohort

A novel aspect of our analysis is introducing a "grace period" [29] to consider the elapsed time for a child to start treatment and become compliant. We, therefore, account for the period in which, once a child and their clinician decide that the patient should initiate medication, it may take several weeks to complete the clinical tests (laboratory analysis) before the treatment starts. Thus, the targeted trial protocol might specify a grace period to comply with it if they initiate medication. Likewise, the possible presence of waiting lists could also induce us to consider this grace period. However, no clinical information on this issue is available for the appropriate length of this period. In this sense, we considered comparable periods for each child when accounting for this grace period. Initially, we accounted for a common before/after diagnosis period of 8 and 12 months. We excluded 1, 2 or 3 months immediately after becoming diagnosed with ADHD for each of these spans for any of the used econometric procedures.

We ran three sets of sensitivity analyses on our main results to test for (1) sensitivity of our definition of ADHD overdiagnosis, (2) restricting our visits related to injuries or risky behaviour to those at hospitals or emergency rooms, and (3) disentangling the type of risky behaviour.

Results

Descriptive results

We describe ADHD prevalence for children in Catalonia based on our definition of overdiagnosis. We restricted our analysis to those ever diagnosed and 2013–2017 to consider a homogeneous period to account for all provider units. Collapsing our population dataset (1,071,120 total population) to those diagnosed children provides us with a final population of 49,768 individuals, of whom 26,227 have been ever medicated. We observed those who did not adhere to medications (we accounted for the number of prescriptions) and those who re-engaged with medication after quitting. These percentages were 13.21% and 13.23%, respectively (3,464 individuals). Figure 1 depicts yearly prevalence rates by gender and age cohort. It shows a higher prevalence rate for older boys than their younger counterparts. We observed an increase in prevalence from 2013 to 2015, followed by relatively stable levels at around 7% for older boys (15–19 years old). All other gender-age cohorts remain relatively stable over the period. Given that we considered a homogenous population starting in 2013, we are not concerned about differences in trends.

Table 1 shows the average characteristics over 2013–2017 of individuals based on their condition regarding being diagnosed and then medicated, compared to not having ADHD. As expected, older cohorts were more medicated, had higher birth frequencies in the last

Table 1 Descriptive statistics for 2013–2017: not diagnosed, diagnosed, and medicated. Percentages within the category

	Not diagnosed period	Diagnosed period	Medicated
Age boundaries			
1–4 yo	6.72	0.44	0.05
5–9 yo	47.18	18.06	13.19
10–14 yo	36.59	46.57	53.55
15–19 yo	9.51	34.93	34.21
Average age	9.47	12.89	13.04
Date of birth			
1st quarter	20.60	20.37	19.99
2nd quarter	22.49	22.29	22.27
3rd quarter	27.01	27.11	27.05
4th quarter	29.90	30.23	30.69
Female	28.73	27.32	24.94
Spanish	92.58	94.39	96.84
Exempted	5.71	5.05	4.26
10% copayment	7.61	8.84	10.10
40% copayment	53.86	55.94	51.23
50% copayment	31.07	28.11	32.34
60% copayment	1.26	1.30	1.95
Excluded from copayment	0.49	0.76	0.12

Note: co-payment levels depend on the condition of being an active worker or pensioner, whereas pharmacy limits exist for less wealthy individuals. See [32] for an extensive explanation of these co-payment levels.

quarter of the year, and mainly were Spanish and boys. Concerning copayment rates and out-of-pocket limits, consistent with previous literature, those with worse economic conditions (10% copayment and exempted) showed greater rates of medication and diagnosis than those not diagnosed with ADHD [5].

Table 2a Negative binomial regression results for injuries: marginal effects

Overall period	Negative binomial	IV Negative binomial
% period medicated after diagnosis	-0.721 (0.10)***	-0.802 (0.11)***
% period medicated & dropped after diagnosis	-0.457 (0.10)**	-0.414 (0.11)**
No individuals	26,227	26,227

Figure 2 depicts differences in the average yearly visits related to injuries or risky behaviour by a group of individuals, according to being diagnosed and medicated. Prevalence shows a higher number of visits for those being diagnosed, especially for injuries, compared to those never diagnosed and those diagnosed and medicated. Medicated show a similar result to those never diagnosed. For risky behaviour, differences between the three groups are smaller because of incidence but show the same pattern. Figure 2 also shows the average number of visits related to specific comorbidities. Indeed, those being diagnosed with ADHD showed a more significant number of visits related to obesity and other mental illnesses (learning disability, depression, and anxiety) but not for asthma. However, fewer visits related to most of these comorbidities are observed once medicated.

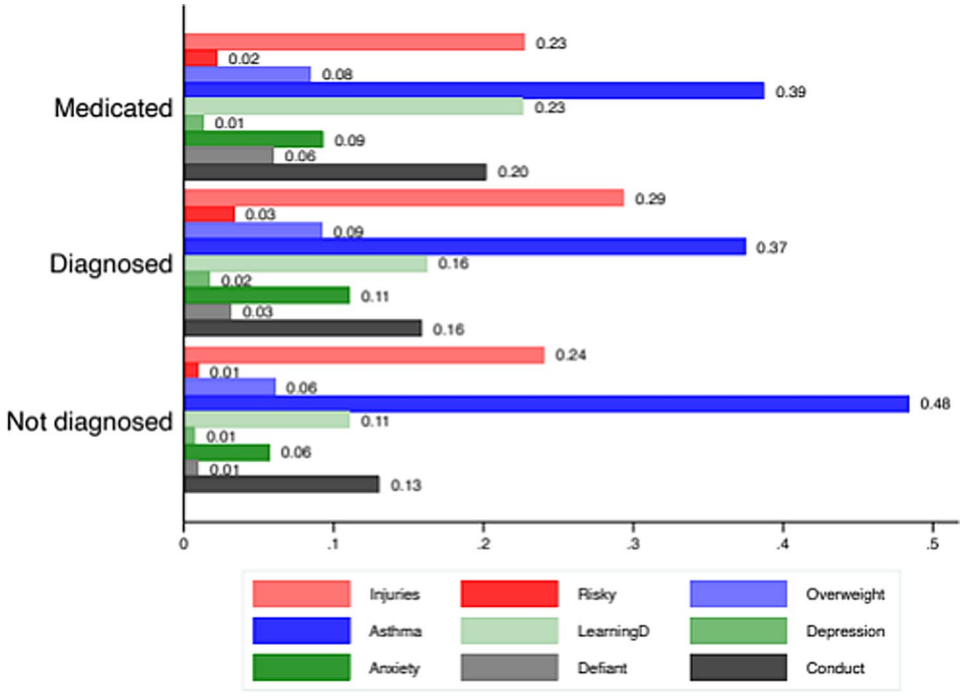

Fig. 2 Average yearly visits over 2013–2017 related to injuries, risky behaviour and comorbidities

Table 2b Negative binomial regression results for risky behaviour: marginal effects

Overall period	Negative binomial	IV Negative binomial
% period medicated after diagnosis	-0.084 (0.07)	-0.007 (0.06)
% period medicated & dropped after diagnosis	-0.059 (0.06)	-0.003 (0.08)
No individuals	26,227	26,174

Econometric results

Tables 2a and 2b display results for visits related to injuries and risky behaviour, using negative binomial regression and employing either instrumenting or not. Our instrument was statistically significant, and the first stage performed excellently (F = 90.0 in a linear specification). See Table 1 in the appendix for the complete list of coefficients. Regarding injuries, both marginal effects indicate that medication significantly reduced the number of visits. Indeed, for the IV estimation, this coefficient represents 0.96 and 0.47 times the average value and the standard deviation of the number of visits related to injuries over the pre-medication period. We also observed a reduction in the variable representing when individuals dropped medication after being diagnosed and medicated. However, in the case of risky behaviour, none of our estimation results is statistically significant.

Next, we considered a homogeneous span for all individuals and a grace period (excluding the period immediately before and after the month of the first diagnosis). Results are shown in Tables 3a and 3b. The results are robust, regardless of the span or grace period. Our estimates still show a reduction in the number of visits related to injuries given and the proportion of months being medicated. However, the longer the span, the more minor the effect, although these coefficients still represent 0.87 and 0.43 times the average value and the standard deviation of the number of visits related to injuries over the pre-medication period. Again, the impact of medication did not affect the number of visits related to risky behaviour.

Table 4a Negative binomial regression results for injuries based on our categorisation of ADHD overdiagnosis: marginal effects

Span 12 months_90days_IV negative binomial	Highly likely	Potentially likely	Not very likely
% period medicated after diagnosis	-0.364 (0.16)**	-0.610 (0.20)***	-0.766 (0.24)***
% period medicated & dropped after diagnosis	-0.013 (0.14)	-0.374 (0.20)	-0.430 (0.27)
No individuals	12,206	8,448	3,764

Table 4b Negative binomial regression results for risky behaviour based on our categorisation of ADHD overdiagnosis: marginal effects

Span 12 months_90days_IV negative binomial	Highly likely	Potentially likely	Not very likely
% period medicated after diagnosis	0.089 (0.08)	-0.242 (0.14)*	0.036 (0.14)
% period medicated & dropped after diagnosis	0.181 (0.09)**	-0.307 (0.23)	0.181 (0.24)
No individuals	12,189	8,421	3,758

Sensitivity analysis

For the sensitivity analysis, we re-estimated our principal analysis using instrumenting negative binomial regressions but instead splitting the population by our categorisation of ADHD overdiagnosis (highly likely, potentially likely, and not very likely). Tables 4a and 4b show these results in which we used a homogeneous span of 12 months and a grace period of 90 days. Compared to previous results shown in Tables 3a & 3b, the impact of medication on risky healthcare use maintains its statistically

Table 3a Negative binomial regression results for injuries: marginal effects considering a homogenous span and a grace period

IV Negative binomial	Span 8 months_30 days	Span 8 months_60 days	Span 8 months_90 days	Span 12 months_30 days	Span 12 mnths_60 days	Span 12 months_90 days
% period medicated after diagnosis	-0.754 (0.13)***	-0.731 (0.10)***	-0.745 (0.10)***	-0.660 (0.11)***	-0.617 (0.10)***	-0.657 (0.10)***
% period medicated & dropped after diagnosis	-0.329 (0.14)***	-0.404 (0.10)***	-0.439 (0.10)***	-0.262 (0.11)**	-0.369 (0.10)***	-0.437 (0.10)***
No individuals	23,749	25,005	25,422	22,328	23,813	24,418

Table 3b Negative binomial regression results for risky behaviour: marginal effects considering a homogenous span and a grace period

IV Negative binomial	Span 8 months_30 days	Span 8 months_60 days	Span 8 months_90 days	Span 12 months_30 days	Span 12 mnths_60 days	Span 12 months_90 days
% period medicated after diagnosis	-0.002 (0.05)	0.004 (0.05)	0.007 (0.05)	-0.006 (0.05)	0.003 (0.05)	0.001 (0.05)
% period medicated & dropped after diagnosis	0.020 (0.08)	0.017 (0.08)	0.015 (0.08)	0.018 (0.08)	0.012 (0.08)	0.005 (0.08)
No individuals	23,700	24,954	25,730	22,281	23,764	24,368

significant reduction in the number of visits related to injuries for each one of the categories. Notwithstanding, the magnitude of the reduction only holds for the 'not very likely' category. For those highly likely to be ADHD individuals, the magnitude of the coefficient drops to half the previous magnitude. This reduction is not as significant for those who are 'potentially likely'. Results for risky behaviour remain not statistically significant, although there is an impact for those who dropped medication.

In a further sensitivity analysis, we followed Dalsgaard et al. [20] by only examining visits related to injuries or risky behaviour that strictly occurred at hospitals or emergency rooms. Results are shown in Tables 5a and 5b. Again, we observe a reduction in the number of injuries-related visits because of medication. However, the magnitude of this effect is significantly lower, probably expressing those visits related to severe injuries. The same pattern was found in our categorisation of the disease based on how likely individuals are not to be misdiagnosed. Again, no statistically significant results for the visits related to risky behaviour are observed.

Finally, we disentangled the type of risky behaviour strictly for visits related to risky behaviour because they are consistently insignificant. Figure 3 depicts risky behaviours, showing that the only category in which diagnosed (and medicated) showed a lower number of visits is the one related to STDs. We, therefore, re-estimated the model dropping this risky behaviour and grouped tobacco, drugs, and alcohol. Table 5b, the last column, shows our estimates without including STDs, given that this occurrence is infrequent. Results were held again and were not statistically significant.

Table 5a Negative binomial regression results for injuries based on our categorisation of ADHD overdiagnosis: marginal effects for hospitals/emergency visits only

Span 12 months_90days_IV negative binomial	Overall	Highly likely	Potentially likely	Not very likely
% period medicated after diagnosis	-0.247 (0.05)***	-0.155 (0.05)**	-0.203 (0.08)**	-0.272 (0.11)***
% period medicated & dropped after diagnosis	-0.162 (0.04)***	-0.037 (0.06)	-0.085 (0.07)	-0.136 (0.12)
No individuals	24,418	12,206	8,448	3,764

Table 5b Negative binomial regression results for risky behaviour based on our categorisation of ADHD overdiagnosis: marginal effects for hospitals/emergency visits only

Span 12 months_90days_IV negative binomial	Overall	Highly likely	Potentially likely	Not very likely	Overall without STDs
% period medicated after diagnosis	-0.016 (0.01)	-0.020 (0.01)	-0.003 (0.03)	-0.083 (0.06)	-0.016 (0.01)
% period medicated & dropped after diagnosis	0.017 (0.02)	0.018 (0.02)	0.018 (0.03)	0.005 (0.08)	0.015 (0.02)
No individuals	24,368	12,189	8,421	3,758	24,368

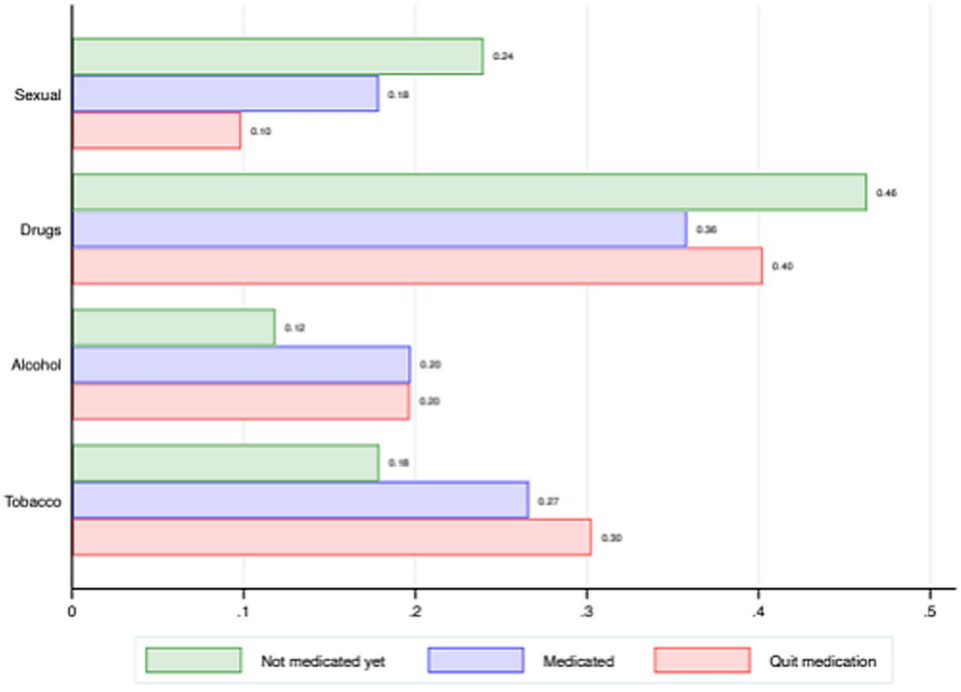

Fig. 3 Kind of risky behaviour by medication category and gender

Discussion

Our results indicate that ADHD medication significantly reduces the number of visits related to injuries but has no discernible effect on visits related to risky behaviours. This discrepancy between injuries and risky behaviours is somewhat unexpected, as previous research has often suggested a broader benefit of medication in reducing various types of risky behaviour (e.g., substance abuse, sexual risk-taking) among individuals with ADHD. The absence of a medication effect on risky behaviours warrants closer scrutiny to explore potential mechanisms and explanations.

A key mechanism that may explain the reduction in injury-related visits is the role of medication in managing core ADHD symptoms, particularly impulsivity and inattention, which are strongly linked to accidents and injuries. ADHD is characterised by heightened impulsivity, a lack of attention to detail, and difficulty in delaying gratification—traits that increase the likelihood of engaging in behaviours that lead to accidents. By improving attention and reducing impulsivity, medication may enable individuals to make safer decisions in risky situations, thereby reducing the number of injuries. Our findings are in line with studies such as Dalsgaard et al. [20], which observed a similar reduction in injury rates following the use of ADHD medication. Thus, improvements in cognitive control are likely to be one of the main drivers behind the observed decrease in injury-related healthcare visits.

However, the lack of a similar reduction in visits related to risky behaviours suggests that these types of behaviours may not be as directly influenced by medication. One possible explanation is that while medication targets the cognitive and behavioural aspects of ADHD, it may have a limited effect on behaviours driven by social factors or peer influences, such as substance use, sexual risk-taking, or reckless driving. These behaviours are often shaped by environmental factors that medication alone may not address. For example, peer pressure, social learning, and the desire to fit in may lead children and adolescents with ADHD to engage in risky behaviours, even if their impulsivity is reduced by medication.

Additionally, risky behaviours such as substance use or sexual risk-taking tend to emerge later in adolescence, often in conjunction with other social and psychological factors. Medication may be effective in the short term at reducing impulsive behaviour in specific contexts, such as physical injuries. Still, it may have less immediate or direct impact on risky behaviours that develop over a longer time frame. These behaviours are also influenced by factors that extend beyond ADHD symptoms, such as comorbid mental health conditions (e.g., depression, anxiety) or family and environmental stressors, none of which are directly addressed by ADHD medication.

Moreover, medication's effect on risky behaviours could be mediated through other mechanisms, such as improvements in executive functioning, self-regulation, or social relationships. Medication may help children with ADHD become better at managing their emotions or decision-making in some contexts, but this may not necessarily prevent engagement in risky behaviours if external pressures or other underlying issues drive these behaviours. For example, research has shown that children with ADHD often experience difficulties in peer relationships, which can heighten their susceptibility to peer influence and risky behaviours [31]. Medication may help improve these social challenges, but the impact on risky behaviours may remain limited without addressing the broader psychosocial context.

The inability to test these mechanisms directly in our study is a clear limitation, and future research should attempt to disentangle these complex interactions. Specifically, it would be valuable to examine whether improvements in specific cognitive or behavioural domains (e.g., self-control, executive function) mediate the relationship between medication and risky behaviours. Furthermore, the role of comorbidities such as conduct disorder, substance abuse, or mood disorders should be explored, as these may interact with ADHD symptoms to influence engagement in risky behaviours. Longitudinal studies that track the development of both injuries and risky behaviours over time would also help clarify the impact of medication on these outcomes across different life stages.

Lastly, another critical consideration is the possible impact of medication adherence. Our study assessed medication adherence based on prescription fills but did not account for the actual dosage or consistency of medication use. Variations in how consistently children take their medication could affect the strength of its impact on injuries and risky behaviours. Future research could investigate the dose-response relationship between medication adherence and outcomes to understand better how long-term, consistent medication use may alter injury and risky behaviour trajectories.

Conclusion

Our findings suggest that medication for ADHD reduces the frequency of injury-related healthcare visits but does not appear to have a similar effect on risky behaviours. While the reduction in injuries may be attributed to improved impulse control and attention regulation, the absence of an effect on risky behaviours indicates that these are influenced by a wider range of social and psychological factors. Future research should aim to identify specific mechanisms, such as cognitive improvements or social influences, and explore how comorbidities and medication adherence interact with these outcomes to

provide a clearer understanding of the impact of ADHD treatment on both injuries and risky behaviours.

Appendix

Table A1 Full list of coefficients

Overall period/ IV Negative binomial	Injuries	Risky behaviour
Age	0.033 (0.006)***	0.064 (0.008)***
Female	-0.353 (0.031)***	-0.014 (0.021)
Spanish	0.014 (0.078)	-0.022 (0.054)
Overweight	0.448 (0.068)***	0.028 (0.036)
Learning deficit	0.225 (0.040)***	0.099 (0.072)
Depression	0.019 (0.099)	0.227 (0.084)***
Asthma	0.200 (0.053)***	-0.023 (0.023)
Anxiety	0.461 (0.056)***	0.158 (0.033)***
Conduct disorder	0.510 (0.050)***	0.378 (0.040)***
Defiant disorder	0.648 (0.099)***	0.406 (0.088)***
Pharmacy limit Up to 8.23€	0.279 (0.069)***	0.053 (0.040)
Pharmacy limit Up to 18.52€	0.032 (0.111)	-0.037 (0.041)
Pharmacy limit Up to 61.75€	-0.914 (0.262)***	-0.181
ABS income	0.007 (0.006)	(0.014)***
No variation side effects	-0.026 (0.045)	-0.002 (0.002)
Increase side effects	0.692 (0.056)***	-0.004 (0.024)
% period medicated after	-0.802 (0.108)***	0.057 (0.028)**
diagnosis	-0.414 (0.107)***	-0.007 (0.057)
% period medicated & dropped	0.866 (0.079)***	0.003 (0.083)
after diagnosis		0.245 (0.049)***
Under therapy		
Health area (abs) fixed effects	YES	YES
No individuals	26,227	26,174

Author contributions

TM contributed to Conceptualization; Data curation; Formal analysis; Funding acquisition; Software; Roles/Writing - original draft; and Writing - review & editing.RJ contributed to Conceptualization; Methodology; Roles/Writing - original draft; and Writing - review & editing.JC contributed to Conceptualization; Methodology; Project administration; Writing - review & editing.DR contributed to Data curation; Software.

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Data availability

The data sets analysed during the current study are private due to consisting of administrative registers that belong to the regional public administration and, so on, do not available on request. Jordi Cid and Toni Mora obtained permission to use this data from public administration.

Declarations

Ethical approval

The Ethical Review Board approved the study in Hospital Trueta & IAS, Girona (Spain).

Competing interests

The authors declare no competing interests.

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