The Journal of Child Psychology and Psychiatry

Journal of Child Psychology and Psychiatry **:* (2018), pp **–** doi:10.1111/jcpp.12991

Attention deficit hyperactivity disorder late birthdate effect common in both high and low prescribing international jurisdictions: systematic review

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Background: Multiple studies have found that the youngest children in a classroom are at elevated risk of being diagnosed with, or medicated for, ADHD. This systematic review was conducted to investigate whether this late birthdate effect is the norm and whether the strength of effect is related to the absolute risk of being diagnosed/medicated. **Methods:** A literature search of the PubMed and ERIC databases and snowball and grey literature searching were conducted. **Results:** A total of 19 studies in 13 countries covering over 15.4 million children investigating this relationship were identified. Three other studies exploring related topics were identified. The diversity of methodologies prevented a meta-analysis. Instead a systematic review of the 22 studies was conducted. A total of 17 of the 19 studies found that the youngest children in a school year were considerably more likely to be diagnosed and/or medicated than their older classmates. Two Danish studies found either a weak or no late birth date effect. There was no consistent relationship between per-capita diagnosis or medication rates and the strength of the relative age effect, with strong effects reported in most jurisdictions with comparatively low rates. **Conclusions:** It is the norm internationally for the youngest children in a classroom to be at increased risk of being medicated for ADHD, even in jurisdictions with relatively low prescribing rates. A lack of a strong effect in Denmark may be accounted for by the common practice of academic 'redshirting', where children judged by parents as immature have a delayed school start. Redshirting may prevent and/or disguise late birthdate effects and further research is warranted. The evidence of strong late birthdate effects in jurisdictions with comparatively low diagnosis/medication rates challenges the notion that low rates indicate sound diagnostic practices. **Keywords:** ADHD; relative age; late birthdate.

Introduction

Despite being one of the most commonly diagnosed and medicated childhood psychiatric disorders in the world, Attention Deficit Hyperactivity Disorder (ADHD) is a controversial diagnostic entity. Much of the controversy stems from the fact that the diagnosis is based on third-party (often teacher and parent) reports of behaviour, because 'no biological marker is diagnostic for ADHD' (American Psychiatric Association, 2013).

These behaviours – which include making careless mistakes, not seeming to listen, not following through on instructions, disliking homework, losing things, being forgetful in daily activities, fidgeting, climbing excessively, having difficulty playing quietly, talking excessively and interrupting – are often displayed in school settings (American Psychiatric Association, 2005). Although paediatricians, psychiatrists and, in some jurisdictions, non-specialist medical doctors formally diagnose ADHD, teachers usually play a central role by providing an assessment of a child's behaviour. Furthermore, a 2003 US study found that, in most cases, teachers were the first to suggest a diagnosis (Sax & Kautz, 2003).

Relative age or late birthdate effects, where the oldest children in educational or sporting age-based cohorts tend to outperform and have better mental health outcomes than their younger peers, have long been recognised (Bell & Daniels, 1990). A study of 10,438 British 5–15-year-olds found that younger children in a school year were more likely to be diagnosed with a psychiatric disorder (Goodman, Gledhill, & Ford, 2003). In recent years, there has been a focus on relative age effects on the diagnosis and treatment of childhood ADHD. This study consolidates international evidence of the ADHD late birthdate effect and investigates the relationship between the strength of the effect and absolute rates of diagnosis and/or medication use.

Methods

Search strategy

A literature search of PubMed was conducted on 12 March 2018 using (ADHD AND month of birth) OR (ADHD AND birth

Conflict of interest statement: No conflicts declared.

month) OR (ADHD AND date of birth) OR (ADHD AND month born) OR (ADHD AND birthday) OR (ADHD AND birth day) OR (ADHD AND birthdate) OR (ADHD AND birth date) OR (ADHD AND youngest in class) OR (ADHD AND relative age in classroom) OR (ADHD AND oldest in class) OR (ADHD AND youngest in classroom) OR (ADHD AND oldest in classroom). On the same date, a literature search of the ERIC database (Education Resources Information Center sponsored by US Department of Education) was also conducted, using identical terms. In addition, snowball and grey literature searching were conducted.

Selection criteria

Any study published in English that identified statistical information in relation to the probability of being diagnosed with or medicated for ADHD (or Attention Deficit Disorder or Hyperkinetic Disorder) and relative age (date or month of birth) was included. This encompassed studies that were designed to investigate the relationship and those that incidentally provided this information (e.g. studies investigating the effect of season of birth on ADHD diagnosis or medication use). The main variables identified in each study were the relative risk of late born (compared with early born) children in a recommended school year cohort being medicated and/or diagnosed, and the proportion of children in each study of children being medicated and/or diagnosed. The specific measures used in each study (calendar month or months for comparison and age range of students) vary between studies.

The review was conducted in accordance with preferred reporting for systematic reviews and meta-analyses (PRISMA) guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009). As no patients or members of the public were involved, and this study involved the review of publicly available documents, no ethics committee approval was required.

Results

Figure 1 below summarises the literature search process method. The PubMed search identified 152 papers; however, only 16 were relevant to this study. Three of these papers (letters to the editor etc.) related to other papers which are all discussed in this review and offered no additional relevant information and were thus excluded. No extra relevant studies were identified among the 47 papers identified in the ERIC search. Initial grey literature search identified three more studies, while snowball search of the 16 relevant records identified six additional studies not identified by the PubMed or ERIC searches, leaving a total of 22 studies for inclusion.

Of these 22 studies, 19 explored the relationship between late birthdate within school intake cohorts and ADHD diagnosis. Of the 19 studies, 15 reported medication use and only nine reported diagnosis rates. Three other studies explored related topics (season of birth and ADHD, birthdate and adult ADHD symptomology). The diversity of methodologies in the studies meant that it was not appropriate to undertake a meta-analysis. Instead the 19 studies (conducted in 13 countries) are discussed separately.

A total of 17 studies – five in the USA, two in Spain and one each in Canada, Finland, Germany, Holland, Iceland, Israel, Norway, Sweden, Taiwan and Australia – found that children who were the youngest in their school year were more likely than their classmates to be medicated for, and/or diagnosed with, ADHD. Two Danish studies found a weak or no late birthdate effect. These 19 studies have a combined total population of over 15,400,000 children (approximate medication rate of 2.4% among the 15 studies that reported medication use). They are discussed below, and summarised in Appendix S1, with studies from the same country grouped together in descending order of the total number of children in the largest study in a country.

Large studies investigating the late birthdate effect for ADHD

Ten of the largest eleven studies are population-wide studies in nine countries that each cover at least 310,000 children, with a minimum 5,900 medicated or diagnosed. The remaining smaller studies each had a total population of less than 35,000 children, with fewer than 2,000 medicated. As discussed below, the two large scale studies from Denmark (Dalsgaard, Humlum, Nielsen, & Simonsen, 2014; Pottegard, Hallas, Hernandez, & Zoega, 2014) have significant cohort overlap, with the larger of the two (Pottegard et al., 2014) having a more robust methodology. The key measures (mean medication rate and late birthdate effect) of nine of these 10 large-scale studies (Dalsgaard et al., 2014 is not included) are plotted in Figure 2. Following this, another large scale study (Boland, Shahn, Madigan, Hripcsak, & Tatonetti, 2015) that reviewed the relationship between date of birth and a range of diseases and eight smaller studies that investigate the ADHD late birthdate effect, and then three other related studies are discussed.

The largest of the studies is a German study (Schwandt & Wuppermann, 2016) that reviewed the health insurance records from 2008 to 2011 of roughly 7.2 million children (approximately 90% of all German children aged 9–13 in this period). A number of children – most of whom were out of their recommended age group school cohort (primarily entry delayed for a year) – were excluded, so the final number analysed was 6,585,039. The proportion of 9–13 year-olds reported as receiving medication over the 4 years was 2.7%, with 3.8% reported as having been diagnosed with ADHD. The study reviewed records from 16 German states with different school entry cut-off dates. Among children aged 9–13 at any time between 2008 and 2011, researchers found large increases in ADHD rates around cut-off dates, amounting to a 22% increased risk for the youngest children in an age cohort (born the last month before the cut-off) compared with children born just after them who were the oldest (first month) in the next age cohort. These changes occurred ‘at different months across [German] states in accordance with the different cut-off dates’.

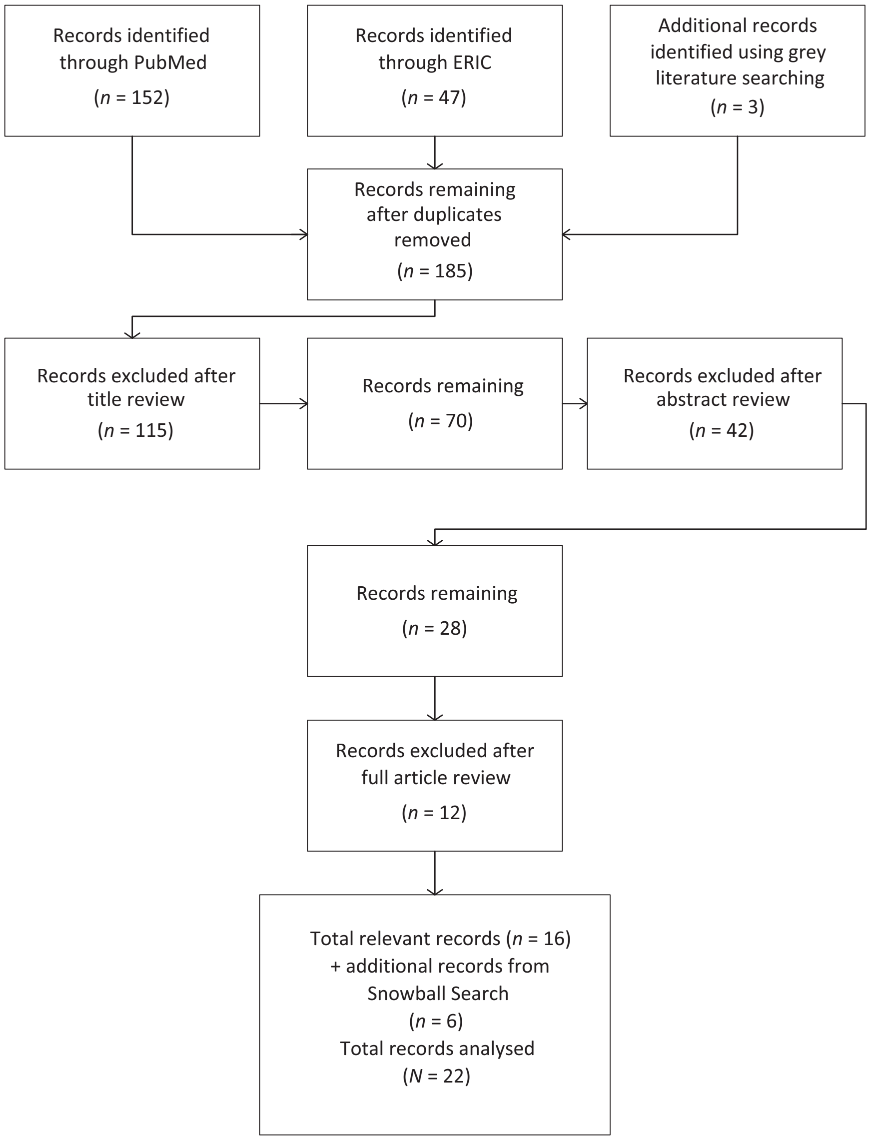

Figure 1 Literature search process with inclusion and exclusion criteria

The late birthdate effects demonstrated in the study were weaker in the first two grades and peaked in fourth and fifth grade, before moderating in later grades. One factor identified as a possible explanation for this trend was that academic performance becomes important in third and particularly fourth grade, and new ADHD diagnoses of relatively young children may occur then as a response to age-related differences in academic performance (Schwandt & Wuppermann, 2016).

The Swedish study (Halldner et al., 2014) reviewed the records of all people born from 1940 onwards, and residing in Sweden during July 2005 to December 2009. This included 1,821,939 children aged 6–17 years, of whom 17,565 (0.96%) received medication (calculated from Halldner et al., 2014 table 1, p. 899). Children born in November and December had a 39% higher risk of being medicated and a 30% higher risk of being diagnosed than their oldest classmates (born the previous January and February). This late birthdate effect was strongest in children aged 6–7 (70% increased medication use risk) and decreased progressively among older children (20% increased medication use risk among adolescents aged 16 and 17). The late birthdate effect tapered further in early adulthood, so that after age 35 there was no discernible difference. The study also reviewed diagnosis status, and similar patterns were displayed. Despite the relative age differences, the authors found no differences in parent or self-reported ADHD symptoms by birth month. This was one of only two studies that reported the relationship between month of birth and parent-reported ADHD symptoms.

In contrast to all other studies that reported both diagnosis and medication rates, the diagnosis rate (0.6%) in the Swedish study (for children aged 6–17) was considerably lower than the medication rate (0.96%). However, this study reported the proportion of children with a diagnosis of hyperkinetic disorder as defined in ICD-10. For many psychiatric disorders, including ADHD, diagnostic rates using DSM criteria are significantly higher than those using the equivalent disorder in ICD-10 (Sorensen, Mors, &

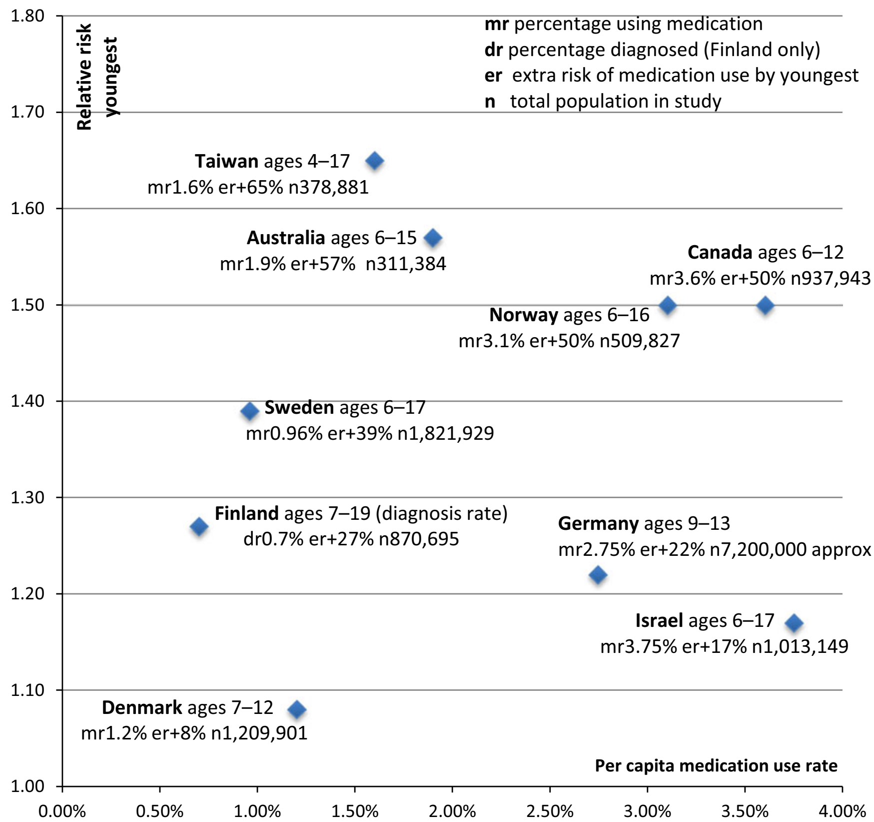

Figure 2 Relative medication use risk (youngest vs. oldest) against per capita medication use rate

Thomsen, 2005). It may be that some Swedish children who met the broader diagnostic criteria for ADHD, but were not diagnosed with Hyperkinetic Disorder, received medication.

A Danish study (Pottegard et al., 2014) reviewed the records of 1,209,901 children aged 7–12, including 932,032 children in their recommended school year, of whom 10,932 (1.2%) received medication. Among children in their recommended school year across the period 2000–2011, there was an average 8% increased risk (95% CI: 1.04–1.12) for children born between October and December (the youngest) compared with their older classmates born between January and March (the oldest).

In Denmark, the recommended school year intake matches the calendar year. However, it is very common in Denmark for late-born children to have delayed school entry, with 40% of children (boys 51%, girls 29%) born in October, November and December starting late, compared to only 4% of children born in January, February or March (Pottegard et al., 2014). The authors proposed that ‘the high proportion of relatively young children with delayed school entry in Denmark may play a role in the near absence of a relative age effect’.

Another large Danish study (Dalsgaard et al., 2014) with an overlapping sample, was published shortly before the research led by Pottegård. It included many of the same children, but the sample was only 35% of the size. It reviewed the records of all 418,396 children born between July 1990 and June 2001, of whom 8,720 (2.1%) children ‘purchased’ ADHD medication after the age of seven. The authors found no effect of ‘being born in the beginning of January compared to the end of December on the likelihood of having purchased ADHD medication’ (OR 1.0014, 95% CI: 0.9996–1.0031).

According to Dalsgaard et al. ‘In Denmark, school entry rules imply that children born in December are typically enrolled in school 1 year earlier than children born in January’. The paper makes no reference to the effect of the very common Danish practice of delayed entry for late-born children, particularly boys. The lead author was contacted to confirm whether ‘the calculation of relative risk in your paper was based on the assumption that all children started school in line with these school entry rules’; but he did not respond. If, as appears likely, no adjustment was made for late starters, this would have hidden any late birthdate effect, because a disproportionate number of nominally young, late-born children (born in December) would actually be among the oldest in their class. As Danish data from the more robust study led by Pottegard et al. (2014) are included in Figure 2, the results of this study are omitted there.

Elsewhere, Dalsgaard et al. have suggested that the lack of a late birthdate effect in Denmark may be due to diagnostic practices being less subjective because only specialists can diagnose ADHD (Dalsgaard, Humlumb, Nielsen, & Simonsen, 2012). However, in most other studies where a strong late birthdate effect exists, diagnosis is also restricted to specialists.

The Israeli study (Hoshen, Benis, Keyes, & Zoega, 2016) reviewed the records of 1,013,149 children aged between 6 and 17 years from 2006 to 2011, and found rising rates of 'one-year prevalence' use of ADHD stimulant prescribing, from 2.6% in 2006 to 4.9% in 2011. The youngest third of children in class – born August to November – were more likely to use medication than the oldest third – born December to March – (risk ratio (RR) 1.17, 95% confidence interval (CI) 1.12–1.23) or the middle third (RR 1.06, 95% CI: 1.01–1.11). As in the Swedish study, the late birthdate effect 'diminished as children were older in absolute age' (Hoshen et al., 2016).

An important limitation of the Israeli study is that researchers could not identify children who had been 'accelerated or delayed from the expected grade level' (Hoshen et al., 2016). It is likely that the increasingly common Israeli practice of delayed entry for late-born children partly explains why the late birthdate effect was not as strong as in other studies (Hoshen et al., 2016).

The Canadian study (Morrow et al., 2012) reviewed the records of 937,943 children in British Columbia, aged 6–12 years at any time between 1 December 1997 and 30 November 2008. Approximately 33,775 (3.6%) of these children received medication at some time (calculated from Morrow et al., 2012 table 1, p. 756). There was an increased risk of both being diagnosed (boys +30%, 95% CI: 1.23–1.37; girl s + 70%, 95% CI: 1.53–1.88) and taking medication (boys +41%, 95% CI: 1.33–1.50; girls +77%, 95% CI: 1.57–2.00) for the youngest children in a class (born in December) compared with the oldest (born the previous January).

The strength of the late birthdate effect remained relatively stable throughout the 11-year study, despite increasing diagnosis and medication rates. The effect was present among all age groups of children but, as with the Swedish and Israeli studies, was weaker in older children. The risk for medication use rose month by month for both genders from January to September, and plateaued from September to December. The authors suggest this plateauing may occur because late-born children (born in October to December) who show ADHD type behavioural problems may be held back a year, giving them more time to develop sociable behaviours.

The Finnish study (Sayal, Chudal, Hinkka-Yli-Salomaki, Joelsson, & Sourander, 2017) examined the birth month distribution of 870,695 children aged 7–19, of whom 6,136 (0.7%) were ever diagnosed with ADHD. The chances of a child being diagnosed before age 10 were 64% higher (95% CI: 1.48–1.81) for the youngest third in a class (born September to December) compared with their older classmates born from January to April. The effect was not as strong among older children. Across the entire 7–19 age range, boys born between September and December were 26% (95% CI: 1.18–1.35) more likely to be diagnosed than boys born from January to April. For girls aged 7–19, the increased risk was 31% (95% CI: 1.12–1.54). For both genders combined, there was a 27% increased risk of diagnosis (calculated from Sayal et al., 2017 table 2, p. 5).

The Norwegian study (Karlstad et al., 2016) reviewed the records of all Norwegian children born between 1998 and 2006 from their sixth birthday until 31 December 2014. In Norway, delayed (or early) enrolments are rare (Karlstad et al., 2016). Of the 509,827 children aged 6–16, 15,717 (3.1%) received ADHD medication at some time during this period and 3.4% were diagnosed. Boys born from October to December (the youngest children in a class) had a 41% (adjusted hazard ratio 1.4, 95% CI: 1.4–1.5) higher rate of medication and a 43% higher diagnosis rate than older boys born from January to March of the same year. For late-born girls, the elevated medication risk was +79% (adjusted hazard ratio 1.8, 95% CI: 1.7–2.0), with an increased diagnosis rate of +75% (percentages calculated from Karlstad et al., 2016 table 1, p. 345). A supplementary analysis restricted to 17,017 siblings from 7,690 mothers, adjusted for gender and age, revealed a 70% greater risk of ADHD medication use for late-born children (October to December) compared with their early-born siblings (January to March).

Unlike most of the other studies, the late birthdate effect was most marked in higher grades. In Norway, the first testing of academic performance occurs late in grades four and five, coinciding with an increase in the strength of the late birthdate effect (Karlstad et al., 2016).

In the Taiwanese study (Chen et al., 2016), the total population of children was 378,881, of whom 6,062 (1.6%) received medication and 2.3% had ever been diagnosed. Among children aged 4–17, there was 65% (95% CI: 1.48–1.83) increased risk (boys +63%, girls +71%) of being diagnosed and a 73% (95% CI: 1.53–1.97) increased risk (boys +76%, girls +65%) of taking medication for the youngest children in a class (born in August) compared with the oldest (born the previous September). The late birthdate effect was stronger in early school years than in later school years.

The Australian study (Whitely, Lester, Phillimore, & Robinson, 2017) examined the birth month distribution of 311,384 Western Australian children aged 6–15, of whom 5,937 (1.9%) received medication (4,677 [2.9%] of 158,675 boys; 1,260 [0.8%] of 152,709 girls - not reported in original study). There was a high degree of compliance with recommended age input (98%) and, to the limited extent that it occurs, most out-of-year children were late-born children with delayed entry. For children aged 6–10, the youngest in a class (born in June) were approximately twice as likely (boys RR 1.93, 95% CI: 1.53–2.38; girls 2.11, 95% CI: 1.57–2.53) to take medication as the oldest (born the previous July). For children aged 11–15, those born in June were 30% more likely (boys 1.26, 95% CI: 1.30–1.52; girls

1.43, 95% CI: 1.15–1.76) to be medicated than those born the previous July. The increased risk for all children (both genders combined) was 57% (not reported in original study). Similar patterns were found when comparing children born in the first three (or six) months and the last three (or six) months of the school-year intake.

Figure 2 (above) is a scatter diagram showing the medication rate (diagnosis rate for the Finnish study) versus relative risk for the nine countries in which large studies have been conducted. The smallest of these studies had a total population of over 310,000. The largest study with both population and diagnosis/medication data not included in the scatter diagram had a total population of less than 35,000 children.

All nine studies found a tendency for relatively young children to be medicated/diagnosed at a higher rate than their older classmates (ranging from 1.08 in Denmark through to 1.65 in Taiwan). However, there is no consistent relationship between the prescribing rate and the strength of the late birthdate effect. If anything, there is a weak inverse relationship (lower medication rate associated with a stronger effect), but there are differences in methodology – particularly diverse age ranges and the extent of unidentified delayed school entry – that make direct comparisons problematic. For example, the inclusion of 18 and 19 year-olds in the Finnish study is likely to have reduced the strength of the reported late birthdate effect (based on diagnosis rather than prescribing). The most obvious conclusion that can be drawn from these nine studies is that the late birthdate effect occurs in both high and low prescribing/diagnosing jurisdictions.

Another very large study (Boland et al., 2015) reviewed a New York Medical Centre's records for 1,749,000 individuals born between 1990 and 2000, and examined the association between 1,688 diseases and birth month. It found a rising trend across the year for the diagnosis of ADHD, peaking in November. In New York the school intake year mirrors the calendar year, with the youngest children born in December. The study did not report absolute medication or diagnosis rates and therefore could not be plotted in Figure 2.

Smaller studies investigating the late birthdate effect

The largest of the studies conducted in the USA that focussed solely on ADHD (Evans, Morrill, & Parente, 2010) reviewed the diagnosis and medication use data for children from multiple US states from three different sources, the National Health Interview Survey (NHIS) (1997–2006), the Medical Expenditure Panel Survey (MEPS) (1996–2006) and private claims data (2003–2006). It compared diagnosis and medication rates for children born in the 120 days after the school start cut-off date (the oldest in class) with those of children born in the 120 days before the cut-off (the youngest). The NHIS data included 53,212 person/year observations. 9.7% of the youngest, and 7.6% of the oldest, were diagnosed. The MPES data included 47,423 person/year observations. 4.5% of the youngest, and 4.0% of the oldest, used stimulants. The private claims data (2003–2006) included 72,885 person/year observations. 6.5% of the youngest, and 5.2% of the oldest, used stimulants. The authors concluded that children born in the 120 days after the cut-off date (the oldest in class) had a significantly lower risk of being diagnosed and being prescribed stimulants than those born in the 120 days before the cut-off (the youngest; Evans et al., 2010).

The authors also discussed how academic redshirting (delayed entry) was most common among late-born children, especially boys, and 'children with diagnosed development problems were more than twice as likely as those without such diagnoses to have delayed entry' (Evans et al., 2010). Like the Israeli study, this may result in an underestimation of the strength of the late birthdate effect.

Another US study (Elder, 2010) used data from a nationwide longitudinal survey of health and wellbeing for 11,784 children from 1998 to 2007. By 2007, when most children were in eighth grade (aged approximately 13), 6.4% were diagnosed with ADHD and 4.5% regularly used stimulants. In fifth grade, when the children were approximately 10 years old, those children born fewer than 181 days before their state's cut-off date (the youngest) were roughly 50% more likely to be diagnosed with ADHD (7.5% vs. 5.1%) and to use behavioural medications (5.4% vs. 3.5%) than those born fewer than 181 days after the cut-off date.

The study, the second of the two studies that reported the relationship between month of birth and parent-reported ADHD symptoms, also found that a child's birthdate 'strongly influences teachers' assessments of whether the child exhibits ADHD symptoms but is only weakly associated with similarly measured parental assessments'. This study built on prior research by the same lead author that found evidence of a range of relative age effects, including increased probability of grade repetition and diagnoses of learning disabilities such as ADHD. An additional year of age at entry of kindergarten was found to decrease the probability of an ADD or ADHD diagnosis by two-thirds (Elder & Darren, 2009).

An earlier US study (Schneider & Eisenberg, 2006) examined 2002 data from a nationally representative sample of 9,278 mostly third grade children. 5.44% of these students had been diagnosed with ADHD. Information about medication use was not collected. The study found that relatively younger children (born in the last 3 months of their school intake year) were 69% more likely to have been diagnosed than those born in the first 3 months (OR: 1.69, 95% CI: 1.10–2.61).

The first published research ever to suggest an ADHD relative age effect was a US study (LeFever, Dawson, & Morrow, 1999). It reviewed the records of 2,177 children who were 'young-for-grade' (a year or younger than expected age for grade) or 'old-for-grade' at public schools in two US cities. It concluded that 'being young for one's grade was positively associated with medication use' (LeFever et al., 1999). However, there were conflicting results, with a very strong extra medication risk in one city and, paradoxically, a reverse late birthdate effect in the other. In city B, 62.7% of young-for-grade students and 10.1% of old-for-grade students were medicated for ADHD. In contrast, in city A, 3.7% of young-for-grade students and 12.4% of old-for-grade students were medicated. Because, unlike all the other studies reviewed here, it analysed the relative age effect in children who were well outside their recommended year, it is of limited relevance to the late birthdate effect in children within the recommended year group.

In a Spanish study (Librero, Izquierdo-Maria, Garcia-Gil, & Peiro, 2015) data from 2013 were obtained from the information systems of the Valencia Ministry of Health for 20,237 children aged 6–12 years, of whom 1.73% were treated for ADHD (boys: 2.70%; girls: 0.71%). The prevalence of pharmacological treatment in the youngest children (born in the 6 months from July to December) was 51% higher than in their older classmates (born from January to June) (calculated from Librero et al., 2015 table 1, p. 473). Another Spanish study (Rivas-Juesas, Gonzalez de Dios, Benac-Prefaci, Fernandez-Martinez, & Colomer-Revuelta, 2015) reviewed the records of 3,469 patients who attended a child neurology clinic between 1992 and 2012. 61.6% of those with suspected ADHD were born between July and December.

An Icelandic study (Zoega, Valdimarsdottir, & Hernandez-Diaz, 2012) reviewed the data from all children born in Iceland in 1994, 1995 and 1996 for whom academic and health records were available. Of the 11,785 children in the study 740 (6.3%) received stimulant medication at some time between 2003 and 2008. Children in the youngest third of a class (born between September and December) had a 50% higher likelihood of receiving stimulants (8.0% compared to 5.3%) than the oldest third (born between January and April).

A study in the Netherlands (Krabbe, Thoutenhoofd, Conradi, Pijl, & Batstra, 2014) analysed the GP records of 2,218 children between the ages of 5 and 12, of whom 85 (3.8%) had ever been prescribed methylphenidate, the most commonly used medication for ADHD in Holland. Relatively young pupils (born in August and September) were 143% more likely (2.43 times as likely) to be prescribed methylphenidate than their older classmates (born in December and January). Children born in October and November were excluded from the study because parents decide when these children start school, with many having a delayed start. The study also reviewed the awareness of teachers and GPs of prior studies demonstrating a late birthdate effect. A majority of GPs (70%) and teachers (67.5%) reported not being aware of an association between birth month and ADHD medication use. Another small Dutch study (Jeronimus, Stavrakakis, Veenstra, & Oldehinkel, 2015) into relative age effects across a range of educational and psychosocial measures found little evidence of relative age effects; however, this study did not investigate the relative risk of being diagnosed or medicated for ADHD.

Other related studies

Two other studies, both very small and methodologically weak, have also investigated the relationship between date of birth and ADHD. The earliest (Mick, Biederman, & Faraone, 1996) was a US study of 140 Caucasian boys diagnosed with ADHD and 120 boys without ADHD diagnoses. The study found a relationship between month of birth and probability of being diagnosed, but suggested that there may be a seasonal pattern of birth for some subtypes of ADHD that may be related to seasonally mediated viral infections.

More recently, a Canadian study (Kowalyk, Davis, Wattie, & Baker, 2014) reviewed the distribution of ADHD symptoms by relative age and season of birth among adults, and found no link. It did not identify the proportion diagnosed or medicated by month of birth, and therefore is of little significance in determining if the ADHD any late birthdate effect carries into adulthood from childhood.

Of greater significance is another Danish study (Atladottir et al., 2007) that used the health records of the 669,995 children born in Denmark from 1990 to 1999 to investigate seasonal variations in birth of children diagnosed with neurodevelopmental disorders, including 2,033 diagnosed with hyperkinetic disorder (similar to ADHD combined type). The authors analysed the data in order to identify if seasonal variations 'could suggest etiological factors that follow a seasonal pattern'. The authors found no 'convincing' season of birth variations for autism-spectrum-disorder subtypes. However, they found 'there was some evidence of a seasonal effect for hyperkinetic disorder, with higher rates in autumn and lower in spring'. For seasonal analysis purposes, December (the last month of the Danish school year intake) was grouped with the other winter months, January and February (the first 2 months of the school year intake). A graph (Figure 1, p. 241) in the paper identified a modest rising trend across the months of the calendar year, peaking in September then declining somewhat in November and December, when many redshirted children are born, before plummeting in January. These results are consistent with the existence of a late birthdate effect.

Discussion

Collectively, these independent studies from 13 countries demonstrated that the youngest children in a classroom are more likely to be diagnosed with and medicated for ADHD than their older classmates, regardless of the absolute rate of diagnosis and medication. Apart from the Danish studies, which were inconclusive (discussed below), all studies unambiguously demonstrated a late birthdate effect.

Our review has some limitations, primarily emanating from the variety of methodologies and measures in the studies reviewed, and the fact that they were population studies, without individual-level data. They reported across diverse age ranges. Most reported medication rates, but some included only stimulants, while others included the less commonly prescribed atomoxetine, with the proportion of children medicated/diagnosed ranging from a high of 6.3% (aged 7–14 medicated with stimulants in the Icelandic study; Zoega et al., 2012) to a low of 0.7% (aged 7–19 diagnosed in the Finnish study; Sayal et al., 2017). The Dutch study (Krabbe et al., 2014) reported only methylphenidate use. Several also reported diagnosis rates. One US study (Schneider & Eisenberg, 2006) reported only a diagnosis rate. The rates were calculated on different time bases. Several studies compared the last month before the cut-off date with the first month after (Chen et al., 2016; Dalsgaard et al., 2014; Morrow et al., 2012; Schwandt & Wuppermann, 2016; Whitely et al., 2017). Some compared the last 3 months with the first 3 months (Karlstad et al., 2016; Pottegard et al., 2014). Four compared the last third (4 months) with the first third (Evans et al., 2010; Hoshen et al., 2016; Sayal et al., 2017; Zoega et al., 2012), and two compared the first half of the year with the second half (Elder, 2010; Librero et al., 2015).

The different methodologies and measures used make direct comparisons of the strength of the late birthdate effects difficult. It seems likely that comparisons between the last and first month (e.g. Australia (Whitely et al., 2017), Taiwan (Chen et al., 2016)) will show more difference than those studies that compare older and younger thirds (e.g. Israel (Hoshen et al., 2016), Finland (Sayal et al., 2017)). However, the pattern of an elevated risk of medication/diagnosis for relatively young children is common even in jurisdictions with relatively low diagnosis and medication rates. For instance, the Australian study, with a medication rate of 1.9% reported a doubled medication use risk rate among children aged 6–10 (youngest month compared to oldest month; Whitely et al., 2017). On the same last versus first month basis, the Taiwanese study (1.6%, aged 4–17, 73% increased risk) showed similar patterns (Chen et al., 2016). Most notably, the Swedish study, with a reported medication rate of 0.95% (Halldner et al., 2014), and the Finnish study, with a reported diagnosis rate of 0.7%, (Sayal et al., 2017) both reported strong ADHD late birthdate effects particularly among young children.

The studies conducted in Sweden (Halldner et al., 2014), Israel (Hoshen et al., 2016), Canada (Morrow et al., 2012), Finland (Sayal et al., 2017), Norway (Karlstad et al., 2016), Australia (Whitely et al., 2017), the largest ADHD specific US study (Evans et al., 2010) and Dalsgaard et al. (2014) Danish study could not identify the ADHD medication and/or diagnosis status of children who were out of their recommended school-year cohort. In studies where details were reported, out-of-recommended-year school attendance predominantly involved delayed entry by late-born boys. Redshirting has also been shown to be relatively common in children diagnosed with developmental problems (West, Meek, & Hurst, 2000).

The disproportionate redshirting of late-born children at elevated risk of being diagnosed with ADHD may hide the full impact of late birthdate effects, because these children are typically removed from the late-born sample. This is likely to be more significant in jurisdictions in which redshirting is common (such as Israel (Hoshen et al., 2016) and Denmark (Pottegard et al., 2014)) than in jurisdictions such as Norway (Karlstad et al., 2016) and Western Australia (Whitely et al., 2017), where there is a high level of compliance with recommended school year intake.

Unlike the other studies, the Danish studies demonstrate a weak or non-existent late birthdate effect (Atladottir et al., 2007; Dalsgaard et al., 2014; Pottegard et al., 2014). In Denmark, the majority of late-born boys were redshirted. As suggested by Pottegard et al. (2014) allowing parents to redshirt children they consider too young for school may reduce or remove any late birthdate effect. However, there are dangers in simply assuming that redshirting leads to desirable outcomes such as eliminating relative age effects. As discussed above, redshirting may hide the full impact of the late birthdate effect. It is also possible that the greater age spread associated with increased flexibility may increase the potential for age related immaturity to influence educational and other life outcomes in other children. There could even be contradictory effects whereby redshirted children achieve better academic and social outcomes and reduced rates of ADHD than they would have if they began school ‘on time’, but other children suffer stronger relative age effects from having older children in their class. Further research into the effects of redshirting on the ADHD late birthdate and other relative age effects is warranted.

Despite the limitations described above, the main finding of this study is clear. School entry cut-off dates, even when they occur mid-season, delineate significant changes in medication and/or diagnosis rates. This finding does not support the season of birth hypothesis suggested by Atladottir et al. (2007)

and Mick et al. (1996). With the exception of the German (Schwandt & Wuppermann, 2016) and Norwegian studies (Karlstad et al., 2016) the late birthdate effect was stronger in early years of school. This is most likely a reflection of the age difference being greater in relative terms in younger children than older children resulting in more pronounced age-related immaturity.

The reasons for the German (Schwandt & Wuppermann, 2016) and Norwegian (Karlstad et al., 2016) studies showing a different trend, with older ages showing a stronger late birthdate effect, are unclear. It may be related to academic testing and ranking of performance, which first occurs in these countries at ages 9–10. Relative age-related poor academic performance at these ages may be mistakenly attributed to undiagnosed ADHD. It could be that age-related behavioural immaturity is the primary driver in other jurisdictions, but age-related academic disadvantage is a more significant driver of the ADHD late birthdate effect in Germany and Norway.

An interesting feature of the majority of studies that reported gender specific late birthdate effects (Canada (Morrow et al., 2012), Norway (Karlstad et al., 2016), Finland (Sayal et al., 2017) and Australia (Whitely et al., 2017)) is that the effect was stronger for girls than boys, although in all studies boys were many times more likely to be diagnosed and medicated than girls. It is puzzling that girls, with a much lower diagnosis and medication rate than boys, show a stronger late birthdate effect. Further investigation is required to establish whether this is a consistent pattern and if so, why it is occurring.

It has long been debated whether ADHD is caused by neurobiological malfunction. Research led by Shaw found that children with ADHD tend to have cortical development that 'lagged behind that of typically developing children by several years' and that treatment with psychostimulants is a 'possible but unlikely' cause (Shaw et al., 2007). The temporary nature of the delay, the possibility (however remote) of stimulant induced brain atrophy, and the late birthdate effect demonstrated in multiple studies, suggest that, rather than being diagnosed and medicated, impulsive and/or inattentive children should be supported through the extra time they need to mature. This is particularly the case for young-for-grade children who may seem more hyperactive and/or inattentive than their peers, but in reality are acting in an age appropriate manner and their age related immaturity needs to be accommodated.

The diagnostic criteria of ADHD – in particular making careless mistakes, not 'seeming to' listen, failing to finish school work, being disorganised, disliking schoolwork or homework, blurting out answers and leaving a seat when remaining seated is expected – are all evidence of a child's failure to comply in a school environment. Teachers are usually asked to complete a check list of ADHD behavioural diagnostic criteria for a child suspected of having ADHD. The authors of several studies have proposed that the most likely mechanism driving the late birthdate effect is some teachers rating the behaviour of the youngest children in their class against classroom norms without due regard to their birthdate, resulting in higher rates of diagnosis and subsequent medication than are warranted.

Ultimately clinicians, not teachers, diagnose ADHD. However, a 2003 US study found 'that in the majority of cases teachers are the first to suggest a diagnosis of ADHD' (Sax & Kautz, 2003). Even when teachers are not the first to suggest a diagnosis, the information they provide to clinicians still often plays a central role in the process. Ideally both clinicians and teachers should be cognisant of the potential for relative age to affect the external presentation of ADHD diagnostic criteria.

Two studies investigated the relationship between month of birth and parent-reported ADHD symptoms. Both found no association (Elder, 2010; Halldner et al., 2014). Parents may compare the behaviour of their child to siblings, relatives or friends; but, unlike teachers, they are unlikely to regularly compare the behaviour of relatively young-for-class children to older classmates. Parents are therefore less likely to mistakenly identify relative age related immaturity as the symptoms of ADHD. This highlights the importance of clinicians being aware of the potential for a late birthdate effect in teacher ratings and, as is recommended in DSM5, considering the child's behaviour in both home and school settings.

Teachers and clinicians failing to take appropriate account of relative age is one of many non-biological factors that have been associated with higher rates of ADHD diagnosis and medication use. Gender, ethnicity of students and teachers (Schneider & Eisenberg, 2006), divorce (Hjern, Weitoft, & Lindblad, 2010), poverty (Russell, Ford, Rosenberg, & Kelly, 2014), parenting styles (Johnston, Mash, Miller, & Ninowski, 2012), low maternal education, lone parenthood and the receipt of social welfare (Hjern et al., 2010), sexual abuse (Weinstein, Staffelbach, & Biaggio, 2000), sleep deprivation (Thakkar, 2013), perinatal issues (Schmitt & Romanos, 2012), artificial food additives (McCann et al., 2007), mobile phone use (Byun et al., 2013), clinician speciality (Parliament, Legislative Assembly, 2004), geography and regulatory capture (Whitely, 2014), have all been associated with an increased risk of an ADHD diagnosis.

Allen Frances, the prominent US psychiatrist who led the American Psychiatric Association's Task Force on DSM-IV (American Psychiatric Association, 2005), has cited studies from the USA (Evans et al., 2010), Canada (Morrow et al., 2012), Taiwan (Chen et al., 2016), and Iceland (Zoega et al., 2012), as providing 'conclusive proof' ADHD is over-diagnosed (Frances, 2016/2017). He has repeatedly been critical of US prescribing rates and has argued that a diagnostic rate of around 2%–3% would best balance harms and benefits (Frances, 2015).

Schwandt and Wuppermann's analysis appears to support Frances' position. They found a strong linear relationship between the strength of the late birthdate effect and ADHD rates in cross-national and German state jurisdictions:

> Cross-country variation in cut-off jumps [the late birthdate effect] is highly predictive of a country's average ADHD level and that this positive relationship is remarkably linear. Moreover, it is very similar to the relationship observed across German states. In other words, countries and regions with strong jumps in ADHD rates around age cut-offs have also higher overall ADHD rates, perhaps because cut-off jumps proxy for a general tendency to mis- and over-diagnose ADHD.(Schwandt & Wuppermann, 2016)

This assertion was based on interstate (within Germany) comparisons, and international data from Danish (Dalsgaard et al., 2014) Canadian (Morrow et al., 2012) USA (Elder, 2010) and Icelandic (Zoega et al., 2012) studies. However, the data from the large Swedish (Halldner et al., 2014), Finnish (Sayal et al., 2017), Taiwanese (Chen et al., 2016), Australian (Whitely et al., 2017), studies and the much smaller Spanish study (Librero et al., 2015), which all show strong late birthdate effects at relatively low rates of prescribing, were not included. Although most of these five studies were published after Schwandt and Wuppermann wrote their paper, it is puzzling that they cited the Swedish study, which includes detailed data on the number of children using medication for a total population of over 1.8 million children (Halldner et al., 2014), but did not include it in their 'cross-country' analysis (Schwandt & Wuppermann, 2016).

The five studies from jurisdictions with reported diagnosis/medication rates in line with, or lower than Frances' estimated ideal target range, are inconsistent with the 'positive… remarkably linear' relationship noted in (Schwandt and Wuppermann (2016) study.

Conclusions

It is unclear whether allowing parents to have greater discretion in deciding when their child begins school alleviates or disguises the ADHD late birthdate effect. Further research on this issue is warranted. However, it is clear that it is the norm internationally for the youngest children in a classroom to be at increased risk of being diagnosed with and medicated for ADHD, even in jurisdictions with relatively low prescribing rates. This evidence challenges the notion that low rates indicate sound diagnostic practices. Teachers and clinicians need to be aware of the potential for relative age related immaturity to be misdiagnosed as ADHD and adjust their teaching and diagnostic practices accordingly.

Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article:

Appendix S1. Summary of the 22 studies identified in the literature search.

Data S1. Prisma 2009 Checklist.

Acknowledgements

No funding was provided for this research. As all information sources are publicly available documents, ethics approval was not required. The authors have declared that they have no competing or potential conflicts of interest.

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Key points

What is already known:

- The oldest children in age-based educational or sporting cohorts tend to outperform their younger peers.
- Some studies have found that the youngest children in a classroom are more likely to be diagnosed with or medicated for ADHD than their older classmates.

What this study adds:

- It establishes that it is usual for the youngest children in a classroom to be at a significantly increased risk of being medicated for ADHD, even in jurisdictions with relatively low diagnosis/prescribing rates.
- Academic 'redshirting' (allowing parental discretion to delay school entry) is associated with a weaker demonstrated late birthdate effect; however, it is unclear whether this prevents and/or disguises the effect.

Strengths and limitations of this study

- This study incorporates research covering over 15 million children from 13 countries on four continents (Europe, North America, Asia and Australia), with a wide range of diagnosis and medication use rates.
- The original studies analysed used significantly different methodologies and measures, which made direct comparisons of the strength of the late-birthdate effects difficult.
- In most studies, it was not possible to identify students who started school before or after the recommended school entry date.

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Accepted for publication: 29 August 2018