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Impact of the School Environment on Medical Treatment of Attention Deficit Hyperactivity Disorder: A Population-Wide Register Data Study of School-Wide Positive Behavioral Interventions and Supports

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Although attention deficit hyperactivity disorder (ADHD) is among the most heritable psychiatric childhood disorders, social and gene–environment interactions seemingly play an important role in the etiology of ADHD. Consistent with this, this study finds that School-Wide Positive Behavioral Interventions and Supports (SWPBIS) reduced the likelihood of pharmacotherapeutic treatment for ADHD at age 14–16 by 12%, using population-wide Norwegian register data and a difference-in-difference design (N = 698,364, birth cohorts 1990–2002, 48.7% girls, 5.7% immigrant background). At-risk students in schools with high fidelity of implementation are driving these intervention effects. Overall, the findings indicate that children with a genetic disposition for ADHD are more likely to avoid medical treatment in an organized and predictable school setting with a focus on positive reinforcement.

The increase in diagnosis and treatment of attention deficit hyperactivity disorder (ADHD) since the 1990s has raised concerns that disruptive and immature children in schools are increasingly treated with stimulants instead of addressing their behavioral, emotional, and academic problems through behavioral interventions (Currie, Stabile, & Jones, 2014; LeFever, Arcona, & Antonuccio, 2003). As an illustration, children born just a month apart from the school enrollment cutoff date are considerably more likely to be diagnosed with ADHD and treated with stimulants than older children within the same birth cohort (Chen et al., 2016; Elder, 2010; Karlstad, Furu, Stoltenberg, Håberg, & Bakken, 2017; Krabbe, Thoutenhoofd, Conradi, Pijl, & Batstra, 2014; Whitely, Lester, Phillimore, & Robinson, 2017). Generally, this suggests that the diagnosis and treatment of ADHD are influenced by normative and social contexts, as well as teachers' subjective perception of poor behavior (Elder, 2010).

Furthermore, whereas ADHD is among the most heritable psychiatric childhood disorders, gene–environment interactions seem to play an essential role in the etiology of ADHD (de Zeeuw, van Beijsterveldt, Lubke, Glasner, & Boomsma, 2015). Depending on a child's genetic makeup, variation in teaching methods, rules, and other school environment characteristics may trigger behavioral problems in some classrooms but not others. Thus, school interventions that reduce or prevent early-onset behavioral problems and promote positive adjustment, or provide teachers with strategies to manage these behavioral problems, may diminish

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students' need for pharmacotherapeutic treatment (Eiraldi, Mautone, & Power, 2012). To investigate this, we use population-wide register data to study the effects of the School-Wide Positive Behavioral Interventions and Support (SWPBIS) model on licit prescriptions of ADHD medication at age 14–21 in Norway.

Children with ADHD have an increased risk of strained social relationships (Eiraldi et al., 2012), academic failure (Currie & Stabile, 2006; Fletcher & Wolfe, 2008), criminal activity (Fletcher & Wolfe, 2009), and poor labor market outcomes (Fletcher, 2014). Thus, early treatment reducing ADHD symptoms may be cost-effective (Fletcher, 2014; Fletcher & Wolfe, 2009) and a key to ensuring opportunities for all children regardless of disabilities (Reicher, 2010). Furthermore, teachers report a higher level of stress and frustration when teaching students with ADHD (Greene, Beszterczey, Katzenstein, Park, & Goring, 2002), and disruptive students, including students with ADHD, impair the academic achievements of both their classmates (Aizer, 2008; Carrell & Hoekstra, 2010; Figlio, 2007; Fletcher, 2010; Lazear, 2001) and their siblings (Fletcher & Wolfe, 2008).

Compared to psychosocial interventions, treatment of ADHD using stimulant medications, the most common pharmacotherapeutic agent for ADHD, is controversial because of potential adverse long-term side effects of stimulants coupled with limited evidence that it improves ADHD symptoms and the quality of life for children with ADHD (Storebø et al., 2015). Additionally, whereas some studies indicate that stimulants may mitigate the consequences of ADHD, taken together, studies have failed to find that stimulants improve educational and labor market outcomes for children with ADHD (cf. Currie et al., 2014; Fletcher, 2014; Keilow, Holm, & Fallesen, 2018).

Thus, psychosocial interventions in home and school are by many regarded as the recommended first line of treatment for children with mild to moderate symptoms of ADHD (Storebø et al., 2015; Wolraich et al., 2019). These recommendations reflect a goal to target skill development rather than merely treating symptoms. Moreover, treatment sequencing studies have demonstrated treating ADHD with behavioral interventions and then supplementing with medication when necessary results in better behavioral outcomes and less use of stimulant medications in the longer run, compared to using pharmacological interventions early (Page et al., 2016; Pelham et al., 2016).

The school environment is ideal for psychosocial interventions as they occur in a daily-life context and reach all children, and SWPBIS has been highlighted as one of several promising approaches (Boxmeyer et al., 2018; Eiraldi et al., 2012). The SWPBIS model is a universal, whole-school prevention strategy that aims at altering staff behaviors and create a predictable, consistent, and positive school environment and thereby reduce externalizing problem behaviors among students (Bradshaw, Waasdorp, & Leaf, 2012). The goal is to limit minor behavioral and concentration problems and prevent more severe problem behaviors, including aggression, truancy, bullying, and vandalism.

Although the SWPBIS model targets all students, many of its interventions are particularly relevant for students at risk of ADHD, such as daily report card, rewards, and social skills training (Evans et al., 2016; Fabiano et al., 2010; Pfiffner et al., 2016; Power et al., 2012). The SWPBIS model aims to increase structure and predictability in the classroom setting, which may benefit children with symptoms of ADHD in particular, as they function poorly in unstructured and unpredictable environments. Additionally, the focus on positive reinforcement in SWPBIS may be especially beneficial for students with a genetic disposition for ADHD as they otherwise receive frequent negative feedback on their challenging classroom behavior (for a more detailed discussion, see Eiraldi et al., 2012). By providing an organized and predictable school setting, focusing on positive reinforcement, and teaching appropriate behavior and social skills, SWPBIS may relieve ADHD symptoms and, therefore, the need for ADHD medications.

A large body of research has examined the effects of SWPBIS on behavioral problems in the United States, finding strong support for positive short-term effects of SWPBIS on externalizing problems in schools such as office discipline referrals, suspension rates, and school attendance (Chitiyo, May, & Chitiyo, 2012; Horner, Sugai, & Anderson, 2010; Lee & Gage, 2019; Mitchell, Hatton, & Lewis, 2018). However, the evidence on whether the positive intervention effects persist is limited, as few studies have followed students after they left the intervention school (Borgen et al., 2021; Jensen, 2020). Furthermore, although there is suggestive evidence of positive effects of psychosocial interventions in schools and home for ADHD children (DuPaul, Eckert, & Vilardo, 2012; Pelham & Fabiano, 2008), including components of the SWPBIS model (Eiraldi et al., 2012), no study has examined effects of SWPBIS on the prescription of ADHD medication.

The Present Study

This study examines the influence of SWPBIS on the prescription of ADHD medication using a difference-in-difference (DiD) design and population-wide Norwegian register data. A concern in the intervention literature is whether the evidence from controlled environments is reproduced in actual educational settings (Bradshaw, Waasdorp, & Leaf, 2015; Flay et al., 2005; Hulleman & Cordray, 2009). Access to existing large-scale register data gives us a unique opportunity to investigate the impact of the SWPBIS model that has operated under normal conditions and has been scaled up to include about 10% of the student population. Combining student outcomes (here later ADHD medication) from registers with implementation data from schools, we check whether intervention effects are strongest for schools that implement the model with fidelity. Moreover, we use the width of register data to forecast the risk of ADHD medication based on individual and family characteristics (Caspi et al., 2017) and investigate whether children at risk of being prescribed ADHD medication are influenced the most by the SWPBIS model.

Method

Study Setting

In Norway, compulsory education starts at the age of 6 and lasts for 10 years, with primary education in Grades 1–7 and lower secondary education in Grades 8–10. Compared to other European countries, Norway has an inclusive school setting without many special schools (Ogden, 2014). All schools are publicly funded, and few schools are privately run.

Teachers and other school personnel play a vital role in the early part of the diagnostic process of ADHD. In the United States, teachers are often the first to suspect ADHD (Sax & Kautz, 2003) and may also play a formal role in the diagnostic process (Charach, Chen, Hogg-Johnson, & Schachar, 2009; Phillips, 2006). In Norway, symptoms of ADHD in the school setting would typically result in a meeting between parents and teachers, and where the school health service and the educational and psychological counseling service may be present (Helsedirektoratet, 2013). If there are concerns about ADHD diagnosis, the next step is to get a referral to specialist health care from the child's general practitioner, where evaluations and ratings from the school and the educational and psychological counseling service play a role in the referral and, subsequently, in the diagnostic process (Helsedirektoratet, 2018).

Whereas the worldwide prevalence of ADHD was estimated at 5.3% about 15 years ago (Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007), the cumulative incidence during childhood and adolescence in Norway in the same period is estimated to be somewhere between 3 and 4%, and about 80% of these children receive pharmacotherapeutic treatment (Surén et al., 2012). Pharmacological treatment of ADHD is relatively restrictive in Norway. Diagnosis and initial prescription of ADHD medication are restricted to specialist health care, with general practitioners only recently (from 2014 and onwards) being allowed to maintain prescription of ADHD medication initiated by the specialist health care (Karlstad et al., 2017). Furthermore, ADHD medication should only be prescribed when other measures, such as psychosocial interventions or special needs education, are tried out and proven insufficient (Helsedirektoratet, 2013).

The SWPBIS Model

SWBPIS is implemented by more than 26,000 schools in the United States and internationally (Gage, Whitford, & Katsiyannis, 2018; Pas, Ryoo, Musci, & Bradshaw, 2019), including about 10% of elementary schools in Norway (called N-PALS in Norway; Borgen, Kirkebøen, Ogden, Raaum, & Sørlie, 2019). The Norwegian model is an adapted version of SWPBIS, as developed by Sprague and Walker (2005). However, except for minor adaptions of the training materials, no changes were made to the original model when SWPBIS was transported to Norway. The core model components, basic training, and implementation features of the Norwegian version are identical to those of the U.S. version.

The local implementation of the SWPBIS model in Norway is led by a leadership team within each school. A team of five to six representatives is appointed at each school, and this team is trained and supervised by a local coach for 2 years (2 hr/10 training sessions per year). The school teams are trained to plan, inform, conduct, monitor, and report on their schools' implementation process and outcomes. The school teams advise and teach the rest of the staff in the key model and implementation features. The prevention model involves all staff and students and takes approximately 3–5 years to implement fully. Weaker program effects are thus expected the first couple of years compared to 3–5 years after the intervention is initiated (Madigan, Cross, Smolkowski, & Strycker, 2016).

The focus of SWPBIS is on positive, systematic, data-driven, educative, and reinforcement-based practices conducted within a framework of research-based, collective (school-wide), proactive, and predictable approaches. Direct behavioral teaching and interventions are combined with school-wide modifications of the social learning environment. The core model components are (a) school-wide positive behavior support strategies, in which 3–5 positively formulated school rules are taught and followed up by systematic praise and supervision from staff; (b) monitoring of student behavior across all school areas, for example, with a web-based assessment and evaluation system (School-Wide-Information System); (c) immediate corrections of problem behavior by all staff using clear, consistent, and predictable consequences; (d) classroom management skills training for teachers; (e) parent information and collaboration strategies; (f) small-group instruction or training in academic or social skills for students at risk; and (g) individually tailored interventions and support for high-risk students (further described in the following section). The intervention schools use web-based assessment and feedback to ensure that relevant data support decisions about actions and that the interventions are implemented and sustained with high fidelity.

The SWPBIS is organized according to the principle of matching interventions to students' risk level (Sørlie & Ogden, 2015). More specifically, the intervention model relies on a three-tiered system of evidence-based preventions and supports. Tier 1 interventions (universal, primary prevention) apply to everyone and all settings in the school with the goal to "prevent problems by defining and teaching consistent behavioral expectations across the school setting and recognizing students for expected and appropriate behaviors" (Lohrmann, Forman, Martin, & Palmieri, 2008, p. 256). Tier 2 interventions (selected, secondary prevention) are designed for students at moderate risk for severe behavior problems and who might not respond sufficiently to the universal interventions. Students at moderate risk often receive time-limited small group instruction or training in academic or social skills or the Check-In/Check-Out program (Todd, Campbell, Meyer, & Horner, 2008). Tier 3 (indicated, tertiary prevention) targets the few students with or at high risk of conduct disorder. High-risk students' interventions include a functional behavior support plan with individual special education and intensive individual social skills training programs, such as the Stop-Now-and-Plan program (Augimeri, Farrington, Koegl, & Day, 2007). The various elements make up a set of interventions aiming at the norms and behavioral codes of the totality of the school environment.

Evaluations of SWPBIS in Norway has found positive intervention effects on behavioral outcomes (Sørlie, Idsoe, Ogden, Olseth, & Torsheim, 2018; Sørlie & Ogden, 2015) and classroom order (Borgen et al., 2019), with the overall intervention effects driven by effects for the 2.5% of students with persistent high behavior behavioral problems (Sørlie et al., 2018). No effects have been found for students on a persistent low (84.4%), decreasing (7.9%), or increasing (5.3%) trajectory of externalizing behavior problems (Sørlie et al., 2018). Likewise, no effects of SWPBIS have been found on short-term academic achievement, bullying victimization, or school well-being (Borgen et al., 2019) and the long-term probability of dropout and youth crime (Borgen et al., 2021).

Participants

The primary data source in this paper is population-wide Norwegian register data, covering all students born between 1986 and 2004 ($N = 1{,}068{,}493$). The full sample is used in the descriptive parts of the paper (Figure 1) and in some sensitivity tests, whereas the main intervention effects are estimated using the students born between 1990 and 2002 ($N = 698{,}364$) for which we can observe ADHD medication at the ages 14–16. The characteristics of the data can be found in Table 1. In the analysis sample, 3.5% of the students have received ADHD medication at least once from 14 to 16 years old. Approximately 7% of the students in the analysis sample attend a SWPBIS school, and 93% attend a control school. In this study's birth cohorts, 5.7% of students are immigrants or children of immigrants, and 48.7% are girls.

All Norwegian elementary schools (Grades 1–7) were included in the study ($N = 2{,}366$), whereof 216 of the schools in our sample (9%) had implemented SWPBIS. The total number of schools that have implemented SWPBIS in Norway is 244, however; we exclude 11 lower secondary schools that do not have grades seven or lower, eight schools

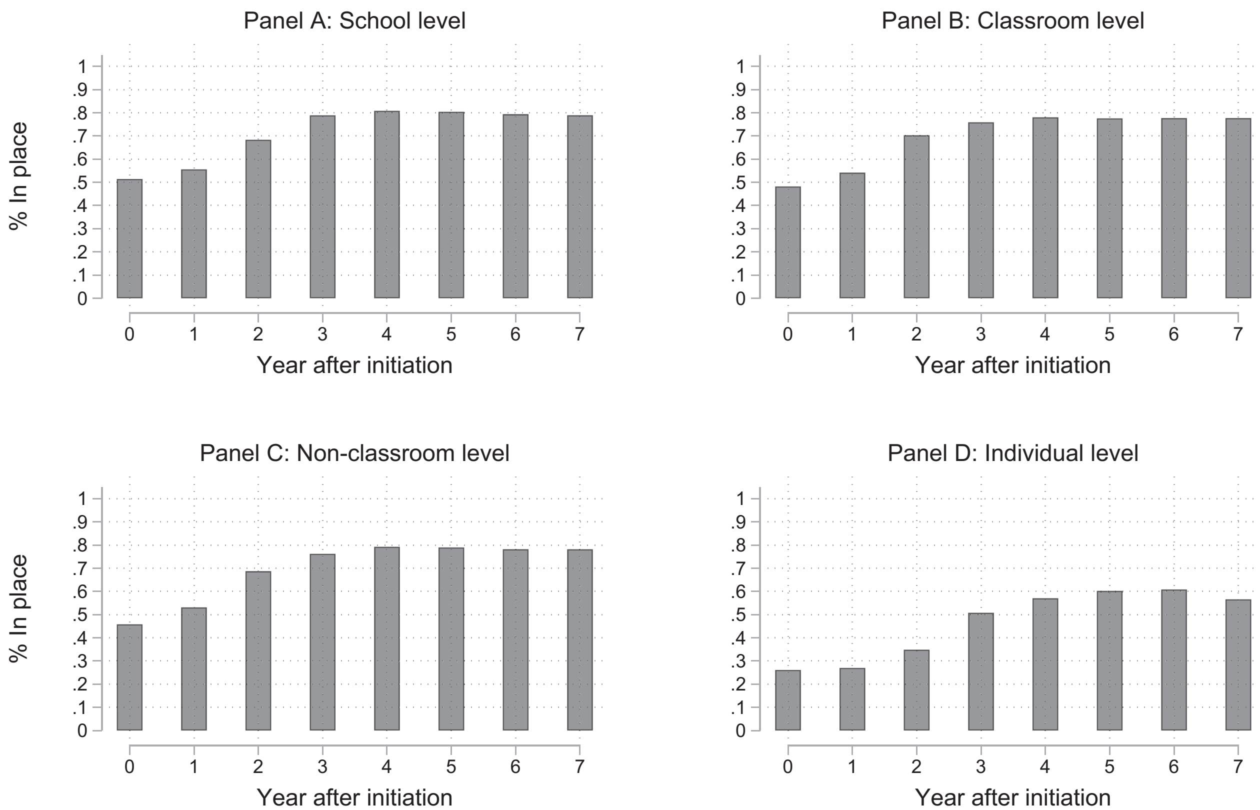

Figure 1. Fidelity of implementation.
Note: SWPBS school teachers' and school staffs' perception about fidelity at the school level (Panel A), classroom level (Panel B), non-classroom level (Panel C), and individual level (Panel D).

that we did not find in the school registers, and nine schools that were not likely attended school for any student (see Appendix S1). Each school and student has a unique identifier that allows matching SWPBIS schools to student-level population-wide register data from residential addresses (further described in the following section). In this study, students are defined as exposed to SWPBIS if they attended Grades 4–7 at the time or after a school starts implementing the model. The share of exposed students has increased from close to zero before the 1994 birth cohort to about 11% of those born in 2000 and later (Appendix S15, Figure A15.1).

For 207 (of the 216) schools that implement SWPBIS, we can observe whether the intervention is implemented in accordance with the model (fidelity) using the Effective Behavior Support Self-Assessment Survey (46 items; Sugai, Horner, & Todd, 2003). All teachers and school staff in SWPBIS schools perform this survey annually, and it measures the perceived fidelity at the school level (18 items), at the classroom level (11 items), in individual cases (8 items), and in common areas like hallways and the playground (9 items). The fidelity measures range from 0% to 100%, and an 80% threshold score on the fidelity scale is often considered necessary for the SWPBIS model to be adequately implemented (Solomon, Tobin, & Schutte, 2015).

Various fidelity measures have different strengths and weaknesses. Self-reported fidelity measures are generally more prone to reporting biases than assessments of fidelity by an external observer (e.g., social desirability bias). In contrast, external observers are more likely to overlook or misinterpret some features (Bradshaw, Debnam, Koth, & Leaf, 2009). Even so, our fidelity measure may be less sensitive to changes in school practice compared to other fidelity measures. Most schools reach about 80% fidelity in our data by 3–4 years on the overall school level, classroom level, and nonclassroom level (Panels A–C in Figure 1). In contrast, few schools reach the 80% threshold at the individual level (Panel D). Low individual-level fidelity may mean that few schools adequately

Table 1
Descriptive Statistics of Sample Used in Studying Effects of SWPBIS

	N	*M*	*SD*	Min	Max
ADHD medications 14–16	698,364	0.035	0.183	0	1
Treatment school					
Before implementation	698,364	0.038	0.190	0	1
Exposed 1 year	698,364	0.010	0.097	0	1
Exposed 2 years	698,364	0.009	0.097	0	1
Exposed 3 years	698,364	0.009	0.096	0	1
Exposed 4 years	698,364	0.008	0.090	0	1
Control school	698,364	0.926	0.262	0	1
Year of birth	698,364	1996.037	3.678	1990	2002
Gender	698,364	0.487	0.500	0	1
Native	698,364	0.943	0.232	0	1
Immigrant	698,364	0.009	0.094	0	1
Children of immigrant	698,364	0.048	0.214	0	1
Age of immigration	698,364	0.046	0.454	0	6
Parental earnings rank	698,364	51.417	27.971	1	99
Father's education	698,364	4.350	1.703	0	9
Mother's education	698,364	4.450	1.712	0	9
Parental social welfare	698,364	0.354	1.146	0	6
Father's year of birth	698,364	1964.126	6.664	1917	1987
Mother's year of birth	698,364	1967.037	5.9881	1939	1987
Birth order	698,364	1.931	1.011	1	17
Number of siblings	698,364	2.002	1.243	0	18

Note. ADHD = attention deficit hyperactivity disorder; SWPBIS = School-Wide Positive Behavioral Interventions and Supports.

implement SWPBIS in Norway. However, the average scores in this study are similar to scores in a previous randomized controlled effectiveness trial from the United States; in that study, the School-Wide Evaluation Tool suggested better implementation in the same schools (Bradshaw, Mitchell, & Leaf, 2010).

Irrespective of the reason for relatively low fidelity, we face a trade-off between strictness and statistical precision when studying intervention effects by fidelity. A strict cutoff ensures that the high-fidelity group consisting of only well-implemented schools with potentially stronger intervention effects. But since they are few, effect estimates are less precise with larger standard errors. In the main results, we distinguish between schools with an average score on the four subdimensions at or above 75% by 4 years (81 schools) and schools that do not reach this 75% threshold (114 schools). The 75% threshold cuts a balance between a reasonable well-implemented group of schools and acceptable precision. If we increase the cutoff to 80%, the high-fidelity group drops by 40%, and the standard errors of the estimates increase by 30% (Appendix S16, Table A16.1).

Measures

For the intervention schools, the treatment variable tracks each school grade cohort's position relative to the year of program intervention, from 4 years before the intervention to 4 years after the intervention. The treatment variable contains nine unique values (−4, −3, −2, −1, 1, 2, 3, 4, 99), and we construct seven dummy-coded variables that are included in the regression analyses (−1 as the reference category and 99 is excluded). Students finishing elementary school (seventh grade) the school-year before the implementation of SWPBIS are labeled −1. The next cohort, exposed to SWPBIS for 1 year (seventh grade), is labeled 1. Cohort 4 is the first cohort exposed through Grades 4–7. Since exposure equals time since implementation, by definition, any differential effects across cohorts will capture the combined impact of length of exposure for the individual and length of implementation time at the school. The control schools are assigned the arbitrary value 99 for all school cohorts. However, there is no within-school variation in the treatment variable for control schools (see analytic design below), and the coefficient of this value is not estimated.

Information on pharmaceutical drugs is based on data from the Norwegian Prescription Database (NorPD), a monitor of all drugs dispensed by prescriptions in Norway since 2004 (we have data from 2004 to 2018). Drugs purchased without a prescription (over the counter) are not included, nor are drugs supplied to hospitals and nursing homes. Drugs in NorPD are classified according to the WHO Anatomical Therapeutic Chemical (ATC) classification system, and we focus on centrally acting sympathomimetics (ATC code N06BA), which among children in Norway is primarily used to treat ADHD. The overwhelming majority of children prescribed ADHD medications in Norway have an ADHD diagnosis, but we cannot rule out that a few may have received it for other diagnoses. In the main analyses, we measure whether students have received one or more prescriptions for ADHD medications the calendar year they turn 14, 15, or 16 (recorded as 1 if a drug, 0 otherwise).

Whereas stimulant medications such as amphetamines and methylphenidates are the primary pharmacotherapeutic agents for treating ADHD, nonstimulants such as atomoxetine are sometimes used for patients who experience adverse effects of stimulants or are nonresponsive to them (Gajria et al., 2014). Among students prescribed medications for ADHD between ages 14–16 in our data, 92% have been treated with stimulant methylphenidates, whereas 14% have been treated with nonstimulant atomoxetine (Appendix S12, Table A12.1). When taking into account the difference in prescription rates, trends in intervention effects are similar for stimulants and nonstimulants (Appendix S12, Figure A12.1), and we choose to look at stimulants and nonstimulants combined in the main analyses.

Individual control variables are year of birth (dummy coded), gender, parents' earnings at age 11–15 in percentile rank (linear and quadratic term), father's educational level (9 dummy-coded variables), mother's educational level (9 dummy-coded variables), immigrant background (2 dummy-coded variables), age of immigration (6 dummy-coded variables) number of siblings (linear and quadratic term), birth order (linear and quadratic term), father's year of birth (linear and quadratic term), mother's year of birth (linear and quadratic term), parents social welfare recipients (number of years when the child is 0–15 years). We estimate intervention effects separately for regions with low- and high prescription rates of ADHD in supplementary analyses. The municipalities where 4% or more of the students are treated with ADHD medications at ages 14–16 are considered high prescription rates regions, whereas the rest are regarded as low prescription rates regions. (Appendix S14, Figure A14.2 compares effects with the cutoff between low and high prescription regions being 3%, 3.5%, 4%, and 4.5%).

The DiD Model

Schools implementing interventions like SWPBIS are potentially different from other schools. They may experience higher levels of problem behavior or have more proactive management or local school administrations. We use a DiD design to account for schools selecting into SWPBIS on characteristics of schools or students that are constant across cohorts. In essence, this design compares changes in outcomes between subsequent cohorts of students *within* schools following the implementation of SWPBIS. Nevertheless, the control schools contribute crucially to the estimation; trends in outcomes common to all schools are accounted for by comparing changes within SWPBIS schools relative to changes in other (control) schools. One advantage of the DiD model is that it accounts for all time-invariant differences between schools, such as stable school traits, teacher characteristics, and student characteristics, irrespective of proxies for these differences.

We study the effects of program exposure in Grades 4–7 on students' later outcomes. The unit of observation is the student, and the basic model is:

$$Y_{ics} = \beta_0 + \beta T_{cs} + \delta X_{ics} + \gamma_c + \mu_s + \varepsilon_{ics}, \qquad (1)$$

Y_{ics} is ADHD drug use at age 14–16 (1 if drug use, 0 otherwise) of a student i belonging to cohort c that attended school s in Grades 4–7. Cohort refers to the year students exit elementary school (and exposure to SWPBIS ends). Since T indicates whether a given cohort in a given school was enrolled after the implementation of SWPBIS ($T = 1$), β is the effect on student outcome of having attended a SWPBIS school. β_0 is a constant term, γ_c is the cohort-fixed effect, μ_s is school-fixed effect, and X_{ics} are observed student characteristics. We use ordinary least squares and cluster residuals at the school level. Using logistic regression produces similar coefficient patterns but generally lower p-values (Appendix S8, Table A8.1).

The key identifying assumption is that the ADHD drug at age 14–16 across cohorts would be parallel for students of SWPBIS schools and control schools, in the *absence* of the SWPBIS intervention (net of the effects of changes in observed student characteristics). Although this "parallel trends" assumption is untestable, we can evaluate its credibility by comparing trends in student outcomes of cohorts of program and nonprogram schools, where all students had left the SWPBIS schools before the program was implemented. Before implementation, students' outcomes in (eventual) SWPBIS schools may differ from those in other schools. Still, if these differences are stable across cohorts, we can have confidence in our identification strategy. In Appendix S2, Figure A2.1, we estimate the effects of SWPBIS with leads and lags of program implementation:

$$Y_{ics} = \beta_0 + \sum_{p=-4}^{4} \beta_p T_{csp} + \delta X_{ics} + \gamma_c + \mu_s + \varepsilon_{ics}, \qquad (2)$$

where β_p parameters identify any preprogram differentials ($p < 0$) and postimplementation effects ($p > 0$) as $T_{csp} = 1$ when the outcome of the cohort is measured *with a time distance of p years* since the implementation of the program. β_{-1} is set equal to 0 and provides a reference for the effect estimates for the other years. For example; β_3 measures the effect on Y for students exiting elementary school 3 years after the implementation of SWPBIS relative to the outcomes of students exiting elementary school just before implementation, that is, the effect of being exposed to SWPBIS for 3 years (Grades 5–7).

Any indication of intervention effects on ADHD drug use before the implementation suggests a violation of the identifying assumption of similar trends in the absence of the program. Conversely, if there are no differences between cohorts within the same school before the implementation (net of differences explained by time-varying covariates and general time trends)—that is, the preimplementation estimates are close to zero—this suggests that the assumption holds, and the effect estimates are valid. We find few significant differences across cohorts in the preimplementation years (Appendix S2, Figure A2.1), and this holds when allowing trends to vary with the school county (Appendix S7, Figure A7.1).

All in all, we find that outcome differentials of the preimplementation cohorts are stable, which suggests that any significant differentials for the post-years can be interpreted as causal effects of the program. In the main analyses, we present results where we compare the intervention effects ($p > 0$) with the preintervention cohorts (reference category):

$$Y_{ics} = \beta_0 + \sum_{p=1}^{4} \beta_p T_{csp} + \delta X_{ics} + \gamma_c + \mu_s + \varepsilon_{ics}. \quad (3)$$

Identification of At-Risk Students

In the spirit of Caspi et al. (2017), we define the student population at risk of ADHD medications by using predetermined characteristics of each student and his/her family. Based on a logistic regression model, we estimate the risk of being prescribed ADHD medications at ages 14–16 using only individuals in control schools born between 1990 and 2002. The logistic regression model includes the individual control variables described in the data and variable section, along with (a) dummies for the county of residence, (b) interactions between the individual control variables and gender, and (c) interactions between the individual control variables and immigrant background. Then, we use the coefficients from the logistic regression model to predict the probability of ADHD medications in the control schools and the SWPBIS schools. The distribution of the estimated propensity score is shown in Appendix S4, Figure A4.1. Finally, the students with the 50% highest predicted probability of ADHD medications is classified as at-risk students.

Linking Students to Schools in Register Data

Norway does not maintain a registry of the elementary school students attend. Therefore, we impute school attended from residential addresses, explained in detail in Appendix S1. This imputation will cause some misclassification of the school attended and thus of program exposure: some students will be incorrectly classified as exposed or not exposed to the program. This type of misclassification could bias the effect estimates either upwards or downwards; however, this study's misclassification will probably cause a slight attenuation bias in the effect estimates. Assuming it is conditionally random, we argue in Appendix S1 that the effect estimates are attenuated by a factor of about 0.9, and we can inflate coefficients and standard errors by about 11% ($1/0.9 = 1.11$) to adjust for the bias. Since this adjustment is relatively minor, we will not implement it as part of our estimator but instead, refer to it in the result presentation.

Analysis Plan

The analyses were more confirmatory in nature than exploratory. This study was based on the directional hypothesis that SWPBIS reduced ADHD prescriptions, laid out in the data access application (Regional Committees for Medical and Health Research Ethics, project #2018/2520). Furthermore, the DiD design and data-driven identification of at-risk students were decided in the data access application. However, several choices were made after looking at the data, such as the age interval in which the ADHD medications were measured, the classification of high-risk regions, and the high-fidelity cut-off. Our approach has been to check whether the results are robust to these choices and include the robustness checks in Supporting Information.

Results

Prescription Rates of ADHD Medications

The prescription rates of ADHD medications have increased over time and follow an inverted U

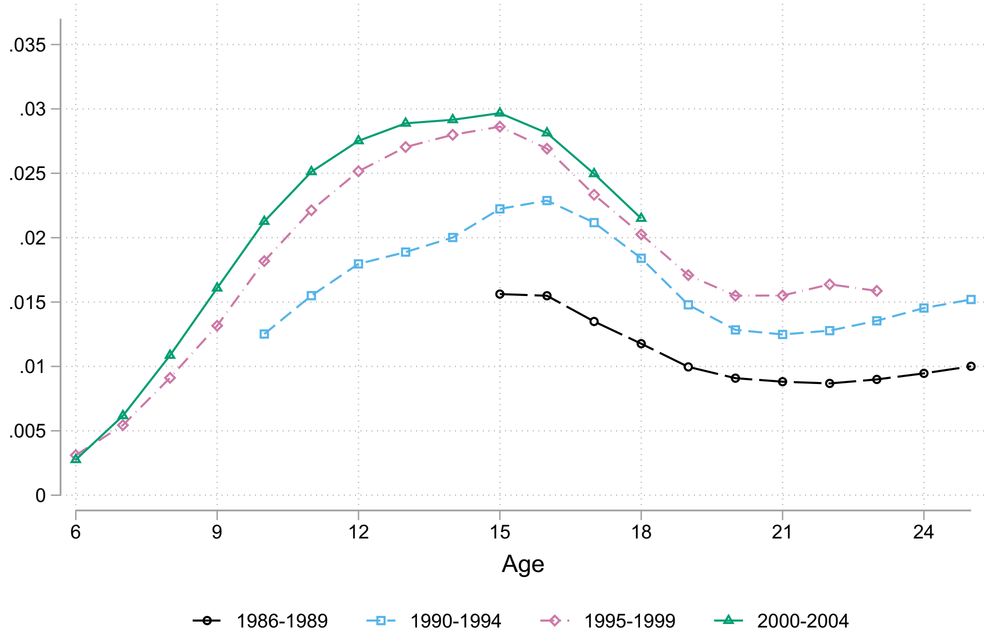

Figure 2. Prescription rates of ADHD medications by age and birth cohort. ADHD = attention deficit hyperactivity disorder. [Color figure can be viewed at wileyonlinelibrary.com]

shape in age (Figure 2). First, few are treated with ADHD medications before school starting age of 6. Then, the proportion increases to age 14, where about 3% are prescribed ADHD medications for the latest birth cohorts, before falling to about 1.5% when turning 20. Second, whereas about 1.5% of 15-year-olds born in the late 1980s were prescribed ADHD medications, the proportion is about 3% among similar aged children born 15 years later.

Compared to students in other Norwegian schools, the students in schools that later become SWPBIS schools tend to have more students treated with ADHD medications in ages 14–16, with significant differences remaining after controlling for student composition (Appendix S3, Table A3.1 and Figure A3.1). Thus, schools with higher levels of behavioral problems are more likely to implement school interventions such as SWPBIS. This self-selection highlights the need for a research design able to correct for stable differences in outcomes across schools that are not captured by observable proxies.

Main Intervention Effects

The effects of SWPBIS based on DiD models, comparing differences between cohorts within the same schools, are displayed in Table 2 and Figure 3, with the main effect estimates shown in column 1 of Table 2 and Panel A of Figure 3. We expect program effects to be minor in the first year after implementation as it takes time to fully implement the SWPBIS model (Madigan et al., 2016); consistent with this, we find no effects of SWPBIS for those exposed for 1 year. For students exposed for 2 years or more, coefficients are all negative, with significant effects for those exposed to the SWPBIS model in 4 years. Our design does not allow us to disentangle whether the more substantial influence for those exposed 4 years are caused by differences in the number of years of exposure (i.e., "dosage"), increasing fidelity of implementation at the school over time, or the grade in which the students are exposed (4th vs. 7th grade).

The average intervention effect after 2–4 years show that SWPBIS reduces the likelihood of being prescribed ADHD medications by 0.42 percentage points when students are 14–16 years old. Although this effect may appear small, it should be interpreted in terms of the baseline prescription rate of 3.5%. The effect is sizeable relative to the baseline prescription rate; initiation of SWPBIS reduced prescribed ADHD medication by 12% compared to what would have happened in the absence of the intervention (.0042/.035). Likewise, evaluated in terms of odds ratios, SWPBIS reduced the odds of being prescribed ADHD medication by 13%, as shown by the logistic regression model in Appendix S8, Table A8.1.

Table 2
Effects of Exposure to SWPBIS in 4th–7th Grade on ADHD Medications Age 14–16. Separate Coefficients by the Number of Years Exposure in Panel A and Average Effects Across 1–4 and 2–4 Years in Panel B

	Main	Fidelity		At-risk	
	(1)	(2)	(3)	(4)	(5)
	All students	Low-fidelity schools	High-fidelity schools	Not at-risk students	At-risk students
Panel A					
Exposed 1 year	.0016 (.0030)	.0038 (.0044)	.0018 (.0054)	−.0015 (.0024)	.0028 (.0052)
Exposed 2 years	−.0040 (.0025)	−.0042 (.0036)	−.0028 (.0043)	.0001 (.0029)	−.0083 (.0042)*
Exposed 3 years	−.0017 (.0029)	.0044 (.0042)	−.0063 (.0046)	−.0009 (.0024)	−.0028 (.0051)
Exposed 4 years	−.0068 (.0029)*	.0037 (.0038)	−.0091 (.0046)*	−.0017 (.0026)	−.0125 (.0050)*
Panel B					
1–4 years	−.0027 (.0018)	.0001 (.0024)	−.0041 (.0032)	−.0010 (.0017)	−.0052 (.0034)
2–4 years	−.0042 (.0020)*	−.0012 (.0026)	−.0061 (.0033)+	−.0008 (.0018)	−.0079 (.0036)*
N	698,364	671,984	665,555	337,838	358,230

Note. The average effects are obtained using a linear combination of coefficients. Standard errors clustered on the schools in parentheses. The same control schools are included in the analyses reported in columns (2) and (3), and the number of observations differs because of the different number of low- and high-fidelity schools. Because of the missing municipality, 2,296 students are left out of columns (4) and (5) compared to column (1).
+$p < .10$. *$p < .05$.

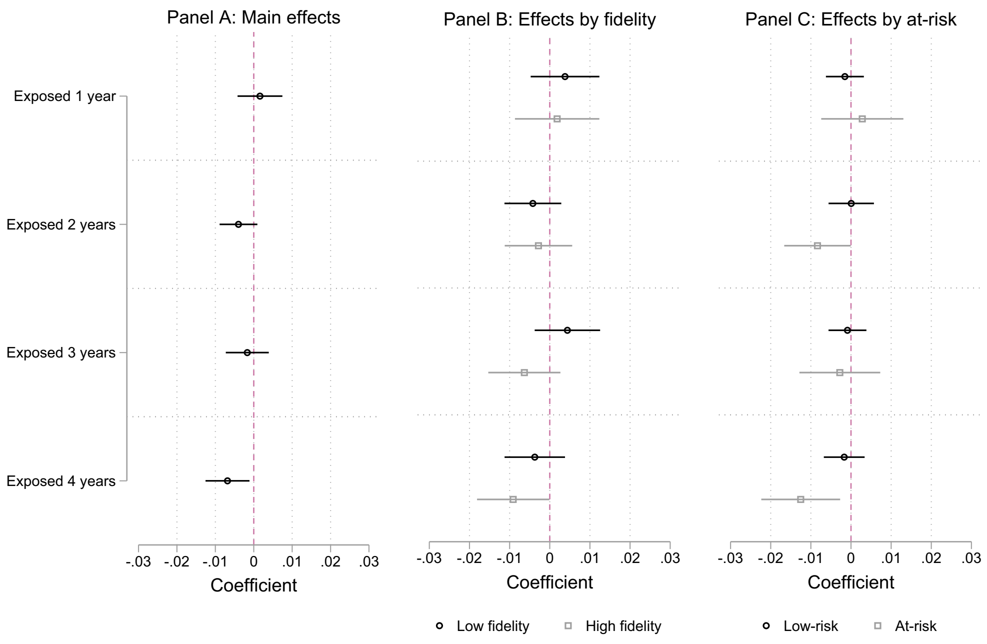

Figure 3. Effect estimates of SWPBIS on ADHD medications age 14–16 with 95% CI, based on Table 2.
Note. Standard errors are clustered on the school level. ADHD = attention deficit hyperactivity disorder; SWPBIS = School-Wide Positive Behavioral Interventions and Supports. Treatment effects for all students are shown in Panel A. Separate treatment effects for low- and high-fidelity schools are displayed in Panel B and low- and at-risk students in Panel C. [Color figure can be viewed at wileyonlinelibrary.com]

For all students born in 1996 and later, we can observe ADHD medications before the intervention (at age eight). Using these cohorts allows us to examine whether the results are robust to the inclusion of ADHD medications before the intervention. In support of our main findings, intervention effects are similar with and without controls for ADHD medication at age eight (Appendix S13,

Figure A13.1). However, the confidence intervals are wider in this subsample, and the effects of SWPBIS are less conclusive than in the full sample.

There are considerable regional differences in the prescription rates of ADHD medications in Norway, which could be caused by differences in treatment practices, differences in the prevalence of behavioral problems, or both. When estimated separately for low- and high-prescription rates regions, intervention effects are limited to areas with a high ADHD medication rate (Appendix S14, Figures A14.1 and A14.2).

In the main models, we estimate intervention effects in the three consecutive years after being exposed to the intervention (exposure ends at age 13, outcome measured at ages 14–16). Nevertheless, supplementary analyses where we follow students from ages 14 to 21 suggest that intervention effects persist until they are in their early 20s (Appendix S5, Figure A5.1). Furthermore, having a longer follow-up period of schools shows that the reduced likelihood of ADHD medications in ages 14–16 persists for students exposed to SWPBIS from 1st to 7th grade (Appendix S11, Figure A11.1).

Intervention Effects by Fidelity

Studies have indicated that intervention effects are related to the degree of program fidelity (Weare & Nind, 2011). Thus, we have checked whether intervention effects are stronger for schools that implement SWPBIS with fidelity than for schools with poor implementation. In our data, most schools reach about 80% fidelity by 3–4 years on the overall school level, classroom level, and nonclassroom level (Figure 1). However, few schools reach the 80% threshold at the individual level (Panel D).

To ensure a sufficient number of schools within the high fidelity group, we distinguish between schools that score at or above 75% by 4 years (81 schools) and schools that do not reach 75% (114 schools). We find indications that the overall intervention effects are driven mainly by high-fidelity schools (Table 2). In schools with high fidelity, the intervention reduces the probability of prescribed ADHD medications at age 14–16 by 0.61 percentage points ($p = .065$). In contrast, the corresponding effect size is a low 0.12 and far from significant at the 10% level or lower in schools with insufficient implementation.

Intervention Effects for At-Risk Students

Only a small group of students have symptoms of inattention, hyperactivity, and impulsivity that impairs their functioning at home and school, and therefore being at risk of getting a diagnosis of ADHD and being prescribed ADHD medications. Although other treatments are recommended and used, < 4% of all students have been prescribed ADHD medications in their mid-teen (Figure 2), suggesting that the number of students at risk of being prescribed ADHD medications is small. Most likely, the average effect of SWPBIS on ADHD medications (in the first column of Table 2) is driven by a substantial reduction among the limited number of at-risk students.

Ideally, we would like to identify the effect of SWPBIS on this group of at-risk students. However, for the purpose of identifying intervention effects among at-risk students, register data without personal trait characteristics have limitations, and we are limited to removing students with a very low likelihood of ADHD medications. Based on a logistic regression model that includes observed student characteristics such as gender, socioeconomic background, and immigrant background, we predict the risk of being prescribed ADHD medications at age 14–16. We find that 11% of the students in the top decile of our estimated risk distribution were actually prescribed ADHD medications, compared to 0.7% of the students in the lowest decile (Appendix S4, Figure A4.1). This difference of ten percentage points highlights the importance of family background and gender for ADHD treatment. Nevertheless, we cannot isolate students with an absolute high probability of being prescribed ADHD medications; even among the students with the 10% highest risk, 89% are not prescribed ADHD medications.

There is no definite cutoff that defines students at risk. Instead, we face a trade-off between the precision of the estimated intervention effects (improved by larger sample size) and the sensitivity (those classified as at-risk students have a high probability of prescriptions). In the main analyses of at-risk students, we distinguish between the students with the 50% highest and lowest predicted risk, of which 5.6% and 1.5% receive ADHD medications, respectively (Table 2; Figure 3). As expected, intervention effects for students who have a low risk of being prescribed ADHD medications are small and not statistically significant; compared to what would have happened in the absence of the intervention, the point estimate suggests that the intervention reduces the likelihood of prescriptions by 0.05 percentage points only. In contrast, for students with the 50% highest risk, the intervention reduces the likelihood of being prescribed ADHD medications by 0.79 percentage points. When looking at at-risk groups defined as students with the 40%, 30%, 20%, and 10% highest estimated risk, intervention effects are stronger but also less precise (Appendix S9, Figure A9.1).

Furthermore, the overall intervention effects are primarily driven by at-risk students in schools with high implementation quality (Appendix S10, Figure A10.1). In schools with low fidelity, the likelihood of ADHD medications is neither reduced for at-risk students nor other students. In schools with high fidelity, ADHD-related prescriptions are only reduced for at-risk students. Among at-risk students in high-fidelity schools, the intervention reduces the likelihood of prescriptions by 1.2 percentage points (or 21% if measured relative to the baseline prescription rate of 5.6% in this group) when looking at average intervention effects for students exposed 2–4 years.

Discussion

The increase in diagnosis and medical treatment of ADHD since the 1990s has sparked an ongoing debate on excess diagnosis and overmedication (Anderson, 1996; Moffitt & Melchior, 2007; Sciutto & Eisenberg, 2007; Wang et al., 2017), with some studies raising concerns that disruptive and immature children are increasingly treated with stimulants (Currie et al., 2014; LeFever et al., 2003). Concurrent with this trend, concerns for adverse effects of behavioral problems on child development, and the long-term risk of academic failure, labor market exclusion, and health problems associated with such problems, has motivated the development and implementation of prevention and intervention efforts in schools (Caspi et al., 2017; Duncan & Magnuson, 2013). This paper studies whether SWPBIS influences the prescription of ADHD medications in youth.

Whereas other studies have found that SWPBIS reduces behavioral problems in schools such as discipline referrals and suspension rates (for systematic reviews, see Chitiyo et al., 2012; Horner et al., 2010; Lee & Gage, 2019; Mitchell et al., 2018), no previous studies have examined whether this reduction in behavioral problems lowers the likelihood of ADHD medications. Although SWPBIS is not developed specifically to treat ADHD, psychosocial interventions are the recommended first line of treatment for children with mild to moderate symptoms of ADHD (Storebø et al., 2015; Wolraich et al., 2019), and studies have shown that starting treatment of childhood ADHD with behavioral interventions rather than medications results in the best behavioral outcomes (Pelham et al., 2016).

For students with a genetic disposition for ADHD, SWPBIS may relieve ADHD symptoms by teaching appropriate behavior and social skills and by providing an organized and predictable school setting with a focus on positive reinforcement, thereby avoiding triggering behavioral problems (Eiraldi et al., 2012). Consistent with this hypothesis, we find that SWPBIS reduces the likelihood of being prescribed ADHD medications in ages 14–16 by 12%, with effects being stronger for at-risk students and in schools that implement with fidelity. These intervention effects persist until the students are in their early 20s, suggesting that SWPBIS has a long-term impact on pharmacotherapeutic treatment.

Fidelity of Implementation

There is an increasing focus on large-scale implementation of prevention programs (Pas & Bradshaw, 2012). When interventions are evaluated under near-optimal conditions of delivery, which is often the case in randomized controlled trials, intervention effects are likely to be stronger than in more uncontrolled real-world conditions where the fidelity of implementation typically is lower (Flay et al., 2005; Hulleman & Cordray, 2009; Stuart, Bradshaw, & Leaf, 2015). In this paper, we study the effects of SWPBIS within a public school system where 10% of the schools have implemented SWPBIS, of which many have a poor implementation. More than half of all SWPBIS schools in Norway did not reach an overall 75% fidelity threshold within 4 years after initiation of the intervention. We find no effects of SWPBIS in these low-fidelity schools, consistent with a scale-up penalty when prevention programs go to scale (Welsh, Sullivan, & Olds, 2010).

Persistency of the Intervention Effects

Since most previous studies have a short follow-up period, there is scarce evidence on whether effects of fixed-time behavioral interventions fade out over time or whether they have long-lasting effects by reducing the individual student risk of entering a dysfunctional developmental trajectory. Specifically for ADHD, the chronic nature of the symptoms would suggest that sustained gains over time of psychosocial interventions assumedly requires continuous interventions (Eiraldi et al., 2012). The functioning of ADHD children is a complex ongoing interplay between their genetic predispositions *and* their environment; by re-entering an unstructured and unpredictable environment, children with ADHD symptoms are likely to revert to old behavioral patterns. Surprisingly then, this study suggests that a school intervention that stops at age 13 does influence exposed students up to their early 20s.

As we lack information on ADHD symptoms and diagnosis, we can only speculate why the effects of SWPBIS persist. Structuring fundamental aspects of the social environment in a critical phase of child development may prevent behavioral problems from developing through enduring epigenetic mechanisms (Schuch, Utsumi, Costa, Kulikowski, & Muszkat, 2015). Persistent effects may also be explained by the social skills component of the model. A third type of explanation for these long-term effects is path dependence and the timing of the intervention. Although the persistence of treatment of ADHD is low (Gajria et al., 2014), intervening in the age group before pharmacotherapeutic treatment of ADHD peaks may prevent the onset and subsequent long-term use of ADHD medications for children with mild to moderate symptoms of ADHD.

Contextual Sensitivity and Limitations

This study is the first to examine the effects of SWPBIS on ADHD medications, and it is open for debate whether these effects are likely to be found in other contexts. Generally, evaluations of SWPBIS in Norway have typically found less evidence of intervention effects than in the United States, although differences in outcome variables and implementation make it hard to compare studies from different countries. For example, whereas effects on classroom order have been found in Norway, previous studies have not found any intervention effects on bullying victimization, poor school behavior, academic achievements, school dropout, and youth crime (Borgen et al., 2019, 2021). Moreover, whereas a previous study from Norway found short-term effects on behavioral outcomes for a 2.5% high-risk group only (Sørlie et al., 2018), a U.S. study found effects of SWPBIS both for high-risk (6.6%) and for at-risk (23.3%) students (Bradshaw et al., 2015). One explanation for intervention effects for a broader group of students in the United States is that the prevalence of behavioral problems, including ADHD, is higher in the United States than in Norway (Rescorla et al., 2012). Thus, our estimates may be conservative estimates of what may be the effects in the United States.

Our estimates may also be conservative for methodological reasons. Despite high-quality register data and a solid empirical strategy, our results are subject to methodological limitations. Imputing school from residential address introduces measurement error in program exposure that biases the results toward zero by a factor of about 0.9. Under the reasonable assumption that misclassification is conditionally random, adjusting the coefficients would increase the overall intervention effects from 0.42 percentage points to 0.47 percentage points. Additionally, the effect estimates reflect observed outcomes compared to the outcomes one would have expected in the absence of SWPBIS, including that the program and control schools may initiate other interventions or act differently in other ways. Intervention effects are attenuated if control schools implement other effective programs or if there is program contamination to nearby schools not implementing SWPBIS. In this study, data on other programs were not available.

Conclusion

This study illustrates the potential of existing large-scale data for developmental science (Davis-Kean & Jager, 2017) when combined with quasi-experimental methods. By linking program implementation data to various Norwegian administrative registers and accounting for the selection of schools into programs using a DiD design, we find that the SWPBIS model reduces prescriptions of ADHD medications by 12% at ages 14–16. This effect persists until the students are in their early 20s. Our results indicate that this average effect is mainly driven by a substantially larger impact on at-risk students in schools with high implementation quality.

Lower prescription rates of ADHD medications could imply that the changes in the school environment caused by the SWPBIS model improves the functioning of children at risk of ADHD, thereby reducing the need for medication. Another interpretation is that at-risk children engage in other treatment options (or forgo treatment) due to the SWPBIS model. Because of the potential long-term unfavorable side effects of ADHD medications (Storebø et al., 2015), less medication may be beneficial in itself, as long as the intervention provides strategies to manage ADHD symptoms successfully. More research is needed to uncover whether the effects of SWPBIS on ADHD medications reflect changes in child behavior and functioning rather than changes in treatment strategies. Another avenue for future work includes exploring whether SWPBIS lowers children's dosage among those who take ADHD medications. Our study implies that a cost-effectiveness analysis of SWPBIS should incorporate the effects on ADHD medication as one of the many potential student outcomes.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's website:

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