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Publication Information

Chen, Kelly and Phipps, Shelley. (2021). "“Why Can’t You Sit Still?”: The Effect of Daily Physical Activity on Childhood Inattention/Hyperactivity and the Educational Gender Gap". *Social Science & Medicine, 284*, 114232. https://doi.org/10.1016/j.socscimed.2021.114232

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"Why Can't You Sit Still?" The Effect of Daily Physical Activity on Childhood Inattention/Hyperactivity and the Educational Gender Gap

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Abstract

Despite the compelling evidence of the long-run consequences of childhood inattention/hyperactivity and harmful side effects of stimulant medication, relatively little is known about accessible non-pharmacological options to reduce inattentive/hyperactive behaviours. This study evaluates the effect of daily exercise on inattentive/hyperactive behaviours among young children by leveraging evidence from a quasi-experiment generated when 3 Canadian provinces adopted mandatory requirements for all students in grades 1 through 6 to participate in 20-30 minutes of daily physical activity at school between 1994 and 2009. By exploiting plausibly exogenous variations in the timing of implementation and duration of physical activity mandated as well as over 20,000 observations on a sample of nationally representative children, our difference-in-differences estimates indicate that brief bouts of daily exercise at school effectively reduce inattention/hyperactivity in children – with the beneficial effect enhanced by the duration of exercise mandated. Importantly, most of the exercise effect is concentrated on boys. Since boys' higher rates of inattention/hyperactivity contribute to the explanation for boys' lagging academic motivation and achievement, we argue that providing more scope for physical activity during the school day might be a feasible policy option not only for reducing inattentive/hyperactive behaviours, but also for helping to close the educational gender gap in the longer run.

Keywords: Inattentive/Hyperactive Behaviour, ADHD, Physical Activity, Elementary School-Aged Children, Educational Gender Gap

JEL Classification Numbers: I14 I24 J13 I18

Acknowledgement: The authors are indebted to Philip Oreopoulos and Catherine Haeck for insightful comments. All opinions expressed, and all errors and omissions, are entirely our own. (Declarations of interest: none.)

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1 Introduction

Characterized by an ongoing pattern of inattention, hyperactivity, and impulsivity, ADHD is one of the most commonly diagnosed behavioural disorders for children, particularly boys (e.g., Elder, 2010; Skounti et al., 2007) with evidence that symptoms continue through adolescence and into adulthood (e.g., Biederman, 1998). Research indicates that ADHD can be associated with worse academic outcomes, lower occupational status, poor social relationships, more motor offences, and higher substance abuse (e.g., Fletcher and Wolfe, 2008). And, these long-term negative effects are apparent even for children exhibiting levels of inattentive/hyperactive (I/H) behaviour well below clinical thresholds (Currie and Stabile 2006).

Of concern, then, is the fact that the prevalence of ADHD is growing, for example from 6% in 1996 to 10% in 2016 for US children aged 4 to 17 (Xu et al. 2018), with similar patterns apparent globally (e.g., Skounti et al. 2007). Associated with increases in ADHD diagnosis are increases in ADHD stimulant medication use (e.g., methylphenidate and amphetamines) (Raman et al. 2018) which have raised concerns regarding medication safety and effectiveness in young children. Apart from common short-term side effects, recent research indicates that stimulants have little positive benefit and even harmful effects on child academic achievement, behavioural outcomes and social skills (Currie et al. 2014). Moreover, as many as 20% of children do not respond successfully to ADHD medication even after the second stimulation is tried (Cornelius et al. 2017). Yet, despite the compelling evidence of negative long-term consequences of childhood inattention/hyperactivity and harmful side effects of stimulant medication, relatively little is known about accessible non-pharmacological options to reduce inattentive/hyperactive (I/H) behaviours.

We address this knowledge gap by examining whether increased physical activity might

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provide an accessible non-pharmacological way of reducing I/H behaviour. Specifically, we ask whether province-wide programmes, introduced in Canada to help young children get more physical activity at school, may have reduced their I/H behaviours. These programmes, adopted at different times by 3 Canadian provinces between 2000 and 2008, required all elementary school students – regardless of parental socioeconomic status – to participate in 20-30 minutes of additional daily physical activity (DPA) at school. Although not explicitly the target of these programmes, we explore whether they nonetheless had the consequence of reducing I/H behaviours.

A further, and, we argue, related issue that has drawn recent attention from both scholars and the popular media (e.g., Fortin et al., 2012) is that girls' academic achievement has surpassed boys'. In 2020 in Canada, for example, 34% of men aged 25 to 34 had a bachelor's degree or above compared to 46% of women of the same age (Statistics Canada, 2021). Explanations for this phenomenon currently available in the literature include: higher returns to a university degree for women (e.g., Buchmann and Diprete, 2006; Jacob, 2002); changing gender norms and associated increased aspirations of young women (e.g., Fortin et al., 2012); a larger negative impact of parental divorce/separation on boys (Bertrand and Pan, 2013). However, Cunha and Heckman (2009) argue that the early years are critical for child development and that non-cognitive behaviours such as inattention/hyperactivity are complementary with the development of cognitive skills. Thus, in a second substantive part of the paper, we ask whether observed increases in inattention/hyperactivity, particularly for young boys, may contribute to the gender gap in educational attainment. Specifically, do differences between brothers and sisters in liking for school, school performance and even parental aspirations for their children's eventual level of education relate to differences between brothers and sisters in levels of inattention/hyperactivity?

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The remainder of the paper is organized as follows. In the first part of the paper, , we estimate the impact of DPA programmes introduced in 3 Canadian provinces on I/H behaviour of elementary school-aged children. Sections 2.1-2.2 describe the institutional background, data, and methodology. Sections 2.3-2.7 report our main regression results and estimates likely compliance with these programmes. The second major part of the paper, contained in Section 3, quantifies the role of inattention/hyperactivity on the gender gap in academic outcomes. Discussion is provided in Section 4. Section 5 offers conclusions.

2 Does DPA Affect I/H Behaviour?

2.1 Data

Between September 2005 and September 2008, 3 Canadian provinces, Alberta, Ontario, and British Columbia started to mandate that all students in grades 1 to 6 participate in a minimum of 20-30 minutes of DPA organized by the school. The form of physical activity can be designed based on resources available within the school and can allow for student choice. School authorities also have the flexibility to use instructional (e.g., Physical Education (PE) or "gym" class) and non-instructional (e.g., intramurals) hours to implement the DPA. However, though the form and intensity of physical activity may vary across schools, a minimum of 20-30 minutes of DPA is required for each student, regardless of parental socioeconomic status (see Appendix A for more discussions).

Through an intent-to-treat (ITT) design, we exploit variations in the timing of implementation and duration of physical activity mandated as plausibly exogenous increases in the physical activity of young children in the provinces implementing these programmes to estimate the effect of increased exercise on I/H behaviours. We use data from two nationally representative surveys: 1) the Statistics Canada National Longitudinal Survey of Children and

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Youth (NLSCY); 2) the Public Use Microdata File of the Canadian Community Health Survey (CCHS). Since the NLSCY data were accessed within a Statistics Canada Research Data Centre and all results were vetted by a Statistics Canada analyst to ensure individual respondent privacy in accordance with the Canadian Statistics Act and the CCHS public use files are anonymized before they are made available to researchers, no ethical approval of this study was required.

The primary data source for this study is cycles 1 through 8 (1994-2009) of Statistics Canada's NSLCY. The NLSCY is a nationally representative dataset of Canadian children that tracks their development and well-being from birth to early adulthood, with data collection occurring at 2-year intervals. The first survey round took place in the September of 1994 with a sample of 22,831 children aged 0-11. In addition to following the original longitudinal children, a new cohort aged 0-1 was added at each new cycle until the July of 2009. Most information for children under the age of 10 is reported by a parent, specifically the parent selected as the person "most knowledgeable about the child" (or, PMK, the mother in over 90% of cases) during a personal interview in the home.

We select children in grades 1 through 6 over the period of 1994-2009, whose I/H behaviours were observed in an earlier cycle at ages 3 to 4, so that we can control for the I/H behaviour prior to school entry. The measure of inattention/hyperactivity is based on parent rather than teacher reports, both because of the unavailability of teacher reports in later cycles of the NLSCY and because teacher perceptions may be systematically correlated with a child's age relative to classmates (Elder, 2010). In all survey years, parents of young children were asked to assess how often, in the home setting, their child: 1) can't sit still or is restless, 2) is easily distracted, has trouble sticking to any activity, 3) can't concentrate, can't pay attention for long, 4) is impulsive, acts without thinking, 5) has difficulty waiting for his turn in games or groups, 6)

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can't settle to anything for more than a few minutes, and 7) is inattentive. For each behaviour, the parent can choose: "never or not true" (=0); "sometimes or somewhat true" (=1); or, "often or very true" (=2). Responses are summed to construct a scale ranging in value from 0 to 14, with a high score indicating the highest level of I/H behaviour. The mean I/H score for all children in our data sample is 3.9, though boys have higher scores than girls (4.5 compared to 3.4) (see row 1 of Table 1). Note that the NLSCY I/H score aligns nicely with the kinds of behaviours which, in their more extreme form, would be used to diagnose ADHD (Charach et al., 2010). However, given past research suggesting that diagnosis of ADHD may be biased (e.g., Elder 2010) we prefer to work with a score describing the full range of I/H behaviours – from none at all to clinical ADHD.

Table 1: Means/Frequencies of Key Variables (Children in Grades 1 through 6 in the NLSCY 1994-2009)

	All Children (1)	Boys (2)	Girls (3)
Outcome Variable			
I/H Score	3.943	4.512	3.363***
Covariates			
Boy	0.505	--	--
Child age in months	103	103	103
Relative age to grade/Youngest student in class	0.485	0.473	0.497**
Presence of activity limitation	0.065	0.073	0.056***
Public school	0.777	0.794	0.760***
Catholic school, publically funded	0.178	0.165	0.192***
Private school	0.044	0.040	0.048**
PMK University and above	0.232	0.236	0.227
PMK Some postsecondary	0.256	0.262	0.250
PMK High school	0.409	0.401	0.416
PMK Less than high school	0.103	0.101	0.107
PMK immigrant	0.156	0.152	0.161
Lone parent family	0.173	0.178	0.168
Step family	0.062	0.066	0.057
Equivalent family income	37,980	38,175	37,779
Children in Alberta (DPA of 30 mins/day in 2005)	0.088	0.089	0.086
Children in Ontario (DPA of 20 mins/day in 2005)	0.289	0.292	0.287
Children in British Columbia (DPA of 30 mins/day in 2008)	0.048	0.049	0.048
N	23890	12020	11870

Notes: (1) Throughout all tables pertaining to the use of data from the NSLCY, sample sizes are randomly rounded to the nearest 10 to minimize potential disclosure risk, as required by Statistics Canada. (2) The number of stars indicates the p-value of a statistical test on whether girls and boys have different means/frequencies of a given characteristic. *p<0.1, **p<0.05, ***p<0.01

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Table 1 also presents the means/frequencies of other characteristics for all children in our sample (column 1) and for boys and girls separately (columns 2-3). Note that only 4.4 percent of children attended private schools. In Canada, while all children enter grade 1 in the year they turn 6, the school entry age cut-off date varies across provinces and over time. In an earlier study on the inattention/hyperactivity effect of school entry age (Chen et al. 2015), we find that being young in class causes greater I/H behaviour, exacerbating any I/H behaviour exhibited prior to school entry. To isolate the effect of the DPA programmes from that of school-entry legislation we take into account the child's relative age for grade throughout the analysis; about half of the full sample had a birthday 6 months before the school start cut-off. Finally, of all children living in a DPA province, the majority resided in Ontario (68%), where the DPA mandate was 20 rather than 30 minutes per day.

Splitting the sample by child gender reveals very few differences in respect of observed characteristics, except that boys are more likely to attend public schools (95.9% vs. 95.2%), to have an activity limitation (7.3% vs. 5.6%); boys are less likely to be one of the younger students in class (47.3% vs. 49.7%), perhaps because they are more likely to have been held back relative to usual entry age.

2.2 Methodology

To explore how DPA affects the I/H behaviour of children, we begin with a standard difference-in-differences (DD) model that compares changes in inattention/hyperactivity for children in DPA provinces whose physical activity at school was potentially increased through the DPA to changes in inattention/hyperactivity over the same time period for children in other provinces where similar programmes were not introduced:

$$I/H_{ipt} = \alpha + \gamma DPA_{ipt} + X_{ipt}{}'\theta + \sigma_p + \pi_t + \epsilon_{ipt} \quad (1)$$

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where I/H_{ipt} is child i's I/H score who lived in province p at survey year t. The key independent variable, DPA_{ipt} is modelled in 2 different ways, as a dummy variable, equal to 1 if a DPA programme was enacted in province p and survey year t (and 0 otherwise), and as a continuous variable, taking the value of 20 for children in Ontario, 30 in Alberta and British Columbia (and 0 otherwise) after the enactment of DPA. The latter allows us to test a dose-response effect of daily exercise on inattention/hyperactivity by specifically evaluating the beneficial role of activity duration. The province fixed effects σ_p take into account province-specific determinants of I/H behaviour that evolve slowly over time, such as average expenditure per pupil; the year fixed effects π_t account for nationwide time-varying shocks to I/H behaviour common in all provinces, such as the introduction of Universal Child Care Benefit in 2006. The vector X controls for child- and family-level attributes correlated with the province of residence and incidence of inattention/hyperactivity simultaneously: child absolute age and age squared, relative age for grade, type of school attended, presence of disability, inflation-adjusted family equivalent income, family structure, PMK education (in 4 categories), and immigrant status. Here we divide gross income by the square root of family size to account for differences in need for families of different size.

The coefficient γ is our DD estimate. If the child's province of residence, and hence exposure to the DPA requirement is independent of unobserved determinants of inattention/hyperactivity, γ can be interpreted as the causal effect of DPA on I/H behaviours. To the extent that DPA was not being carried out as intended in terms of duration, intensity, and frequency, γ can also be viewed as an ITT parameter, representing a lower bound estimate of the impact of daily exercise on inattention/hyperactivity. While under-estimating the true impact of the DPA programmes, the ITT interpretation avoids the danger that our results will be biased

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upwards, as differences in physical activity level may be associated with hidden characteristics that affect I/H behaviours, if participation in the programme is optional or the amount of required DPA is correlated with the area or school's socioeconomic status.

One important concern with the DD model specified in equation (1) is that estimates of γ may be biased if the counterfactual outcomes in DPA provinces, conditional on the set of observable characteristics, do not exhibit similar patterns as those in the rest of Canada in the absence of the DPA programmes. This is possible if, for example, children in DPA provinces tend to have lower levels of I/H behaviours pre-DPA relative to children in the rest of Canada because of the pro-health sentiment in DPA provinces. We therefore exploit the longitudinal nature of the NLSCY and investigate whether the growth trajectory in inattention/hyperactivity of DPA children deviates from that in the rest of Canada for those who exhibit the same level of I/H behaviours before they arrive at school entry age, by including the child's I/H score observed at age 3 or 4 ($I/H_{ipt,3to4}$):

$$I/H_{ipt} = \alpha + \beta I/H_{ipt,3to4} + \gamma DPA_{ipt} + X_{ipt}{}'\theta + \sigma_p + \pi_t + \epsilon_{ipt} \tag{2}$$

Since this lagged dependent variable specification relies on a less stringent identifying assumption, we treat it as our preferred model. Consequently, province-specific linear time trends are omitted from our analysis, as their effects will be subsumed by those of pre-school I/H scores.

Finally, we use the NLSCY longitudinal survey weights to reflect representativeness and adjust for non-response. Standard errors are clustered at the province level to allow for potential serial correlations in I/H scores within province across years. Given that clustered standard errors can produce misleading inferences when the number of clusters is small and that the problem can be further exacerbated when the clusters vary appreciably in size (Cameron et al. 2008;

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MacKinnon and Webb 2017), as do Canadian provinces, we employ the wild cluster bootstrapped t-statistics proposed in Cameron et al. (2008) for statistical inferences. To ease the interpretation of our results, all non-binary outcomes are standardized for all children to have a mean of 0 and a standard deviation (SD) of 1. The coefficients can thus be interpreted in terms of changes in SDs.

2.3 Robustness Tests

To provide further evidence that our findings are not driven by unobserved pre-treatment differences between DPA children and those in the rest of Canada, we perform a series of robustness checks. First, we conduct a formal test of the common trend assumption, by replacing the dependent variable in equation (2) with the I/H scores observed at age 3/4 *for the same children*. Failure to find any differential trends in inattention/hyperactivity among the same children prior to the implementation of DPA across provinces would suggest that the common trend assumption is likely satisfied. We then re-estimate equation (2) using randomly generated placebo programmes by pretending the DPA polices were enacted 2-4 years earlier than their actual implementation date. If the DPA programmes indeed caused the effects in the outcome, then these lead variables should not be significant in the regressions, indicating, once again, that the anticipatory effects or pre-existing trends are unlikely a serious concern in our context. Third, we experiment with some alternative data samples, model specifications, and definitions of control and treatment groups. While only a fraction of the children in our sample reported attending private schools (4.4%), we replicate our analysis for children in public schools to rule out the possibility that the results are driven by differences in parental choice of schools, school quality, and resources of support for children, especially for those with the highest I/H scores (e.g., diagnosed ADHD) and/or in special education. Similarly, there could be systematic

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differences in pre-existing activity levels between rural children and children living in urban and suburban areas that could potentially bias our results. We thus re-run our regressions additionally controlling for the urbanicity gradient. Additional investigations are also conducted using children living in Quebec, the other large province in Canada in addition to Ontario, British Columbia, and Alberta, as an alternative comparison group, and using each individual DPA site as an alternative treatment group to check the sensitivity of our results.

Fourth, we utilize a child fixed effects model, given the panel nature of the data:

$$I/H_{ipt} = Z_{ipt}{}'\delta + \gamma_0 + \gamma_i + \pi_t + \epsilon_{ipt} \quad (3)$$

In this regression, γ_i is the child fixed effect and Z_{ipt} is the vector of time-varying variables, including the child's exposure to the DPA. Relative to equation (2), this specification controls for unobserved child and family level heterogeneity which is stable over time that potentially contaminates our earlier results. Unfortunately, for budgetary reasons, the NLSCY dropped a considerable number of older children in later cycles. Implementing the child-level fixed effects strategy requires us to restrict analysis to a small subsample of children who were aged 5 years old in 2000, 2002, 2004 and 2006 and also attended school at the time of the survey (see Table A3). In addition, given that the school entry age cut-off dates adopted by most Canadian provinces were after September 1, attending school at the age of 5 would imply that the child was born before the school start cut-off and therefore had been the younger student in class. Since there is evidence that being young in class itself increases the incidence of ADHD symptoms (Chen et al. 2015), misdiagnosis, and thus treatment of ADHD (Elder 2010), results estimated for this subsample may not be generalized to other children who do not fit this profile. We therefore are inclined to treat the results obtained from equation (2) as our preferred estimates.

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Finally, we examine the issue of whether children's levels of physical activity actually increased as a result of the mandated DPA programmes. That is, did most schools in the DPA provinces actually manage to ensure 20-30 minutes of activity daily by all elementary school children? How intensively did children themselves choose to engage in programming introduced? Since the NLSCY does not record the time use of children at school, we instead use the Public Use Microdata File of the CCHS, collected during the same time period for slightly older children (i.e., in grades 7-8 vs. grades 1-6) who were also affected by the DPA mandates. Because British Columbia children in this age range would mostly not be covered by the programme, we exclude them from the analysis. Specifically, we estimate a variant of equation (2) by replacing the I/H score with self-reported activity frequency, duration, and intensity created as products of responses to a series of questionnaire items that ask about physical activities performed in the previous 3 months, such as walking, running, exercise class, and any other self-described form of physical activity participation. Since these measures encompass activities engaged both during and outside of school hours, we consider them as net time spent being active, after taking account of the complementarity/substitutability of outside-school and in-school exercise.

2.4 Regression Results

Regression results for the full NLSCY sample are reported in Table 2. Columns 1 and 2 present results obtained using unadjusted (equation 1) and adjusted (equation 2) for child-level heterogeneity, that is, their pre-school I/H. Columns 3 and 4 show results from equation 2 for boys and girls separately. One main point to take away from these results is that the inclusion of pre-school I/H score has little impact on the estimated DPA coefficients. Controlling for pre-existing conditions prior to school entry, an extra 20-30 minutes of exercise every day at school

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as a result of the DPA programmes significantly reduces I/H scores by 7% of a SD for all children in grades 1 through 6, although the effect is mainly concentrated on boys. Following the introduction of DPA, on average, boys exhibit less I/H behaviour relative to their pre-school level by 9% of a SD. The I/H behaviour of girls falls as well, but the changes are not statistically significant. Conditional on participation, an additional 10 minutes of daily exercise reduces inattention/hyperactivity further by 0.3% of a SD for boys.

To gauge the magnitude of these effects, it is helpful to compare them with the effects of living with a lone parent, which is a strong predictor of I/H behaviour across data samples. All else equal, growing up in a lone-parent household is associated with a 14% and 17% of a SD higher I/H score, respectively, for all children and boys in particular. Thus, the size of effect for participating in the DPA programmes is roughly 50% as large as the lone-parent association, though in the opposite direction. As expected, we also find that boys have a significantly higher level of inattention/hyperactivity than girls by 26% of a SD, and that children with the highest I/H scores as pre-schoolers are also likely the ones who have the highest I/H scores in class (by 14% of a SD).

An additional policy relevant question is whether the beneficial effect of DPA is greater or smaller for children exhibiting higher levels of I/H behaviour prior to school entry. To the extent that these children are more likely to take medication when the pre-existing condition is severe, this investigation also sheds light on the issue of whether DPA offers larger benefits when used in combination with medication for children who are already medicated. Given that diagnostic practices have changed over time and that ADHD diagnosis as well as subsequent drug/psychiatric treatment may be a result of physical activity performed at school, we use pre-school I/H score in the top quartile as a proxy for the measure of ADHD diagnoses. Specifically,

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we re-estimate equation 2 while controlling for an interaction term between DPA and the child's I/H quartile at age 3 or 4 (column 1). We also estimate equation 2 separately for children of pre-school I/H score in different quartiles (columns 2-5 and 7-10) to allow for potential nonlinearities (Table A3). Overall, we find consistent evidence that children with potential ADHD diagnoses or those who with most severe behavioural issues at age 3 or 4 benefit most from the programme with a reduction of I/H behaviour by 8-16% of a SD (columns 1 and 6 in Panel A); this is again particularly marked for boys (17-33% of a SD). It is worth noting that while the full girl sample results suggest no impact of the DPA, this is not the case for girls in the lowest pre-school I/H cohort (columns 2 and 7 of Panel C). Are the particular behaviours more likely exhibited by girls with higher overall I/H scores less amenable to reduce via exercise programme? Section 2.7 performs a formal test of this hypothesis.

2.5 Robustness Checks for Identifying Assumptions

Table A4 presents results from a series of robustness checks for our identifying assumption. Panel A reports results from regressing pre-school I/H scores against the same set of control variables used in equation 2, except for the pre-school I/H score itself. Given that the DPA mandates should not have an effect on this age group, results from this exercise serves as a falsification test of our main results. It is certainly not a perfect placebo test, but we would expect the effects to be much smaller for younger children than for the treatment group. As shown, while all the estimated coefficients are negative, suggesting a somewhat decreased incidence of inattention/hyperactivity in DPA provinces over time relative to that in the rest of

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Table 2: Difference-in-Differences Estimates of Daily Physical Activity Effect on Inattention/Hyperactivity (Children in Grades 1-6 in the NLSCY 1994-2009)

	DPA Participation				DPA Duration			
	Full Sample Eq. 1 (1)	Full Sample Eq.2 (2)	Boys Eq.2 (3)	Girls Eq. 2 (4)	Full Sample Eq.1 (1)	Full Sample Eq.2 (2)	Boys Eq.2 (3)	Girls Eq. 2 (4)
I/H Score at age 3 to 4		0.138 ***	0.139 ***	0.136 ***		0.138 ***	0.139 ***	0.136 ***
		(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)
DPA	-0.095 *	-0.069 **	-0.089 **	-0.055	-0.003	-0.003 **	-0.003 **	-0.002
	(0.052)	(0.025)	(0.026)	(0.341)	(0.129)	(0.042)	(0.050)	(0.413)
Lone Parent	0.167 ***	0.136 ***	0.168 ***	0.105	0.168 ***	0.136 ***	0.169 ***	0.105
	(0.006)	(0.006)	(0.000)	(0.118)	(0.006)	(0.006)	(0.000)	(0.117)
Boy	0.361 ***	0.256 ***			0.363 ***	0.261 ***		
	(0.000)	(0.000)			(0.000)	(0.000)		
Mean I/H Score	3.943	3.943	4.512	3.363	3.943	3.943	4.512	3.363
SD I/H Score	3.135	3.135	3.271	2.875	3.135	3.135	3.271	2.875
N	23890	23890	12010	11870	23890	23890	12010	11870

Notes: 1) Standard errors are clustered at the province level. In parentheses, we report wild cluster bootstrapped p-values (1000 replications and Rademacher/Webb weights). 2) Covariates include the child's age and age squared, school type, presence of disability, family income, family structure, parental education and immigrant status. 3) Outcomes are standardized for all children to have a mean of 0 and a SD of 1. $^{*}\ p < 0.1$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$

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Canada, especially among girls, in none of the cases is the coefficient statistically significant. Panels B and C report results from a replication of the analysis assuming that the DPA mandates were enacted 2 and 4 years earlier, respectively, than their actual implementation dates, as an alternative test of the pre-treatment trends. As expected, none of the coefficients on the lead variables are significant at conventional levels. Panels D-I show that our results are fundamentally unchanged after the exclusion of children attending private schools and with the addition of an urbanicity gradient, as well as with the use of alternative control and treatment groups (more details see Online Appendix B).

Panel J of Table A4 reports the regression results obtained from the child-level fixed effects model for the subsample of 5-year-olds who were attending school at the time of the survey (equation 3). While the estimated effect size of DPA for boys nearly doubles, the qualitative pattern of findings is essentially the same as before: 1) DPA children exhibit a significant reduction in I/H behaviours relative to non-participating ones, and 2) the daily exercise effect is stronger for boys than for girls. As mentioned before, since the 5-year-olds under analysis are coincidentally the younger students in the classroom, the estimated DPA effect could either under-estimate the true impact of exercise, if being young in classroom concurrently causes greater inattention/hyperactivity or result in an over-estimation if these children exhibit higher levels ADHD behaviours (and therefore are less likely to experience the ceiling effect of DPA) or tend to be treated for ADHD (e.g., drug therapy or psychiatric counseling). Results presented in this section may therefore not be generalizable to the full population.

2.6 Further Evidence on Programme Compliance

Next, we explore the question of whether or not the DPA mandates actually increased

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physical activity of the children covered by the programme using data from the CCHS. Table A5 provides means/frequencies of relevant variables for the 12-to-14-year-olds under analysis (for more discussions see Online Appendix C). Mirroring regression results found for the I/H behaviours among 12-to-14-year-old students in the NLSCY (Table A6), Table A7 reports a significant increase in the overall levels of physical activity among 12-to-14-year-olds in the CCHS -- surveyed at roughly the same time -- with respect to frequency and duration (Panel A) as well as intensity (Panel B) after the implementation of DPA. Importantly, the gender-specific heterogeneity in the DPA effect on physical activity, as presented in Table A8, resembles that observed for the patterns in I/H behaviours of children in grades 1 though 6 reported earlier (Columns 3 and 4 of Table 2). While girls spent more net time participating in physical activities than did boys, only a fraction of the time was spent pursuing activities that last for a sustained period of time or at an elevated intensity (see Appendix D for more discussion). Thus, it is plausible that boys might be more active than girls during the DPA periods or that in-school exercise might be a complement to out of-school physical activity for boys and a substitute for girls, as some relevant studies argue (e.g., Cawley et al. 2013). Indeed, a few studies find that boys have a relative preference for play/games that leads to a higher level of physical activity (e.g., Telford et al. 2016). While research examining the additional gains from raising physical activity beyond low intensity produce mixed results for children diagnosed with ADHD, more aerobic-based exercise is demonstrated to exert a greater beneficial effect than other types of activity (Cornelius et al. 2017).

2.7 Might the Measure for I/H Behaviour Play a Role?

Why would the same DPA programme impact boys more than girls? While the evidence on patterns of physical activity provides one explanation to the observed gender-specific effect

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of DPA, the measure for I/H behaviour used in the analysis may also play a role, if the I/H behaviour more evident for girls (e.g., inattentiveness and low self-esteem) are less amenable to reduction via exercise than those predominantly presented in boys (e.g., hyperactivity and impulsivity). To test this hypothesis, we split the I/H score into inattentive and hyperactive parts, based on the American Psychiatric Association's diagnostic criteria for ADHD in children (American Psychiatric Association, 2013) and replicate our analysis. As shown in Table A9, while daily exercise tends to have a slightly larger impact on behaviours characterized as hyperactive/ impulsive as opposed to inattentive, most DPA effects continue to concentrate on boys, suggesting the construction of our I/H measure is unlikely a main driver of the observed asymmetric responses across gender.

3 Does Inattention/Hyperactivity Help to Explain the Educational Gender Gap?

3.1 Data and Methodology

Given the finding that the inattention/hyperactivity of boys was reduced more than that of girls through the introduction of daily exercises, in the second section of the paper we present evidence on the role of inattention/hyperactivity in educational gender gap as a means to gauge the longer-term impact of DPA on children. To this end, we link the level of I/H behaviour to observed gender gaps in outcome measures that reflect the parent's assessment of the child's attitude toward school, his/her over-all performance at school, the parent's hope for the child's future educational attainment as well as the child's score in a standardized math test by estimating the following sibling fixed effects model:

$$Y_{ijk} = \beta_0 + \beta_1 I/H_{ij} + W_{ij}'\phi + \lambda_j + \epsilon_{ijk} \tag{5}$$

where Y_{ijk} is outcome k, for child i, in family j; W_{ij} is a vector of child-specific characteristics, including gender, birth order, health status, age in months, school grade and

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survey year. Since siblings may not be observed in the same survey year, we also control for inflation-adjusted family equivalent income, family structure, PMK education, gender, marital and employment status when estimating the model. While sibling fixed effects models may fail to capture important individual-level factors that jointly affect child health status and academic performance, it is impractical to estimate models with child-level fixed effects in the absence of external interventions, since ADHD is a symptom that typically emerges before the child's 7th birthday.

To conduct the analysis, we select children from brother-sister families who are between 6 and 11 years of age and whose sibling is also between 6 and 11 years and observed in the data. Observations from 1994-2009 are pooled so that the sample size is maximized. With these restrictions, we have a sample of just over 2000 brother-sister pairs. Boys comprise 60% of children in the top quartile of the distribution; girls comprise 60% of children in the bottom quartile (Figure A1). Moreover, if we compare each brother to his sister (column 5 of Table A10), we find that 29% of brothers have higher I/H scores than their sisters (not controlling for age); only 14% of sisters have higher scores than their brothers.

To assess the child's attitude toward school, we use answers to the question: "With regard to how this child feels about school, how often does he/she look forward to going to school?" Response possibilities are: "Almost never," "Rarely," "Sometimes," "Often," or "Almost always." While a majority of parents say their 6-to-11-year-old children "almost always" look forward to going to school; this is true for 75% of sisters compared to only 60% of brothers (Figure A2). Comparing responses of individual sibling pairs, we find, unconditionally, that 15.4% of brothers like school less than their sisters; only 6.6% of sisters like school better than their brothers.

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To gauge the child's over-all success at school, we use PMK answers to the question: "Based on your knowledge of his schoolwork, including report cards, how is [your child] doing overall?" Response possibilities are: Very well, well, average, poorly, very poorly. For our analyses, we code from 1 to 5, with 5 corresponding with "very well." Similar patterns are again evident. Parents report that 55.8% of sisters are doing "very well" compared to 41.5% of brothers (Figure A3). And, in a within family comparison, 18.9% of boys are doing worse than their sisters while only 8.8% of boys are doing worse than their sisters.

Parental hopes for the child's eventual educational attainments are assessed through the question: "How far do you hope he/she will go in school?" Possible responses include: 1) primary/elementary school; 2) secondary or high school; 3) community college, CEGEP or nursing school, trade, technical or vocational school or business college; 4) university. Given extremely small sample sizes for "primary/elementary school," we have aggregated these 2 categories. Although perhaps less marked, there is even a difference in parental "hopes" for their children's future level of educational attainment. University level education is the "hoped for" level for 6-to-11-year-old daughters in 76% of cases compared to 71% of cases for sons (Figure A4).

We also study math test scores, a more objective educational outcome. NLSCY children aged 7 to 13 are given a grade-specific Mathematics Computation Exercise. The math test is a shortened version of the mathematical operations test of the standardized Canadian Achievement Tests, Second Edition. We use scores standardized for age, grade and month in which the test was administered. As illustrated in Table A10, there is a much smaller difference between brothers and sisters in standardized math scores than for the other non-cognitive outcomes we study; and, this is the one outcome where brothers are less likely to perform worse than their

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sisters (24.6% of brothers have a lower math score than their sister; 27% of sisters have a lower math score than their brother).

3.2 Regression Results

Regression results, with standard errors clustered at the child level, are reported in Table A11. For all cases except math test scores, brothers have significantly "worse" outcomes than sisters, controlling for differences in age in months, grade, health status and birth order (column 2), as well as parental characteristics (column 3). These differences remain significant when we add the I/H score to the models, but the brother-sister difference is reduced by as much as half. Specifically, the "brother" coefficient falls by 25% for "liking school," by 48% for "success at school," and by 31% for parental educational hopes. While no gender gap is observed for math test scores – echoing what Currie and Stabile (2006) find for Canadian children using the NLSCY data – I/H behaviour adversely affects child math performance and appears to be a more serious risk factor in boys than in girls. We observe a sign switch of the "boy" coefficient from negative to positive once the I/H scores are included in the model, implying that the negative consequences of I/H behaviour for math scores are greater for boys than girls. Online Appendix E addresses the possibility that these results are driven by potential bias in parental reports and/or the children in our sample being treated for ADHD.

4 Discussion

Despite growing concerns over the risk of sedentary behaviour, children are becoming increasingly inactive at school. In Canada, only 48% of school administrators report providing daily PE to all students (Active Healthy Kids Canada, 2018). Around the globe, childhood physical inactivity has reached crisis level, according to the Active Healthy Kids Global Alliance (AHKGA) after examining 10 common indicators related to the physical activity of children in

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49 countries from 6 continent. At the same time, diagnosed ADHD has been increasing in many countries.

In this paper, we ask whether there may be a causal link between these trends by leveraging plausibly exogenous variations in the level of physical activity induced by the adoption of a DPA mandate in three provinces of Canada. We identify the causal impact of DPA on I/H behaviour through a lagged-dependent-variable-augmented DD method and the use of a nationally representative sample of children from the NLSCY. Our DD estimates indicate that mandating daily exercise is a non-drug-based strategy that effectively reduces ADHD behaviours for elementary-school aged children overall, but with a much stronger beneficial effect on boys than on girls. This is particularly true for boys who had exhibited higher levels of inattention/hyperactivity prior to school entry. There is no evidence that the findings are driven by any simultaneous changes in public policies or individual-level unobserved heterogeneity.

Although our main analysis relies on an ITT design because we have no measures of physical activity in the NLSCY, we do document, using an alternative data set, that overall physical activity increased for older children aged 12 to 14 who were also covered by the DPA programmes in two provinces. Moreover, since increases in physical activity were particularly marked for the boys, this lends credence to the idea that increases in physical activity were the pathway to lower inattention/hyperactivity. Using the percentage of DPA children who reported participating in sustained (i.e., lasting ⩾ 15 minutes) physical activities during school days (i.e., monthly frequency ⩾ 20 times) in the CCHS over our sample period as a rough indicator for programme compliance rate (63%; see Table A5), the Local Average Treatment Effect (LATE) of DPA would be a 11% and 14% of a SD reduction in I/H behaviour for children overall and boys, respectively.

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Based on the results obtained through our brother-sister fixed effects models in the second part of the paper, a decline in I/H behaviour of 14% of a SD or approximately 0.5 points among boys, where the DPA effect is concentrated, would result in a boost in boys' liking for school by 3% of a SD, school success by 6% of a SD, and relative parental educational hopes for boys by 2% of a SD, as rated by the parent. If so, a 20-30 minutes of mandated exercise per day would have the potential of reducing the observed gender gap in parent-assessed attitude toward school, overall success at school, and parental expectation by 10%, 20%, and 18%, respectively. While we do not observe any gender gap in standardized math test scores, we do find I/H behaviour to be a significant risk factor for child math performance. Given that boys have much higher levels of inattentive/hyperactive behaviours (even relative to their sisters), and that they are more inattentive/hyperactive before they start school and thus, tend to benefit most from the DPA programmes, this result emphasizes the point that to the extent that daily exercise reduces I/H behaviour, it will improve boys' relative performance on standardized math tests, though the magnitude could be modest.

The present findings need to be interpreted in the context of some data and methodological limitations. First, since we make inference about programme compliance through data from the CCHS on a group of older children, the estimated LATE of DPA is only accurate to the extent that the programme-induced physical activities for young adolescents are comparable to those for elementary school-aged children. There is a theoretical possibility that exercise-related habit formed during childhood becomes difficult to break or young adolescents develop greater autonomy over exercise choices, though existing research (on the impact of state-level PE requirements) has found little empirical support to these hypotheses (Sabia et al. 2017). Second, because the NLSCY was discontinued after 2009, we have limited post-treatment

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data to evaluate the longer-term effect of daily exercise on I/H behaviour. More information will allow us to capture potentially time-lagged responses to the programmes and cumulative effect of DPA on I/H behaviour, offering additional insights to aid in the design of effective future physical activity intervention efforts. Finally, while the observed patterns in DPA-induced physical activities are consistent with those found for reductions in I/H behaviour and that inattention/hyperactivity did not seem to present in a different fashion for girls than current measure captures, further explorations are needed to fully understand why girls are less affected by the DPA programmes. First, parents may be more likely to report boys' behaviour on the I/H scale than they do for girls, since internalizing behaviours are less readily observed than externalizing behaviours. Previous research has shown that clinical samples of ADHD children often report more symptoms about themselves than parent do and emphasized the combination of self-report and parent rating scales to increase awareness of internalizing problems particularly salient in girls with ADHD (Skogli et al. 2013). Although reliable self-reports may be hard to obtain from young children, the inclusion of alternative measures for I/H behaviour could yield different results. Second, boys may improve more because they have more room to improve, given that they exhibit much higher levels of I/H behaviours than girls do. Third, boys and girls might respond to physical activity opportunities in varying ways. Tantillo et al. (2001), for example, find that there are sex-related responses to exercise among children with ADHD, such as spontaneous eye blinks, acoustic startle eye blink response, and motor impersistence. Additional investigations along these lines could be important extensions of current study.

Given these caveats, this study makes several principal contributions to the literature. First, we provide the first causal evidence that the effect of a provincewide/statewide physical activity invention extends beyond body weight to benefit mental health and human capital

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acquisition for young children. Existing experimental and quasi-experimental research on the role of physical activity in child development have focused on classroom movement breaks, recess, and before and after school programmes (e.g., Grieco et al. 2009) and dealt with inventions at the classroom- or school-level, whose participants are not necessarily representative of children in the general population. There is also a small strand of literature on the effect of state-level PE requirements on overweight and obesity for elementary and secondary school-aged children in the US (e.g., Cawley et al. 2013; Sabia et al. 2017), who generally find little evidence that PE-induced increases in physical activity generate substantial body weight declines. While PE classes typically offer opportunities for physical activity, they are primarily designed to teach students the skills and knowledge needed to engage in physical activity and/or sustain an active lifestyle rather than providing actual physical activity experiences. In this sense, it is not a priori clear whether a more targeted approach that ensures bodily movement for a sustained period of time can be a viable solution to benefit children, especially when implemented in conjunction with existing PE curricula. More importantly, none of the above-mentioned studies have addressed the linkage of physical activity intervention with inattention/hyperactivity or non-cognitive skill formation, a key element of human capital shown to have lasting implications for children’s educational attainment and eventual labor market success (e.g., Cameron and Heckman 1998).

Second, because of the universal nature of the DPA programmes, we are able to assess the effectiveness of DPA on children who have not been diagnosed or who are untreated for ADHD. Although a number of controlled studies find that vigorous aerobic exercise may be a helpful longer-term treatment alternative for children with ADHD (e.g., Tantillo et al., 2002), even perhaps altering the development trajectory of the condition (Pontifex et al. 2013; Smith et

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al. 2013) none of which we are aware include un-diagnosed children as part of their treatment group. Our study thus provides a novel finding that DPA reduces inattentive/hyperactive behaviours even for children whose behaviours are well below clinical levels for ADHD diagnosis and demonstrates the effectiveness of physical activity on this group of "at risk" children.

Third, the variations provided through the quasi-experiment that we study enable us to investigate a dose-response relationship and therefore speak to the question of optimal duration that has rarely been investigated (e.g., Cornelius et al. 2017).

Fourth, the ability to track each child over time enhances the internal validity of the research, relative to existing cross-sectional studies (e.g., Nelson and Gordon-Larsen 2006), allowing us to better control for confounding factors and to establish a temporal relationship between physical activity and I/H behaviour.

Last, but not least, our investigation of whether I/H behaviours matter for the observed gender gap in academic outcomes marks a departure from most previous work in the strand of studies on gender gaps in educational performance (see Buchmann et al. (2008) for a review). While the problem of "boys not liking school" is well-documented, our analysis is the first to provide evidence through brother-sister comparisions that their, on average, higher levels of inattention/hyperactivity is a potential explanation for why boys lag behind.

5 Conclusion

By comparing changes in parent-reported I/H scores in DPA provinces versus the rest of Canada among children who exhibit *the same* levels of I/H behaviour prior to school entry, we present evidence that mandating 20-30 minutes of exercise every day at school lowers I/H scores among elementary school-aged children, on average, by 7% of a SD, roughly 50% as large as the

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lone-parent association, though in the opposite direction. Conditional on participation, an additional 10 minutes of exercise per day reduces the I/H scores further by 0.4% of a SD. We find, moreover, that the effects of the DPA mandates are driven by boys (9% of a SD), particularly boys with pre-school I/H score in the top quartile (17-33% of a SD).

Given that differences in inattention/hyperactivity among boys relative to girls explain a fourth to one half of currently observed gender differences in academic success of young children – that boys like school less than girls, perform less well than girls, and why their parents have, on average, lower hopes for their sons' eventual academic attainments, this implies that interventions such as the mandate of DPA for young children at school would contribute to improving boys' relative motivation/performance. Calculations using our estimates suggest that a 20-30 minutes of exercise per day has the potential to reduce the above-mentioned gender gaps in attitude toward school, overall success at school, and parental educational hopes by 10%, 20%, and 18%, respectively.

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