



Prospective associations between participation in leisure-time physical activity at age 6 and academic performance at age 12



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ABSTRACT

For many children, leisure time represents a privileged moment to engage in physical activity. This study aims to examine prospective associations between kindergarten participation in leisure-time physical activity and academic performance by the end of sixth grade. Gender-specific associations are also explored. Participants are from the Quebec Longitudinal Study of Child Development, a 1997–1998 birth cohort from the province of Quebec, Canada ($n = 2837$). When children were age 6 (2004), mothers reported on their child's participation in three types of leisure-time physical activity (sports, other structured physical activities, and unstructured physical activities). At age 12 (2010), children's academic indicators were reported by teachers and by children themselves. Academic outcomes were then linearly regressed on leisure-time physical activity participation, while controlling for individual and family confounders. Unstructured physical activities were the most popular among both girls and boys. Sports were the second most popular activity among boys, whereas other structured physical activities were the second most popular among girls. Higher overall participation in leisure-time physical activity at age 6 was associated with better teacher-reported grades in language and math ($\beta = 0.075$ and $\beta = 0.102$, respectively) and self-reported grades in language ($\beta = 0.103$), as well as with higher classroom engagement ($\beta = 0.077$,) at age 12. Regression coefficients are standardized. All the associations were significant ($p \leq .05$). Promoting leisure-time physical activity may be an effective way to encourage children to be active and to help them improve their academic performance, both leading to long-term wider benefits.

1. Introduction

The increasing prevalence of physical inactivity, along with its associated risks, has become a major global public health concern (Kohl et al., 2012). International physical activity guidelines recommend that children accumulate at least 60 min per day of moderate to vigorous physical activity (World Health Organization, 2010). In Canada, only 9% of youth satisfy these recommendations (ParticipACTION, 2016). Nowadays, many children choose to spend their leisure time in front of a screen instead of engaging in more active pursuits (Pagani et al., 2010a; Sigman, 2012).

Extant research suggests that participation in physical activity during childhood is associated with relatively immediate physical, cognitive, psychological, and social benefits (Janssen and LeBlanc, 2010; Landry and Driscoll, 2012). For many children, leisure time represents a privileged moment for participation in various physical

endeavors that can foster their development (Arundell et al., 2015; Fredricks and Eccles, 2006). Leisure-time physical activities come in different forms. There are individual or team sports with an instructor or trainer, other structured physical activities (e.g. dance, martial arts, circus arts), and unstructured physical activities (e.g. free active play). Worldwide, sports remain a popular physical activity, with 65% of children participating after school (Arundell et al., 2015; Felfe et al., 2016).

Academic performance during childhood, often measured through grades or other indicators of school engagement, represents a robust predictor of later educational attainment (Heckman, 2006; Heckman et al., 2013). School readiness and high school completion are associated with personal and academic success in adolescence and adulthood (Heckman, 2006; Heckman et al., 2013; Pagani et al., 2010b; Entwisle and Alexander, 1993). However, gender gaps in academic achievement during elementary and middle school are well

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documented: girls tend to outperform boys in language and reading, whereas boys tend to show an advantage in math (Robinson and Lubienski, 2011). Moreover, middle school transition represents a crucial period in adolescent development and predicts chances of high school dropout, with boys being at greater risk than girls (Pagani et al., 2010b; Archambault et al., 2009).

Previous studies have examined the link between physical activity and academic performance (Howie and Pate, 2012; Donnelly et al., 2016; Singh et al., 2012). A systematic review including 125 cross-sectional studies found positive associations between different forms of physical activity (e.g. physical education, sports, level of physical condition) and academic outcomes (such as cognitive tests and school grades) in youth (Howie and Pate, 2012). In a more recent systematic review, 32 studies were examined to explore cross-sectional associations between physical activity and academic achievement, the influence of acute physical activity on cognitive tasks, and the effects of physical activity interventions on academic outcomes (Donnelly et al., 2016). Although some favorable results were found, the findings were mixed and inconsistent (e.g. positive associations for girls but not boys). Another systematic review, including only longitudinal studies ($n = 14$), also found a beneficial influence of physical activity on academic success in children (Singh et al., 2012). However, for most of these studies, the time-lag between predictor and outcomes was of 2 years or less. Furthermore, studies included in the above systematic reviews varied considerably in terms of methodological control of confounders, experimental design, sampling, and instrumentation, thus making it difficult to appreciate the contribution of physical activity involvement to school outcomes.

Neurobiological and psychosocial mechanisms have been proposed as potential pathways to explain the link between physical activity and academic performance (Lubans et al., 2016). The first pathway involves physiological mechanisms produced by exercise, such as increases in cerebral blood flow and positive brain plasticity (Herholz et al., 1987; Hillman et al., 2008). This could explain the role that participation in physical activity plays in improving executive function, the mental processes that govern cognitive control and behavior (Best, 2010; Tomporowski et al., 2011; Verburch et al., 2014). The second pathway is related to cognitive and social mechanisms. In this sense, physical activity offers various opportunities to learn skills that can then be transferred to other learning scenarios (Piaget, 1968). Furthermore, according to social learning theory, interactions with peers in different contexts provide a variety of learning experiences that can contribute to child development (Bandura, 1977). From this perspective, sports and other structured physical activities would be most promising for children, given that they exercise more cognitive control. These also teach children how to behave cooperatively, follow instructions, and work as a team to achieve common goals. It could be argued that physical activity could help children learn cognitive and social skills, such as self-regulation, cooperation, conflict-resolution, responsibility, and autonomy (Blair and Diamond, 2008; Piché et al., 2015).

Even if results from previous studies suggest positive associations between physical activity and academic performance, the potential contribution of leisure-time physical activity on the prediction of academic outcomes over a wide time span has yet to be examined. A prospective design, which uses longitudinal data and controls for pre-existing and concurrent confounders, can elucidate the specific benefits associated with participating in leisure-time active pursuits. Moreover, gender-based analyses may allow the comparison between active and less active girls, and between active and less active boys. Such findings would help shed light on the most optimal time investment for children's waking hours outside of the kindergarten classroom.

The purpose of this study is to examine longitudinal associations between kindergarten participation in leisure-time physical activity and academic performance by the end of sixth grade. More specifically, we aim to estimate the prospective influence of child overall participation in three types of activities (sports, structured, and unstructured physical

activities) at age 6 on various academic outcomes (teacher-reported and self-reported grades in language and math, and classroom engagement) at age 12. It is expected that children with a higher level of participation in early leisure-time physical activity will later show better academic performance, compared to those with lower levels of participation. Additionally, we aim to explore if the benefits of leisure-time physical activity on academic performance are the same for girls and boys. That is, are physically active boys and girls better off academically than their less active same-gender counterparts?

2. Methods

2.1. Participants

Data from the Quebec Longitudinal Study of Child Development was used for this study. This representative sample, composed of 2837 babies born between 1997 and 1998 in the Canadian province of Quebec, was randomly selected and stratified by provincial region. Of the eligible participants, 18% had to be excluded because of various reasons: 93 were ineligible due to their First Nation status, 186 were untraceable, and parents of 438 of them refused participation at the 5-month baseline assessment. The remaining 2120 children (82% of the original eligible sample) were followed-up longitudinally. Informed consent was obtained annually from the parents during early childhood and biennially from parents, teacher, and children during school age. The study was approved by the Institutional Review Board of the University of Montreal.

2.2. Predictor: participation in leisure-time physical activity (age 6 years – 2004)

Mothers were asked: “In the last 12 months, outside of school hours, how often has your child: a) taken part in sports with a coach or instructor (except dance or gymnastics)?; b) taken lessons or instruction in other organized physical activities with a coach or instructor such as dance, gymnastics, martial arts or circus arts?; c) taken part in unorganized sports or physical activities without a coach or instructor?” For each item, five response choices were possible: almost never (= 0), once a month (= 1), once a week (= 2), few times per week (= 3), and almost every day (= 4). From the sum of these responses, a continuous score, ranging from 0 to 12, was computed for each child and used in the analyses.

2.3. Outcomes: academic indicators (age 12 years – 2010)

Self-reported average marks for language (French) and math (score 0–100%) were obtained. Teachers also reported the child's average mark (expressed in percentage) both in language and in math. In addition, to estimate classroom engagement, teachers were asked to indicate how often the child demonstrated each of the following social/personal skills and work habits: worked cooperatively with other children; followed directions; followed rules; followed instructions; completed work on time; worked independently; listened attentively; worked neatly and carefully; put a lot of effort into work; participated in class; asked questions when he/she did not understand. For each item, three response choices were possible: never or rarely (= 0), sometimes (= 1), and often or always (= 2). A scale was created from the sum of these 11 items ($\alpha = 0.89$). The classroom engagement scale has already been used in previous studies (Pagani et al., 2010b).

2.4. Individual and family control variables (from 5 months to age 6 years – 1998–2004)

2.4.1. Individual

To account for gender differences, this variable, which was directly obtained from birth records, was included as a control variable

Table 1
Descriptive statistics for leisure-time physical activities, academic outcomes, and individual and family control variables.

Predictor	Overall			Girls		Boys	
	Percentage	Mean (SD)	Min-max	Percentage	Mean (SD)	Percentage	Mean (SD)
Leisure-time physical activity ^{a,b} (age 6)		4.33 (2.39)	0–11		4.24 (2.38)		4.42 (2.39)
Sport activity with instructor		0.91 (1.24)	0–4		0.71 (1.11)		1.13 (1.32)
	0 = almost never	63.1%		69.7%		56.1%	
	1 = once a month	0.4%		0.8%		0.0%	
	2 = once a week	18.8%		18.5%		19.2%	
	3 = few times per week	17.5%		11.0%		24.4%	
	4 = almost everyday	0.2%		0.0%		0.3%	
Other structured physical activities		0.67 (1.07)	0–4		0.86 (1.12)		0.49 (0.99)
	0 = almost never	70.3%		61.3%		78.9%	
	1 = once a month	0.4%		0.5%		0.4%	
	2 = once a week	21.0%		29.2%		13.0%	
	3 = few times per week	8.1%		8.7%		7.5%	
	4 = almost everyday	0.2%		0.3%		0.1%	
Unstructured physical activities		2.68 (1.33)	0–4		2.61 (1.32)		2.75 (1.35)
	0 = almost never	13.0%		12.9%		13.1%	
	1 = once a month	5.4%		5.7%		5.2%	
	2 = once a week	15.8%		19.0%		12.5%	
	3 = few times per week	32.4%		32.5%		32.3%	
	4 = almost everyday	33.4%		29.9%		36.9%	
Control variables			Overall	Girls	Boys		
			Percentage	Percentage	Percentage		
Gender	0 = girls		48.8%				
	1 = boys		51.2%				
Difficult temperament (age 1.5)	0 = below 50th percentile		51.6%	54.3%	49.0%		
	1 = above 50th percentile		48.4%	45.7%	51.0%		
Cognitive skills (age 2)	0 = above 50th percentile		27.8%	28.7%	26.9%		
	1 = below 50th percentile		72.2%	71.3%	73.1%		
TV in bedroom (age 4)	0 = no		86.9%	87.2%	86.6%		
	1 = yes		13.1%	12.8%	13.4%		
Level of physical condition (age 6)	0 = same or higher than others		96.4%	96.8%	96.0%		
	1 = lower than other children		3.6%	3.2%	4.0%		
Maternal education (5 months)	0 = completed high school		84.0%	83.9%	84.1%		
	1 = no high school diploma		16.0%	16.1%	15.9%		
Family configuration (age 6)	0 = two parents		84.4%	85.7%	83.1%		
	1 = single parent		15.6%	14.3%	16.9%		
Academic outcomes			Overall	Girls	Boys		
			Mean (SD)	Mean (SD)	Mean (SD)		
Grades in language (TR) ^b (age 12)			76.86 (10.98)	79.36 (10.37)	74.18 (10.99)		
Grades in language (SR) ^b (age 12)			78.54 (10.65)	81.05 (9.46)	75.80 (11.19)		
Grades in math (TR) ^b (age 12)			77.74 (11.70)	78.37 (11.62)	77.07 (11.77)		
Grades in math (SR) ^b (age 12)			80.06 (11.80)	80.08 (11.49)	80.05 (12.14)		
Classroom engagement (TR) ^b (age 12)			18.81 (4.34)	19.97 (3.11)	17.55 (5.07)		

Data from the Quebec Longitudinal Study of Child Development (1997–1998 birth cohort) – Quebec, Canada.

(SR) = self-reported; (TR) = reported by the teacher.

^a Leisure-time physical activity = sport activity with instructor + other structured physical activities + unstructured physical activities.

^b Applies when treated as a continuous variable.

(girls = 0, boys = 1). At age 1.5, mothers' perception of the child's temperament was assessed, through six items reflecting difficult and unpredictable temperament ($\alpha = 0.80$). Higher scores indicate a more difficult temperament than lower scores (coded as 0 = below the median and 1 = above the median). At age 2, the Imitation Sorting Task was administered by a trained examiner to evaluate the children's stage of cognitive development (attention working memory, and behavioral inhibition) (Alp, 1994; Fitzpatrick and Pagani, 2012). In this case, higher scores reflect better cognitive skills than lower scores

(coded as 0 = above the median and 1 = below the median). Screen-time being an indicator of sedentariness, children were asked, at age 4, if they had a TV in their bedroom (no = 0, yes = 1). At age 6, mothers were asked to rate the level of physical condition of their child in comparison to other children (same or higher than others = 0, lower than others = 1).

2.4.2. Family

Mothers reported on their level of education (completed high

Table 2

Adjusted unstandardized regression coefficients (*b*) with [95% Confidence Interval (CI)] and standardized coefficients (β) reflecting the association between individual and family control variables and overall participation in leisure-time physical activity at age 6.

Variable	Leisure-time physical activity	
Gender	<i>b</i> = 0.175 [−0.018; 0.369]	β = 0.037
Difficult temperament	<i>b</i> = −0.093 [−0.297; 0.112]	β = −0.020
Cognitive skills	<i>b</i> = −0.135 [−0.344; 0.075]	β = −0.025
TV in bedroom	<i>b</i> = −0.013 [−0.314; 0.287]	β = −0.002
Level of physical condition	<i>b</i> = −0.595 [−1.093; −0.096]	β = −0.046*
Maternal education	<i>b</i> = −0.563 [−0.801; −0.325]	β = −0.087***
Family configuration	<i>b</i> = −0.562 [−0.811; −0.312]	β = −0.086***

Data from the Quebec Longitudinal Study of Child Development (1997–1998 birth cohort) – Quebec, Canada.

We conducted a linear regression including all the control variables in the same model. For the control variables, a score of 0 represents the lower-risk group and a score of 1 represents the higher-risk group; for gender, a score of 0 was given to girls and a score of 1 was given to boys (refer to Table 1). Values are corrected for attrition bias.

* $p \leq .05$.

*** $p \leq .001$.

school = 0, no high school diploma = 1) when the child was 5 months old, and on the family configuration (two parents = 0, single parent = 1) at age 6.

Control variables were coded in a way that a score of 0 always represents the lower-risk group and a score of 1 always represents the higher-risk group.

2.5. Statistical analyses

We conducted linear regression analyses, using SPSS software, to examine the relationship between overall participation in leisure-time physical activity at age 6 and academic outcomes at age 12. Several variables, statistically or substantially related to either the predictor or the outcomes, were included in the model as control variables to reduce the possibility of competing explanations and omitted variable bias. More specifically, individual child factors (gender, difficult temperament, cognitive skills, bedroom TV, and level of physical condition) and family factors (maternal level of education and family configuration) were included as potential confounders.

Gender-based analyses were also conducted to examine these associations for girls and for boys, comparing the more active with the less active within each gender group. Finally, we conducted post-hoc analyses to compare the relative contribution of each type of leisure-time physical activity on the academic outcomes. In this case, for each one of the outcomes, the individual participation scores for each of the three types of physical activity (sports, other structured physical activities, and unstructured physical activities), along with the control variables, were included in the same model to account for mutual adjustment.

Thus, our adjusted model aims to examine the unique and the relative contribution of participation in leisure-time physical activities on the prediction of academic outcomes, by controlling for other individual and family confounding variables. An alpha level of 0.05 (two-tailed) was used to indicate statistical significance.

2.6. Attrition

This longitudinal study used data from a population-based sample that was obtained from multiple sources, at different ages. As reported in the online appendix (Table A.1), *t*-tests were conducted to compare participants with and without complete data on classroom engagement at age 12. Compared to children with incomplete data, those with complete data were less often boys (48% vs 54%; $t_{2221} = 2.939$; $p = .003$) and were more likely to have a bedroom TV (16% vs 11%;

$t_{1665} = -3.580$; $p = .000$).

Missing data was imputed using SPSS multiple imputation which uses a stochastic algorithm to generate probable values for the missing observations, based on available complete data on auxiliary variables. Ten individual datasets (which are copies of the original complete data with slight differences in the imputed values) are then created and combined. The resulting pooled output, based on probability, includes the estimated results as if the original dataset had been complete (Cummings, 2013). The results reported in the following section are thus corrected for attrition bias.

3. Results

Descriptive statistics of predictor, outcomes, and control variables are reported in Table 1. The mean (and standard deviation) for the overall participation in leisure-time physical activity was 4.33 (2.39), with scores ranging from 0 to 11. As reported in the online appendix (Table A.2), the means for the predictor were not significantly different between girls and boys, suggesting that overall participation rates were similar for both genders.

The proportion of children participating once or more per week in unstructured physical activities (82%) was higher than that of those participating in sports (37%) or in other structured physical activities (29%). Unstructured physical activities were the most popular among both girls and boys (with participation rates of 81% and 82%, respectively). The second most popular activity among boys was sports (44% participated at least once a week), whereas the second most popular activity among girls was other forms of structured physical activities (38% participated at least once a week).

Significant differences were found between girls and boys on several academic outcomes. Results for the *t*-tests are reported in the online appendix (Table A.2). Girls showed better teacher-reported (79.36 vs 74.18; $t_{924} = 7.383$; $p = .000$) and self-reported (81.05 vs 75.80; $t_{1338} = 9.304$; $p = .000$) language grades than boys. Also, compared to boys, girls showed higher classroom engagement (19.97 vs 17.55; $t_{776} = 8.988$; $p = .000$). Math grades were not significantly different between girls and boys.

Table 2 reports the association between individual and family control variables and leisure-time physical activity at age 6. Level of physical condition, maternal education, and family configuration were all three significantly associated with the predictor. Participation in leisure-time physical activity was higher for children whose level of physical condition was the same or higher than others. Children whose mothers had completed high school and those living with both parents also showed higher participation rates.

Associations between predictor and outcomes are reported in Table 3. For each of the five academic outcomes, we conducted a separate linear regression, including the predictor and the seven control variables. Leisure-time physical activity was significantly associated with four out of the five academic outcomes ($p \leq .05$). Children with higher levels of participation at age 6 presented better school performance at age 12. More specifically, a one unit increase in participation in leisure-time physical activity was related to a 0.35 and a 0.46 unit increase in language grades (teacher-reported and self-reported, respectively). Every unit increase in participation also corresponded to a 0.50 unit increase in teacher-reported math grades. Furthermore, every unit increase in participation corresponded to a 0.14 unit increase in classroom engagement.

As also reported in Table 3, individual and family characteristics made their own unique contributions to predicting outcomes. Gender, cognitive skills, maternal education, and family configuration were all significantly associated with several or all academic outcomes. Compared to girls, being a boy predicted lower language (both teacher-reported and self-reported) and math grades (teacher-reported), respectively. Boys also showed lower classroom engagement than girls. Having cognitive skills below the median at age 2 predicted lower

Table 3

Adjusted unstandardized regression coefficients (*b*) with [95% CI] and standardized coefficients (β) reflecting the association between overall participation in leisure-time physical activity at age 6 and academic outcomes at age 12.

Variable	Grades in language (TR)	Grades in language (SR)	Grades in math (TR)	Grades in math (SR)	Classroom engagement (TR)
Leisure-time physical activity	<i>b</i> = 0.346 [0.028; 0.664] β = 0.075*	<i>b</i> = 0.459 [0.127; 0.792] β = 0.103**	<i>b</i> = 0.501 [0.086; 0.917] β = 0.102*	<i>b</i> = 0.383 [-0.003; 0.769] β = 0.077	<i>b</i> = 0.140 [0.001; 0.279] β = 0.077*
Gender	<i>b</i> = -5.343 [-6.561; -4.124] β = -0.243***	<i>b</i> = -5.100 [-6.256; -3.943] β = -0.240***	<i>b</i> = -1.667 [-2.818; -0.515] β = -0.071**	<i>b</i> = 0.326 [-0.973; 1.625] β = 0.014	<i>b</i> = -2.383 [-2.871; -1.895] β = -0.275***
Difficult temperament	<i>b</i> = 0.254 [-0.975; 1.483] β = 0.012	<i>b</i> = -0.211 [-1.389; 0.967] β = -0.010	<i>b</i> = -0.148 [-1.850; 1.555] β = -0.006	<i>b</i> = -1.192 [-2.413; 0.029] β = -0.051	<i>b</i> = 0.111 [-0.435; 0.656] β = 0.013
Cognitive skills	<i>b</i> = -3.111 [-4.597; -1.624] β = -0.127***	<i>b</i> = -2.129 [-3.298; -0.960] β = -0.090***	<i>b</i> = -2.659 [-4.384; -0.934] β = -0.102**	<i>b</i> = -2.697 [-3.853; -1.541] β = -0.102***	<i>b</i> = -0.723 [-1.245; -0.202] β = -0.075**
TV in bedroom	<i>b</i> = 0.159 [-1.941; 2.259] β = 0.005	<i>b</i> = 0.143 [-1.643; 1.929] β = 0.005	<i>b</i> = 0.158 [-2.014; 2.330] β = 0.005	<i>b</i> = 0.061 [-2.249; 2.370] β = 0.002	<i>b</i> = 0.586 [-0.229; 1.400] β = 0.046
Level of physical condition	<i>b</i> = -1.891 [-5.845; 2.063] β = -0.032	<i>b</i> = 0.287 [-3.115; 3.688] β = 0.005	<i>b</i> = -0.877 [-4.787; 3.033] β = -0.014	<i>b</i> = -0.137 [-3.632; 3.359] β = -0.002	<i>b</i> = -0.270 [-2.140; 1.601] β = -0.012
Maternal education	<i>b</i> = -7.111 [-9.065; -5.158] β = -0.238***	<i>b</i> = -5.855 [-7.391; -4.319] β = -0.202***	<i>b</i> = -7.309 [-9.703; -4.915] β = -0.229***	<i>b</i> = -5.702 [-7.535; -3.868] β = -0.177***	<i>b</i> = -2.022 [-2.982; -1.063] β = -0.171***
Family configuration	<i>b</i> = -2.500 [-4.985; -0.014] β = -0.083*	<i>b</i> = -0.806 [-2.309; 0.697] β = -0.028	<i>b</i> = -2.972 [-5.421; -0.522] β = -0.092*	<i>b</i> = -2.058 [-3.969; -0.147] β = -0.063*	<i>b</i> = -0.791 [-1.680; 0.097] β = -0.066

Data from the Quebec Longitudinal Study of Child Development (1997–1998 birth cohort) – Quebec, Canada.

We conducted a linear regression including leisure-time physical activity and the control variables in the same model to predict each one of the outcomes. For the control variables, a score of 0 represents the lower-risk group and a score of 1 represents the higher-risk group; for gender, a score of 0 was given to girls and a score of 1 was given to boys (refer to Table 1). Values are corrected for attrition bias.

(SR) = self-reported, (TR) = reported by the teacher.

* $p \leq .05$.

** $p \leq .01$.

*** $p \leq .001$.

teacher-reported and self-reported grades, both in language and in math, as well as lower classroom engagement at age 12. Lower maternal education was also associated with lower teacher-reported and self-reported language and math grades, as well as with lower classroom engagement. Being in a single-parent family was associated with lower teacher-reported language grades and with both teacher-reported and self-reported math grades.

Gender-based analyses were conducted to see if participation in leisure-time physical activity showed relative benefits in academic performance for girls and boys. As reported in Table 4, the same adjusted model was used separately for each gender group. Girls with higher participation showed increases in teacher-reported math grades and self-reported grades (both in language and math), compared to their less active counterparts. Boys with higher participation showed higher self-reported language grades than their less active counterparts.

Post-hoc analyses were conducted to compare the relative contribution of each type of leisure-time physical activity on the prediction of academic performance. Results are reported in Table 5. Every unit increase in participation in sports was significantly associated with a 0.54 and a 0.58 unit increase in self-reported grades (language and math, respectively). Participation in other structured physical activities and in unstructured physical activities was not significantly associated to the academic outcomes.

4. Discussion

Given that the current generation of children spend a greater amount of time engaging in sedentary behavior (such as watching TV, playing videogames, or surfing the Internet), promoting physical activity from an early age has become paramount (Sigman, 2012; Heath et al., 2012; Nguyen et al., 2016; Salmon et al., 2007). To parents, leisure-time physical activity might represent an interesting practical

Table 4

Adjusted unstandardized regression coefficients (*b*) with [95% CI] and standardized coefficients (β) by gender, reflecting the association between overall participation in leisure-time physical activity at age 6 and academic outcomes at age 12 for girls and boys, separately.

Variable	Leisure-time physical activity	
	Girls	Boys
Grades in language (TR)	<i>b</i> = 0.306 [-0.093; 0.704] β = 0.070	<i>b</i> = 0.376 [-0.058; 0.810] β = 0.082
Grades in language (SR)	<i>b</i> = 0.366 [0.001; 0.731] β = 0.092*	<i>b</i> = 0.543 [0.059; 1.026] β = 0.116*
Grades in math (TR)	<i>b</i> = 0.500 [0.059; 0.941] β = 0.102*	<i>b</i> = 0.496 [-0.054; 1.046] β = 0.101
Grades in math (SR)	<i>b</i> = 0.458 [0.074; 0.841] β = 0.095*	<i>b</i> = 0.309 [-0.258; 0.876] β = 0.061
Classroom engagement (TR)	<i>b</i> = 0.124 [-0.045; 0.294] β = 0.095	<i>b</i> = 0.154 [-0.027; 0.335] β = 0.073

Data from the Quebec Longitudinal Study of Child Development (1997–1998 birth cohort) – Quebec, Canada.

We conducted the same linear regression model for girls and boys, separately, including all the control variables except for gender. Values are corrected for attrition bias.

(SR) = self-reported, (TR) = reported by the teacher.

* $p \leq .05$.

option that could enhance multiple spheres of their child's development, including academic performance (Arundell et al., 2015; Fredricks and Eccles, 2006). Not much research has investigated the long-term

Table 5

Adjusted unstandardized regression coefficients (*b*) with [95% CI] and standardized coefficients (β) reflecting the relative contribution of each type of leisure-time physical activity at age 6 on academic outcomes at age 12.

Variable	Type of leisure-time physical activity		
	Sport activity with instructor	Other structured physical activities	Unstructured physical activities
Grades in language (TR)	<i>b</i> = 0.366 [−0.236; 0.968] β = 0.041	<i>b</i> = 0.535 [−0.071; 1.142] β = 0.052	<i>b</i> = 0.207 [−0.383; 0.798] β = 0.025
Grades in language (SR)	<i>b</i> = 0.543 [0.009; 1.078] β = 0.063*	<i>b</i> = 0.499 [−0.048; 1.047] β = 0.050	<i>b</i> = 0.365 [−0.193; 0.924] β = 0.046
Grades in math (TR)	<i>b</i> = 0.523 [−0.162; 1.208] β = 0.055	<i>b</i> = 0.414 [−0.345; 1.172] β = 0.038	<i>b</i> = 0.541 [−0.116; 1.197] β = 0.062
Grades in math (SR)	<i>b</i> = 0.576 [0.005; 1.147] β = 0.060*	<i>b</i> = 0.286 [−0.379; 0.951] β = 0.026	<i>b</i> = 0.292 [−0.305; 0.888] β = 0.033
Classroom engagement (TR)	<i>b</i> = 0.212 [−0.049; 0.474] β = 0.061	<i>b</i> = 0.227 [−0.015; 0.468] β = 0.056	<i>b</i> = 0.029 [−0.209; 0.267] β = 0.009

Data from the Quebec Longitudinal Study of Child Development (1997–1998 birth cohort) – Quebec, Canada.

For each outcome, the three types of leisure-time physical activity, along with the control variables, were included in the same linear regression model. Values are corrected for attrition bias.

(SR) = self-reported, (TR) = reported by the teacher.

* $p \leq .05$.

benefits of early participation in such endeavors.

Our findings reveal that, among the different types of leisure-time physical activity, unstructured activities are the most popular for six-year-old children. Participation rates for sports and other structured physical activities were lower for both girls and boys.

As expected, kindergarten overall participation in leisure-time physical activity was associated with better academic outcomes by the end of sixth grade, above and beyond multiple potential individual and family confounding variables. We found that higher participation in leisure-time physical activity predicted superior language and math school grades (both teacher-reported and self-reported). Participation was also associated with higher levels of classroom engagement at age 12. This suggests that children participating in leisure-time physical activity at an early age have greater chances of succeeding in school later in life, which might, in turn, lead to other long-term positive consequences.

Previous studies have found that when it comes to academic achievement, the benefits of physical activity are more pronounced for girls than for boys (Donnelly et al., 2016). Our gender-based findings suggest that physical activity may help close the pre-existing gender gap in academic achievement. Compared to their less active counterparts, higher participation in boys was associated with higher grades in language, helping them get closer to girls' level of performance. For girls, higher participation was associated to increases in math grades, helping them equalize boys' level of math performance. Therefore, this salutary influence may improve chances of high school completion, career opportunities, and personal and social adjustment for both genders, but differently.

When the different types of leisure-time physical activities are compared, it seems that only sports play a significant role on later academic performance, but not the participation in other structured or unstructured physical activities. These findings are similar to those reported in previous studies (Felfe et al., 2016; Piché et al., 2015).

Nevertheless, positive results were found when the overall participation was considered, suggesting that the amount of physical activity accumulated by the children during their leisure time is more important than the type of activity itself.

Multiple processes could explain our findings. First, the association between participation in leisure-time physical activity and academic outcomes might be a consequence of the positive influence that exercise has on brain and cognition (Lubans et al., 2016). Engaging in physical activity can produce structural and physiological changes in the brain, as well as an increased activation of the cortical regions that control cognitive processes needed for goal-oriented behavior (Hillman et al., 2008; Best, 2010; Tomporowski et al., 2011; Verburgh et al., 2014; Alvarez-Bueno et al., 2017). This suggests a critical role, not only for school readiness and academic success during childhood, but also for personal and socio-emotional adjustment throughout the life course (Diamond and Lee, 2011). Second, the cognitive demand required by social interactions generated during certain types of leisure-time physical activity (such as team sports) may help children hone complex self-regulation skills. These can then be transferred toward controlling attention and behavior, following instructions, and respecting rules in the school context (Blair and Diamond, 2008; Piché et al., 2015). Optimal self-control in childhood not only prevents school failure, but is also associated with more prosocial behavior and less rule breaking and criminality in adolescence, and better health and finances in adulthood (Moffitt et al., 2011; Murray and Farrington, 2010).

4.1. Limitations and strengths

This study has certain limitations that merit discussion. First, as with most longitudinal studies, there was incomplete data. Multiple imputation was conducted to minimize attrition bias. Second, participation in leisure-time physical activity was reported by mothers and academic performance was measured through teacher-reported and self-reported indicators. Although physical activity was not directly assessed nor was academic performance measured by standardized tests, data was obtained from multiple sources (mothers, children, and teachers). Third, control of baseline levels of academic performance was not implemented. However, the design did adjust for pre-existing cognitive skills, temperament, maternal education, and family configuration, which account for a large component of variance in baseline academic performance. Fourth, the present study focused on leisure-time physical activity. Therefore, the time spent by children being physically active during school time was not considered. Finally, participation in leisure-time physical activity was a naturally occurring phenomenon where children, or their parents, chose to participate or not. Thus, given the nonexperimental nature of the design, causal links with academic outcomes cannot be inferred.

Despite these limitations, this is, to our knowledge, the first study to longitudinally examine associations between leisure-time physical activity and academic performance over several years (from kindergarten to the end of sixth grade). The use of a prospective design with birth cohort data represents a major strength. Controlling for individual and family confounding variables allowed us to discount competing explanations and thus estimate the unique contribution of participating in leisure-time physical activity prior to formal school entry on academic outcomes prior to the middle school transition. Higher participation was positively associated with the academic outcomes, and even if the effects found were small, they remain important considering the long-term implications of academic success.

5. Conclusions

Our findings indicate that children who participate in leisure-time physical activity during kindergarten show better academic performance at the end of sixth grade, compared to those who do not engage in these active endeavors. Active girls and boys performed better in

school than their less active counterparts. Promoting leisure-time physical activity may therefore be an effective way to enhance academic success, leading to long-term wider benefits. In addition, the promotion of leisure-time physical activity can encourage children to be more active. This may prevent them from later leading a sedentary lifestyle and its multiple associated health risks that could ultimately affect their life course (Kohl et al., 2012). Childhood participation in leisure-time physical activity could ultimately benefit society by reducing disparities in health and education (Ruglis and Freudenberg, 2010; Pagani and Fitzpatrick, 2014).

Conflict of interest statement

The authors declare that there are no conflicts of interest. The authors have no competing interests.

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Contributor's statement

The first author contributed to the overall conception and design, data analytic strategy, interpretation of data, and the production of the multiple drafts of the manuscript. The second and third authors contributed to the concept and design of the study, the data analytic strategy, the secondary analyses and their interpretation, and the critical revisions of the different drafts for important intellectual content. All authors provided final approval of the version submitted for publication.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.yjmed.2018.10.017>.

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