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Article

Examining individual, interpersonal, and environmental influences on children's physical activity levels

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ABSTRACT

The purpose of this study was to explore individual-level socio-demographic factors and interpersonal-level factors related to social support, as well as the potential role of neighborhood and school environments that may influence the physical activity (PA) levels of children (ages 9–11). Child and parent questionnaires included individual and interpersonal factors, and PA behaviour. Home postal codes were used to determine the neighbourhood the child resides within, as well as their geographic accessibility to recreation opportunities. The models were assessed using a series of cross-classified random-intercept multi-level regression models as children's PA may be affected by both the school they attend and the neighbourhood in which they live. In the unadjusted model, PA varied significantly across school environments (γ = 0.023; CI: 0.003–0.043), but not across neighbourhoods (γ = 0.007; CI: -0.008 to 0.021). Boys were found to be more active compared to girls (b = 0.183; CI: 0.092–0.275), while the level of PA was lower for children whose fathers achieved post-secondary education (b = - 0.197; CI: -0.376 to 0.018) than for those whose parents completed only high school. The addition of the individual-level correlates did not have a substantial effect on level 2 variances and the level 2 variance associated with school environment remained statistically significant. At the interpersonal level, children's perception of parental support (b = 0.117; CI: 0.091–0.143) and peer support (b = 0.111; CI: 0.079–0.142) were positively related to PA. The level 2 variance for the school environment became statistically non-significant when the interpersonal factors were added to the model. At the environmental level, geographic accessibility did not have a significant association with PA and they did not significantly affect level 1 or 2 variance. As many children do not accrue sufficient levels of PA, identifying modifiable determinants is necessary to develop effective strategies to increase PA.

1. Introduction

Physical activity (PA) is an integral component of health and well-being (Janssen & LeBlanc, 2010), yet many children do not accrue sufficient levels of activity. Results from the 2012 to 2013 Canadian Health Measures Survey revealed that the majority (91%) of children and youth (ages 5–17 years) did not meet Canada's recommended guideline of 60 minutes of moderate-to-vigorous PA (MVPA) daily (Statistics Canada, 2015). The high rate of inactivity is not unique to Canada, with four-fifths of adolescents (ages 13–15) worldwide not reaching public health guidelines for recommended levels of PA (Hallal et al., 2012). Given that PA habits developed at a young age tend to persist into adulthood, it is essential to establish active lifestyles early (Telama et al., 2014).

The determinants of PA are complex and wide-ranging (Biddle, Atkin, Cavill & Foster, 2011; Sallis, Prochaska & Taylor, 2000). Socio-ecological models propose that these factors may be at an individual (e.g., age, sex, ethnicity, and socio-economic status [SES]),

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interpersonal (e.g., parental and peer support), or environmental level (e.g., neighbourhood and school characteristics) (Biddle et al., 2011; Sallis et al., 2000).

Several individual-level factors have been associated with PA among children and youth. Declines in PA levels with age are particularly notable in the literature, with decreases more apparent among females than males, especially during adolescence (Biddle et al., 2011; Colley et al., 2011; Sallis et al., 2000). Within Canada, boys tend to be more active than girls (Breslin et al., 2012; Colley et al., 2011; Koezuka et al., 2006); however, other studies have not found the same trend (Tucker et al., 2009). There are also growing disparities amongst subgroups of children, as certain ethnic groups and recent immigrants participate in less PA (Singh, Yu, Siahpush & Kogan, 2008; Tremblay, Bryan, Perez, Ardern, & Katzmarzyk, 2006). One Canadian study found only 32% of new immigrants participate in organized PA once a week compared to 55% for non-immigrants (Cragg, Cameron, Craig, & Russell, 1999). In a large sample of children in the United States (n = 68,288, ages 6–17), immigrant children were more likely to be inactive and participated in less sports than children born in the United States (Singh et al., 2008). The relationship between SES and PA among children and youth has been inconclusive (Sallis et al., 2000), yet SES indicators such as parental income and education have been found to be strongly related to participation in structured PA (i.e., those activities that are planned, including organized sports or physical education classes) (Estabrooks, Lee, & Gyurcsik, 2003; Lasheras, Aznar, Merion, & Lopez, 2001; Tandon et al., 2012).

In addition, interpersonal-level or social factors have been known to influence PA behaviour. Several studies suggest that support from parents is positively associated with children's PA (Beets, Vogel, Forlaw, Pitetti, & Cardinal, 2006; Biddle et al., 2011; Duncan, Duncan, & Strycker, 2005). Parental support for PA often comprises actions, such as providing encouragement, providing transportation to PA opportunities, watching children participate in activities, and actively engaging with children in activity (Beets et al., 2006; Duncan et al., 2005; Trost & Loprinzi, 2011). Furthermore, through modeling, parents' PA behaviours may also influence children's PA, although evidence of this relationship has not been consistent (Biddle et al., 2011; Trost & Loprinzi, 2011). In addition to support from parents, children who have supportive friends and peers have also been found to be more physically active (Fitzgerald, Fitzgerald, & Aherne, 2012), whereas those who experience negative peer interactions may become less physically active (Beets et al., 2006; Salvy, Haye, Bowker, & Hermans, 2012; Salvy et al., 2009).

In recent years, there has been a growing interest in the effects of physical environmental factors on PA among children (Ding, Sallis, Kerr, Lee, & Rosenberg, 2011; Tucker et al., 2009). Efforts to understand the influence of environmental factors have concentrated on the relationship between PA and the proximity and accessibility of recreational opportunities within a child's neighbourhood as these may permit or limit children from being active. Researchers have found that access to recreational facilities, parks, and playgrounds is related to higher levels of PA (Davison & Lawson, 2006; Ding et al., 2011; Estabrooks et al., 2003; Sallis et al., 2000; Slater et al., 2010; Tucker et al., 2009). In a recent study conducted in London, Canada, researchers found that children (aged 9–14, n = 435) from neighbourhoods with greater access to parks with sports fields and multi-use path space had significantly higher levels of MVPA when controlling for individual and neighbourhood socio-demographic factors (Mitchell, Clark, & Gilliland, 2016). Other neighbourhood environmental correlates of PA identified among children have included traffic speed/volume, mixed land use, residential density, walkability (Ding et al., 2011), and SES (Crawford et al., 2008). Previous research has also suggested that within-community differences in how individuals interact with the physical environment play an important role, as not all residents of the same neighbourhood have equal PA opportunities (Giles-Corti & Donovan, 2002; Slater et al., 2010).

Additionally, a number of studies have examined the variation in PA across school physical environments (Faulkner, Zeglen, Leatherdale, Manske, & Stone, 2014; Leatherdale, Manske, Faulkner, Arbour, & Bredin, 2010), and different school characteristics have been examined, such as availability of equipment, activity structures in school play areas, school size, facilities, number of teachers, programs, and policies related to PA (Davison & Lawson, 2006; Morton, Atkin, Corder, Suhrcke, & van Sluijs, 2016; Naiman, Leatherdale, Gotay, & Masse, 2015). However, findings on the influence of school environmental factors on PA have been mixed (Czerwinski, Finne, Kolip, & Bucksch, 2015; Gomes, dos Santos, Zhu, Eisenmann, & Maia, 2014; Naiman et al., 2015; van Sluijs et al., 2011); with some indicating that individual-level factors may be more influential on PA (Czerwinski et al., 2015; Pereira et al., 2016).

Thus, it is evident that PA behaviours among children may not only depend on individual factors but also on interpersonal factors. There is also some limited evidence that children's PA may be affected by the physical environments in which these behaviours take place, specifically, by neighbourhood and school environments. However, due to inconsistent results, further examination of potential variation in PA across neighbourhood and school environments is warranted. Thus, the purpose of this study was to explore the role of individual and interpersonal level factors, as well as the potential role of neighborhood and school environments that may influence the PA levels of grade 5 children (ages 9–11 years) in London, Canada. A better understanding of the effects of these factors may improve the design and characteristics of PA interventions, to reverse declining PA levels, and consequently improve the overall health of Canadian children.

2. Methods

2.1. Study design and research protocol

The data for this study were derived from the Grade 5 ACT-i-Pass (G5AP) community-based PA intervention conducted in London during the 2014–15 school year. The G5AP offered all grade 5 children who attend one of 99 London schools (i.e., 93 English-speaking, 5 French-speaking, and 1 private school) free access to various PA facilities (e.g., Boys & Girls Club, YMCA, pools, arenas) and programs (e.g., basketball, dance, floor hockey) for an entire school year. A full description of the longitudinal G5AP intervention evaluation study design can be found elsewhere; the present study uses only baseline data (Gilliland et al., 2015). Ethical approval for this study was obtained from the University's Non-Medical Research Ethics Board and the participating local school boards (2 English and 2 French boards).

2.1.1. Recruitment and participation rates

In May 2014, all 3677 children in grade 4 from elementary schools within London (n = 99) were invited to participate in the G5AP intervention. Over the next 12 months, these children had the opportunity to register for the intervention and use the recreational facilities and programs for free. In total, 1709 eligible children registered for the G5AP, for a recruitment rate of 46.5%, and were asked to participate in a baseline survey. In total, 1440 parents and 957 children completed the baseline survey for the response rates of 84.3% and 56.0%, respectively. Several significant differences were found related to the uptake of the G5AP intervention (Wilk et al., 2017). Those in neighbourhoods with higher average income and a higher proportion of recent immigrants and those who were actively recruited (i.e., by interactive school presentations) were significantly more likely to register than those who were passively recruited (i.e., given a brochure).

We used the following inclusion criteria to reach our final sample for this study: (1) child enrolled in the program by October 2014; (2) consent was provided to participate in the research study; (3) child lived in London; and (4) home location (postal code) was available in the data. After applying the inclusion criteria, the final sample available

to the analysis consisted of 1517 records, including 940 responses from children and 1419 responses from parents.

2.2. Data collection tools

2.2.1. Child questionnaire

The child questionnaire was developed using previously validated tools for an earlier project (Human Environments Analysis Laboratory, 2017; Mitchell et al., 2016), and has since been used successfully with over 1700 children in grades 4–8. The survey elicited information on socio-demographics, PA levels, and perceived parental and peer support.

2.2.2. Parent questionnaire

The parent questionnaire was developed and well-tested with parents participating in our previous studies (Mitchell et al., 2016), and it captured additional information about household characteristics such as postal code, parental education level, current employment status, and household income. The questionnaire also assessed parental influences on their child's PA and asked questions pertaining to parental support.

2.3. Measurement instruments

2.3.1. Outcome: child physical activity levels

The child survey elicited self-reported PA data using questions derived from the Physical Activity Questionnaire for Children (PAQ-C) (Kowalski, Crocker, & Faulkner, 1997). The PAQ-C is a self-administered 7-day recall questionnaire scientifically-validated for children 8–14 years of age. Although the PAQ-C is not able to provide estimates regarding the frequency, time, and intensity of PA, it does have a strong validity for reliably measuring general levels of PA in elementary school-aged children (Crocker, Bailey, Faulkner, Kowalski, & McGrath, 1997; Janz, Lutuchy, Wenthe, & Levy, 2008). The PAQ-C includes 9-items and asks individuals to rate how much PA they have done over the past week (Kowalski et al., 1997). These items include ratings based on a child's physical activity behaviours during different times throughout the day (i.e., gym class, recess, lunch recess, after school and before supper, after supper, weekend), frequency of physical activity over the previous week, and the frequency in which they participate in various activities over the previous 7 days (e.g., hockey, soccer, dance, skipping). The overall PAQ-C score was determined by averaging the child's responses to each of the 9 items, resulting in a continuous score between 0 and 4; a higher score indicates a higher PA level.

2.3.2. Individual-level factors

The following individual-level socio-demographic characteristics were used: sex (male versus female); immigration status (born in Canada or immigrated to Canada > 5 years ago versus immigrated to Canada ≤ 5 years); ethnic identity (white versus non-white); mother and father's level of educational attainment (i.e., high school or less, collage/university degree, postgraduate education); mother and father's work status (employed [full-time or part-time] versus other); household income (a 15-point scale ranging from [0] '< $20,000' to [15] '≥ $150,000'); and family structure (lone parent versus two-parent family). Information on child's sex was obtained from the child questionnaire, while data on immigration status and ethnic identity came from parent and child questionnaires; all other individual-level socio-demographic variables were derived from parent questionnaire.

2.3.3. Interpersonal/social factors

Two types of parental social support for PA were assessed via the parent questionnaire: parental level of PA (i.e., role modeling) and parental support (i.e., encouraging children to be physically active, providing transportation, watching children participate in PA, and being active with children) for PA. Specifically, parental PA levels were assessed using the short version of the International Physical Activity Questionnaire (IPAQ), which is an acceptable measurement of physical activity on a continuous scale (Craig et al., 2003). Previous evaluations of the IPAQ from 14 studies found good test-retest reliability and when compared against accelerometer data, there was fair to moderate agreement between the two measures (Craig et al., 2003). The IPAQ provides information on the amount of time parents spent walking and in moderate to vigorous intensity PA during the last week. Responses to the IPAQ were scored and normalized as per the scoring protocol (International Physical Activity Questionnaires Group, 2005). For this study, the total score for PA was used, which accounts for the duration and frequency of walking, moderate-intensity, and vigorous-intensity activities over 7 days. An overall score for each respondent ranging from 0 to 720 min of PA per week was computed and this value was transformed into a scale of hours per week, which ranged from 0 to 12.

A measure of parental support for PA was derived from a series of questions pertaining to four dimensions that have been previously associated with children's PA: 1) encouraging children to be physically active, 2) providing transportation to places to do physical activities or sports, 3) watching children participate in PA, and 4) being active with children (Prochaska, Sallis, & Long, 2001; Trost et al., 2003). The questions were phrased to elicit responses about how often during a typical week parents engage in one of the above four activities (i.e., "During a typical week, how often have you encouraged your child to do physical activities or play sports?"), and they were captured on a 5-point Likert scale: (0) None, (1) Once, (2) Sometimes, (3) Almost Daily, and (4) Daily. A corresponding set of four questions on the child questionnaire assessed child's perception of parental support for PA. These questions pertain to the same four dimensions of parental support that were on the parent questionnaire (i.e., "During a typical week, how often has a member of your family watched you participate in PA or play sports?"). However, the responses on the child questionnaire were captured on a 7-point scale to make them more interpretable: (0) Never, (1.5) 1–2 days, (3.5) 3–4 days, (5.5) 5–6 days, and (7) Daily. The responses from each parent and each child for the four questions were averaged and converted into two continuous scales measuring parental support for PA and child's perception of parent support (Dowda et al., 2011).

Finally, a measure of peer support for PA was derived from a combination of four questions on the child questionnaire which focused on the presence of encouragement from friends, PA behaviour of friends, teasing, and praise (i.e., "During a typical week, how often do your friends tell you that you are doing well in physical activities or sports?"). Responses to these questions were captured on a 7-point scale: (0) Never, (1.5) 1–2 days, (3.5) 3–4 days, (5.5) 5–6 days, (7) Daily and were averaged to produce a continuous peer support score.

2.3.4. School and neighbourhood environments

School environments were defined as the school that each child attended at the time of recruitment. Neighbourhood environments were defined as the census tracts (CT) in which home postal codes are located (Estabrooks et al., 2003; Janssen & Rosu, 2015; Larsen & Gilliland, 2008). In Canadian urban cities, CTs are small and relatively stable geographic areas with a population size between 340 and 10,950 persons and are reasonable proxies for 'neighbourhoods'.

In addition to taking into account how children are distributed across CTs, we used three measures of geographic accessibility (i.e., the proximity of places/opportunities to be active) to measure the effect of specific neighbourhood environmental factors: 1) distance to the nearest recreational facility; 2) distance to the nearest school playground; and 3) distance to the nearest park. These proximity factors were measured objectively in GIS (ArcGIS 10.1) as the shortest distance (along the street network) between child's home postal code and the nearest site in each of the three categories. The environmental data on recreational facilities, school playgrounds, and parks were supplied by

the Planning Division of the City of London. No specific measures of school physical environments were used in this study.

2.3.5. Control variables

Considering that two different recruitment methods were employed to invite children to register for the G5AP intervention, we developed a binary variable indicating whether children were (1) actively recruited through a classroom presentation or (0) passively recruited through a letter and brochure distributed through their school. To adjust for differences in child age related to the extended recruitment and data collection period (May-October, 2014), we used child age in years (9, 10, and 11) as a second control variable.

2.4. Data analysis

Frequency distributions for categorical variables and descriptive statistics for continuous variables were computed, as well as statistics assessing distributional assumptions and multicollinearity. Considering that one of the objectives of this study was to assess across-neighbourhood and across-school variability in children's PA, we ran a series of cross-classified random-intercept multi-level regression models.

Cross-classified models are becoming increasingly used in social research and provide a way to study phenomenon that can be influenced by classification in multiple environments. As children's behaviours may be affected by both the school they attend and the neighbourhood in which they live, multi-level cross-classified models provide a way to analyze data that are not purely hierarchical (Goldstein, 1994). Modeling the classifications of communities that individuals belong to enables researchers to gain valuable insight into the influence and contribution of each of these environments (Goldstein, 1994).

These models can produce estimates of the effects of factors measured at individual and interpersonal levels as fixed effects (level 1), while the overall effects of school and neighbourhood environments are estimated as random effects (level 2). It is expected that these two environments have an independent effect on children's PA since schools and home CTs are not nested within one another; not all children residing in a given CT attend the same school nor do all students attending a given school reside in the same CT.

To assess the effect of the selected correlates on PA, we specified a series of hierarchical models using a step entry of individual-, interpersonal-, and environmental-level variables. First, a null (empty) model was run to estimate the overall variability in PA within and between school and neighbourhood environments by calculating the intra-class correlation coefficients (ICCs). Then, the first block of variables entered in the null model consisted of individual-level factors (i.e., sex, immigrant status, ethnic identity, mother's educational attainment, father's educational attainment, mother's work status, father's work status, household income, and household structure) [Model 1]. The second block consisted of interpersonal-level variables (i.e., parental support for PA, parental PA levels, and child's perception of parental and peer support for PA) [Model 2]. The third block contained variables measuring geographic accessibility, measured at an individual level (i.e., distance to closest recreation facility, school playground, and park) [Model 3].

Proportional reductions in within- and between-group variability were computed to assess the magnitude of the effects of the correlates of PA at each level. Household income, parental PA levels, parental support for PA, child's perception of parental and peer support for PA, and the three measures of geographic accessibility were represented in the statistical models as continuous variables while all other correlates were entered as categorical variables. In all models, we controlled for method of recruitment and child age. For the continuous variables, we tested for both linear and quadratic effects; however, none of the quadratic effects were found to be statistically significant. Statistical significance of all estimates was assessed at the $p = 0.05$ level. SAS 9.4 was used for all analyses (SAS Institute Inc., 2016).

2.4.1. Post-stratification non-response weights

Although our survey had a relatively high overall participation rate of 41.26% for a voluntary survey, non-response is still one of the most significant threats to the validity of the statistical estimates. To address this potential bias explicitly, we computed post-stratification non-response weights by taking advantage of the available information on the distribution of all grade 5 children in the target population across 539 dissemination areas (DAs) in London. DAs are roughly uniform in terms of population size, typically consisting of a population of approximately 400 to 700 persons and their boundaries follow roads or other physical borders. To estimate these weights, we divided the total counts of children in each DA by the number of children represented in the sample. For instance, the estimated weight for 5 recruited children from a DA with a total number of 10 children in grade 5 was estimated to be 2. These weights brought the sample distribution closer into line with the population of grade 5 children across the 452 DAs that are represented in the sample. However, they did not account for the non-response from children residing in the remaining 114 DAs that are not represented in sample as none of the children or their parents from these DAs participated in the survey; some of these DAs may have no children in grade 5 or be unpopulated due to non-residential land uses. The non-response weights ranged in values from 1 to 8 and we replaced 5.75% of weights above 4 with the value of 4. The non-response weights were standardized (rescaled) to ensure that the sample size is equal to 1517 and were used in all analysis to account for differential participation probabilities across DAs.

2.4.2. Treatment of missing data

The outcome variable and most of the correlates of PA had a substantial percentage of missing values (see Table 1). We assumed that the missing data patterns for variables measuring child's sex, age, and family structure were non-ignorable and created separate categories for missing values. To address the problem of missing data for all other variables, we conducted 100 imputations. The imputation model consisted of all variables that were used in the analysis as well as 14 auxiliary variables, all measured at the DA level: proportion of population under 19, lone parent families, recent immigrants, visible minorities, individuals not speaking one of the official languages, residents with less than high school education, movers in the last five years, private dwellings assessed to be not suitable, income from government transfers, movers in the last five years, private dwellings assessed to be not suitable, subsidized housing; average age, household income, number of rooms per dwelling, value of a dwelling; and unemployment rate. Inclusion of auxiliary variables in the imputation model is recommended when a substantial proportion of data is missing and when imputing missing values for the dependent variable (Enders, 2010). We used SAS's proc mi and proc mianalyze procedures (SAS Institute Inc., 2016) with the fully conditional method (FCS) which relies on different conditional distributions for each class of imputed variables. We specified discriminant function for all categorical variables, predictive mean matching for household income, and linear regression for all other continuous variable. Considering that a relatively large proportion of participants had missing data and uncertainty related to multiple imputation procedures, we conducted a sensitivity analysis by re-running all the models with only the data from 940 children who responded to the child questionnaire. The results of this analysis are contained in Supplementary Table 2.

3. Results

3.1. Descriptive statistics

Table 1 presents the weighted descriptive statistics for continuous variables and frequency distributions for categorical variables included in the analysis.

A total of 1517 children or their parents provided baseline data for

Table 1
Descriptive statistics of the sample (N = 1517).

Variable	Category	Mean/Frequency	SD/Percent	Missing (n)	Missing (%)
Child's PA (PAQ-C)		2.32	0.72	581	38.30%
Perceived Parental Support		3.69	1.95	604	39.82%
Perceived Peer Support		4.47	1.57	597	39.35%
Parent's PA (IPAQ)		2.91	2.31	204	13.45%
Parental Support		2.37	0.79	176	11.60%
Distance to Rec Facility		1.93	0.98	0	0.00%
Distance to School		0.97	0.66	0	0.00%
Distance to Park		0.71	0.48	0	0.00%
Household Income		6.18	4.81	483	31.84%
Child's Sex	Girls	456	49.86	602	39.70%
	Boys	459	50.14		
White	No	1052	70.42	23	1.53%
	Yes	442	29.58		
Recent Immigrant	No	1377	93.81	49	3.21%
	Yes	91	6.19		
Mother's Education	High school or less	261	18.73	125	8.22%
	College/university	931	66.86		
	Graduate school	201	14.41		
Father's Education	High school or less	347	26.28	196	12.91%
	College/university	774	58.61		
	Graduate school	200	15.11		
Mother's Employment	Employed	971	72.07	169	11.15%
	Other	377	27.93		
Father's Employment	Employed	1120	89.76	269	17.71%
	Other	128	10.24		
Single Parent	No	756	82.59	602	39.66%
	Yes	159	17.41		
Recruitment Method	Passive	622	40.99	0	0.00%
	Active	895	59.01		
Child's Age	9	258	28.29	604	39.79%
	10	600	65.74		
	11	54	5.96		

the G5AP intervention study attending 99 schools in London, and the average number of children per school was 15.95. We collected data from 83, out of 110 CTs in London, with the average of 18.28 children per CT (neighbourhood). The sample distribution ranged from 1 to 65 and from 1 to 48 children per school and per neighbourhood, respectively.

For children with available data points, the average value for the PAQ-C scale, the outcome variable, was 2.32 (SD = 0.72), measured on the 5-point scale from 0 to 4. In terms of the individual level correlates of PA, 50.1% of children were boys, the majority was either born in Canada or immigrated to Canada more than 5 years ago (93.8%), and identified themselves as white (70.4%). Most of the mothers (81.3%) and fathers (73.7%) had at least college or university education and most mothers (72.1%) and fathers (89.8%) worked full- or part-time. As many as 17.4% of children reported living in a single parent family. The average IPAQ score for parents was 2.91 out of 12 (SD = 2.31) and their average level of parental support was 2.37 out of 4 (SD = 0.79). Child's perception of parental support for PA (M = 3.69; SD = 1.95) was, on average, lower than the level of peer support for PA (M = 4.47; SD = 1.57). The average distance to the closest recreation facility was 1.93 km (SD = 0.98), while the average distances to school playgrounds (M = 0.97 km; SD = 0.66) and parks (M = 0.71 km; SD = 0.48) were shorter. Supplementary Table 1 contains the comparable statistics for a sample of 940 children who responded to the child questionnaire.

3.2. Multilevel cross-classified models

Table 2 shows fix effects from the cross-classified multilevel model assessing the relationship between child's PA and individual (Model 1), interpersonal (Model 2), and environmental (Model 3) level correlates while Table 3 shows the random effects (level 1 and level 2 variances).

3.2.1. Null model

The estimates for the variances from the null model indicate that the level of PA among children in grade 5 varies significantly across school environment (γ = 0.023; 95% CI 0.003–0.043) but not across neighbourhood environment (γ = 0.007; 95% CI -0.008 to 0.021), while most of the variation in PA can be attributed to individual level (ε = 0.476; 95% CI 0.411–0.542). These estimates correspond to an ICC of 0.046 for school environment and an ICC of 0.013 for neighbourhood environment, indicating that school and neighbourhood environments account for 4.6% and 1.3% of the total variance in PA, respectively.

3.2.2. Role of individual-level factors

Model 1 contains all socio-demographic factors: sex, immigration status, ethnic identity, parental educational attainment and work status, household income, and family structure. As indicated in Table 2 (Model 1), only estimates related child's sex (b = 0.183; 95% CI 0.092–0.275) and father's level of educational attainment (b = -0.197; 95% CI -0.376 to 0.018) were statistically significant, controlling for the effects of other correlates. Socio-demographic correlates accounted for 2.3% of the level 1 variance observed in the Null Model by reducing of the within-group variance from 0.476 to 0.465. The addition of these correlates to the model did not have a substantial effect on level 2 variances.

3.2.3. Role of interpersonal factors

In Model 2, we added the four correlates measuring various aspects of social support: parental level of PA, parental support for PA, and child's perception of parental and peer support for PA. Only child's perception of parental support and peer support were statistically significant and, as expected, had positive effects on children's PA. Specifically, a one unit increase in the scores for parental and peer support, both measured on a 7-point scale, was estimated to increase PA level by 0.117 and 0.111 units on a 4-point scale. The previously

Table 2
Fixed effects of fix effects from the multilevel model assessing the relationship between child's PA and individual (Model 1), interpersonal (Model 2), and environmental (Model 3) level correlates (N = 1517).

Fixed effects	Category	Model 1				Model 2				Model 3			
		Est	SE	L-CI	U-CI	Est	SE	L-CI	U-CI	Est	SE	L-CI	U-CI
Intercept		2.157	0.114	1.933	2.381	1.187	0.139	0.913	1.460	1.137	0.144	0.854	1.420
Child's Sex	Girls	0.000				0.000				0.000			
	Boys	0.183	0.047	0.092	0.275*	0.150	0.041	0.069	0.231*	0.151	0.041	0.070	0.232*
	Missing	-0.154	0.328	-0.798	0.489	0.008	0.296	-0.572	0.588	0.016	0.296	-0.565	0.596
Recent Immigrant	No	0.000				0.000				0.000			
	Yes	-0.122	0.114	-0.347	0.102	-0.127	0.102	-0.327	0.073	-0.126	0.101	-0.325	0.074
Visible Minority	No	0.000				0.000				0.000			
	Yes	-0.098	0.060	-0.216	0.019	-0.083	0.054	-0.189	0.022	-0.085	0.054	-0.191	0.020
Mother's Education	High school or less	0.000				0.000				0.000			
	College/university	0.076	0.071	-0.064	0.215	0.032	0.064	-0.093	0.158	0.030	0.064	-0.095	0.156
	Graduate school	0.024	0.102	-0.176	0.224	0.031	0.090	-0.146	0.209	0.024	0.090	-0.153	0.201
Father's Education	High school or less	0.000				0.000				0.000			
	College/university	-0.074	0.064	-0.201	0.052	-0.067	0.057	-0.178	0.045	-0.064	0.056	-0.175	0.047
	Graduate school	-0.197	0.091	-0.376	-0.018*	-0.182	0.082	-0.344	-0.020*	-0.178	0.082	-0.340	-0.017*
Mother's Employment	Other	0.000				0.000				0.000	.		
	Employed	0.073	0.060	-0.045	0.192	0.057	0.055	-0.051	0.164	0.052	0.055	-0.056	0.160
Father's Employment	Other	0.000				0.000				0.000			
	Employed	-0.019	0.093	-0.201	0.163	-0.049	0.082	-0.210	0.112	-0.048	0.082	-0.209	0.113
Household Income		0.000	0.008	-0.016	0.016	-0.004	0.007	-0.018	0.010	-0.006	0.007	-0.021	0.008
Single Parent	No	0.000				0.000				0.000			
	Yes	-0.057	0.068	-0.191	0.076	-0.078	0.061	-0.197	0.041	-0.082	0.060	-0.200	0.037
	Missing	-0.205	0.338	-0.869	0.458	-0.293	0.300	-0.882	0.296	-0.320	0.299	-0.907	0.267
Parental PA						-0.007	0.011	-0.028	0.014	-0.006	0.011	-0.027	0.015
Parental Support						0.054	0.029	-0.003	0.111	0.052	0.029	-0.005	0.109
Perceived Parental Support						0.117	0.013	0.091	0.143*	0.117	0.013	0.091	0.143*
Perceived Peer Support						0.111	0.016	0.079	0.142*	0.111	0.016	0.080	0.143*
Distance to Rec Facility										0.038	0.028	-0.016	0.092
Distance to school										0.042	0.039	-0.035	0.119
Distance to park										-0.071	0.049	-0.168	0.027

* Statistically significant at $p < 0.05$.

observed significant effects associated with child's sex and parental education remained statistically significant, although slightly attenuated.

The addition of interpersonal correlates to the model reduced the level 1 variance by 21.9%, compared to the previous model (from 0.465 to 0.364) suggesting that interpersonal factors account for a relatively large proportion of the within variance in the outcome variable. Similarly, the level 2 variance for the school environment was reduced by 48.7% from 0.023 to 0.012 and became statistically non-significant (95% CI -0.002 to 0.025). However, in the analysis involving the sample of 940 children, this result remained statistically significant (95% CI 0.004–0.042), suggesting that the main results of the analysis are sensitive to the pattern of missing data (see Supplementary Table 3). The statistically non-significant level 2 variance associated with neighbourhood environment was not affected by the addition of interpersonal factors.

3.2.4. Role of geographic access factors

In the final model (Model 3), we added a block of variables measuring geographic accessibility, including distance to: the closest recreational facility, school playground, and park. None of these effects were statistically significant and their presence in the model did not substantively affect the magnitude of the previously observed significant effects or the pattern of level 1 and level 2 variances.

4. Discussion

The present study assessed the influence of individual, interpersonal, and environmental factors on the PA levels of grade 5 children. Understanding how these factors impact PA is required to develop and implement appropriate programs that will help reverse the trend of increasing rates of inactivity among children and youth (Bauman et al., 2012). By using cross-classified multi-level techniques, we were also able to simultaneously estimate the impact of school and neighbourhood environments on PA as each of these two contexts may have characteristics that promote or hinder PA (see Fielding & Goldstein, 2006 for more detail about these techniques). Students were nested in both schools and neighbourhoods, as they do not always attend school in the same neighbourhood they reside. Moreover, only examining the role of one of these two environments as a source of variation in

Table 3
Random effects of multi-level models at individual, school, and neighbourhood levels (N = 1517).

Variances	Null Model				Model 1				Model 2				Model 3			
	Est	SE	L-CI	U-CI	Est	SE	L-CI	U-CI	Est	SE	L-CI	U-CI	Est	SE	L-CI	U-CI
Level 1	0.476	0.033	0.411	0.542*	0.465	0.034	0.399	0.532*	0.364	0.026	0.312	0.415*	0.361	0.026	0.311	0.412*
Level 2 - Schools	0.023	0.010	0.003	0.043*	0.023	0.010	0.002	0.043*	0.012	0.007	-0.002	0.025	0.011	0.007	-0.002	0.024
Level 2 - Neighbourhoods	0.007	0.008	-0.008	0.021	0.006	0.007	-0.008	0.020	0.007	0.006	-0.005	0.020	0.007	0.007	-0.006	0.020
ICC - Schools	0.046				0.046				0.030				0.029			
ICC - Neighbourhoods	0.013				0.012				0.019				0.019			

* Statistically significant at $p < 0.05$

children's PA may lend to an overreliance on the importance of that particular environment and inadequate control for potentially important and confounding effects of the omitted environment (Fielding & Goldstein, 2006). Results from cross-classified multi-level models may be useful in tailoring and designing interventions and programs aimed at improving the levels of PA among children.

In the current study, school and neighbourhood environments accounted for 4.6% and 1.3% of the total variance in PA, respectively; however, only the school-level variance was statistically significant in the unadjusted model. Previous research conducted in Ontario, Canada, indicated significant between-school variation, estimated at 3.0%, for time spent in MVPA among grade 9–11 students (n = 22,117) (Hobin et al., 2012). Slightly higher levels of variance were reported by Leatherdale et al. (2010) and Faulkner et al. (2014): school-level differences accounted for 4.8% of the variability for MVPA (Leatherdale et al., 2010), 7.3% of the variability in being highly active (Leatherdale et al., 2010), and 6.7% of the variability in time spent in light-to-vigorous activity (Faulkner et al., 2014). In line with our study, Prince et al. (2011) found no significant variability across neighbourhoods for level of PA, however this finding was among adults.

At the individual level, as in previous research (Biddle et al., 2011; Breslin et al., 2012; Colley et al., 2011; Hallal et al., 2012; Tucker, 2008), boys were found to be more active compared to girls. Biddle et al. (2011) suggest that the general terms in which PA is assessed may not highlight the variance in the types of activities which may have more apparent gender effects. Contrary to our expectations, and to previous research (O'Loughlin, Paradis, Kishchuck, Barnet, & Renaud, 1999), the level of PA was lower for children whose fathers achieved the highest level of educational attainment than for those whose fathers completed only high school. No statistically significant associations were observed between the other individual level correlates and PA. We used age only as a control variable to adjust for differences in child age related to the extended recruitment and data collection period; however, age has been consistently found to be a correlate of PA among children; with PA levels decreasing as children get older (Biddle et al., 2011; Craggs, Corder, van Sluijs, & Griffin, 2011; Sallis et al., 2000). Additionally, in line with findings from other studies (Biddle et al., 2011), the results from this study did not reveal any statistically significant association between ethnicity or immigration status and children's PA.

At the interpersonal level, children's perception of parental support and peer support were both positively related to PA. Alternatively, parental PA and parental support for PA were not significantly related to children's PA. It is a common assumption that children of active parents will be active themselves; however, findings from a systematic review suggest that effect of parental PA on children's level of PA is mixed (Biddle et al., 2011). Welk and colleagues did not find parental PA (role modeling) to be a major influence on children's (grade 3–6) PA (Welk, Wood, & Morss, 2003). This is possibly because the majority of children do not spend the entire day with their parents, and therefore direct modeling is infrequent; however, modeling from peers may be a more likely PA influence at this age. Furthermore, given the subjective assessment of both parent and child PA, it is possible that had objective measures of PA been adopted, such as accelerometry, a statistically significant relationship may have been observed. For example, a study by Fuemmeler, Anderson, & Masse (2011), using accelerometry on both the child (grades 4 and 5) and parents reported that greater parental MVPA was associated with increased child MVPA. As such, future research should consider utilizing objective measurements of parent-child PA (e.g., accelerometers) and better define the context of parental PA behaviour to gain a more thorough understanding of this relationship (Trost & Loprinzi, 2011).

Moreover, previous research has found parental support for PA to be a strong positive correlate of children's PA (Beets, Cardinal, & Alderman, 2010; Gustafson & Rhodes, 2006; Trost & Loprinzi, 2011; Yao & Rhodes, 2015). Although our study did not mirror these findings, we did find that children's perceptions of parental support were positively associated with PA. In a study of PA correlates in an American population, Heitzler and colleagues also found that children's (9–13 years old) perception of parental support were strongly related to participation in organized PA (Heitzler, Martin, Duke, & Huhman, 2006). Pugliese and Tinsley (2007) reported that children and adolescents were more likely to be inactive if they perceived that their parents did not provide support for PA.

Peer support has also been acknowledged as an important correlate of PA among children (Beets et al., 2006; Duncan et al., 2005). Duncan et al. found that perception of support from friends was associated with higher levels of PA among youth ages 10–14 years (Duncan et al., 2005). Moreover, among 5th to 8th grade students (ages 10–14 years old), Beets and colleagues found that the provision of support by peers was the only significant form of social support related to PA (Beets et al., 2006). Social support is an important factor to consider when examining children's PA, specifically children's perception of support may be more influential than parent reported support (Barr-Anderson, Robinson-O'Brien, Haines, Hannan, & Neumark-Sztainer, 2010). With the addition of interpersonal factors to the model, level 1 variance was reduced by 21.9% which indicates that these factors account for a substantial amount of variation in children's PA. Furthermore, level 2 variance across schools was reduced by 48.7%, suggesting that approximately half of the previously observed across school variance can be explained by compositional factors; that is, children attending different schools, on average, receive different levels of social support. The level 2 variance associated with neighbourhood environment was not affected by the addition of interpersonal factors to the model and was not statistically significant.

Lastly, at the neighbourhood level, we explored the role of geographic accessibility, specifically, distance to the closest: (1) recreational facility, (2) school playground, and (3) park. Contrary to the results from previous studies, we found no relationship between level of PA and these distance variables and their addition to the model did not affect the level 1 or 2 variances. Tucker et al. found positive associations between both subjective and objective assessments of proximity to and accessibility of parks, playgrounds, and recreation facilities and youths' (ages 12–14 years, n = 811) PA in London, Canada (Tucker et al., 2009). Reviews on the influence of the neighbourhood physical environment on children's (3–18 years old) PA also revealed a positive association between PA and access/proximity to recreation facilities (Davison & Lawson, 2006; Ding et al., 2011). It is not clear why our results contradict the above findings, given two of these studies were conducted in the same city as the present research, but confirms the need for future investigations using multilevel approaches to considering these factors.

4.1. Limitations

Despite the interesting and valuable findings, potential limitations need to be discussed. First, the cross-sectional design of this study is a limitation as no causal inferences can be made from the findings. Thus, the associations reported in this study should not be interpreted as such. Secondly, as in many other studies investigating human behaviours, the proposed theoretical and statistical models may exclude some factors that affect PA among children, resulting in mis-specification bias. While the present investigation explored factors at a variety of levels, in the future, it is recommended to test models with more comprehensive sets of factors as well as models exploring how these factors are correlated with each other (to assess their direct and indirect effects on PA).

Third, we only focused on the proximity of parks and recreational facilities, but the quality of these facilities was not included in our analyses. We know from previous investigations that composition and quality of parks and recreation facilities is important in determining whether people will or will not use facilities (Tucker, Gilliland, & Irwin, 2007). Future research should include variables pertaining to both

accessibility and quality of places to be active to obtain a better understanding of the facilitators and barriers related to PA. Additionally, although we objectively measured distance to recreational facilities, our measures are focused on opportunities, rather than true exposure to these facilities. We measured what opportunities were available around a participant's home, but not whether the participant accessed these facilities. To measure access would require more direct methods of observation, using additional tools such as GPS tracking (e.g., Mitchell et al., 2016). Moreover, the current study used CTs to define neighbourhoods as it has been previously used as a proxy in urban cities, however other definitions could lead to different results.

Fourth, given the self-report nature of this study, the accuracy of the reported PA levels, and other constructs used in this study, should be considered with caution as they are subject to error and reporting bias (LeBlanc & Janssen, 2010). For instance, although the PAQ-C is a previously-validated tool that has been well used in previous studies (Kowalski et al., 1997), direct measures of PA would be preferential. Nevertheless, considering the scale of this population-level study, direct measurement would not have been feasible.

Finally, it is expected that the post-stratification procedures and non-response weights computed in this study reduced potential self-selection bias. However, we acknowledge that the non-response weights cannot eliminate completely this bias and the reasons for survey non-participation are complex and often depend on various unobserved individual and contextual characteristics. Moreover, the post-stratification procedure adopted here assumed that individuals residing in DAs are homogenous and share similar characteristics. Although it is expected that children and their parents residing in a single DA are, on average, more similar to each other than children from other DAs, it would be incorrect to suggest that they are the same (Healy & Gilliland, 2012).

5. Conclusions

Despite the limitations, this study makes several important contributions. First, it is one of the first studies to examine an entire population of an age cohort in a mid-sized Canadian city. Also, we attempted to increase the generalizability of the results by assessing the relationship between the study population and the sample by incorporating non-response weights and treating explicitly the problem of missing data. Another strength of this study was the ability to assess multiple predictors of PA at different levels of the socio-ecological model; combining factors at individual, interpersonal, and environmental levels. Moreover, by conducting a multilevel cross-classified analysis we considered both across-school and across-neighbourhood variability in PA. To our knowledge, this is the first study that attempted to evaluate the effects of these two important environments simultaneously. Given the amount of time children spend in school and in their neighbourhoods, both environments are influential for children's behaviours. Furthermore, responses came from multiple sources of data (two questionnaires, census of population, and geographic information) potentially limiting the effect of common method variance often observed in studies based exclusively on survey data.

To improve the health of children, health promotion initiatives should be aimed at highlighting the benefits associated with being active and the importance of children's perceptions of parental and peer support. As parents are one of the primary providers of opportunities for children to be active and they exert considerable control over children's behaviours, it is critical that parents demonstrate support for PA to their children (Beets et al., 2010). In subsequent studies, it would be beneficial to investigate facilitators and barriers that parents with children encounter regarding providing support to be active. Furthermore, given that girls tend to be less active than boys, additional attention should be focused on increasing PA in this population. The study also showed the importance of the school environment for promoting children's PA; future research needs to identify the specific elements of school environments (e.g., PA equipment, programming, social factors) which encourage higher levels of PA. In general, the findings from this study support previous research on individual, interpersonal, and environmental correlates of PA. As many children do not accrue sufficient levels of PA (Colley et al., 2011), the study of determinants, especially those that are modifiable, is necessary to develop effective strategies to increase PA. It is important that the findings from studies examining these factors are then applied to improve behaviour change interventions.

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Ethical statement

Ethical approval for this study was obtained from the University of Western Ontario's Non-Medical Research Ethics Board (REB#10394), the four public school boards and one private school.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.ssmph.2017.11.004.

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