Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Healthy movement behaviours in children and youth during the COVID-19 pandemic: Exploring the role of the neighbourhood environment

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A B S T R A C T

This paper explores patterns of increased/ decreased physical activity, sedentary and sleep behaviours among Canadian children and youth aged 5-17 years during the COVID-19 pandemic, and examines how these changes are associated with the built environment near residential locations. A cluster analysis identified two groups who were primarily distinguished by the changes in outdoor activities. Compliance to 24-hour movement guidelines was low among both groups. For children, houses (versus apartments) was correlated with increased outdoor activities; proximity to major roads was a barrier. For youth, low dwelling density, and access to parks in high-density neighbourhoods, increased the odds of increased outdoor activities during the pandemic. Our findings can inform future urban and health crisis planning practices by providing new insights into the desirable public health messaging and characteristics of healthy and resilient communities.

1. Introduction

There is substantial evidence indicating the benefits of healthy movement behaviours during childhood. Recently released Canadian 24-h movement guidelines recommend that children and youth accumulate 60 min of moderate-to-vigorous physical activity (MVPA), several hours of unstructured and unrestricted light physical activity, low levels of sedentary behaviours (e.g., no more than 2 h of recreational screen time), and eight to 11 h of uninterrupted sleep depending on their age (Canadian Society for Exercise Physiology, 2020a; Tremblay et al., 2016). When children and youth adhere to these recommendations, there are notable physical and mental health benefits. More specifically, research indicates that active children and youth demonstrate enhanced cardiometabolic function, musculoskeletal health, cognitive function, and immune function, as well as reduced symptoms of depression and anxiety (Carson et al., 2016; Dale et al., 2019; Lasselin et al., 2016; Yogman et al., 2018).

However, a 2019 survey showed that only 15% of Canadian children were meeting the 24-h movement guidelines (ParticipACTION, 2020). Movement behaviours have been further impacted by the recent and ongoing coronavirus disease (COVID-19) crisis. On March 11, 2020, the World Health Organization (WHO) announced a global COVID-19 pandemic, due to the risks of acute respiratory disease posed by this novel virus (Xu et al., 2020; WHO, 2020). Given that the COVID-19 virus spreads primarily through respiratory droplets and contact routes (Xu et al., 2020), the outbreak led to policies and guidelines to implement physical distancing, which have significantly affected how children and youth spend their time outside their home. While specific recommendations vary between countries and regions, in most Western countries including Canada, the measures include maintaining physical distance from others by two or more metres (except those living in the same household), prohibiting social gatherings, cancelling team sports and

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related events, and closing playgrounds and parks (in some jurisdictions) (Govt. of Canada, 2020; The Canadian Urban Institute, 2020). Most public schools and school grounds were closed across the country in response to the pandemic and classroom lessons were replaced by homeschooling and online learning.

With the closure of common indoor and outdoor places for children and youth to engage in physical activity, such as schools, playgrounds, and recreational facilities, it is not surprising that a recent Canadian study found that on average less than 3% of children and youth were meeting the movement guidelines at the height of restrictions relating to the COVID-19 outbreak (Moore et al., 2020). While many opportunities for physical activity and outdoor play were restricted, there may be patterns in children and youths' participation in various healthy movement behaviours. It is possible that some children and youth have increased their participation in a combination of various healthy movement behaviours, while others may have become more sedentary overall, demonstrating increases in a combination of behaviours that do not involve physical activity.

The neighbourhood environment where children and youth spend most of their day influences the extent and variety of physically active and sedentary behaviours (Mitra et al., 2017). As such, it is also important to explore the environmental contexts within which healthy movement behaviours may thrive and thus can be considered more resilient to public health emergencies. During the COVID-19 pandemic restrictions, neighbourhood outdoor spaces such as back/front yards, sidewalks, quiet streets and local parks/trails (where use is allowed), are seemingly even more important places for children and youth to engage in physical activity throughout the day. Hypothetically, limited access to these built environment features (e.g., when living in an apartment building or in a dense living environment) could lead to a pronounced decline in children and youth's healthy movements.

This paper addresses these important research gaps using data from a national survey of healthy movement behaviours of Canadian children and youth aged 5–17 years during the pandemic. In this paper, we focus on the patterns of increased/decreased physical activity, sedentary and sleep behaviours, a topic that has yet to be examined in the emerging COVID-19 related literature. More specifically, two novel research questions are explored: 1) are there distinct patterns of increased or decreased healthy movement behaviours among children and youth during the COVID-19 pandemic? And 2) how are the changes in healthy movement behaviours associated with the built environment near residential locations of these children and youth? A systematic examination of the relationship between an increase/decrease in healthy movement behaviours and the neighbourhood built environment characteristics during the COVID-19 virus outbreak can inform future health crisis planning practices in important ways, while providing new insights into the desirable characteristics of healthy and resilient communities.

2. Current literature on patterns in children's daily movement

The existing literature on children's physical activity broadly conclude that large proportions of children and youth are spending their daily time being sedentary and are failing to meet the recommended levels of daily physical activity (Carson et al., 2017; Cooper et al., 2003; Copperman and Bhat, 2010; Gao et al., 2017; Goodman et al., 2011; Oliver et al., 2015; Raux et al., 2016; Raux et al., 2016, 2016; Stone et al., 2012). A smaller body of research has more directly examined patterns of daily activity and/or movement behaviours, sometimes referred to as the 'activity lifestyles' among children (Mitra et al., 2017; Nelson et al., 2005; Seghers and Rutten, 2010; Voulgaris et al., 2016). Conceptual works have suggested that a high level of physical activity in one part of the day may be compensated by other activities during the day that require relatively low physical activity engagements, and that individuals may demonstrate relatively stable physical activity levels over time due to this activity compensation (Gomershall et al., 2013; Goodman et al., 2011). While empirical research on this is limited, Voulgaris et al. (2016) reported that active school travellers spent less time exercising and engaging in structured extracurricular activities. Others have found higher screen use among children who reported higher levels of participation in organized sports (Nelson et al., 2005; Seghers and Rutten, 2010). In contrast, Mitra et al. (2017) rejected this activity compensation hypothesis, arguing that most children who are physically active in some parts of the day are likely to be active throughout the day and vice versa.

The social-ecological models of health behaviour emphasize the importance of the social and environmental contexts within which healthy behaviours may thrive (Mitra and Manaugh, 2020; Rhodes et al., 2019; Sallis et al., 2008). Using this theoretical approach, empirical research over the past two decades has explored how a child's socio-demographic characteristics, economic conditions and the neighbourhood built environment may relate to various healthy movement behaviours, including active transportation (walking/cycling) (Larouche et al., 2014; Mitra et al., 2016), independent mobility (Mitra et al., 2014; Riazi and Faulkner, 2019), outdoor play (Faulkner et al., 2015; Lambert et al., 2019) and sleep (Grander, 2019). A detailed discussion of this literature is beyond the scope of this study, but broadly, proximity to destinations (e.g., school, parks) and perception of child safety (e.g., traffic danger, stranger danger) are frequently reported as major barriers to a child or youth's outdoor physical activity participation (Waygood et al., 2020).

Previous research, although limited in its scope, has explored the socio-demographic correlates of a child's movement behaviour patterns or activity lifestyles, finding that boys have more active profiles than girls (Gorely et al., 2007; Seghers and Rutten, 2010; Voulgaris et al., 2016) and also that participation in organized activities and sports is more common among children from higher-income households (Nelson et al., 2005; Sener et al., 2011). Results relating to a child's age and household composition remain mixed, but Canadian children from non-Caucasian backgrounds were found to demonstrate low engagement in active play combined with high levels of reading and screen time (Mitra et al., 2017). Mitra et al. (2017) also found some associations between urban versus suburban locations and daily movement behaviour profiles among children in Toronto, Canada. But beyond these broad-level urban location-based explorations, the neighbourhood environment-related correlates of movement behaviour patterns remain understudied.

3. Data and methods

3.1. Movement behaviours survey

This study uses secondary data from a recent survey designed and conducted in April 2020 (i.e., one month after the announcement of the global pandemic and at the height of restrictions) by ParticipACTION. Adult household members/parents were surveyed to assess changes in children and youth movement behaviours during COVID-19. ParticipACTION (www.participaction.com) is a non-profit organization in Canada that promotes healthy living and fitness. Maru/Matchbox, a third-party market research company, was hired to conduct the survey on behalf of ParticipACTION. Maru/Matchbox has a panel of >120,000 Canadians available for surveys at any given time, who provide consent to participating in surveys when signing up as panel members. For this particular survey, ParticipACTION requested Maru/Marchbox to recruit 1500 families with children aged 5–17 years, representing Canadians in terms of their child's age, gender, ethnicity, geography, and socioeconomic status.

Email invites were sent to eligible panel members, who were stratified into two groups: families with a child aged 5–11 years (50%) or those with a youth aged 12–17 years (50%). Participants provided passive consent again by agreeing to complete this specific survey, and received small cash incentives ($0.50-$3 CDN) and prize opportunities as rewards for completing surveys. Households where a family member

had contracted COVID-19 or if the family was in self-isolation were excluded. The eligible participants were offered the opportunity to participate in an online survey in either English or French, which took 15 min to complete. Parents with more than one child were asked to respond for the child whose name came first alphabetically when completing the survey. The full recruitment details and survey protocol can be found elsewhere (Moore et al., 2020). Ethics approval for secondary data analysis was obtained from Ryerson University's Research Ethics Board (REB-2020-188).

The initial dataset included 1503 survey responses. Respondents with missing or implausible data were then excluded ($n = 31$), resulting in an analytical sample of 1472. Geographic representation of the sample is illustrated in Fig. 1.

3.2. Health behaviour measures

The survey collected parental and child demographic information. Parents were asked to self-report changes in their child's movement behaviours during the COVID-19 outbreak compared to before the COVID-19 outbreak. A total of 11 movement behaviours were considered: 1) walking or cycling, 2) physical activity or sport outside, 3) physical activity or sport inside, 4) household chores, 5) playing outside, 6) playing inside, 7) screen time, 8) social media use, 9) other non-screen-based sedentary activities (e.g. reading, puzzles), 10) sleep duration, and 11) sleep quality. Responses were reported using a 5-point Likert type scale, ranging from 'a lot less' (score = 1) to 'a lot more' (score = 5).

Parents also self-reported time spent on various movement behaviours. From this data, children and youth meeting the Canadian MVPA guidelines (i.e. ≥60 min of MVPA, at least six days of the week) were identified and expressed as a binary variable (Canadian Society for Exercise Physiology, 2020b). Compliance with the 24-h movement guidelines was identified based on 1) meeting the MVPA guidelines, 2) meeting the age-specific recommendations for sleep duration, and 3) ≤ 2 h of screen time (average between weekday and weekend assessments) (Canadian Society for Exercise Physiology, 2020).

3.3. Built environment measures

In the survey, participants reported their residential location using

Fig. 1. Residential locations of survey sample.

their six-digit postal code. Canadian postal codes represent small geographical areas with an average of 14 households per postal code. These locations were then approximated to the dissemination area (DA, the smallest geographical area for which Canadian census data are reported, constituting about 400–700 people), and the neighbourhood built environment, within a 1 km straight-line radius of DA centroids was characterized.

A total of seven built environment variables were considered. 1) Dwelling type (whether the household lives in a house versus an apartment) data was available from the online survey. 2) Access to parks (total number of parks, playgrounds and open recreational areas within 1 km; z-scores) was measured using the land use layer of the CanMap RouteLogistics 2014.2 dataset provided by DMTI Spatial Inc (2014). Other variables were 3) Dwelling density (density of dwelling units within 1 km; z-scores), 4) Intersection density (density of 3- or 4-way street intersections within 1 km; z-scores), 5) Points of interest density (density of non-residential destinations, businesses, and institutions within 1 km; z-scores), 6) Transit stop density (total number of transit stops within 1 km; z-score) and 7) Distance to major road (distance to the nearest collector road or highway; z-scores), which were obtained from the Canadian Urban Environmental Health Research Consortium (CANUE) (CANUE, 2018; CANUE, 2020; Ross et al., 2018, DMTI Spatial Inc, 2016; DMTI Spatial Inc, 2020a; DMTI Spatial Inc, 2020b).

Some postal codes from the survey data could not be mapped to the built environment dataset (n = 16), either due to incorrect information or currency issues (i.e., the postal codes in the CANUE built environment data were current to the year 2014). As a result, our final dataset for the multivariate analysis including the built environment characteristics consisted of $n = 1456$ observations.

3.4. Statistical analysis

Patterns in healthy movement behaviours were identified using a cluster analysis approach. A *k*-means cluster analysis was conducted to identify distinct groups of children and youth where those in the same 'cluster' demonstrated similar movement behaviours. We explored changes in the 11 movement behaviours from before to during the COVID-19 virus outbreak (i.e., 'a lot less' to 'a lot more') in order to identify these clusters, where every participant was allocated to a cluster based on minimum in-cluster sums of squares. The cluster analysis was conducted using two, three and four clusters. A two-cluster solution converged most rapidly and produced the most interpretable results, with a reasonable distribution of the sample between each cluster.

The socio-demographic differences between different clusters (or the groups of children and youth demonstrating similar changes in movement behaviours) were preliminarily tested using chi-square analysis. Finally, binomial logistic regression models were estimated to examine the correlates of cluster membership. The primary purpose of this multivariate analysis was to explore the relationship between neighbourhood built environment and patterns of healthy movement behaviours. Not surprisingly, several of these built environment variables were highly correlated with each other. To avoid multi-collinearity, in our multivariate analysis we only included the correlated variables (e.g., dwelling density and points of interest density) one at a time, and the variable that produced a greater improvement in the log likelihood of the model was kept. Following this process, our final multivariate models included four built environment variables: dwelling type, dwelling density, access to parks, and distance to major road. Statistically different socio-demographic characteristics (based on chi-square tests) were explored as control variables in our multivariate analysis. Model coefficients are also shown in terms of Odds Ratios ($OR = e^{\beta}$), which represent the odds of "success" (or membership to a cluster) in response to a one-unit change in an explanatory/independent variable.

4. Results: healthy movement behaviours among children and youth during the COVID-19 pandemic

Survey data, collected one month after the announcement of a global COVID-19 pandemic, was analyzed to explore changes in healthy movement behaviours among Canadian children and youth during the pandemic. The sample represented the Canadian population with regard to geography, ethnicity, and age distribution (a detailed description of the sample can be found in Moore et al., 2020). Most parents were college or university graduates (89%), worked full-time (70%) and lived in houses versus apartments (72%). Of the children and youth, 53% were aged between 5 and 11 years, the other 47% were 12–17 years old, and 53% of them were boys.

With regard to changes in children and youths' healthy movement behaviours during the COVID-19 pandemic, the majority reported a decrease in outdoor activities, including less walking or biking (53%), less outdoor physical activity and sport (64%), and less outdoor play (51%). In contrast, indoor play and screen time increased for the majority of children and youth (53% and 79% respectively) (Table 1). More youth than children experienced a decrease in physical activity-related

Table 1
Parent-reported changes in movement behaviours among Canadian children and youth during the COVID-19 pandemic (approximately one month after global pandemic announcement).

Change in healthy behaviour	All children and youth		Children (5–11 years)		Youth (12–17 years)	
	Frequency	%	Frequency	%	Frequency	%
Walk or bike						
Decrease	783	53.2	328	47.3	455	58.4
Same	388	26.3	173	25.0	215	27.6
Increase	301	20.5	192	27.7	109	14.0
Physical activity or sport outside						
Decrease	939	63.8	409	59.0	530	68.0
Same	327	22.2	157	22.7	170	21.8
Increase	206	14.0	127	18.3	79	10.1
Physical activity or sport inside						
Decrease	500	34.0	188	27.1	312	40.1
Same	596	40.5	289	41.7	307	39.4
Increase	376	25.5	216	31.2	160	20.5
Household chores						
Decrease	121	8.2	50	7.2	71	9.1
Same	793	53.9	369	53.2	424	54.4
Increase	558	37.9	274	39.5	284	36.5
Playing outside						
Decrease	754	51.2	329	47.5	425	54.6
Same	455	30.9	182	26.3	273	35.0
Increase	263	17.9	182	26.3	81	10.4
Playing inside						
Decrease	103	7.0	45	6.5	58	7.4
Same	588	39.9	225	32.5	363	46.6
Increase	781	53.1	423	61.0	358	46.0
Screen time						
Decrease	54	3.7	26	3.8	28	3.6
Same	259	17.5	127	18.3	132	16.9
Increase	1159	78.8	540	77.9	619	79.5
Social media use						
Decrease	77	5.3	48	6.9	29	3.7
Same	738	50.1	432	62.3	306	39.3
Increase	657	44.6	213	30.7	444	57.0
Other non-screen based sedentary activities						
Decrease	106	7.2	47	6.8	59	7.6
Same	650	44.2	246	35.5	404	51.9
Increase	716	48.6	400	57.7	316	40.6
Sleep duration						
Decrease	101	6.8	60	8.7	41	5.3
Same	762	51.8	445	64.2	317	40.7
Increase	609	41.4	188	27.1	421	54.0
Sleep quality						
Decrease	209	14.2	92	13.3	117	15.0
Same	1012	68.7	486	70.1	526	67.5
Increase	251	17.1	115	16.6	136	17.5

movements during the pandemic, including walking/biking, outdoor or indoor physical exercise and outdoor play. In contrast, higher use of social media and more non-screen based sedentary activities were reported for children, when compared to youth (Table 1).

4.1. Movement behaviour patterns

We first aimed to identify statistical patterns in which various healthy movement behaviours may have changed (i.e., increased, decreased, or stayed the same) during the COVID-19 pandemic. To this end, we explored changes in 11 different movement behaviours using a cluster analysis approach. The analysis identified two distinct groups of children and youth who demonstrated similar changes in various movement behaviours-cluster 1: children and youth with *Increased Outdoor Activities* ($n = 654$; 44% of all children and youth) and cluster 2: those with *Decreased Outdoor Activities* ($n = 818$; 56% of all). Fig. 2 shows the normalized cluster means for all 11 movement behaviours for each group, where zero means no change since COVID-19-related restrictions were imposed, a positive value means an increase, and a negative value represents a decline in a particular movement outcome.

Cluster 1 (*increased outdoor activities*) demonstrated increased walking/biking and increased outdoor play after COVID-19 related restrictions were imposed. A higher increase in household chores and other non-screen based sedentary activities (e.g., reading, crafts, puzzles) compared to the other group were reported. While these children and youth were also spending more time playing indoors and in front of digital screens, the average increase was much lower than the other cluster.

In contrast, cluster 2 (*decreased outdoor activities)*, which constitutes the majority of our sample, is distinguished by a large decline in walking or biking and physical activity participation (both outdoors and indoors) and at the same time, by large increases in indoor play, screen time and social media use. These children and youth are sleeping more than before (more so than those with *increased outdoor activities*) but the average reported sleep quality declined by a small amount.

A much higher proportion of children and youth with *increased outdoor activities* were meeting the MVPA guidelines (27% versus 12% of those with *decreased outdoor activities*) (Table 2). Among both clusters, only a very small proportion were meeting the 24-h activity guidelines; however, clearly more children/youth with *increased outdoor activities* were meeting the guidelines than those with *decreased outdoor activities* (5% and 1% respectively).

With regard to socio-demographic characteristics, a higher proportion of younger children clustered into the *increased outdoor activities* group, compared to youth. Children from multi-child households were also more common in the *increased outdoor activities* cluster. We did not find any gendered difference between the two clusters. Household income was associated with cluster membership, with a greater proportion of children and youth with *decreased outdoor activities* classified as low income. Other variables, such as parental education, ethnicity or age were not correlated (Table 2).

Table 2
Socio-demographic characteristics of *increased outdoor activities* and *decreased outdoor activities* clusters.

	Cluster 1: Increased Outdoor Activities %	Cluster 2: Decreased Outdoor Activities %	P (chi-sq)
Meet MVPA guidelines	26.5	11.6	<0.001
Meet 24-h movement guidelines	4.9	1.0	0.003
Household income			0.037
Less than 35k	6.4	8.6	
35k to 75k	20.2	25.6	
75k to 150k	47.4	41.1	
More than 150k	14.2	13.7	
No data	11.8	11.1	
Parent's employment			0.835
Employed	82.5	83.0	
Unemployed	17.5	17.0	
Parent's education			0.218
Highschool or less	12.8	10.0	
College or some university	36.7	38.9	
University degree	50.5	51.1	
Multiple children household	64.8	57.1	0.003
Child's age			<0.001
5–11 years	54.6	41.1	
12–17 years	45.4	58.9	
Child's Gender			0.713
Boy	53.2	52.2	
Girl or other	46.8	47.8	
Child with disability	8.1	9.0	0.575

4.2. Correlates of movement behaviour change

Having identified clear patterns in movement behaviour changes, our second research question was to explore the association between movement behaviours and the neighbourhood environment near residential locations. Logistic regression models identified the correlates of *increased outdoor activities* (versus *decreased outdoor activities*).

The results indicate that children and youth living in houses were more likely to be a member of *increased outdoor activity* cluster compared to those living in apartments (OR = 1.39) (Table 3). Distance to the nearest major road also had a positive but statistically moderate (α =

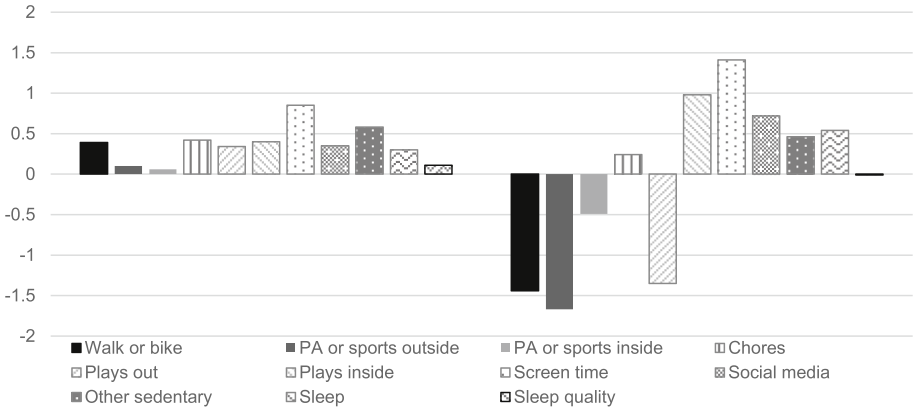

Fig. 2. Cluster means relating to changes in various movement behaviours during COVID-19 pandemic, for two groups of children and youth identified using a *k*-means cluster analysis.

Table 3
Correlates of *increased outdoor activities* cluster membership (versus *decreased outdoor activities* cluster membership), results from binomial logistic regression.

	Coef. (β)	Std. E.	OR	Pr (>|z|)
Age 5–11 years (re: 12–17 years)	0.57	0.11	**1.77**	< **0.001**
Multi-child household	0.13	0.11	1.14	0.240
Income of less than $35 (ref: $35,000 to 75,000)	0.11	0.24	1.12	0.650
Income of $75,000 to $150, 000 (ref: $35,000 to 75,000)	0.38	0.14	**1.46**	**0.000**
Income of more than $150,000 (ref: $35,000 to 75,000)	0.30	0.19	1.35	0.110
House (ref: Apartment)	0.33	0.14	**1.39**	**0.017**
Dwelling density	-0.39	0.11	**0.68**	< **0.001**
Access to parks	-0.06	0.06	0.94	0.380
Distance to major road	0.11	0.06	***1.12***	***0.073***
Dwelling density X Access to parks	0.17	0.05	**1.19**	**0.002**
Intercept	-1.14	0.17	**0.32**	< **0.001**

Note: Coefs in **bold** are statistically significant at α = 0.05; coefs in ***bold italics*** are significant at α = 0.10.
Model fit: Null deviance: 2001.3 on 1455 degrees of freedom; Residual deviance: 1909.9 on 1444 degrees of freedom; AIC: 1933.9.

0.1) association, indicating that those living further from a major road (i.e. collectors or highways) were more likely to cluster into the *increased outdoor activities* group.

Similarly, dwelling density was negatively associated with *increased outdoor activity,* suggesting that those living in high-density neighbourhoods may demonstrate less healthy movement behaviours during a pandemic. However, Table 3 also indicates that for those living in higher density areas, access to parks within 1 km increased the probability of being in cluster 1 (i.e. *increased outdoor activities)* (OR = 1.19).

Regarding socio-demographic characteristics, children, compared to youth, were significantly more likely to be a member of *increased outdoor activities* cluster (versus *decreased outdoor activities)* during the COVID-19 pandemic. Those coming from higher income households ($75,000–150,000 CAD household income, compared to $35,000–75,000 CAD household income) were also more likely to cluster into *increased outdoor activities* (Table 3).

Next, separate models were estimated for children and youth in order to explore differences in the correlates of *increased outdoor activities* cluster membership; the results indicate some age-related differences (Table 4). For example, youth from multi-child households, and those from higher income households (household income more than $75,000) were more likely to demonstrate *increased outdoor activities*. No such socio-demographic correlates were evident among children.

With regard to the built environment, major differences were observed between children and youth. Children living in houses were highly likely to be members of *increased outdoor activities* cluster, but no such association was observed among youth (Table 4). Proximity to major streets was a barrier to *increased outdoor activities* among children, but not for the youth. Access to parks was negatively associated with a child's membership to *increased outdoor activities*, but for youth, access to parks particularly in neighbourhoods with high dwelling density increased the odds of clustering into *increased outdoor activities* group during the pandemic.

5. Discussion and conclusions

The recent COVID-19 outbreak has forced governments across the world, including Canadian provincial and municipal governments, to take unprecedented steps to restrict gatherings and movements, in order to stop the spread of the virus. Children and youths' mobility is affected due to the closure of schools, playgrounds, recreational facilities and in a small number of communities, public parks-places that are considered typical and safer places for them to play and engage in physical activity. As a result of these restrictions, it is widely believed that children and youths' healthy movement behaviours will decline. Overall, results from our recent research (Moore et al., 2000) support this speculation with less than 3% of Canadian children and youth meeting the 24-h movement guidelines during the COVID-19 virus outbreak and related restrictions, compared to 15% meeting the guidelines in 2019 before the COVID-19 outbreak (ParticipACTION, 2020). Within this context, this study explored if some children and youth have managed to increase healthy movement behaviours (versus others who have become less active), perhaps by taking advantage of more available time (e.g., no school) and an enabling neighbourhood built environment.

A cluster analysis identified two district groups of children and youth based on changes in 11 movement behaviours. We found that some children and youth have indeed become more active and are walking/biking and playing more and have increased outdoor physical activity (i.e., with *increased outdoor activities*), confirming that during the pandemic, physical inactivity may not be the only possible outcome. However, the majority of Canadian children and youth (56%) demonstrated patterns of *decreased outdoor activities* during the COVID-19 pandemic, with increased screen time and other sedentary behaviours. Overall, we did not find much evidence of activity compensation (Gomershall et al., 2013; Goodman et al., 2011), and as a result, there was a large difference in physical activity levels between the two groups. Only 12% of children and youth in the *decreased aoutdoor activities* cluster met the MVPA guidelines, compared to 27% of those in the *increased outdoor activities* cluster. Compliance to 24-h movement guidelines was low among both groups (1% and 5% respectively).

These results have significant short- and long-term public health implications. The benefits of large-scale and strict mobility restrictions

Table 4
Correlates of *increased outdoor activities* cluster membership (versus *decreased outdoor activities* cluster membership)- difference between children and youth.

	Children (5–11 years)				Youth (12–17 years)			
	Coef. (β)	Std. E.	OR	Pr (>|z|)	Coef. (β)	Std. E.	OR	Pr (>|z|)
Multi-child household	-0.13	0.18	0.88	0.450	0.31	0.15	**1.36**	**0.041**
Income of less than $35k (ref: $35,000 to 75,000)	0.14	0.34	1.15	0.670	0.33	0.33	1.39	0.310
Income of $75,000 to $150, 000 (ref: $35,000 to 75,000)	0.32	0.21	1.38	0.120	0.49	0.21	**1.63**	**0.017**
Income of more than $150,000 (ref: $35,000 to 75,000)	0.14	0.28	1.15	0.610	0.49	0.27	***1.63***	***0.064***
House (ref: Apartment)	0.72	0.20	**2.05**	< **0.001**	-0.06	0.20	0.94	0.750
Dwelling density	-0.26	0.15	***0.77***	***0.079***	-0.57	0.17	**0.57**	< **0.001**
Access to parks	-0.19	0.10	***0.83***	***0.067***	0.05	0.09	1.05	0.580
Distance to major road	0.20	0.10	**1.22**	**0.039**	0.04	0.08	1.04	0.630
Dwelling density X Access to parks	0.06	0.08	1.06	0.440	0.30	0.08	***1.35***	***<0.001***
Intercept	-0.52	0.24	**0.59**	**0.029**	-1.14	0.22	***0.32***	***<0.001***

Note: Coefs in **bold** are statistically significant at α = 0.05; coefs in ***bold italics*** are significant at α = 0.10.
Model fit: Children (5–11 years): Null deviance: 947.24 on 683 degrees of freedom, Residual deviance: 888.78 on 673 degrees of freedom, AIC: 910.78. Youth (12–17 years): Null deviance: 1025.94 on 771 degrees of freedom, Residual deviance: 995.21 on 761 degrees of freedom, AIC: 1017.2.

on reducing virus transmission are not well known. While physical distancing and other measures (e.g., hand hygiene, wearing masks) have been shown to play an important role in reducing transmission, it is unclear whether closing outdoor spaces has made similar contributions. In fact, in the context of COVID-19 it may be even more important to provide children and youth opportunities for outdoor physical activity and play. Outdoor play opportunities increase the likelihood of children meeting the movement guidelines, since children that play outdoors tend to be more active, sit less, and sleep better (Tremblay et al., 2015). Outdoor time can also provide children and youth a necessary refuge during times of stress (Yogman et al., 2018) and build a more robust immune system (Lasselin et al., 2016). Further, there is evidence that transmission of COVID-19 is lower outdoors compared with indoors (Qian et al., 2020). Thus, as reopening of public spaces begins across various Canadian provinces and elsewhere across the world, outdoor play spaces including playgrounds should arguably be prioritized as a means to enhance movement behaviours and overall health in all children and youth but particularly for those aged 12–17 years from lower-income households. As we enter the recovery period for COVID-19, and plan for future pandemics, it is important to balance concerns of virus transmission with evidence-based strategies to keep children active and playful.

Moreover, the COVID-19 pandemic is a significant disruption that has the potential to change urban planning policy and practice in the long-term. Since the 1970s, practitioners and researchers alike have emphasized dense urban development as a means to promote environmental and social sustainability, livability and economic prosperity (Bramley and Power, 2009; Ewing and Cervero, 2017; Newman and Kenworthy, 1999). Dense communities are also considered healthy communities, as they enable walking, biking and easy access to recreational/sports facilities for adults and children alike (Frumkin et al., 2004; Mitra and Manaugh, 2020). During the current pandemic, large metropolitan areas had higher infection and death dates compared to low-density communities, fueling popular and scholarly discussions around the future of density as an urban planning principle (Florida, 2020; Rocklöv & Sjö;din, 2020). It is worth noting that while some high-density cities (e.g., New York and London) have had the worst outbreaks of the COVID-19 virus, others such as Singapore and Tokyo did not have a similar experience (Florida, 2020). This has led urbanists to argue that urban density is likely only one factor of many that makes a place vulnerable to a similar public health emergency. As we begin to recover from this pandemic and realign our urban planning principles with public health resiliency as a priority (along with other goals mentioned above), what will the future communities look like in the post-COVID-19 period? Our study begins to address this question with a specific focus on children and youth.

Results from logistic regression models indicate implications of neighbourhood design on changes in healthy movement behaviours during a pandemic. Neighbourhoods with low dwelling density and those that are further from major roads were associated with *increased outdoor activities*. In contrast, living in an apartment likely discouraged healthy movement behaviours, particularly among children aged 5–11 years. Low density may create a perception of greater ease to physically distance because there may be fewer people outside. In addition, across Canada, people were advised to "stay home" during the pandemic, leading to very limited economic activities and travel. It appears that many households with small children are taking the opportunity of improved traffic and personal safety on neighbourhood streets to engage in physical activity. Speculatively, with many parents staying at home, child supervision may also have become easier.

However, high-density (and high-rise) communities may not be a universal barrier to *increased outdoor activities* during a pandemic or similar public health emergencies. Instead, neighbourhoods with higher densities and with better access to parks are more likely to help youth stay active outdoors when compared to communities with lower dwelling density and limited access to parks. At a time when major cities are beginning to accommodate a high demand for family-oriented housing units in central-city locations through compact neighbourhood design (e.g., City of Toronto, 2017; Ignatieva and Berg, 2014), our findings emphasize the importance of parks and open spaces. For the health and wellbeing of the youth and overall community resiliency, access to opportunities for outdoor activity, play and recreation is critical and should be an important land use component to consider when planning for higher-density (presumably central-city) neighbourhoods.

But in the short-term during the post COVID-19 recovery period, targeted public health strategies to get these families active is critically important. For example, public health messaging may encourage households to be active during family time with children. Particularly in the higher-density communities, parents and caregivers should be specifically encouraged to become role models for their children in staying active and spending time outdoors (ParticipACTION, 2020b). Such strategy remains critical specifically for children living in multi-unit residences (e.g., apartment buildings) with less access to personal outdoor space.

Contrary to our initial expectation, access to parks within 1 km of a 5-11-year old child's residence was negatively associated with *increased outdoor activities* (which is the cluster of children that demonstrated healthier movement behaviours overall) during the COVID-19 pandemic. The outcome may partly be explained by pandemic-time closures of school grounds and playgrounds, which are usual places to play for children (and less so for youth). Due to the unavailability of these opportunities, which were defined as parks in our built environment data, many children are likely compensating that time with more sedentary behaviours inside the home. Excess screen-based sedentary behaviours among children and youth remains a significant public health concern, particularly if some children continue to remain engaged in high levels of sedentary behaviours in the post-pandemic period (Jones et al., 2013).

This study is one of the first to explore changes in children and youth movement behaviours during the COVID-19 pandemic. Uniquely, we used detailed built environment data near residential locations to examine the potential role of the neighbourhood environment on healthy movements.

However, the generalizability of our findings is somewhat limited by the data. First, our study examines healthy movement behaviours of children and youth aged between 5 and 17 years, and as a result the findings may not be generalized to younger children. Second, while our analysis was based on a large national sample, it is a cross-sectional data where changes in movement behaviours were reported by parents using a subjective scale (i.e., "a lot less" to "a lot more") and were not objectively measured. Some parents may feel driven to over-report their child's physical activity levels and under-report their child's sedentary behaviours due to social desirability. As a result, our results can be considered more "conservative" wherein the actual levels of healthy movement behaviours may be even lower during the pandemic than what was reported in the survey. The alternative approach to surveying children and youth, arguably, may also produce unreliable responses. Moreover, a large national survey of children and youth can be logistically and ethically challenging (for example, most if not all third party market research firms, such as the one who collected data for this research, only collect data from adults). Third, our analysis explores neighbourhood built environment characteristics but we did not have information on how available outdoor spaces (e.g., back yard, sidewalk, street) were actually utilized. Fourth, the paper explores 24-h movement behaviours across two broadly defined groups identified through a cluster analysis. This approach is appropriate in exploring patterns of movement behaviours, but this generalization may have masked nuanced differences between individual children/youth, their households, and residential locations.

Finally, it is important to emphasize here that there are some geographical variations in the public health restrictions such as park closures across Canada (Govt. of Canada, 2020; The Canadian Urban

Institute, 2020). A recent descriptive analysis shows that provinces with the highest number of COVID-19 cases and related deaths have imposed the most stringent restrictions on outdoor access (de Lannoy et al., 2020). Within each province, municipalities have also implemented their own restrictions with varied scopes. A detailed examination of the impacts of such policy and guidelines on children and youths' healthy movement behaviour could not be conducted here due to lack of data at the time of analysis, but would be an important topic for future research.

To conclude, this study provides important insights into the movement patterns of children and youth, and our findings highlight the importance of the neighbourhood environment in enabling healthier behaviours during the COVID-19 pandemic. These findings will inform public health policies as we recover from this current crisis and prepare for future pandemics. The results will also inform urban planning policy and design guidelines in the post-COVID-19 period. As we continue to gain novel insights from our experiences during the pandemic, these learnings will be important for creating stronger, healthier, and more resilient communities.

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