CORRELATES OF CHANGES IN CHILDREN'S INDEPENDENT MOBILITY DURING THE COVID-19 PANDEMIC: A CANADIAN NATIONAL LONGITUDINAL STUDY

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DEDICATION

To my husband, whose unwavering guidance, patience, and encouragement made a world of difference. You have been my greatest source of strength. Thank you for having my back and believing in me, even when I doubted myself. May we always find the strength to overcome life's challenges together and supporting each other along the way.

ABSTRACT

Children's independent mobility (CIM) is linked to higher physical activity in cross-sectional research, but studies describing factors influencing changes in CIM are lacking. The objective of this study was to examine the social-ecological correlates of changes in CIM and whether correlates differ by gender. Every six months between December 2020 and 2021, Canadian parents of 7- to 12-year-olds (n=2291 at baseline) were surveyed to assess mobility licenses (children's permission to do certain activities independently). Linear regression models adjusted for child age, gender, and household income were conducted. Average CIM increased (0.65±1.30 licenses) throughout the follow-up period. Boys experienced a smaller increase in CIM compared to girls (β: -0.60; 95%CI: -1.13, -0.06). Child age (β: 0.08; 95%CI: 0.03, 0.14) and each unit increase in the parental Tolerance of Risk in Play Scale (β: 0.02; 95%CI: 0.00, 0.04) were associated with increased CIM whereas parental crime safety concerns (β: -0.19; 95%CI: -0.37, -0.02) were negatively associated. Children whose parents were neither employed full-time nor homemakers had lower CIM than those of full-time working parents (β: -0.40; 95%CI: -0.74, -0.06). Child gender interacted with parent employment: boys whose parent did not work full-time had a greater increase in CIM (β: 0.52; 95%CI: 0.08, 0.95). In gender-stratified models, boys with a disability (β: 0.49; 95%CI: 0.08, 0.89) and from middle- vs. high-income households (β: 0.34; 95%CI: 0.05, 0.63) had greater increases in CIM. Findings show that correlates of changes in CIM span multiple levels of influence, and these correlates differ significantly between boys and girls, highlighting the importance of examining gender-specific factors when examining changes in CIM.

Future interventions to increase CIM could target modifiable variables, including parental risk tolerance and perceived crime safety.

CONTRIBUTION OF AUTHORS

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ETHICS STATEMENT

This study protocol was approved by the Human Participant Research Committee of the University of Lethbridge (protocol 2020-097). Participants in this study consented electronically after reviewing an information letter. Information about participants will remain confidential to the researcher.

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LIST OF ABBREVIATIONS

Can-ALE	Canadian Active Living Environments
CIM	Children's Independent Mobility
CPTED	Crime Prevention Through Environmental Design
GLM	Generalized Linear Models
MVPA	Moderate-to-Vigorous Physical Activity
TRiPS	Tolerance to Risk in Play Scale
UNICEF	United Nations International Children’s Emergency Fund
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Children's Independent Mobility (CIM): Background and Significance

According to the World Health Organization (WHO), physical inactivity is a global public health problem (WHO, 2020). Even though regular physical activity improves physical and mental health in people of all ages, the best available evidence suggests that 80% of adolescents and 27% of adults are not meeting the WHO's recommended physical activity levels (WHO, 2022). According to the Canadian Health Measures Survey, moderate-to-vigorous physical activity (MVPA) among Canadian children and youth did not change from 2007 to 2015 (Colley et al., 2017). Data from that survey indicate that only 7% of children and youth in Canada are accumulating 60 minutes of MVPA at least six days a week, and 33% are achieving a weekly average of at least 60 minutes of MVPA per day (Colley et al., 2017). The latter corresponds to the most recent wording of the WHO physical activity guidelines (Bull et al., 2020; WHO, 2020). It is evident that a higher level of physical activity and lower sedentary behavior are associated with lower adiposity and better cardio-metabolic and mental health in children and youth (Biddle & Asare, 2011; Ekelund et al., 2004; Page et al., 2005; Saunders et al., 2016; Tremblay et al., 2011). Therefore, it is essential to help children achieve the recommended level of physical activity daily.

CIM may be considered as one factor that influences children's physical activity. This term was introduced by Hillman et al. (1990), and it represents children's ability to move freely around their neighborhood without adult supervision. CIM commonly includes non-motorized activities, such as walking and cycling (Marzi & Reimers, 2018).

Researchers have defined and interpreted CIM in different ways. More commonly, it has been operationalized through CIM licenses (e.g., permissions related to independent walking, cycling, and taking public transport without adult supervision) (Larouche et al., 2017; Schoeppe et al., 2014). Sometimes, it has been described based on territorial range (indicating how far a child can travel on their own) or as a range of destinations where children can play and travel without adult supervision (Page et al., 2009; Rissotto & Tonucci, 2002; Van Viet, 1983). In some studies, levels of CIM were quantified using mobility diaries (Kytta, 2004).

CIM is associated with more active transport, outdoor play, and overall physical activity in children (Larouche et al., 2020; Mackett et al., 2007; Page et al., 2009; Schoeppe et al., 2014; Wen et al., 2009; Veitch et al., 2008). It is an essential facilitator of children's health and well-being (Gray et al., 2023; Larouche et al., 2024; Saunders et al., 2016; Schoeppe et al., 2014) as well as social, motor, and cognitive development (Riazi & Faulkner, 2018; Shaw et al., 2015). For example, CIM can help children improve their risk assessment, spatial apprehension, and navigational skills (Rissotto & Tonucci, 2002). A greater level of CIM provides children an improved self-confidence and a way to communicate more with their peers indoors and outdoors (Prezza et al., 2001; Prezza & Pacilli, 2007). An Italian study found that higher CIM during childhood result in less intense fear of crime and stronger sense of community in adolescence (Prezza et al., 2001). On the other hand, low CIM levels can inversely affect children's emotional, social, and cognitive development (Kytta, 2004). For example, children with lower levels of CIM were reported to interact less with adults beyond their family members (Prezza & Pacilli, 2007).

1.2 Trends in the prevalence of CIM

There has been a dramatic decline in CIM over the last few decades worldwide. The seminal study by Hillman et al. (1990) indicated that the percentage of 7- and 8-year-olds who were allowed to travel home from school alone declined from 80% to 9% from 1971 to 1990. A cooperative research project of the Policy Studies Institute (London) compared CIM in 16 countries across the world which showed that CIM was highest in Finland, followed by Germany, Norway, Sweden, Japan, and Denmark (Shaw et al., 2015). In contrast, children in Portugal, Italy, and South Africa enjoyed the lowest freedom to travel independently (Shaw et al., 2015). Even though CIM was highest in Finland, still the proportion of children who independently travelled both to and from school significantly declined from 1990 to 2010 in neighbourhoods representing different levels of urbanization (from 89% to 70% in the small town, from 82% to 50% in the inner city, and from 85% to 77% in the rural village involved in the study) (Kytta et al., 2015). This decline was attributed to the increasing distance of school journeys, which has also been identified as a key barrier to engage in active travel in previous studies (Carver et al., 2012; Fyhri & Hjorthol, 2009). In Australia, the prevalence of children's independent travel to school declined by 29% between 1991 and 2012 (Schoeppe et al., 2016). Similar trends have been reported in Scandinavian countries such as Denmark, Finland, and Norway (Fyhri et al., 2011). From 1990 to 2010, the proportion of CIM in Germany and England dropped for two of the six licenses of CIM (cross main road alone and travel home from school alone) (Shaw et al., 2013).

In Canada, there are few studies examining CIM, typically with a narrow geographic scope (Buliung et al., 2009; Buliung et al., 2017; Delisle Nyström et al., 2019;

Mitra et al., 2014; Riazi et al., 2021), and none of these studies reported temporal changes in CIM. However, studies have indicated declines in active transportation and/or increases in motorized travel. For example, in Toronto, Canada, the proportion of children (11-13 years) walking to school declined from 53% to 42.5% between 1986 and 2006, but the proportion of those trips that were independent is unclear (Buliung et al., 2009). In addition, national cross-sectional surveys conducted in 2000 and 2010 indicated an 11-point increase in the prevalence of motorized school travel (Gray et al., 2014).

Due to the COVID-19 pandemic and associated restrictions, CIM, outdoor play, and physical activity markedly changed. According to a scoping review of evidence after the first year of COVID-19 pandemic, a consistent decline in physical activity and an increase in sleep duration, screen time, and sedentary behavior was reported (Paterson et al., 2021). For example, a national survey found that only 4.8% of Canadian children met the recommended movement behavior guidelines during the first wave of the pandemic (Moore et al., 2020). According to a national survey conducted in 2020, about 56.6% of Canadian parents perceived no changes, 32.8% reported a decline, and only 10.6% reported an increase in their CIM since the COVID-19 pandemic (Larouche et al., 2022). In a qualitative study from Toronto and Vancouver, the closure of parks, playgrounds, and other outdoor facilities was associated with a reduction in CIM (Riazi et al., 2021). In contrast, another qualitative study conducted in a smaller northern British Columbia community suggested that the pandemic was associated with a reduction in structured activities and an increase in CIM (Pelletier et al., 2021). A mixed-methods study in Finland suggested that the pandemic was associated with reduced organized sport participation, but increased outdoor play, with no effect on CIM (Berg et al., 2023).

However, countries with less COVID-19 restrictions (e.g., Sweden) may have fared better in enhancing CIM by keeping schools open (in-person) and maintaining access to outdoor spaces (Ludvigsson, 2023. This evidence suggests that differences between jurisdictions in COVID-19 policy stringency may have affected CIM during the pandemic.

As CIM is an essential facilitator of physical activity and child development, a perceived decline in the levels of CIM is concerning. Therefore, examining changes in CIM and its correlates is important in the field of public health. The social-ecological model provides a useful framework to conceptualize the correlates of CIM (Larouche & Ghekiere, 2018; Riazi & Faulkner, 2018).

1.3 Social-ecological Model

Social-ecological models have been widely adopted in physical activity and public health research over the last few decades (Golden & Earp, 2012; Kok et al., 2008). They postulate that health behaviors are impacted by multiple levels of influence that can interact (Sallis et al., 2006; Sallis et al., 2015). According to Larouche & Ghekiere (2018), these levels include factors at the individual level (e.g., children's behavior and characteristics), interpersonal level (e.g., the influence of parents and friends), community level (e.g., school policies and practices, and social norms), built and physical environment level (e.g., roads, sidewalks, cycle paths, weather, etc.), and policy level (e.g., policies to support CIM at local, provincial, and national levels). Notably, parents are viewed as the primary gatekeepers of their child's independent travel and their decisions to grant mobility licenses are often associated with characteristics of the environment such as traffic, walkability, and distance to destinations (Faulkner et al.,

2010; Giles-Corti et al., 2009; Mitra, 2013; Riazi et al., 2022). Therefore, understanding the social-ecological correlates of CIM is an important prerequisite for informing future interventions and policies and developing effective strategies to increase CIM.

1.4 Social-ecological Correlates of CIM

In the literature, researchers mentioned different potential contributors to the remarkable decline in CIM over the years. For example, CIM declined in several countries while car use, urbanization, and fear of crime increased (Cordovil et al., 2015; Fyhri et al., 2011). Based on the social-ecological model, CIM is correlated with several socio-demographic, social, and physical environmental attributes (Marzi et al., 2018; Riazi et al., 2019; Sharmin & Kamruzzan, 2017).

In a systematic review, child age and gender were the most examined individual-level correlates (Riazi et al., 2022). Findings from this systematic review suggest that older children have greater level of CIM compared to younger children while association between gender and CIM were categorized as indeterminate. About half of included studies indicated that boys have higher CIM than girls with other studies generally reporting no gender differences. Other socio-demographic characteristics, such as membership of the dominant ethnicity, speaking the majority language at home, a child's confidence, and skills to travel independently, and child's access to house key are consistently positively associated with CIM (Ghekiere et al., 2017; Janssen et al., 2016; Riazi et al., 2022; Villanueva et al., 2013).

Several variables, including parent's perception toward CIM, birth order, and having older siblings were found to be consistently positively associated with CIM at the

interpersonal level whereas parental concerns about traffic safety are consistently negatively associated (Riazi et al., 2022). A recent national study using the baseline data identified that CIM is significantly associated with lower household income, household dog ownership, having older siblings, and living in a household with no motor vehicle (Larouche et al., 2023). At the social-environment level, greater parental concern about traffic safety is associated with lower CIM (Larouche et al., 2023; Riazi et al., 2022). A Canadian study also indicated that the older a parent was granted CIM as a child, the more they restricted their children's CIM (Hecker et al., 2025). Some studies have reported that higher parental concerns about crime safety, strangers, and social dangers in the street limit the opportunities for CIM (Foster et al., 2014; Fyhri et al., 2011; Santos et al., 2013), though the evidence is inconsistent (Riazi et al., 2022). CIM may also be affected by local social networks, cultural behaviors and attitudes, traffic rules, and legislation of a country (Mitra et al., 2014; Shaw et al., 2015), though more research is needed to investigate how these variables may encourage or limit CIM. For instance, strong neighbourhood ties and trust can enhance CIM by making parents feel their community is safe (Mitra et al., 2014).

Finally, geographic region, residential density, access to outdoor space, walking and cycling infrastructure, mother's commute distance deviation from children's school (i.e., a proxy for the convenience of accompanying children on the way to school), and proximity to green space may be positively associated with CIM at the built-environment level while the association with types of urbanization and SES were inconsistent (Riazi et al., 2022).

More research investigating the correlates of changes in CIM is needed given that many potential correlates have only been assessed in a small number of studies and most existing evidence stems from cross-sectional studies that cannot determine the temporal sequence of associations (Riazi et al., 2022).

1.5 Gender as an Effect Modifier

An effect modifier (or moderator) is present when the association between the exposure and the outcome differs in the presence of a third variable (Szklo & Nieto, 2014). Effect modifiers can include modifiable and non-modifiable characteristics (e.g., age, gender, SES, etc.).

Gender is the most examined social-ecological correlate of CIM, with approximately half of studies showing significant differences (typically favoring boys) (Riazi et al., 2022). In this study, it was hypothesized that changes in CIM would differ by gender. Findings from previous observational studies appear to support this possibility. For example, some studies have found that boys experience greater CIM than girls at a given age (Brockman et al., 2011; Foster et al., 2014; Larouche et al., 2023; Mackett et al., 2007). In previous studies, some correlates were found to be significantly associated with CIM when stratified by gender. For instance, parents' perception of traffic safety was found to be positively associated with CIM among girls while parental fear of stranger danger appeared to limit girls' CIM (Foster et al., 2014; Ghekiere et al., 2017). Gender theories postulate that socially determined gender roles based on socialization processes can result in such variations (Kilvington & Wood, 2016; Ristvedt, 2014). This variation could be explained by parents' restrictions towards girls' CIM due to safety

concerns and socializing differences between girls and boys (Brown et al., 2008; Ghekiere et al., 2017). For instance, some studies suggest that boys are granted mobility licenses earlier than girls to travel independently in their neighborhood (Brown et al., 2008; Buliung et al., 2017; Villanueva et al., 2014). Additionally, girls are more likely than boys to experience sexual harassment when traveling on their own (Hampshire et al., 2011; Shute et al., 2008). Schoeppe et al. (2016) also found a significant gender difference in children's independent travel to school (lower proportion of girls travelled independently to school than boys).

Therefore, gender could moderate the association between social-ecological correlates and changes in CIM. If the correlates of CIM vary substantially by gender, this would suggest that different strategies may be needed to promote CIM in boys and girls.

1.6 Study Rationale

According to findings from current research, it is evident that CIM has dramatically declined over the last few decades. Automobile-centric urban planning, intensive safety-focused parenting, and car-oriented city designs have greatly restricted CIM over the past century (Carroll et al., 2015; Gaster, 1992; Tremblay et al., 2015). Since children's physical activity decreases with age (Dumith et al., 2011; Reilly, 2016), the declining level of CIM is alarming, considering global concerns over physical and mental health. CIM helps children engage in physical activity while achieving self-confidence and environmental competency, improve risk assessment and problem-solving skills, and improve fine and gross motor skills (Rissotto & Tonucci, 2002; Schoeppe et al., 2014). Current research on CIM is largely based on cross-sectional studies that cannot

determine the direction of observed associations (Riazi et al., 2022). Specifically, Riazi et al. (2022) identified only three longitudinal studies examining the correlates of CIM, all of which were conducted in Australia.

Among these three studies, Carver et al. (2014) found that about half of children traveled to school independently. For boys, they reported a longitudinal association between the presence of parental rules regarding their child's outdoor play and increased independent school travel, while household car access was inversely associated with CIM. For girls, land use mix was longitudinally positively associated with independent walking/cycling to school, while parental encouragement for CIM and the proportion of main roads in the neighborhood were negatively associated. A finely integrated mixing of residential, commercial, and recreational land uses can enable residents to walk/bike to nearby destinations while segregated land use is typically associated with large distances between locations, which often requires motorized transportation for residents to access work, shopping, or leisure activities (Manaugh & Kreider, 2013).

According to Veitch et al. (2017), the child's enjoyment of walking and cycling activities, parental safety concerns, and proximity to walking tracks were associated with increased children's independent travel on the school journey. Only the mother's agreement that lots of children they and their child know walk/cycle to school was positively associated with children's independent travel (walking/cycling) to local destinations. However, Veitch et al. (2017) collected data from socioeconomically disadvantaged populations in Australia, which might limit the generalizability of their findings.

Love and colleagues (2020) examined the effect of individual, social capital, built environmental factors, and intervention programs on the changes in CIM on the school journey. They found that children who walked or cycled to school and knew their neighbors well had increased levels of CIM. Parental perceptions of neighbors' willingness to help and *not* sharing values with neighbors were also associated with increased CIM on the school journey. The later finding is counterintuitive, but it may suggest that many children living in low-income areas walk to school due to lack of alternatives as previously reported by Pabayo et al. (2012). Only children's independent trips on the weekend were negatively associated with increasing CIM on the school trip. However, none of the active transportation intervention programs (TravelSmart, Ride2School, and Safe Routes to School) examined effectively increased CIM.

All three Australian longitudinal studies examined CIM only in the context of travel to/from destinations and only Veitch et al. (2017) examined the predictors of CIM to/from non-school destinations. Moreover, no study to date has tested the correlates of changes in CIM based on a social-ecological model using nationwide longitudinal data. To address the knowledge gap in this field, a prospective cohort study was conducted to identify factors associated with changes in CIM in a national sample of parents of 7- to 12-year-old across Canada.

1.7 Research Questions

This study extends the previous cross-sectional paper by Larouche et al. (2023). In this study, the following research questions were examined:

1. How did CIM change through the COVID-19 pandemic?

2. What are the factors associated with changes in CIM among 7- to 12-year-old Canadian children based on the social-ecological model?
3. Is the association between social-ecological factors and CIM moderated by gender?

CHAPTER 2: METHODS

2.1 Study Design

A prospective cohort study design was used to explore the research questions. This study design provides appropriate information about the direction of associations (Bauman et al., 2002). A prospective cohort study can assess a large sample while controlling for potential covariates. In this study, parents of 7- to 12-year-old Canadian children comprised the cohort. To ensure the highest reporting quality, I used the Strengthening and Reporting of Observational studies in Epidemiology (STROBE) guidelines for cohort studies (Vandenbroucke et al., 2007), which are a set of recommendations designed to improve the quality and transparency of reporting in observational research.

2.2 Setting

This cohort study was based on data from a national longitudinal study of children's movement behaviors across Canada with a primary objective of examining changes over time in movement behaviors (e.g., physical activity, screen time, sleep, active transportation, outdoor time), CIM as well as their correlates based on the social-ecological model (Larouche et al., 2022). The national longitudinal study started with a sample of 2291 parents of 7- to 12-year-old Canadian children who were selected to represent the target population demographically. Baseline data were collected in December 2020 through Leger (leger360.com), Canada's largest market survey firm. Participants were followed up from December 2020 until June 2022 and follow-up data were collected every six months.

2.3 Participants

All participants were eligible to take part in the national longitudinal study if they met the following inclusion criteria: live in Canada, parents of 7- to 12-year-old children, were able to complete the survey in English or French, and agreed to take part in the survey again at 6-, 12-, and 18-month follow up. Parents with more than one child in the target age range were asked to complete the survey for their child whose name comes first in alphabetical order.

2.4 Data Collection

In December 2020, a national sample of 2,291 parents of 7- to 12-year-old children were recruited across Canada. The same parents were followed up every six months until June 2022. Just over 700 parents participated in the last follow-up. Public health restrictions related to the COVID-19 pandemic became less severe through the study period as indicated by the Bank of Canada's (2022) stringency index declining from 64.0 to 17.0 (out of 100). A parent questionnaire was used to assess several potential correlates representing multiple levels of influence of the social-ecological model (Appendix A). In addition, objective measures of weather (temperature and precipitation) and walkability (the extent to which the built environment around participants' homes supports walking) were obtained based on the parent-reported 6-digit postal codes. Participants completed the survey using a computer-aided web interviewing method. An incentive of $3 (Canadian) was offered to the participants for each completed survey. An additional $10 was offered to those who completed all survey waves.

2.5 Measures

2.5.1 CIM: In this study, CIM was assessed by using Hillman's six mobility licenses that summarise children's permission to do the following things on their own: walk home from school, travel to other places in their neighborhood, cross main roads, cycle on main roads, go outside after dark, and use public transit (Hillman et al., 1990). The responses were dichotomized (1 = yes; 0 = no) for each license. Responses for all six licenses were summed to construct a CIM index ranging from 0 (signifying no CIM) to 6 with higher scores indicating greater CIM. A pilot study by Larouche and colleagues found an excellent test-retest reliability and convergent validity of the CIM index based on parents and children's responses in English and French (Larouche et al., 2017).

2.5.2 Potential Social-ecological Correlates of CIM: Parents reported the age (in years) and gender of the child and parent. Data on parental employment status and household income were collected using standard questions from Leger. Parents also reported other socio-demographic and household characteristics including: household income (CAD$39,999 or less; $40,000–99,999; $100,000 or more; prefer not to answer), employment status (working full time; working part-time; self-employed or freelance work; student; homemaker; unemployed), type of residence (low rise apartment; high rise apartment; townhouse; semi-detached house; detached house; other), province or territory of residence, dog ownership (yes; no), automobile ownership (no; one; two or more), the number of children (less than 18 years) and adults (18 years or older) in the household, whether the child had a mobile phone (yes; no) or a disability/chronic condition (yes; no), and the number of years that the child has lived in Canada (born in Canada; 2 years or less; 3–5 years; 6 years or more).

To assess parental tolerance to risk, an adapted version of the Tolerance of Risk in Play Scale (TRiPS) was used with minor wording changes to facilitate comprehension by English- and French-Canadian parents. The TRiPS has shown a person reliability index of 0.87 and good construct validity (Hill and Bundy, 2014) and had an excellent internal consistency ($\alpha = 0.90$) in the national study at baseline (Larouche et al., 2023). The construct of social cohesion was measured using a validated 5-item subscale (Sampson et al., 1997), which had satisfactory internal consistency ($\alpha = 0.77$) in the national survey (Larouche et al., 2023). Parental concerns about traffic and crime were assessed using subscales from the Neighbourhood Environment Walkability Scale – Youth (Rosenberg et al., 2009). In the national survey, α values for these subscales were 0.53 and 0.90, respectively (Larouche et al., 2023).

To determine the walkability of their home neighborhood based on the Canadian Active Living Environments (Can-ALE) database (Herrmann et al., 2019), participants were asked to provide their 6-digit postal code. A Python™ script (Python Software Foundation, Beaverton, OR) was developed to link postal codes with the corresponding dissemination area (small geographic units with a population of 400–700 people defined by Statistics Canada). For each dissemination area, the Can-ALE includes a categorical variable for neighborhood walkability ranging from 1 indicating the least to 5 denoting the most walkable neighborhoods (Herrmann et al., 2019). The script was also used to obtain data on total precipitation and minimum and maximum temperature during the week preceding the survey from the closest Environmental Canada weather station.

Given the context of COVID-19, parents were asked to report how their children attended school in the past week (in person/online/blended/not applicable) and whether

their household was under isolation in the past week. A 3-level item about parental concerns with COVID-19 was also included in the survey (not concerned/somewhat concerned/very concerned).

2.6 Data Treatment

Participants' province/territory of residence were classified into five geographical regions, namely Pacific (British Columbia and Yukon), Prairies (Alberta, Saskatchewan, Manitoba, Northwest Territories), Ontario, Quebec, and Atlantic (Newfoundland and Labrador, New Brunswick, Prince Edward Island, Nova Scotia). To minimize problems associated with small cell sizes, I restricted the sample to parents aged 20–64 years and children who identified as boy or girl, which is consistent with previous studies on changes in physical activity associated with COVID-19 (Mitra et al., 2020; Moore et al., 2020). Following the data from the national longitudinal study, I recoded parents' occupation (working full-time; homemaker; or others), and type of residence (detached/semi-detached vs. others) (Larouche et al., 2023). Because of the small number of participants living in the most walkable neighborhoods, I combined the Can-ALE classes 4 and 5 based on the observation by Herrmann et al. (2019) that these neighbourhoods are uncommon outside of major cities. Since only 4.5% of participants had no vehicle, I combined them with participants who owned 1 vehicle, which aligns with a longitudinal pilot study on active school transportation (Larouche et al., 2013).

2.7 Analysis Strategy

2.7.1 Sample Description: Descriptive statistics were computed first to examine study participants' demographic characteristics. Means and standard deviations were calculated for continuous variables, and frequency and percentages for categorical variables. The differences in descriptive statistics by child gender were examined using the Chi-squared test and independent samples t-tests, with Cramer's V and Cohen's d as measures of effect size respectively. Using Chi-squared test and independent samples t-tests, I also examined the baseline characteristics of study participants who were lost to follow up versus those who remained in the study. Finally, boxplots and Q-Q plots were used to examine the distribution of data.

2.7.2 Regression Modeling: Using generalized linear models (GLM), I ran bivariate analyses to examine the correlates of changes in CIM. Given the large number of variables, only those with an association with p-value <0.20 in bivariate models (Gropp et al., 2012) were retained for potential inclusion in the multivariate model. I used a forward selection process to get a more parsimonious multivariate model. In this process, I used likelihood ratio tests for examining differences in deviance between models. If the difference exceeded the critical value of the Chi-squared distribution, I retained variables in the final model. Multicollinearity of independent variables was tested and variables with variance inflation factor values (VIF>5) were removed from the final regression model. Age and parental income were considered as potential confounders and controlled for when examining the correlates of CIM irrespective of statistical significance. I checked the potential moderating effect of gender with each variable in the model separately by fitting multiplicative interaction terms. I also built

gender-stratified models to understand gender differences in the correlates of CIM. Since some of these terms were significant, I present models stratified by gender. All statistical tests were performed using SPSS, version 29 (IBM, Armonk, NY). A p-value of <0.05 was used for all statistical inferences. Unstandardized beta coefficients were used to represent the effect size. Missing data were deleted listwise. This approach was adopted because treating the "Prefer not to answer" option for household income as non-missing reduced the overall proportion of missing data to less than 1% for all predictors, except for those related to postal code (weather and walkability), which had a missing data rate of 12.7%, but were deemed inappropriate for imputation.

2.8 Research Ethics Approval

This study protocol was approved by the Human Participant Research Committee of the University of Lethbridge (protocol 2020-097). Participants in this study consented electronically after reviewing an information letter. Information about participants will remain confidential to the researcher.

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CHAPTER 3: MANUSCRIPT

Correlates of changes in children's independent mobility during the COVID-19 pandemic: a Canadian national longitudinal study

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3.1 Abstract

Background: Children's independent mobility (CIM) is linked to higher physical activity in cross-sectional research but longitudinal assessments of correlates of changes in CIM are lacking. The current study investigated social-ecological correlates of changes in CIM and whether they differ by gender.

Method: Every six months between December 2020 and 2021, Canadian parents of 7- to 12-year-olds (n=2291) were surveyed to assess mobility licenses (children's permission to do certain activities independently). This study used linear regression models adjusted for child age, gender, and household income.

Results: Average CIM increased (0.65±1.30 licenses) throughout the follow-up period. Boys experienced a smaller increase in CIM than girls (β: -0.60; 95%CI: -1.13, -0.06). Child age (β: 0.08; 95%CI: 0.03, 0.14) and each unit increase in the parental Tolerance of Risk in Play Scale (β: 0.02; 95%CI: 0.00, 0.04) were associated with increased CIM whereas parental crime safety concerns (β: -0.19; 95%CI: -0.37, -0.02) were negatively associated. Children whose parents were neither employed full-time nor homemakers had lower CIM than those of full-time working parents (β: -0.40; 95%CI: -0.74, -0.06). Child gender interacted with parent employment: boys whose parent did not work full-time had a greater increase in CIM (β: 0.52; 95%CI: 0.08, 0.95). In gender-stratified models, boys with a disability (β: 0.49; 95%CI: 0.08, 0.89) and from middle- vs. high-income households (β: 0.34; 95%CI: 0.05, 0.63) had greater increases in CIM.

Conclusion: Findings show that correlates of changes in CIM span multiple levels of influence. Future interventions to increase CIM could target modifiable variables, including parental risk tolerance and perceived crime safety.

Keywords: Physical activity, Children's independent mobility, Social-ecological model, active transportation, risk tolerance, crime safety.

3.2 Introduction

Children's independent mobility (CIM) facilitates children's physical activity and well-being (Schoeppe et al., 2014) as well as social, motor, and cognitive development (Riazi & Faulkner, 2018; Shaw et al., 2015). The term CIM was introduced by Hillman et al. (1990), and it represents children's freedom to move around their neighborhood without adult supervision. It commonly includes non-motorized activities (e.g., walking and cycling), playing outdoors, and using public transit (Marzi & Reimers, 2018). Researchers found that CIM is associated with more active transportation, outdoor play, and overall physical activity in children (Larouche et al., 2020; Mackett et al., 2007; Page et al., 2009; Schoeppe et al., 2014; Wen et al., 2009; Veitch et al., 2008). It can help children improve their risk assessment, spatial comprehension, and navigational skills (Riazi & Faulkner, 2018; Rissotto & Tonucci, 2002). A greater level of CIM can increase self-confidence and provide opportunities to communicate more with their peers indoors and outdoors (Prezza et al., 2001; Prezza & Pacilli, 2007). Greater levels of CIM during childhood can result in lower fear of crime and stronger sense of community in adolescence (Prezza et al., 2001). Despite all these benefits, declines in the levels of CIM have been reported in many countries over the last few decades (Fyhri et al., 2011; Kytta et al., 2015; Hillman et al., 1990; Schoeppe et al., 2016; Shaw et al., 2013).

The social-ecological model provides a valuable framework to conceptualize the correlates of CIM (Larouche & Ghekiere, 2018; Riazi & Faulkner, 2018). This model postulates that health behaviors are impacted by multiple levels of influence that can interact (Sallis et al., 2006; Sallis et al., 2015). According to Larouche & Ghekiere (2018), these levels of influence include factors at the individual level (e.g., children's

behavior and characteristics), interpersonal level (e.g., the influence of parents and friends), community level (e.g., school policies and practices, and social norms), built and physical environment level (e.g., roads, sidewalks, cycle paths, weather, etc.), and policy level (e.g., policies to support CIM at local, provincial, and national levels). Based on this model, CIM is correlated with several socio-demographic and physical environmental attributes (Marzi et al., 2018; Riazi et al., 2019; Sharmin & Kamruzzan, 2017). In a systematic review, child age and gender were the most examined individual-level correlates (Riazi et al., 2022), with older children having greater CIM compared to younger children, whereas the association with gender was indeterminate. Other factors, such as membership within the dominant ethnicity, speaking the majority language at home, having siblings, parent's perception toward CIM, a child's confidence and skills to travel independently, and access to a house key were consistently positively associated with CIM (Ghekiere et al., 2017; Janssen et al., 2016; Riazi et al., 2022; Villanueva et al., 2013).

At the built environment level, only parental concern about traffic safety was consistently negatively associated with CIM, whereas residential density, length of residency in one's home, shorter distance to school, access to outdoor spaces (including for walking and cycling), and proximity to green space were consistently positively associated (Riazi et al., 2022). A recent national study using the baseline data identified that greater CIM is significantly associated with lower household income, household dog ownership, and living in a household with no motor vehicle (Larouche et al., 2023). Some studies have reported that greater parental concerns about crime safety, strangers, and social dangers in the street limit the opportunities for CIM (Foster et al., 2014; Fyhri et

al., 2011; Santos et al., 2013), though the evidence is inconsistent (Riazi et al., 2022). In Canada, there are few studies examining CIM, typically with a narrow geographic scope (Buliung et al., 2009; Buliung et al., 2017; Delisle Nyström et al., 2019; Larouche et al., 2023; Mitra et al., 2014; Riazi et al., 2021), and none of these studies reported correlates of temporal changes in CIM.

A national survey found that only 4.8% of Canadian children met the recommended movement behavior guidelines during the first wave of the pandemic (Moore et al., 2020). These guidelines represent a novel approach to health promotion by providing a comprehensive recommendation for a well-balanced 24-hour period, incorporating adequate sleep duration, screen-based sedentary behaviour, and moderate-to-vigorous physical activity (Tremblay et al., 2016). In a qualitative study conducted in Toronto and Vancouver, the closure of parks, playgrounds, and other outdoor facilities was associated with a reduction in CIM (Riazi et al., 2021). In contrast, another qualitative study conducted in a smaller northern British Columbia community suggested that the pandemic was associated with a reduction in structured activities and an increase in CIM (Pelletier et al., 2021). Thus, there may have been geographical differences in children's experiences related to COVID-19.

Current research on CIM is largely based on cross-sectional studies (Riazi et al., 2022). Specifically, a systematic review by Riazi et al. (2022) identified only three longitudinal studies examining the correlates of CIM, all of which were conducted in Australia and examined CIM only in the context of travel to/from school. Of these studies, only Veitch et al. (2017) examined the predictors of CIM to/from non-school destinations. A prospective cohort study was conducted with a representative sample to

investigate how CIM changed through the COVID-19 pandemic, identify the social-ecological factors associated with these changes in a representative sample of parents of 7- to 12-year-olds across Canada, and examine the effect of gender on these associations. If the level of CIM varies substantially by gender, this would suggest that different strategies may be needed to promote CIM in boys and girls.

3.3. Materials and Methods

3.3.1 Study Design, Setting, and Data Collection

This stduy used data from a national longitudinal study that involved a sample of 2291 parents of 7- to 12-year-old children who were selected to represent the Canadian target population demographically (Larouche et al., 2023). Inclusion criteria were: lived in Canada, parents of 7- to 12-year-old children, able to complete the survey in English or French, and agreed to take part in the survey again at 6-, 12-, and 18-month follow-up. Parents with more than one child in the target age range were asked to complete the survey for their child whose name came first in alphabetical order. Baseline data were collected in December 2020 through Leger (leger360.com), Canada's largest market survey firm. Follow-up data were collected every six months until June 2022. Public health restrictions related to the COVID-19 pandemic became less severe through the study period as indicated by the Bank of Canada's (2022) stringency index declining from 64.0 to 17.0 (out of 100). A parent questionnaire was used to assess several potential correlates representing multiple levels of influence of the social-ecological model. In addition, an objective measure of walkability (the extent to which the built environment around participants' homes supports walking) was obtained based on the parent-reported

6-digit postal codes. Participants completed the survey using a computer-aided web interviewing method. An incentive of $3 (Canadian) was offered to the participants for each completed survey. An additional $10 was offered to those who completed all four survey waves. This study protocol was approved by relevant research ethics committees (protocol 2020-097). Participants consented electronically after reviewing an information letter.

3.3.2 Measures

CIM: CIM was assessed using Hillman's six mobility licenses that summarise children's permission to do the following things on their own: walk home from school, travel to other places in their neighborhood, cross main roads, cycle on main roads, go outside after dark, and use public transit (Hillman et al., 1990). The responses were dichotomized (1 = yes; 0 = no) for each license and summed to construct a CIM index ranging from 0 to 6 with higher scores indicating greater CIM. A previous study found good test-retest reliability and convergent validity of the CIM index based on parents and children's responses in English and French (Larouche et al., 2017). A new variable was created to represent the changes in CIM over 12 months where a positive value indicates an increase, a negative value a decrease, and zero represents no change in CIM. Using changes over 12 months minimized potential confounding associated with seasonality and resulted in a larger analytic sample size than changes over 18 months.

Potential Social-ecological Correlates of CIM: Parents reported the age (in years) and gender of the child and parent. Data on parental employment status and household income were collected using standard questions from Leger. Parents also

reported other socio-demographic and household characteristics including household income (CAD$39,999 or less; $40,000–99,999; $100,000 or more; prefer not to answer), employment status (working full time; working part-time; self-employed or freelance work; student; homemaker; unemployed), type of residence (low rise apartment; high rise apartment; townhouse; semi-detached house; detached house; other), province or territory of residence, dog ownership (yes; no), automobile ownership (no; one; two or more), the number of children (less than 18 years) and adults (18 years or older) in the household, whether the child had a mobile phone (yes; no) or a disability/chronic condition (yes; no), and the number of years that the child has lived in Canada (born in Canada; 2 years or less; 3–5 years; 6 years or more).

To assess parental tolerance to risk, an adapted version of the Tolerance of Risk in Play Scale (TRiPS) was used with minor wording changes to facilitate comprehension by English- and French-Canadian parents. The 30-item TRiPS has shown a person reliability index of 0.87 and good construct validity, with a strong positive relationship between participants' self-perceived risk tolerance and their scores (Hill and Bundy, 2014). Also, it showed excellent internal consistency ($\alpha = 0.90$) in the national study at baseline (Larouche et al., 2023). The construct of social cohesion was measured using a validated 5-item subscale (Sampson et al., 1997), which had satisfactory internal consistency ($\alpha = 0.77$) at baseline (Larouche et al., 2023). Parental concerns about traffic and crime were assessed using subscales from the Neighbourhood Environment Walkability Scale – Youth, with higher scores indicating more concerns (Rosenberg et al., 2009). At baseline, α values for these subscales were 0.53 and 0.90, respectively (Larouche et al., 2023).

To determine the walkability of their home neighborhood based on the Canadian Active Living Environments (Can-ALE) database (Herrmann et al., 2019), participants were asked to provide their 6-digit postal code. A Python™ script (Python Software Foundation, Beaverton, OR) was developed to link postal codes with the corresponding dissemination area (small geographic units with a population of 400–700 people defined by Statistics Canada). For each dissemination area, the Can-ALE includes a categorical variable for neighborhood walkability ranging from 1 indicating the least to 5 denoting the most walkable neighborhoods (Herrmann et al., 2019). The script was also used to obtain data on total precipitation and minimum and maximum temperature during the week preceding the survey at the closest weather station.

Given the context of COVID-19, parents were asked to report how their children attended school in the past week (in person/online/blended/not applicable) and whether their household was under isolation in the past week. For the follow-ups, the not applicable option was divided into “school was closed last week” and “home-schooled”, and for the present analyses, we combined these categories as “other”. A 3-level item about parental concerns with COVID-19 was also included in the survey (not concerned/somewhat concerned/very concerned).

3.3.3 Data Treatment

Participants' province/territory of residence were classified into five geographical regions, namely Pacific (British Columbia and Yukon), Prairies (Alberta, Saskatchewan, Manitoba, Northwest Territories), Ontario, Quebec, and Atlantic (Newfoundland and Labrador, New Brunswick, Prince Edward Island, Nova Scotia). To minimize problems

associated with small cell sizes, the sample was restricted to parents aged 20–64 years who identified as man or woman, and children who identified as boy or girl, which is consistent with previous studies on changes in physical activity associated with COVID-19 (Mitra et al., 2020; Moore et al., 2020). I recoded parents' occupation (working full-time; homemaker; or others), and type of residence (detached/semi-detached vs. others) (Larouche et al., 2023). Because of the small number of participants living in the most walkable neighborhoods, I combined the Can-ALE classes 4 and 5 based on the observation by Herrmann et al. (2019) that these neighbourhoods are uncommon outside of major cities. Since only 4.5% of participants at the last follow-up had no vehicle, I combined them with participants who owned only 1 vehicle, which aligns with a pilot study on active school transportation (Larouche et al., 2013).

3.3.4 Data Analysis

I first computed descriptive statistics to examine participants' demographic characteristics. Means and standard deviations were calculated for continuous variables, and frequencies and percentages were used for categorical variables. I used independent two sample t-tests and Chi-squared tests with indicators of effect size, namely Cohen's d (small = 0.2, medium = 0.5, large = 0.8) and Cramer's V (small = 0.1, medium = 0.3, large = 0.5) (Cohen, 1988) to compare differences in descriptive statistics between boys and girls, and between participants who were lost to follow-up and those remained in the study. Finally, boxplots and Q-Q plots were used to examine the distribution of data.

Using generalized linear models (GLM), I ran bivariate analyses to examine the correlates of changes in CIM over 12 months. Given the large number of variables, only

those with an association with p-value <0.20 (Gropp et al., 2012) were retained for potential inclusion in the multivariate model. I used a forward selection process to get a more parsimonious multivariate model. In this process, I used likelihood ratio tests for examining differences in deviance. If the difference exceeded the critical value of the Chi-squared distribution, I retained variables in the final model. Multicollinearity of independent variables was tested and variables with variance inflation factor values (VIF>5) were removed from the final regression model. I considered age and parental income as potential confounders and controlled for them when examining the correlates of CIM. Potential moderating effect of gender was checked with each variable in the model separately by fitting multiplicative interaction terms. I also built gender-stratified models to understand gender differences in the correlates of CIM. Since some of these terms were significant, I present models stratified by gender. All statistical tests were performed using SPSS, version 29 (IBM, Armonk, NY). A p-value of <0.05 was used for all statistical inferences. Unstandardized beta coefficients were used to represent the effect size. Missing data were deleted listwise. I adopted this approach because treating the "Prefer not to answer" option for household income as non-missing reduced the overall proportion of missing data to less than 1% for all predictors, except for those related to postal code (weather and walkability), which had a missing data rate of 12.7% and were deemed inappropriate for imputation.

3.4 Results

3.4.1 Sample Characteristics

Baseline sample characteristics, stratified by gender, are presented in Table 1. Average CIM increased throughout the COVID-19 pandemic (0.65±1.30). 64.4% of parent respondents were women. At baseline, on average, children were 9.9 (±1.7) years and 48.4% were girls. Significant differences in baseline characteristics by child gender were observed. A higher proportion of parent respondents identifying as woman provided responses for girls (66.7% vs 62.4%, $p = 0.034$). Additionally, a greater percentage of boys had disabilities (13.2% vs 8.6%, $p < 0.001$). In contrast, a larger proportion of girls had mobile phones (35.3% vs 30.4%, $p = 0.010$) and resided in households with two or more vehicles (57.7% vs 49.9%, $p < 0.001$).

Table 1: Baseline descriptive characteristics of study participants, stratified by gender.

Variable	Whole sample (n= 2257)		Boys (n= 1165)		Girls (n= 1092)		
	Frequency (%)	Mean (SD)	Frequency (%)	Mean (SD)	Frequency (%)	Mean (SD)	p-value
Changes in CIM		0.65 (1.3)		0.64 (1.3)		0.65 (1.3)	0.938
Child age (years)		9.9 (1.7)		9.9 (1.7)		9.9 (1.7)	0.905
Number of adults in household		2.0 (0.6)		2.0 (0.6)		2.0 (0.6)	0.616
Number of children in household		2.0 (1.0)		2.0 (0.9)		2.0 (1.0)	0.328
TRiPS scale		16.2 (6.5)		16.2 (6.5)		16.3 (6.5)	0.773
Traffic safety scale		2.5 (0.6)		2.5 (0.6)		2.5 (0.7)	0.797
Crime safety scale		2.2 (0.8)		2.2 (0.8)		2.2 (0.8)	0.056

Social cohesion scale	3.5 (0.7)	3.5 (0.7)	3.5 (0.8)	0.722
Parent gender				**0.034**
Man	802 (35.5)	438 (37.6)	364 (33.3)	
Woman	1455 (64.4)	727 (62.4)	728 (66.7)	
Household income (CAD)				0.864
≤ $39,999	256 (11.3)	132 (11.3)	124 (11.4)	
$40k to $99,999	1018(45.1)	532 (45.7)	486 (44.5)	
≥ $100k	779 (34.5)	393 (33.7)	386 (35.3)	
Prefer not to respond	204 (9.1)	108 (9.3)	96 (8.8)	
Region				0.313
Pacific	261 (11.6)	138 (11.8)	123 (11.3)	
Prairies	435 (19.3)	217 (18.6)	218 (20.0)	
Ontario	877 (38.8)	445 (38.2)	432 (39.6)	
Quebec	513 (22.7)	264 (22.7)	249 (22.7)	
Atlantic	171 (7.6)	101 (8.7)	70 (6.4)	
School delivery				0.430
In-person	1629(72.2)	855 (73.4)	774 (70.9)	
Online	379 (16.8)	181 (15.5)	198 (18.1)	
Blended	118 (5.2)	61 (5.3)	57 (5.2)	
N/A (e.g., home schooled)	131 (5.8)	68 (5.8)	63 (5.8)	
Disability/chronic condition				**<0.001**
Yes	248 (11.0)	154 (13.2)	94 (8.6)	
No	2009(89.0)	1011(86.8)	998 (91.4)	
Child owns a mobile phone				**0.012**
Yes	740 (32.8)	354 (30.4)	386 (35.3)	
No	1517(67.2)	811 (69.6)	706 (64.7)	
Type of home				0.072

Detached/semi-detached	1660(73.5)	838 (71.9)	822 (75.3)	
Other	597 (26.5)	327 (28.1)	270 (24.7)	
Dog ownership				0.865
Yes	868 (38.5)	450 (38.6)	418 (38.3)	
No	1389(61.6)	715 (61.4)	674 (61.7)	
Vehicle ownership				**<0.001**
No	136 (6.0)	81 (7.0)	55 (5.0)	
One	909 (40.3)	502 (43.1)	407 (37.3)	
Two or more	1212(53.7)	582 (49.9)	630 (57.7)	
Employment (n= 2245)				0.357
Work full-time	1429(63.6)	740 (63.8)	689 (63.4)	
Homemaker	244 (10.9)	116 (10.0)	128 (11.8)	
Other	572 (25.5)	303 (26.2)	269 (24.8)	
Time child lived in Canada				0.876
5 years or less	107 (4.7)	53 (4.5)	54 (4.9)	
6 years or more	296 (13.1)	151 (13.0)	145 (13.3)	
Born in Canada	1854(82.2)	961 (82.5)	893 (81.8)	
Concerns about COVID-19				0.808
Not concerned	311 (13.8)	156 (13.4)	155 (14.2)	
Somewhat concerned	1226(54.3)	632 (54.2)	594 (54.4)	
Very concerned	720 (31.9)	377 (32.4)	343 (31.4)	
Parent travel mode to work				0.930
Active	292 (14.3)	153 (14.5)	139 (14.0)	
Motorized	1402(68.5)	718 (68.3)	684 (68.7)	
N/A	354 (17.2)	181 (17.2)	173 (17.3)	

Parent travel mode from work				0.746
Active	269 (13.2)	140 (13.4)	129 (13.0)	
Motorized	1433(70.1)	739 (70.5)	694 (69.7)	
N/A	342 (16.7)	169 (16.1)	173 (17.3)	
Walkability (Can-ALE; n=1970)				0.086
1	567 (28.8)	293 (28.7)	274 (28.8)	
2	629 (31.9)	311 (30.5)	318 (33.5)	
3	512 (26.0)	262 (25.7)	250 (26.3)	
4-5	262 (13.3)	154 (15.1)	108 (11.4)	

Note: CIM: children's independent mobility; TRiPS: tolerance to risk in play scale; Can-ALE: Canadian Active Living Environments. Boldface denotes statistically significant differences between boys and girls ($p < 0.05$).

At the end of 12-months, follow-up data were analysed for 941 participants (41.7% of the baseline sample) whose characteristics are provided in Supplementary Material 1. Notably, no significant gender difference in changes in CIM was observed.

Differences in the baseline characteristics of participants who dropped out and those who remained in the study are provided in Table 2. Most of the parent respondents who were lost to follow-up were women (66.4% vs. 33.6% men, $p = 0.022$). The follow-up group had a smaller CIM index (1.7 vs. 2.0, $p = <0.001$) and a higher social cohesion score (3.6 vs. 3.5, $p = 0.014$) compared to those who participated only at baseline. A higher proportion of respondents in the follow-up group resided in a detached/semi-detached home (75.8% vs. 72.0%, $p = 0.043$). Furthermore, the follow-up group had a lower proportion of dog ownership (35.5% vs 40.4%, $p = 0.045$) and households without

access to a motor vehicle (4.6% vs. 7.1%, p = 0.020). All these statistically significant differences were below cut-points for small effect size.

Table 2: Characteristics of participants lost to follow-up vs. those who remained in the study.

Baseline Sample Characteristics	Dropped Out					
	Yes (n=1316)		No (n=941)			
	Frequency (%)	Mean (SD)	Frequency (%)	Mean (SD)	P-value	Effect Size
CIM index		**2.0 (1.7)**		**1.7 (1.6)**	**<0.001**	**-0.16**
Child age		9.9 (1.7)		9.9 (1.7)	0.824	-0.01
Number of adults in household		2.0 (0.7)		2.0 (0.6)	0.605	0.02
Number of children in household		2.0 (0.9)		2.0 (0.9)	0.826	-0.01
TRiPS scale		16.5(6.6)		15.9(6.3)	0.059	-0.08
Social cohesion scale		**3.5 (0.7)**		**3.6 (0.7)**	**0.014**	**0.11**
Traffic safety scale		2.5 (0.6)		2.5 (0.7)	0.558	-0.03
Crime safety scale		2.2 (0.8)		2.2 (0.8)	0.787	-0.01
Parent gender					**0.022**	**0.05**
Man	442 (33.6)		360 (38.3)			
Woman	874 (66.4)		581 (61.7)			
Child gender					0.652	0.01
Boy	674 (51.2)		491 (52.2)			
Girl	642 (48.8)		450 (47.8)			
Household income					0.051	0.06
$39,999 or less	168 (12.8)		88 (9.4)			
$40,000 to $99,999	597 (45.4)		421 (44.7)			
$100,000 or more	438 (33.3)		341 (36.2)			
Prefer not to respond	113 (8.6)		91 (9.7)			
Region					0.561	0.04
Pacific	159 (12.1)		102 (10.8)			
Prairies	263 (20.0)		172 (18.3)			
Ontario	495 (37.6)		382 (40.6)			
Quebec	297 (22.6)		216 (23.0)			
Atlantic	102 (7.8)		69 (7.3)			
School delivery					0.971	0.01
In person	947 (72.0)		682 (72.5)			
Blended	69 (5.2)		49 (5.2)			
Online	221 (16.8)		158 (16.8)			

N/A (e.g., home-schooled)	79 (6.0)	52 (5.5)		
Disability or chronic condition			0.313	0.02
No	1164(88.4)	845 (89.8)		
Yes	152 (11.6)	96 (10.2)		
Child owns a mobile phone			0.615	0.01
No	879 (66.8)	638 (67.8)		
Yes	437 (33.2)	303 (32.2)		
Type of home			**0.043**	**0.04**
Other	369 (28.0)	228 (24.2)		
Detached or semi-detached	947 (72.0)	713 (75.8)		
Dog ownership			**0.023**	**0.05**
Yes	532 (40.4)	336 (35.5)		
No	784 (59.6)	605 (64.3)		
Employment			0.061	0.05
Work full-time	820 (62.6)	609 (65.1)		
Homemaker	133 (10.2)	111 (11.9)		
Other	356 (27.2)	216 (23.1)		
Concerns about COVID-19			0.488	0.03
Not concerned	191 (14.5)	120 (12.8)		
Somewhat concerned	709 (53.9)	517 (54.9)		
Very concerned	416 (31.6)	304 (32.3)		
Time since child lived in Canada			0.065	0.05
5 years or less	74 (5.6)	33 (3.5)		
6 years or more	170 (12.9)	126 (13.4)		
Born in Canada	1072(81.5)	782 (83.1)		
Vehicle ownership			**0.020**	**0.06**
No	93 (7.1)	43 (4.6)		
One	509 (38.7)	400 (42.5)		
Two or more	714 (54.3)	498 (52.9)		
Parent travel mode to work			0.402	0.03
Active	169 (14.2)	123 (14.3)		
Motorized	804 (67.6)	598 (69.7)		
N/A	217 (18.2)	137 (16.0)		
Parent travel mode from work			0.517	0.03
Active	155 (13.1)	114 (13.3)		
Motorized	823 (69.4)	610 (71.1)		
N/A	208 (17.5)	134 (15.6)		

Walkability (Can-ALE class)			0.721	0.03
1	333 (29.6)	234 (27.7)		
2	355 (31.5)	274 (32.5)		
3	285 (25.3)	227 (26.9)		
4-5	153 (13.6)	109 (12.9)		

Note: CIM: children's independent mobility; TRiPS: tolerance to risk in play scale; Can-ALE: Canadian Active Living Environments. Boldface denotes statistically significant differences between participants dropped out and remained ($p < 0.05$). Effect size indicators: Cohen's d (small = 0.2, medium = 0.5, large = 0.8) for continuous variables and Cramer's V (small = 0.1, medium = 0.3, large = 0.5) for categorical variables.

3.4.2 Correlates of Changes in CIM

Individual Level: Table 3 shows the social-ecological correlates of changes in CIM. At the individual level, each year increase in child's age was positively associated with CIM. Boys had smaller increases in CIM compared to girls.

Family Level: Children whose parents were students, part-time worker, or self-employed had smaller increases in CIM compared to those working full-time. Each unit increase in risk tolerance as assessed with the TRiPS was associated with increased CIM. Household income and vehicle ownership were not associated with changes in CIM in the multivariate model.

Social-environment Level: Each unit increase in the crime safety concern scale was linked to a smaller increase in CIM.

Built-environment Level: In the bivariate model (Supplementary Material 2), children residing in Can-ALE–class 1 neighbourhoods experienced greater CIM compared to those living in the most walkable neighbourhoods (Can-ALE classes 4 and

5); however, in the final multivariate model adjusted for confounders, none of the built environment variables were associated with changes in CIM.

Interactions with Child Gender: The association between parents' employment status and changes in CIM varied depending on child gender. Boys whose parent was a student, part-time worker, or self-employed rather than a full-time worker had a greater increase in CIM (Table 3). Other non-significant interaction terms were retained in the final model because they improved model fit.

Table 3: Correlates of changes in CIM.

Variable	β	95% CI	p-value
Child gender – boy (ref: girl)	**-0.60**	**-1.13, -0.06**	**0.030**
Child age – each additional year	**0.08**	**0.03, 0.14**	**0.003**
Child has a disability/chronic illness – yes (ref: no)	0.02	-0.40, 0.45	0.911
Household income - $39,999 or less (ref: $100,000 or more)	0.31	-0.05, 0.67	0.090
Household income - $40,000 to $99,999 (ref: $100,000 or more)	0.20	-0.01, 0.40	0.059
Household income – Prefer not to answer (ref: $100,000 or more)	-0.06	-0.43, 0.30	0.729
Employment – homemaker (ref: full-time work)	0.02	-0.38, 0.42	0.915
Employment – other (ref: full-time work)	**-0.40**	**-0.74, -0.06**	**0.020**
Household vehicle ownership – 1 or no vehicle (ref: ≥ 2 vehicles)	-0.17	-0.37, 0.03	0.088
Parental tolerance to risk in play scale – each unit increase	**0.02**	**0.00, 0.04**	**0.019**
Crime safety concern scale – each unit increase	**-0.19**	**-0.37, -0.02**	**0.029**
Can-ALE neighbourhood – class 1 (ref: class 4-5)	0.19	-0.14, 0.51	0.259
Can-ALE neighbourhood – class 2 (ref: class 4-5)	-0.28	-0.58, 0.03	0.075
Can-ALE neighbourhood – class 3 (ref: class 4-5)	-0.20	-0.50, 0.11	0.215
Child gender – boy (ref: girl) * Having a disability/chronic illness – yes (ref: no)	0.48	-0.10, 1.06	0.102

Child gender - boy (ref: girl) * Parent employment – homemaker (ref: full-time work)	-0.05	-0.62, 0.52	0.870
Child gender - boy (ref: girl) * Parent employment – other (ref: full-time work)	**0.52**	**0.08, 0.95**	**0.020**
Child gender - boy (ref: girl) * Crime safety	0.23	-0.01, 0.46	0.057

Note: β: unstandardized regression coefficients; CI: confidence interval; Can-ALE: Canadian Active Living Environments. Boldface denotes statistical significance ($p < 0.05$). Model fit without interaction terms = 1183.754, model fit with interaction terms = 1164.168.

3.4.3 Gender-stratified Models

Upon stratification by gender (Table 4), boys with a disability or chronic condition had greater increases in CIM. Also, living in a family earning $40,000 to $99,999 annually (ref: $100,000 or more) and higher TRiPS score were significantly associated with increased CIM in boys. Child age at baseline was associated with increased CIM only in girls, whereas parental concern about crime safety was negatively associated. Girls whose parent respondent identified as a student, part-time worker, or self-employed (ref: full-time work) had smaller increases in CIM.

Table 4: Correlates of changes in CIM in boys and girls.

Variables	**Boys**			**Girls**		
	β	**95% CI**	**p-value**	**β**	**95% CI**	**p-value**
Child age – each additional year	0.07	-0.01, 0.15	0.106	0.10	0.02, 0.17	**0.009**
Child has a disability/chronic illness – yes (ref: no)	0.49	0.08, 0.89	**0.018**	0.01	-0.40, 0.42	0.960
Parent employment status – homemaker (ref: full-time work)	-0.04	-0.48, 0.39	0.850	0.08	-0.31, 0.47	0.692

Parent employment status – other (ref: full-time work)	0.10	-0.21, 0.41	0.536	-0.40	-0.74, -0.07	**0.018**
Household income - $39,999 or less (ref: ≥ $100,000)	0.23	-0.29, 0.74	0.383	0.38	-0.12, 0.88	0.134
Household income - $40,000 to $99,999 (ref: ≥ $100,000)	0.34	0.05, 0.63	**0.023**	0.04	-0.24, 0.32	0.763
Household income – Prefer not to answer (ref: $100,000 or more)	-0.04	-0.55, 0.47	0.875	-0.10	-0.63, 0.42	0.707
Household vehicle ownership – 1 or no vehicle (ref: 2 or more vehicles)	-0.15	-0.43, 013	0.291	-0.17	-0.45, 0.10	0.221
TRiPS – each unit increase	0.03	0.01, 0.06	**0.006**	0.01	-0.02, 0.03	0.581
Crime safety scale – each unit increase	0.07	-0.13, 0.27	0.481	-0.23	-0.41, -0.05	**0.010**
Can-ALE neighbourhood – class 1 (ref: class 4-5)	0.18	-0.26, 0.62	0.424	0.18	-0.30, 0.67	0.460
Can-ALE neighbourhood – class 2 (ref: class 4-5)	-0.23	-0.64, 0.18	0.263	-0.34	-0.80, 0.11	0.142
Can-ALE neighbourhood – class 3 (ref: class 4-5)	-0.19	-0.60, 0.23	0.378	-0.21	-0.67, 0.26	0.383

Note: β: unstandardized regression coefficients; CI: confidence interval; TRiPS: tolerance to risk in play scale; Can-ALE: Canadian Active Living Environments. Boldface denotes statistical significance ($p < 0.05$). Model fit for boys' model = 636.772, model fit for girls' model = 518.613.

3.5 Discussion

The current study examined changes in CIM throughout the COVID-19 pandemic and gender differences in the correlates of CIM in a national longitudinal sample of Canadian parents of 7- to 12-year-olds. Average CIM increased over time. In the multivariate model, several correlates of changes in CIM were identified at different levels of influence of the social-ecological model. Also, gender-specific correlates of changes in CIM were identified, suggesting that gender might be an important moderator to examine in future longitudinal and intervention studies.

3.5.1 Individual Level

Child age was positively associated with CIM, which is consistent with a previous systematic review indicating that older children had greater CIM (Riazi et al., 2022). This trend may arise from the correlation between children's age with maturity and parental expectations that children can perform cognitive tasks and exhibit social behaviour (Zebrowitz et al., 1991). As children grow more mature and gain relevant skills and knowledge, parents tend to become more comfortable with allowing their children to roam around their neighbourhood independently. When gender stratification was applied, age was only associated with CIM among girls, which corresponds with the findings of Medeiros et al. (2021) who observed a positive association between age and girls' independent travel to/from school. Yet, boys had significantly smaller increases in CIM compared to girls in this study. Interestingly, boys had greater CIM than girls at baseline (Larouche et al., 2023), and while few boys had all six mobility licenses, there was more room for progression in girls' CIM. Thus, it is possible that CIM increases at an earlier age in boys compared to girls, as suggested by a national study in the United States (Wolfe & McDonald, 2016). Although girls mature earlier than boys, parents may be more protective towards their daughters because of fears of sexual assault and believe that "boys will be boys", reflecting societal attitudes that often tolerate risk-taking behaviour in boys (Riazi & Faulkner, 2018). Nevertheless, a systematic review that included mostly cross-sectional studies found mixed associations between child gender and CIM (Riazi et al., 2022), with some studies reporting greater CIM in boys than girls and others showing no differences. These results emphasize the need for a more nuanced understanding of the development of CIM in boys and girls. Future research should

consider the inclusion of a wider age range, including younger children, to better understand age-related and gender-specific trends in independent mobility.

The cross-sectional study using the same participants only at baseline data, identified that children with disabilities or chronic conditions exhibited lower CIM compared to their counterparts (Larouche et al., 2023). In the current study, when stratified by gender, it was observed that only boys with a disability or chronic condition exhibited a significantly greater increase in CIM over time. Children with chronic diseases and disabilities experienced significant challenges during this period, including disruptions in healthcare access (Baumbusch et al., 2022; Diskin et al., 2022). As pandemic restrictions eased, many barriers to CIM diminished, which may have led to increased opportunities for these children to explore their environments. Reduced restrictions likely alleviated concerns about exposure to COVID-19, enabling greater freedom and mobility. However, the significance of having a disability as a social determinant of health has been comparatively understudied in contrast to other potential correlates of CIM (Ross & Buliung, 2018). Future research should focus on exploring strategies to support CIM among boys and girls with diverse forms of disability or chronic conditions.

3.5.2 Family Level

In the final multivariate model, children whose parent was a student, or working part-time, or self-employed exhibited smaller increase in CIM compared to those whose parents worked full-time. Full-time working parents can face significant time pressures, as highlighted by the US Surgeon General's report on Parental Mental Health & Well-

Being (U.S. Department of Health and Human Services, 2024). Allowing children greater CIM could relieve some of this pressure by reducing the need for constant supervision or driving children to activities. These findings contradict some previous cross-sectional literature, suggesting that children were less likely to experience CIM when their parents were employed full-time (Carver et al., 2013; Shaw et al., 2015). This contrast could be attributed to different factors, including single parenthood, socioeconomic status, discrepancies between work and school schedules (Valentine, 2017), and parents' ability to drive their kids to school on the way to work (Faulkner et al., 2010; McDonald & Aalborg, 2009). In addition, many parents were concerned about the spread of COVID-19 (Riazi et al., 2021), and driving children to school may have been viewed as a way to reduce this risk, which would not have applied to pre-pandemic studies. Upon stratification by gender, this finding remained significant only among girls, suggesting that parental employment related decisions may interact with societal norms, leading working parents to adjust independent travel allowances for boys and girls differently. Future studies could consider exploring how parent's employment status and gendered perceptions influence CIM across different contexts.

In this study, boys from middle-income households exhibited greater increases in CIM compared to those from higher-income households. Children from higher-income households often have less opportunity for independent travel (Hillman et al., 1990; Mackett et al., 2005). This could be influenced by the characteristics of higher-income neighborhoods, which are often less walkable (e.g., cul-de-sacs, larger lots) and more car-dependent, making it easier to drive children rather than encouraging independent travel. Additionally, these households may have greater resources, affording parents more time

to personally transport their children instead of promoting CIM. Previous research indicates that in low-income neighborhoods, children are more likely to walk to school, despite facing a higher risk of traffic injuries, primarily due to the scarcity of alternative transportation options (Pabayo et al., 2012). However, there is a lack of studies examining differences between middle and high-income groups, underscoring a need for future research.

Greater parental tolerance to risk was associated with increased CIM with a small effect size. This finding aligns with a recent British children's play survey, which reported that children whose parents exhibited greater tolerance to risk in play tended to spend more time in unsupervised outdoor activities at a younger age (Dodd et al., 2021). Parents with greater risk tolerance might consider minor risks as part of healthy development and thus encourage their children in exploring and navigating surroundings on their own. On the other hand, less risk-tolerant parents may restrict their CIM out of safety concerns (Faulkner et al., 2025). These findings underscore the importance of risk tolerance in shaping children's opportunities for CIM and highlights the need for parenting strategies to promote a balanced approach to risk management, fostering their CIM while ensuring their safety (Canadian Pediatric Society, 2024). However, gender-stratified models indicated that the association between risk tolerance and CIM was only significant in boys who may be more prone to take risks (Riazi & Faulkner, 2018). Future studies should compare the role of risk tolerance in boys' and girls' CIM.

Children who resided in households with lower vehicle ownership had smaller increases in CIM compared to those from households with at least two vehicles. However, this association was found significant only in the bivariate model and it is

notable that children from households with fewer vehicles had greater CIM at baseline (Larouche et al., 2023), so they may have been granted mobility licenses at an earlier age.

3.5.3 Social-environment Level

It was observed that, increased parental concerns about crime was linked to smaller increases in CIM. This outcome aligns with a study by Janssen et al. (2016) that identified parent's perceived fear of crime in the neighbourhood as one of the strongest correlates of CIM. However, a recent systematic review rated the evidence of an association between crime safety and CIM as "indeterminate" (Riazi et al., 2022). Upon further examination, the current study revealed a gender-specific pattern whereby parental concern about crime safety was significantly correlated with changes in CIM exclusively among girls. As sexual harassment is a pervasive and frequent part of everyday experiences for many girls (Hampshire et al., 2011; Shute et al., 2008), parents of girls may be more concerned about sexual harassment in the context of CIM. Previous research suggests that parental perceptions of risk are influenced in part by perceived societal norms and media representations (Francis et al., 2017), suggesting that interventions could aim to reframe these perceptions.

3.5.4 Built-environment Level

In this study, children residing in less walkable neighbourhoods experienced greater increases in CIM compared to those living in the most walkable neighbourhoods, but this association was only significant in the bivariate model. In the final multivariate model, there was no significant correlates of changes in CIM at the built environment level, even after stratification by gender. Notably, changes in CIM did not vary significantly between

regions. This finding is consistent with recent active school transportation research (Larouche et al., 2024), suggesting that supporting CIM may not require expensive retrofitting of existing environments. Instead, focus could likely be on addressing and modifying parental perceptions to foster greater levels of CIM. However, these findings should be interpreted with caution given that we did not measure several built environment features that are consistently correlated with CIM. In their systematic review, Riazi et al. (2022) reported that residential density, length of residency in one's home, shorter distance to school, access to outdoor spaces (including for walking and cycling), distance to mother's workplace, and proximity to green space were consistently positively associated with CIM. Hence, there is a need for more longitudinal studies examining a broader range of built environment correlates of CIM.

3.4.5 Strengths and Limitations

The longitudinal study design enabled to examine changes in CIM over a 12-month period in a large nationally representative sample of parents of 7- to 12-year-olds at baseline. I used a validated CIM index and considered multiple potential correlates in the analysis. As CIM questions focused on what children were allowed to do at the time of the survey rather than on a particular recall period, recall bias may have been limited. In contrast, respondent attrition was a major limitation that may be partly attributable to the online nature of the survey that prevented researchers from establishing rapport with participants. However, there is little concern related to differential attrition since all statistically significant differences between dropouts and completers for some variables were trivial to small. Given the relatively large sample size and numerous associations examined, the risk of type I error is considerable. As this is one of the first longitudinal

studies examining the correlates of changes in CIM, it was deemed undesirable to adjust for multiple comparisons and future studies are needed to confirm our results (Althouse, 2016). Finally, reductions in COVID-19 restrictions and increases in children attending school in person may have led to an overestimation of average changes in CIM, though an age-related increase was expected based on previous research (Riazi et al., 2022).

3.6 Conclusion

This study provides valuable new insights into the social-ecological correlates of changes in CIM, highlighting significant gender-specific variations. These results emphasize the importance of considering gender, socioeconomic factors, and parental perceptions when developing interventions to promote CIM. Our findings underscore the need for targeted strategies like "The Outside Play" risk reframing tool, which has been shown to be effective (Brussoni et al., 2021) to address modifiable factors such as parental risk tolerance to enhance CIM, which may in turn contribute to higher physical activity levels and improved child health outcomes. Future research could explore the underlying mechanisms of gender differences and investigate how targeted interventions can further promote equitable increases in CIM for all children.

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Competing Interests

The authors declared no competing interests related to this research.

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Contribution of Authors

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Appendix

Supplementary Material 1. Descriptive characteristics of participants at the end of 12 month, stratified by child gender.

Variable	Whole sample (n= 941)		Boys (n= 491)		Girls (n= 450)		
	Frequency (%)	Mean (SD)	Frequency (%)	Mean (SD)	Frequency (%)	Mean (SD)	P-value
CIM index		2.4 (1.9)		2.4 (1.9)		2.3 (1.8)	0.325
Child age (Years)		10.5 (1.5)		10.5 (1.5)		10.6 (1.5)	0.471
Number of adults in household		2.1 (0.7)		2.1 (0.7)		2.1 (0.6)	0.528
Number of children in household		2.0 (0.9)		2.0 (0.9)		2.0 (1.0)	0.517
TRiPS scale		43.2 (6.6)		43.4 (6.5)		43.0 (6.6)	0.336
Traffic safety scale		2.5 (0.6)		2.5 (0.6)		2.5 (0.7)	0.098
Crime safety scale		2.1 (0.8)		2.1 (0.8)		2.2 (0.8)	0.483
Social cohesion scale		3.5 (0.7)		3.6 (0.7)		3.5 (0.7)	0.609
Parent gender							0.516
Man	360 (38.3)		183 (37.3)		177 (39.3)		
Woman	581 (61.7)		308 (62.7)		273 (60.7)		
Household income (CAD)							0.622
$39,999 or less	75 (8.0)		37 (7.5))		38 (8.4)		
$40,000 to $99,999	398 (42.3)		208 (42.4)		190 (42.3)		
$100,000 or more	383 (40.7)		197 (40.1)		186 (41.3)		
Prefer not to respond	85 (9.0)		49 (10.0)		36 (8.0)		
Region							0.815
Pacific	102 (10.8)		52 (10.6)		50 (11.1)		

Prairies	171 (18.2)	94 (19.1)	77 (17.1)	
Ontario	384 (40.8)	193 (39.3)	191 (42.4)	
Quebec	216 (23.0)	114 (23.3)	102 (22.7)	
Atlantic	68 (7.2)	38 (7.7)	30 (6.7)	
School delivery				0.134
In-person	828 (89.7)	434 (89.5)	394 (90.0)	
Online	51 (5.5)	23 (4.7)	28 (6.4)	
Blended	18 (2.0)	9 (1.9)	9 (2.1)	
N/A (e.g., home schooled)	26 (2.8)	19 (3.9)	7 (1.5)	
Disability/chronic conditions				0.879
Yes	104 (11.1)	55 (11.2)	49 (10.9)	
No	837 (88.9)	436 (88.8)	401 (89.1)	
Child owns a mobile phone				0.058
Yes	407 (43.3)	198 (40.3)	209 (46.4)	
No	534 (56.7)	293 (59.7)	241 (53.6)	
Type of home				0.162
Detached/semi-detached	717 (76.2)	365 (74.3)	352 (78.2)	
Other	224 (23.8)	126 (25.7)	98 (21.8)	
Dog ownership				0.481
Yes	355 (37.7)	180 (36.7)	175 (38.9)	
No	586 (62.3)	311 (63.3)	27 (61.1)	
Vehicle ownership				**0.035**
No	42 (4.5)	27 (5.5)	15 (3.3)	
One	397 (42.2)	220 (44.8)	177 (39.3)	
Two or more	502 (53.3)	244 (49.7)	258 (57.4)	
Employment (n=936)				0.582
Work full-time	639 (68.3)	327 (66.9)	312 (69.8)	

Homemaker	102 (10.9)	54 (11.0)	48 (10.7)	
Other	195 (20.8)	108 (22.1)	87 (19.5)	
Time since child lived in Canada				0.526
5 years or less	29 (3.1)	18 (3.7)	11 (2.4)	
6 years or more	117 (12.4)	59 (12.0)	58 (12.9)	
Born in Canada	795 (84.5)	414 (84.3)	381 (84.7)	
Concerns about COVID-19				0.407
Not concerned	206 (21.9)	111 (22.6)	95 (21.1)	
Somewhat concerned	544 (57.8)	274 (55.8)	270 (60.0)	
Very concerned	191 (20.3)	106 (21.6)	85 (18.9)	
Parent travel mode to work				0.068
Active	76 (8.1)	48 (9.8)	28 (6.2)	
Motorized	554 (59.0)	292 (59.6)	262 (58.4)	
N/A	309 (32.9)	150 (30.6)	159 (35.4)	
Parent travel mode from work				0.092
Active	66 (7.0)	41 (8.4)	25 (5.6)	
Motorized	557 (59.4)	296 (60.5)	261 (58.1)	
N/A	315 (33.6)	152 (31.1)	163 (36.3)	
Walkability (Can-ALE class; n=855)				0.179
1	226 (26.4)	111 (24.7)	115 (28.3)	
2	285 (33.3)	148 (33.0)	137 (33.8)	
3	228 (26.7)	117 (26.1)	111 (27.3)	
4-5	116 (13.6)	73 (16.2)	43 (10.6)	

Note: CIM: children's independent mobility; TRiPS: tolerance to risk in play scale; Can-ALE: Canadian Active Living Environments scale; CAD: Canadian dollars. Boldface denotes statistically significant differences between boys and girls ($p < 0.05$).

Supplementary Material 2. Correlates of changes in CIM in bivariate models.

Variable	β	95% CI	p-value
Child gender – boy (ref: girl)	-0.01	-0.18, 0.16	0.938
Child age – each additional year	0.10	0.05, 0.15	**<0.001**
Child has a disability/chronic illness – yes (ref: no)	0.23	-0.05, 0.52	0.111
Parent gender – man (ref: woman)	-0.11	-0.29, 0.07	0.221
Household income - $39,999 or less (ref: $100,000 or more)	0.03	-0.28, 0.35	0.841
Household income - $40,000 to $99,999 (ref: $100,000 or more)	0.08	-0.11, 0.27	0.428
Household income – Prefer not to answer (ref: $100,000 or more)	0.01	-0.30, 0.31	0.960
Household vehicle ownership – 1 or no vehicle (ref: ≥ 2 vehicles)	-0.19	-0.36, -0.02	**0.030**
Type of home – detached/semi-detached (ref: others)	0.20	-0.01, 0.40	0.055
Number of children in household	0.06	-0.03, 0.16	0.174
Parental concern about COVID-19 – not concerned (ref: very concerned)	0.27	-0.01, 0.54	0.062
Parental concern about COVID-19 – somewhat concerned (ref: very concerned)	0.18	-0.01, 0.37	0.056
Parental tolerance to risk in play scale – each unit increase	0.03	0.01, 0.04	**<0.001**
Crime safety scale – each unit increase	-0.18	-0.29, -0.07	**0.002**
Region – Pacific (ref: Atlantic)	-0.29	-0.71, 0.12	0.161
Region – Prairies (ref: Atlantic)	-0.11	-0.48, 0.26	0.548
Region – Ontario (ref: Atlantic)	-0.27	-0.61, 0.08	0.127
Region – Quebec (ref: Atlantic)	-0.10	-0.46, 0.26	0.582
Can-ALE neighbourhood – class 1 (ref: class 4-5)	0.37	0.07, 0.68	**0.016**
Can-ALE neighbourhood – class 2 (ref: class 4-5)	-0.16	-0.45, 0.14	0.301
Can-ALE neighbourhood – class 3 (ref: class 4-5)	-0.16	-0.47, 0.15	0.312

Note: β: unstandardized regression coefficients; CI: confidence interval; Can-ALE: Canadian Active Living Environments scale. Boldface denotes statistical significance ($p < 0.05$).

CHAPTER 4. DISCUSSION AND CONCLUSION

4.1 Purpose

The current longitudinal study aimed to examine the changes in CIM throughout the COVID-19 pandemic and gender differences in the correlates of CIM in a national longitudinal sample of Canadian parents of 7- to 12-year-olds. This was an important research gap given that, in their systematic review about the social-ecological correlates of CIM, Riazi et al. (2022) identified only three longitudinal studies (Carver et al., 2014; Love et al., 2020; Veitch et al., 2017), all of which were conducted in Australia and only examined CIM to/from school. In Canada, there are few studies examining CIM, typically with a narrow geographic scope (Buliung et al., 2009; Buliung et al., 2017; Mitra et al., 2014; Riazi et al., 2021). Therefore, this is the first longitudinal study examining changes in CIM and its correlates in a nationally representative sample in Canada.

Average CIM increased over the study period (Appendix D), which could be due to the combination of children aging, reduced COVID-19 restrictions during the study period (Bank of Canada, 2022), and reopening of schools, public facilities, and parks after the pandemic. In the multivariate model, several correlates of changes in CIM were identified including child age, parental risk tolerance, parental crime safety concerns, and parent employment status. These correlates represent different levels of influence consistent with social-ecological models (Larouche & Ghekiere, 2018; Riazi & Faulkner, 2018).

It was hypothesized that changes in CIM could substantially differ by child gender. Consistent with this hypothesis, multiple gender-specific correlates were found, which could be attributed to varying social, cultural, and developmental factors that influence boys' and girls' behaviors, experiences, and opportunities. However, child gender significantly interacted only with parent employment status.

4.2 Individual Level

Child age at baseline was positively associated with 1-year changes in CIM with a small effect size. This finding was expected given the consistency of evidence showing that older children have greater CIM (Riazi et al., 2022). While age is not a modifiable variable, it is notable that for any given age, a remarkable generational decline has been observed (Hillman et al., 1990; Shaw et al., 2013). This decline may have adverse impacts on children's development and mental health (Gray et al., 2023; Larouche et al., 2024; Rissotto & Tonucci, 2002) and may continue over time in light of recent evidence that parents who have been granted CIM at an older age tend to be more restrictive of their children's IM (Hecker et al., 2024). Collectively, this body of literature underscores a need for interventions to address the delayed development of CIM among children.

A positive association between age and girls' independent travel was observed, which corresponds with the findings of Medeiros et al. (2021). Yet, it was found that boys had significantly lower increases in CIM compared to girls. Since boys had greater CIM than girls at baseline (Larouche et al., 2023), it is possible that CIM increases at an earlier age in boys compared to girls (Wolfe & McDonald, 2016). A recent systematic review categorized the association between child gender and CIM as "indeterminate" (Riazi et

al., 2022). Future research should consider the inclusion of a wider age range, including younger children, to better understand age-related and gender-specific trends in CIM.

Boys with a disability or chronic condition exhibited a significantly higher increase in CIM over time. Researchers recently observed that children with disabilities typically have longer school journeys than their peers, which could potentially limit their independent travel and opportunities for active transportation and CIM (Buliung et al., 2021). Future research should focus on exploring strategies to support CIM among boys and girls with diverse forms of disability or chronic conditions.

Finally, I could not examine race and ethnicity which were found to be consistently associated with CIM in a systematic review by Riazi et al. (2022). In the current study, the time since the child lived in Canada was examined to assess the impact of immigration on CIM. However, this variable was not associated with CIM even in the bivariate model. It is possible that the experience of immigrant children varies depending on linguistic and cultural factors. For example, in a previous multi-site study in Canada, children whose family spoke a minority language at home had lower CIM (Riazi et al., 2019).

4.3 Family Level

Children whose parent was a student, or working part-time, or self-employed exhibited smaller increase in CIM compared to those whose parents worked full-time. Full-time working parents can face significant time pressures (U.S. Department of Health and Human Services, 2024) and allowing children greater CIM could relieve some of this pressure by reducing supervision needs. These findings contradict some previous cross-

sectional studies suggesting smaller CIM among children of full-time employed parents (Carver et al., 2013; Shaw et al., 2015). This contrast could be attributed to different factors, including single parenthood, socioeconomic status, discrepancies between work and school schedules (Valentine, 2017) and household travel interactions (Mitra & Buliung, 2014). Previous literature suggests that urban households tend to travel less and have smaller activity spaces than suburban households (Buliung & Kanaroglou, 2006). Activity spaces is a geographical measure representing the spatial pattern of someone's routine activities, typically in the shape of a polygon (Cagney et al., 2020). When applied to CIM, a larger polygon representing places where a child can go on their own is indicative of greater CIM (Marzi & Reimers, 2018). Also, a proposed polycentric land-use strategy could reduce motorized travel, but its impact may be influenced by household demographics and mobility factors (Buliung & Kanaroglou, 2006). A polycentric approach could redistribute population and infrastructure more evenly, improving access to green spaces and opportunities for CIM. This strategy could increase non-motorized access to local destinations for children who do not live close to the city centre. However, as the current study found no association between walkability and CIM, more research is needed on the association between land use and CIM for making recommendations. As household interactions are likely to involve multiple levels of influence of the social-ecological model, our findings highlight a need for qualitative research to explore the complexity.

In this study, boys from middle-income households exhibited greater increases in CIM compared to those from higher-income households. Higher-income neighborhoods are often less walkable and more car-dependent, and may have greater resources, making

driving children convenient than encouraging CIM. In contrast, children in low-income neighborhoods are more likely to walk to school due to limited transportation options (Pabayo et al., 2012). However, there are limited studies on middle- vs. high-income groups, underscoring a need for future research.

This research revealed that greater parental tolerance to risk was associated with increased CIM. While the effect size appears very small ($\beta = 0.02$), this represents the effect of each additional unit on a 30-item scale. Previous literature suggest that risky outdoor play is positively associated with healthy child development (Brussoni et al., 2015; Dodd et al., 2021; Tremblay et al., 2015). A randomized controlled trial evaluated the effectiveness of a web-based and an in-person intervention aimed at increasing mothers' tolerance for their children's risky outdoor play and found that the web-based intervention can effectively increase parental (mothers') tolerance for risky play at both 1 week and 3 months after the intervention while the in-person intervention showed significantly higher tolerance for risky play at 1 week post-intervention (Brussoni et al., 2021). A recent cross-sectional study using data from the national longitudinal study found that more children in the household and higher household income were associated with greater parental risk tolerance, whereas factors such as concerns about "stranger danger", being very concerned about COVID-19, and parents of children born outside Canada were associated with lower tolerance to risk (Faulkner et al., 2025). These findings highlight the needs for parenting strategies to promote a balanced approach to risk management, fostering their CIM while ensuring their safety (Canadian Pediatric Society, 2024). Yet, gender-stratified models indicated a significant association between

risk tolerance and CIM only in boys, suggesting needs for future studies to compare the role of risk tolerance in boys' and girls' CIM.

4.4 Social-environment Level

It was found that increased parental concerns about crime was linked to CIM with a small effect size, which aligns with a study by Janssen et al. (2016). However, a recent systematic review rated this association as "indeterminate" (Riazi et al., 2022). Upon stratification, parental concern about crime safety was significantly correlated with changes in CIM exclusively among girls. Parental perceptions of risk are influenced in part by perceived societal norms and media representations (Francis et al., 2017), suggesting that interventions could aim to reframe these perceptions.

Riazi et al. (2022) identified that only parental concern about traffic safety was consistently negatively associated with CIM at the social environment level. However, our measure of traffic concerns had low internal consistency at baseline and traffic concerns at baseline may have been minimized by the fact that a large percentage of the population worked from home (Mitra et al., 2020).

4.5 Built-environment Level

In the bivariate model, children residing in less walkable neighbourhoods experienced greater increases in CIM compared to those living in the most walkable neighbourhoods. However, this association was categorized as indeterminate in previous literature (Riazi et al., 2022). This may be because, while walkability is associated with access to destinations within walking distance, it may also be associated with higher traffic

exposure (Riazi et al., 2019). Moreover, walkable areas based on the Can-ALE measure tend to be located closer to city centres and are most common in larger cities (Herrmann et al., 2019). These features may have been negatively associated with CIM during the pandemic. For example, CIM is known to be positively associated with outdoor play, but during the pandemic, Canadian parents perceived increases in outdoor play among children living in houses versus apartments, and this variable may be a proxy of lower density (Mitra et al., 2020) In the final multivariate model, no significant correlates of changes in CIM were found at the built environment level, even after stratification by gender. In their systematic review, Riazi et al. (2022) reported that residential density, length of residency in one's home, shorter distance to school, access to outdoor spaces (including for walking and cycling), distance to mother's workplace, and proximity to green space were consistently positively associated with CIM. Hence, there is a need for more longitudinal studies examining a broader range of built environment correlates of CIM.

4.6 Strengths and Limitations

The longitudinal study design enabled the exploration of changes in CIM over a 12-month period in a large nationally representative sample of parents of 7- to 12-year-olds at baseline. In this study, I used a validated CIM index and considered multiple potential social-ecological correlates across multiple levels of influence as well as the moderating effect of gender in the analysis. However, while examining changes in CIM, this study did not assess whether these changes were associated with key behavioral or health outcomes such as higher physical activity or greater autonomy.

As participants took part in the study voluntarily, those who participated might differ from those who did not volunteer to participate. Thus, volunteer bias might be introduced. In this study, having a large sample size across Canada helped minimize selection bias. However, loss to follow-up was a severe concern, especially given that all data were collected online, limiting the researchers' ability to establish rapport with the participants. Incentives were offered to promote retention, but they had to be modest to prevent undue influence. During data analysis, I used independent two sample t-tests and Chi-squared tests with indicators of effect size, namely Cohen's d (small = 0.2, medium = 0.5, large = 0.8) and Cramer's V (small = 0.1, medium = 0.3, large = 0.5) (Cohen, 1988) to compare differences in the baseline characteristics of study participants who were lost to follow-up and those who remained in the study. The statistically significant differences observed between dropouts and completers were trivial to small, which reduces concerns related to differential attrition.

Given that most of the data for the national longitudinal study were collected directly from the participants, social desirability bias is possible, and it is unclear how it would affect reporting of CIM. Some parents may want to demonstrate that they support CIM while others may want to show that they are being a "good parent" by putting restrictions and/or driving their children to school and other places (Dowling, 2000; Larouche, 2018). Parent report is also subject to recall bias; however, as CIM questions focused on what children were allowed to do at the time of the survey rather than on a particular recall period, recall bias may have been limited.

Given the relatively large sample size (increasing statistical power) and numerous associations examined, the risk of type I error is considerable. However, as this is one of

the first longitudinal studies examining the correlates of changes in CIM, it was deemed undesirable to adjust for multiple comparisons, but future studies are needed to confirm the results (Althouse, 2016).

Finally, reductions in COVID-19 restrictions and increases in children attending school in person may have led to an overestimation of average changes in CIM, though an age-related increase was expected based on previous research (Riazi et al., 2022).

4.7 Recommendations for Future Research and Policy

4.7.1 Research: Findings from this longitudinal study can help identify future research directions. In this study, I measured CIM using Hillman's six mobility licences that summarise children's permission to do the following activities on their own: walk home from school, travel to other places in their neighborhood, cross main roads, cycle on main roads, go outside after dark, and use public transit (Hillman et al., 1990). Future longitudinal studies could consider measuring CIM using different methods such as roaming allowance, territorial range, or activity space (Badland et al., 2011; Berg et al., 2023; Larouche et al., 2024; Loebach & Gilliland, 2016; Vlaar et al., 2019).

Since the findings highlight the influence of modifiable variables such as, parental risk tolerance and perceived crime safety on CIM, future longitudinal studies could explore the long-term impact of interventions aiming to address risk tolerance such as "The Outside Play" (Brussoni et al., 2021) risk reframing tool and neighborhood safety initiatives such as "Crime Prevention Through Environmental Design (CPTED)" (Carter et al., 2003; Cozens et al., 2005) on CIM over time. CPTED is a crime prevention strategy that enhances safety and quality of life by the effective use of the built

environment to reduce the fear and incidence of crime (Crowe, 2000). Future research should also continue to investigate the correlates of parental risk tolerance to inform future interventions (Faulkner et al., 2025).

This study identified gender-specific correlates of changes in CIM, suggesting that gender might be an important moderator to examine in future longitudinal and intervention studies. Future studies are needed to examine how social, cultural, and environmental factors influence CIM and if effects differ between boys and girls. There were not enough participants with other gender identities for modeling purposes, emphasizing the need for future research on non-binary children with adequate statistical power.

It was observed that child gender significantly interacts with parent employment status. Therefore, researchers could investigate the association between parent employment status and CIM to better understand the role of parent employment in shaping CIM. In addition, findings highlight the need for more research exploring household interactions since a strong parent-child active transportation link was found in a recent study using the baseline data (Larouche et al., 2024). These findings suggest that parental behaviors like walking with children and household dynamics such as parental work schedule and travel mode to work can play a significant role in shaping children's activity patterns as well as CIM. This also highlights the need for more research to test interactions across levels of influence of the social-ecological model.

Qualitative studies involving parents and children could provide insights into the barriers and facilitators of CIM from multiple perspectives (Crawford et al., 2017;

Francis et al., 2017). For instance, in-depth interviews with both parents and children could help exploring their experiences, beliefs, and attitudes regarding CIM. Research could also explore the impact of program and policy changes on CIM across diverse socio-economic and geographic contexts (Riazi et al., 2022).

4.7.2 Policy and Practice: Findings from this cohort study may inform future programs and policies to encourage CIM. Our findings suggest that policies should adopt a multi-faceted approach considering both social and environmental factors to improve CIM.

Parental concern about crime was associated with CIM, which aligns with previous research suggesting parent's perceived fear of crime in the neighbourhood as one of the strongest correlates of CIM (Janssen et al., 2016) and parent tolerance to risk (Faulkner et al., 2025). Concern about crime can discourage parents from allowing their children to travel independently (Vlaar et al., 2019). In contrast, parents who experience a strong sense of connection with their neighborhoods community are more inclined to allow their children to travel independently (Prezza & Pacilli, 2007). Policies could focus on creating safe and healthy neighborhoods with place-based interventions that can reduce violence, foster community trust and positive interactions, and promote collective efforts to restore social control (Hohl et al., 2019). For instances, the "Clean and Green" program showed that vacant lot greening was associated with reduced crime, improved perceptions of safety, and increased self-reported physical activity (Branas et al., 2018). While children and adolescents may also benefit, the authors focused on broader community-level impacts, making adults the primary target population. These

interventions could be adapted to alleviate parental concerns about crime and increase their tolerance for CIM.

Previous studies demonstrated the influence of adults, including parents, educators, and other child caregivers in facilitating CIM (Mitra et al. 2014; Schoeppe et al. 2016). Moreover, parents' decision in granting CIM to local destinations are impacted by the perception of their social and built environments (Mitra et al. 2014). Consistent with a recent British children's play survey (Dodd et al., 2021), this study showed that greater parental tolerance to risk was associated with CIM. These findings highlight the needs for parenting strategies to promote a balanced approach to risk management, fostering CIM while ensuring their safety (Canadian Pediatric Society, 2024). Also, these findings underscore the need for targeted strategies like "The Outside Play" risk reframing tool, which has been shown to be effective (Brussoni et al., 2021) to address modifiable factors such as parental risk tolerance to enhance CIM.

In previous research, it was observed that parents' concerns about safety can vary based on gender, with greater fears for girls compared to boys, particularly regarding interactions with strangers (Foster et al., 2014). Hence, it is important to identify and address these gender-specific concerns to ensure that interventions promote CIM equitably for boys and girls. To do so, interventions should ensure equal access to safe routes, encourage confidence-building for both gender and provide opportunities to participate in the planning process. Walking school buses and bicycle trains where groups of children walk or bike to school typically accompanied by adult volunteers, are often implemented by communities with the intention that they serve as a stepping stone to CIM (Larouche & Mendoza, 2018). This concept is like a traditional school bus where

the group walks along a planned route instead of riding in a vehicle, providing a supportive and safe environment to promote social interaction and physical activity (Kong et al., 2009; Neuwelt & Kearns, 2006). In a pilot cluster RCT, a bicycle train intervention was associated with increased child and parent self-efficacy and parental expectations for cycling to and from school in the short term (Huang et al., 2018). More work is needed to investigate whether participants in these interventions progress to CIM at a younger age (Larouche & Mendoza, 2018). Also, policies could empower both boys and girls while considering the specific challenges they face. Finally, monitoring and evaluating the impact of these interventions by gender could further ensure equal benefits and inform adjustments where needed.

Policies at the school, city, and national levels could be implemented to impact CIM. For instance, Japan has successfully promoted high rates of CIM since 1953, through policies and supportive school-level initiatives (Mori et al., 2012). Also, in the US, an increase in walking and bicycling was observed after the implementation of Safe Routes to School programs by the schools who benefited from this >US$1 billion federal program (McDonald et al., 2014). Hence, the study findings suggest that policies could focus on urban and transport planning that promote the development of child-friendly infrastructure such as equitable access to safe and well-maintained schools in all neighborhoods to encourage more children to engage in independent travel. For instance, the United Nations International Children's Emergency Fund (UNICEF)-led Child Friendly Cities Initiative supports urban environments prioritizing children's well-being, including safe mobility, access to green spaces, and inclusive community planning to support their autonomy and development (Brown et al., 2019).

Finally, the current study findings could be targets for future intervention to encourage parents who can act as "gatekeepers" for their children's access to the outside world, educators and teachers providing developmentally appropriate opportunities for risky play (Canadian Pediatric Society, 2024; Tremblay et al., 2015), and city planners and urban developers who can help create child-friendly environments.

4.8 Conclusion

Even though CIM is an essential facilitator of physical activity and health, the dramatic decline in the levels of CIM over the last decades is concerning. This study provides valuable new insights into the social-ecological correlates of changes in CIM, highlighting significant gender-specific variations. These results emphasize the importance of considering gender, socioeconomic factors, and parental perceptions when developing interventions to promote CIM. Notably, it was observed that correlates span multiple levels of influence and identified parental risk tolerance and perceived crime safety as modifiable factors that could be targeted in future interventions. Therefore, by addressing these concerns through community engagement emphasizing the benefits of CIM and interventions to improve perceived safety, it may be possible to enhance CIM. Increased CIM could positively impact children's physical health, wellbeing, social skills, and cognitive development. If successful, it could in turn help mitigate the concerns about childhood obesity, sedentary behaviors, and mental health issues contributing to a greater sense of autonomy, confidence, and social connectedness.

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APPENDICES

Appendix A – Parent Questionnaire
Appendix B - Descriptive characteristics of participants at the end of 12 month, stratified by child gender.

Appendix C - Correlates of changes in CIM in bivariate model.

Appendix D - Changes in CIM by study wave

APPENDIX-A

Parent Questionnaire

- This questionnaire should take about 20 minutes to complete.
- Please answer the questions as per the situation today to the best of your knowledge.
- Your answers will be made anonymous and kept confidential.

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1. Has anyone in your household been diagnosed with COVID-19 within the last two weeks?

   ☐ No

   ☐ Yes

   ☐ No, but we are awaiting test results

2. Was your household under a self-isolation or quarantine order in the last week (i.e., not allowed to leave the house, due to travel or other potential exposure to COVID-19)?

   ☐ No

   ☐ Yes

   ☐ We are self-isolating without being ordered

3. Have adults in your household (aged 18 or over) been partially (first dose) or completely (second dose) vaccinated against COVID-19?

   ☐ No

   ☐ Yes, some adults have been at least partially vaccinated

   ☐ Yes, all adults have been at least partially vaccinated

4. In which province or territory do you live?

   ☐ British Columbia

   ☐ Alberta

   ☐ Saskatchewan

   ☐ Manitoba

   ☐ Ontario

☐ Quebec

☐ New Brunswick

☐ Nova Scotia

☐ Prince Edward Island

☐ Newfoundland

☐ Northwest Territories

☐ Yukon

☐ Nunavut

The following questions ask about your child's movement behaviors in the last week. If you have more than one child who is aged 7-12, please think about the child whose name is first alphabetically.

5. What is your child's first name? _____

6. How did [insert child's name] attend school last week?

☐ In person at school

☐ Online

☐ Blended (a mixture of in person at school and online)

☐ Home-schooled

☐ School was closed last week

7. Were school buses for [insert child's name] school running in the last week?

☐ Yes

☐ No

☐ Not applicable

8. Was [insert child's name] affected by any of the following conditions in the last week? Please select all responses that apply.

☐ Flu or cold

☐ Asthma

☐ Injury

☐ Other. Please specify:

_____

9. How would you describe your current level of concern regarding COVID-19?
    - ☐ Not concerned
    - ☐ Somewhat concerned
    - ☐ Very concerned

10. How old is [insert child's name]? _____ years

11. What gender does [insert child's name] identify as?
    - ☐ Boy
    - ☐ Girl
    - ☐ They identify as [SPECIFY]
    - ☐ I'd rather not say

12. Does [insert child's name] have a diagnosed disability or chronic condition?
    - ☐ Yes [specify]
    - ☐ No

13. In which country was [insert child's name] born?
    _____

14. How many years has [insert child's name] lived in Canada?
    - ☐ They were born in Canada
    - ☐ 2 years or less
    - ☐ 3 to 5 years
    - ☐ 6 years or more

15. What is the 6-digit postal code of [insert child's name] primary residence?
    _____
    - ☐ Prefer not to respond

16. What type of home is [insert child's name] primary residence?
    - ☐ Low rise Apartment/Condo
    - ☐ High rise Apartment/Condo
    - ☐ Townhouse
    - ☐ Semi-detached house
    - ☐ Detached house

☐ Something else [SPECIFY]

17. Please specify the number of adults and children in your household.
    _____ adults (18 years or older)
    _____ children (less than 18 years)

18. Does your family have a dog or dogs?

    ☐ Yes

    ☐ No

19. On average, how many total hours and minutes per day did your child watch TV, use the computer, social media and play inactive video games during their free time over the last week?

    Weekdays (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know
    Weekend (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know

The next questions relate to physical activity…
Moderate-to-vigorous physical activity is any activity that increases your heart rate and makes you get out of breath some of the time. Examples include sports, swimming, soccer, hockey, running, or cycling. Light physical activity is physical activity that does not result in sweat production or shortness of breath. Examples include mild stretching, playing with animals, and leisurely walking.

20. In the last week, how many hours and minutes did your child usually spend in moderate-to-vigorous physical activity in a 24-hour period?

    Weekdays (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know
    Weekend (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know

21. In the last week, how many hours and minutes did your child usually spend in light physical activity in a 24-hour period?

    Weekdays (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know
    Weekend (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know

22. In the last week, how many hours and minutes did your child usually spend sleeping in a 24-hour period (including naps but excluding time spent resting while awake)?

Weekdays (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know

Weekend (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know

23. On a typical **weekday** during the past week, how much time did your child spend playing outdoors (choose only one answer):

☐ None at all

☐ Less than 1 hour

☐ 1 to less than 2 hours

☐ 2 to less than 3 hours

☐ 3 to less than 4 hours

☐ 4 to less than 5 hours

☐ 5 hours or more

24. On a typical **weekend day** during the past week, how much time did your child spend playing outdoors (choose only one answer):

☐ None at all

☐ Less than 1 hour

☐ 1 to less than 2 hours

☐ 2 to less than 3 hours

☐ 3 to less than 4 hours

☐ 4 to less than 5 hours

☐ 5 hours or more

25. On a typical day, the MAIN part of your child's journey TO school is made by…

☐ Walking

☐ Bicycle

☐ Bus, train, streetcar, subway, or boat/ferry

☐ Car, motorcycle, or moped

☐ Other. Please specify: _____

☐ Not applicable; my child attends school at home

26. On a typical day, the MAIN part of your child's journey FROM school to home is made by…

☐ Walking

☐ Bicycle

☐ Bus, train, streetcar, subway, or boat/ferry

☐ Car, motorcycle, or moped

☐ Other. Please specify: _____

☐ Not applicable; my child attends at home

27. Is your child allowed to walk or bike home from school on their own when schools are open?

☐ Yes

☐ No

28. When going to places other than school that are *within walking distance*, is your child taken there or allowed to go on their own?

☐ Usually goes on their own

☐ Usually taken

☐ Varies

29. Is your child allowed to cross main roads on their own?
***Please note**: This question is included for all parents. Please answer even if the answer seems obvious.*

☐ YES

☐ NO

30. Is your child usually allowed to go out *on their own* after dark?

☐ YES

☐ NO

31. a) Does your child have a bicycle?

☐ YES

☐ NO – go to question 32

b) Is your child allowed to cycle on main roads on their own?

☐ YES

☐ NO

32. Is your child usually allowed to travel on local buses on their own (other than a school bus)?

☐ YES

☐ NO

☐ Not Applicable – There are no local buses in our neighbourhood

33. How far from home is your child allowed to roam on their own? *(Only tick <u>one box</u>)*

☐ They are not allowed out on their own

☐ Less than a 5 minute walk away from home

☐ Within a 5-15 minute walk from home

☐ More than a 15 minute walk from home

34. How far from home is your child allowed to roam on their own with friends and/or siblings (unaccompanied by an adult)? *(Only tick <u>one box</u>)*

☐ They are not allowed out on their own

☐ Less than a 5 minute walk away from home

☐ Within a 5-15 minute walk from home

☐ More than a 15 minute walk from home

35. Does your child have a mobile phone?

☐ YES

☐ NO

36. Please indicate how much you agree or disagree with each of the following statements.

Statement	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
a. I am capable of supporting my child's physical activity over the next week					
b. I will have an opportunity to support my child's physical activity over the next week					
c. I am capable of restricting my child's screen time to no more than 2 hours per day over the next week					
d. I will have an opportunity to restrict my child's screen time to no more than 2 hours per day over the next week					
e. I am capable of supporting my child's sleep over the next week					
f. I will have an opportunity to support my child's sleep over the next week					

37. Do you agree or disagree with the following statements about your neighbourhood?

Statement	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
a. People around my neighbourhood are willing to help their neighbours.					
b. This is a close-knit neighbourhood.					
c. People in my neighbourhood can be trusted.					
d. People in my neighbourhood generally					

don't get along with each other.					
e. People in my neighbourhood do not share the same values, attitudes or beliefs.					

38. Please select the answer that best applies to your neighbourhood.

Statement	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
a. There is so much traffic along nearby streets that it makes it difficult or unpleasant for my child to walk (alone or with someone) in our neighbourhood.				
b. The speed of traffic on most nearby streets is usually slow (50 km/h or less).				
c. Most drivers go faster than the posted speed limits in our neighbourhood.				
d. There is a high crime rate in our neighbourhood.				
e. The crime rate in our neighbourhood makes it unsafe for my child to go on walks (alone or with someone) at night.				
f. I am worried about letting my child play outside alone around my home (e.g., yard, driveway, apartment common area) because I am afraid of them being taken or hurt by a stranger.				
g. I am worried about letting my child be outside with a friend around my home because I am afraid my child will be taken or hurt by a stranger.				
h. I am worried about letting my child play or walk alone or with friends in my neighbourhood and local streets because I am afraid my child will be taken or hurt by a stranger.				

i. I am worried about letting my child be alone or with friends in a local or nearby park because I am afraid my child will be taken or hurt by a stranger.				

39. Would you allow your child to do the following activities?

Questions	Yes	No
a. Would you let your child jump down from a height of 3-4 metres?		
b. Would you allow your child to play chase (or tag) with other children?		
c. Would you trust your child to play by themselves without constant supervision?		
d. Would you let your child go head first down a slippery slide?		
e. Would you allow your child to continue playing if they get a few scrapes during play?		
f. Would you let your child have lots of challenges when they play at home?		
g. Would you let your child use a hammer and nail unsupervised?		
h. Would you let your child climb up a tree within your reach?		
i. Would you let your child walk barefoot across a floor after broken glass had been swept up?		
j. Would you let your child walk on slippery rocks close to water?		
k. Would you allow your child to play-fight other children with sticks?		
l. Would you encourage your child to try new things that involve some risk?		
m. Would you allow your child to engage in "rough and tumble" play?		
n. Would you let your child play near the edge of steep cliffs?		
o. Would you allow your child to play in the bush or forest out of your sight?		
p. Would you let your child experience minor mishaps if what they are doing is lots of fun?		
q. Would you let your child run close to an open fire?		
r. Would you let your child swim in the ocean close to the shore while you were watching from the beach?		
s. Would you allow your child to continue playing if there is the potential they may break a bone?		
t. Would you let your child play in a backyard unsupervised?		
u. Would you allow your child to climb a rock wall that goes straight down to the water?		
v. Would you wait to see if your child could manage challenges on their own before getting involved?		
w. Would you let your child climb as high as they want to in trees?		
x. Would you allow your child to ride a bicycle down a steep hill at full speed?		

y. Would you trust your child to play safely?		
z. Would you allow your child to use a sharp knife?		
aa. Would you let your child play in a backyard supervised?		
ab. Would you let your child balance on a fallen tree more than 2 metres above the ground?		
ac. Would you encourage your child to take some risks if it means having fun during play?		
ad. Would you allow your child to climb up a tree beyond your reach?		

The following questions are about you:

40. How old are you? _____ years

41. What gender are you?

Man ☐

Woman ☐

Other, specify: ☐ _____

Prefer not to answer ☐

42. What is your current employment status?

Working full time ☐

Working part time ☐

Self-employed / freelance work ☐

Student ☐

Homemaker ☐

Unemployed ☐

Retired ☐

I can't work because of COVID-19 ☐

Prefer not to answer ☐

43. What is the last year of education that you have completed?

☐ Elementary (7 years or less)

☐ High school, general or vocational (8 to 12 years)

☐ College (pre-university, technical training, certificate, accreditation or advanced diploma (13-15 years))

☐ University certificates and diplomas

☐ University Bachelor (including classical studies)

☐ University Master's degree

☐ University Doctorate (PhD)

☐ Prefer not to answer

44. What is the last year of education that your partner has completed (if applicable)?

☐ Elementary (7 years or less)

☐ High school, general or vocational (8 to 12 years)

☐ College (pre-university, technical training, certificate, accreditation or advanced diploma (13-15 years))

☐ University certificates and diplomas

☐ University Bachelor (including classical studies)

☐ University Master's degree

☐ University Doctorate (PhD)

☐ Prefer not to answer

45. Among the following categories, which one best reflects the total **income**, before taxes, of all the members of your household in the last year?

☐ $19,999 or less

☐ Between $20,000 and $39,999

☐ Between $40,000 and $59,999

☐ Between $60,000 and $79,999

☐ Between $80,000 and $99,999

☐ $100,000 or more

☐ Prefer not to answer

46. Does your household own or lease an automobile?

☐ No ☐ Yes, 1 automobile ☐ Yes, 2 or more automobiles

47. In the last week, how many hours and minutes did you usually spend sleeping in a 24-hour period (including naps but excluding time spent resting)?

Weekdays (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know
Weekend (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know

48. In the last week, how many hours and minutes did you usually spend sedentary (e.g., sitting or reclining) in a 24-hour period?

Weekdays (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know
Weekend (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know

49. In the last week, how many hours and minutes did you usually spend in front of screens during your leisure time in a 24-hour period (e.g., watching TV and videos, playing video games, browsing the web, texting, etc.)?

Weekdays (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know
Weekend (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know

50. In the last week, how many hours and minutes did you spend engaging in moderate-to-vigorous physical activity in a 24-hour period?

Weekdays (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know
Weekend (per day) _____ Hours (Cap at 23) AND _____ Minutes (Cap at 59) – Don't know

51. On a typical day, the MAIN part of your journey TO work is made by…

☐ Walking

☐ Bicycle

☐ Bus, train, streetcar, subway, or boat/ferry

☐ Car, motorcycle, or moped

☐ Other. Please specify: _____

☐ Not applicable; I work from home or do not work

52. On a typical day, the MAIN part of your journey FROM work to home is made by…

☐ Walking

☐ Bicycle

☐ Bus, train, streetcar, subway, or boat/ferry

☐ Car, motorcycle, or moped

☐ Other. Please specify: _____

☐ Not applicable; I work from home or do not work

Thank you very much for your help ☺

APPENDIX - B

Table B1: Descriptive characteristics of participants at the end of 12 month, stratified by child gender.

Variable	Whole sample (n= 941)		Boys (n= 491)		Girls (n= 450)		
	Frequency (%)	Mean (SD)	Frequency (%)	Mean (SD)	Frequency (%)	Mean (SD)	P-value
CIM index		2.4 (1.9)		2.4 (1.9)		2.3 (1.8)	0.325
Child age (Years)		10.5 (1.5)		10.5 (1.5)		10.6 (1.5)	0.471
Number of adults in household		2.1 (0.7)		2.1 (0.7)		2.1 (0.6)	0.528
Number of children in household		2.0 (0.9)		2.0 (0.9)		2.0 (1.0)	0.517
TRiPS scale		43.2 (6.6)		43.4 (6.5)		43.0 (6.6)	0.336
Traffic safety scale		2.5 (0.6)		2.5 (0.6)		2.5 (0.7)	0.098
Crime safety scale		2.1 (0.8)		2.1 (0.8)		2.2 (0.8)	0.483
Social cohesion scale		3.5 (0.7)		3.6 (0.7)		3.5 (0.7)	0.609
Parent gender							0.516
Man	360 (38.3)		183 (37.3)		177 (39.3)		
Woman	581 (61.7)		308 (62.7)		273 (60.7)		
Household income (CAD)							0.622
$39,999 or less	75 (8.0)		37 (7.5))		38 (8.4)		
$40,000 to $99,999	398 (42.3)		208 (42.4)		190 (42.3)		
$100,000 or more	383 (40.7)		197 (40.1)		186 (41.3)		
Prefer not to respond	85 (9.0)		49 (10.0)		36 (8.0)		
Region							0.815
Pacific	102 (10.8)		52 (10.6)		50 (11.1)		
Prairies	171 (18.2)		94 (19.1)		77 (17.1)		

Ontario	384 (40.8)	193 (39.3)	191 (42.4)	
Quebec	216 (23.0)	114 (23.3)	102 (22.7)	
Atlantic	68 (7.2)	38 (7.7)	30 (6.7)	
School delivery				0.134
In-person	828 (89.7)	434 (89.5)	394 (90.0)	
Online	51 (5.5)	23 (4.7)	28 (6.4)	
Blended	18 (2.0)	9 (1.9)	9 (2.1)	
N/A (e.g., home schooled)	26 (2.8)	19 (3.9)	7 (1.5)	
Disability/chronic conditions				0.879
Yes	104 (11.1)	55 (11.2)	49 (10.9)	
No	837 (88.9)	436 (88.8)	401 (89.1)	
Child owns a mobile phone				0.058
Yes	407 (43.3)	198 (40.3)	209 (46.4)	
No	534 (56.7)	293 (59.7)	241 (53.6)	
Type of home				0.162
Detached/semi-detached	717 (76.2)	365 (74.3)	352 (78.2)	
Other	224 (23.8)	126 (25.7)	98 (21.8)	
Dog ownership				0.481
Yes	355 (37.7)	180 (36.7)	175 (38.9)	
No	586 (62.3)	311 (63.3)	27 (61.1)	
Vehicle ownership				**0.035**
No	42 (4.5)	27 (5.5)	15 (3.3)	
One	397 (42.2)	220 (44.8)	177 (39.3)	
Two or more	502 (53.3)	244 (49.7)	258 (57.4)	
Employment (n=936)				0.582
Work full-time	639 (68.3)	327 (66.9)	312 (69.8)	
Homemaker	102 (10.9)	54 (11.0)	48 (10.7)	

Other	195 (20.8)	108 (22.1)	87 (19.5)	
Time since child lived in Canada				0.526
5 years or less	29 (3.1)	18 (3.7)	11 (2.4)	
6 years or more	117 (12.4)	59 (12.0)	58 (12.9)	
Born in Canada	795 (84.5)	414 (84.3)	381 (84.7)	
Concerns about COVID-19				0.407
Not concerned	206 (21.9)	111 (22.6)	95 (21.1)	
Somewhat concerned	544 (57.8)	274 (55.8)	270 (60.0)	
Very concerned	191 (20.3)	106 (21.6)	85 (18.9)	
Parent travel mode to work				0.068
Active	76 (8.1)	48 (9.8)	28 (6.2)	
Motorized	554 (59.0)	292 (59.6)	262 (58.4)	
N/A	309 (32.9)	150 (30.6)	159 (35.4)	
Parent travel mode from work				0.092
Active	66 (7.0)	41 (8.4)	25 (5.6)	
Motorized	557 (59.4)	296 (60.5)	261 (58.1)	
N/A	315 (33.6)	152 (31.1)	163 (36.3)	
Walkability (Can-ALE class; n=855)				0.179
1	226 (26.4)	111 (24.7)	115 (28.3)	
2	285 (33.3)	148 (33.0)	137 (33.8)	
3	228 (26.7)	117 (26.1)	111 (27.3)	
4-5	116 (13.6)	73 (16.2)	43 (10.6)	

Note: CIM: children's independent mobility; TRiPS: tolerance to risk in play scale; Can-ALE: Canadian Active Living Environments scale; CAD: Canadian dollars. Boldface denotes statistically significant differences between boys and girls ($p < 0.05$).

APPENDIX – C

Bivariate Models

Table C1: Correlates of changes in CIM in bivariate models.

Variable	β	95% CI	p-value
Child gender – boy (ref: girl)	-0.01	-0.18, 0.16	0.938
Child age – each additional year	0.10	0.05, 0.15	**<0.001**
Child has a disability/chronic illness – yes (ref: no)	0.23	-0.05, 0.52	0.111
Parent gender – man (ref: woman)	-0.11	-0.29, 0.07	0.221
Household income - $39,999 or less (ref: $100,000 or more)	0.03	-0.28, 0.35	0.841
Household income - $40,000 to $99,999 (ref: $100,000 or more)	0.08	-0.11, 0.27	0.428
Household income – Prefer not to answer (ref: $100,000 or more)	0.01	-0.30, 0.31	0.960
Household vehicle ownership – 1 or no vehicle (ref: ≥ 2 vehicles)	-0.19	-0.36, -0.02	**0.030**
Type of home – detached/semi-detached (ref: others)	0.20	-0.01, 0.40	0.055
Number of children in household	0.06	-0.03, 0.16	0.174
Parental concern about COVID-19 – not concerned (ref: very concerned)	0.27	-0.01, 0.54	0.062
Parental concern about COVID-19 – somewhat concerned (ref: very concerned)	0.18	-0.01, 0.37	0.056
Parental tolerance to risk in play scale – each unit increase	0.03	0.01, 0.04	**<0.001**
Crime safety scale – each unit increase	-0.18	-0.29, -0.07	**0.002**
Region – Pacific (ref: Atlantic)	-0.29	-0.71, 0.12	0.161
Region – Prairies (ref: Atlantic)	-0.11	-0.48, 0.26	0.548
Region – Ontario (ref: Atlantic)	-0.27	-0.61, 0.08	0.127
Region – Quebec (ref: Atlantic)	-0.10	-0.46, 0.26	0.582
Can-ALE neighbourhood – class 1 (ref: class 4-5)	0.37	0.07, 0.68	**0.016**
Can-ALE neighbourhood – class 2 (ref: class 4-5)	-0.16	-0.45, 0.14	0.301
Can-ALE neighbourhood – class 3 (ref: class 4-5)	-0.16	-0.47, 0.15	0.312

Note: β: unstandardized regression coefficients; CI: confidence interval; Can-ALE: Canadian Active Living Environments scale. Boldface denotes statistical significance ($p < 0.05$).

APPENDIX – D

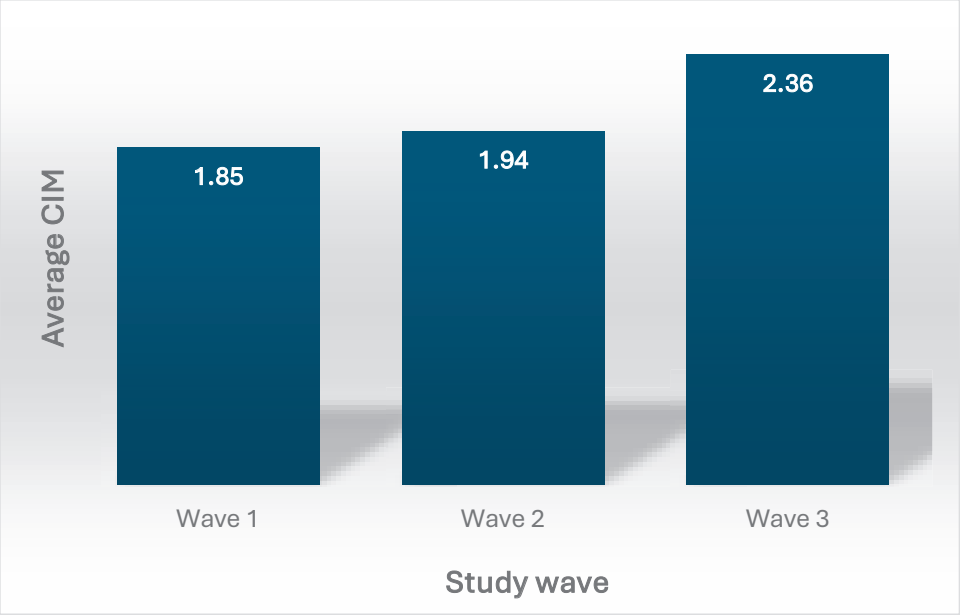

Figure D1: Changes in CIM by study wave