Health Promotion and Chronic Disease Prevention in Canada
Research, Policy and Practice

Volume 39 · Number 5 · May 2019

Inside this issue

To promote and protect the health of Canadians through leadership, partnership, innovation and action in public health.
— Public Health Agency of Canada

Published by authority of the Minister of Health.

ISSN 2368-738X
Pub. 180719
PHAC.HPCDP.journal-revue.PSPMC.ASPC@canada.ca

Également disponible en français sous le titre : *Promotion de la santé et prévention des maladies chroniques au Canada : Recherche, politiques et pratiques*

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Public Health Agency of Canada   Agence de la santé publique du Canada

Canada

https://doi.org/10.24095/hpcdp.39.5.01

Original quantitative research

Self-reported health impacts of caregiving by age and income among participants of the Canadian 2012 General Social Survey

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Abstract

Introduction: Increases in life expectancy and the underlying age structure of the Canadian population have contributed to dramatic increases in the number of seniors who are caregivers. While caregiving is associated with several adverse health impacts, there is a need to better understand how these impacts might be different among older caregivers, and whether those impacts are modified by socioeconomic status.

Methods: We sought to address these research gaps by using cross-sectional data provided by participants of the 2012 Canadian General Social Survey (GSS). Descriptive analyses were performed to compare the self-reported health impacts that participants attributed to caregiving, and how these varied by age and income. Logistic regression analyses were performed to identify which factors were associated with self-reported impacts on overall health among caregivers 65 years of age and older.

Results: The demographic characteristics of the care-providers varied substantially by age with older caregivers having lower incomes and devoting more time to caregiving relative to those who were younger. The self-reported impacts of caregiving on overall health were greatest among those between the ages of 35 and 64, and this pattern was evident across all income groups. Feelings of loneliness and social isolation as a result of caregiving responsibilities appeared to be mitigated by both greater age and income. However, across all age groups, caregiving was more likely to adversely impact exercise habits, healthy eating, and alcohol consumption than to promote more positive behaviours.

Conclusion: Providing care impacts health behaviours and mental health regardless of age and income. However, our findings suggest that older caregivers (who are most often women)—who provide the most hours of care and on reduced incomes relative to younger caregivers—appear less impacted in terms of health behaviours, perhaps as a result of fewer competing demands relative to younger caregivers. Taken together, these findings suggest that support systems must consider caregiver impacts that vary in complex ways across age, sex, and income.

Keywords: cross-sectional study, caregiving, health behaviours, health-related quality of life, Canada

Highlights

- This study was aimed at investigating the social and health impacts of caregiving among senior care providers, and how these impacts differed from younger caregivers.
- The 2012 Canadian General Social Survey was used to analyse self-reported health impacts that participants attributed to caregiving.
- Consistent with previous studies, providing care was found to have detrimental effects on health behaviours related to exercise, diet, and alcohol consumption.
- Among caregivers aged 65 and older, women, compared to men, and those who devoted a greater number of hours to caregiving were more likely to report detrimental impacts on overall health.
- The impacts of caregiving occurred across all income categories. However, although older caregivers were more likely to be in the lowest income group, they reported the least financial hardship due to caregiving.

Introduction

Estimates show that approximately 8 million Canadians 15 years of age and older provide some level of care to family members or friends with a chronic health condition or problem related to aging.[1] The costs associated with providing this care are staggering. For example, in 1996, it was estimated that a total of 276 509 full-time workers would be needed to replace the tasks performed by those providing informal care – an impact estimated to be approximately $5–6 billion.[2] Likewise, it was estimated that each caregiver, on average, would lose $1.2 million in current and future earnings and incur approximately $30 000 in out of pocket

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expenses.[2] The economic toll in Canada has increased substantially since then, due to the rapid growth in the proportion of older adults, which has been fuelled by increases in life expectancy as well as declining fertility rates.[3] Unpaid caregivers, such as family members, tend to provide most of the care for older adults who may be experiencing chronic disease or illness.[4,5]

In addition to the economic costs of caregiving, there can be associated impacts on quality of life. It is well recognized that providing care for a person with a disease, illness, disability, or problem related to aging can be stressful for the care provider.[6] Not only does it require the caregiver to manage their own work, personal and social life (as well as, potentially, the personal and social life of the care recipient), but caring for a family member can also invoke negative emotions related to the fear of losing that person.[7] Several studies have investigated the impacts of caregiving on the psychological health of the caregiver and the general consensus has been that there is a negative relationship between the two.[8-10] A meta-analysis on the psychological impacts of caregiving found that caregivers of older individuals have higher prevalence and incidence of depressive and anxiety disorders compared to non-caregivers.[11] Research in this area has also found that the psychological impacts of providing care vary depending on the sex of the caregiver, as well as the nature of the relationship between the caregiver and the primary care recipient.[12] In addition to psychological impacts experienced by the caregiver, research has also implicated several adverse physical health impacts. For example, caregivers may experience diminished health habits, impaired physiological responses, and even death.[13]

Although the number of caregivers in many developed countries has increased substantially in recent years, there have been relatively few attempts to characterize the health impacts of providing care using population-based national surveys. A recent population-based survey in the UK[14] found that caregivers, relative to those who did not provide care, were more likely to experience poorer health-related quality of life, as well as anxiety and depression. In a large national US sample, caregivers were found to have lower self-reported quality of life, poorer physical functioning and fewer social contacts.[15] Although other national surveys have been undertaken, these have typically focussed on the impacts of providing care for individuals with specific conditions, such as cancer or stroke. In addition, surveys that have attempted to investigate the health impacts of providing care among caregivers have typically described these impacts using survey questionnaires that solicit information from participants about their overall mental and physical health through widely used and validated instruments that measure general health.[12,16] These studies have not typically included questions that ask participants to provide information about how their caregiving activities specifically impact their health and health behaviours (e.g., physical activity, alcohol consumption). In our view, this important change in questionnaire wording may be more appropriate for capturing the health impacts directly related to providing care.

With dramatic increases in longevity in many countries, including Canada, the structure of the population has changed substantially over the past twenty years.[3] From a caregiving perspective, this implies that the age of the caregiver has also increased substantially, as has the age of the care recipient. Likewise, the economic toll of caregiving also appears to have increased dramatically, including to the caregiver him/herself.[2] Thus, the key objectives of this research were to describe variations in the health impacts of caregiving across age groups (with a particular focus on how caregiving may differentially impact senior caregivers compared to younger caregivers), and across socioeconomic status (i.e., household income) of the caregiver.

Methods and materials

Study population

We used cross-sectional survey data collected from the 2012 General Social Survey (GSS), which is currently the most recent iteration of the GSS to collect data on caregiving (with the 2018 GSS forthcoming). The GSS was first administered in 1985 with the overarching objective to gather data on social trends for the purpose of characterizing changes in the living conditions and well-being of Canadians. The GSS was also designed to inform specific social policy issues.

The 2012 GSS collected information on both caregivers and care receivers. This iteration of the GSS included participants who were 15 years of age and older who lived in private households using Random Digit Dialing (RDD) and Computer Assisted Telephone Interviewing (CATI) methods. The sampling frame excluded individuals who resided in the Yukon, Northwest Territories and Nunavut as well as those who lived full time in institutions. In total, there were 23 093 participants of the 2012 GSS, and the overall participation rate was 65.7%.[17] Unlike previous cycles of the GSS, the 2012 version included new questions on the type and severity of long-term health conditions or disability that individuals received or provided care for. Related to the objectives of these analyses, the 2012 GSS also collected information on the impacts of caregiving on the health behaviours of the caregivers. These include behaviours such as participation in physical and social activities. Data were also collected on respondents' main activities, education, income and other sociodemographic characteristics.[18]

Measures

The 2012 GSS asked participants to specifically indicate to what extent providing caregiving impacted their health over the past 12 months. Social and health impacts that were captured and analysed in the present study included caregiver responses that they were: coping "very well" with caregiving (as opposed to "generally well", "not very well", or "not well at all", combined for analyses), seeking professional help for caregiving (i.e., never vs. once, twice, 2 to 3 times, or 4+ times), experiencing financial hardship due to caregiving (yes vs. no), overall health having suffered from caregiving (yes vs. no), feelings of depression (yes vs. no), and feelings of loneliness and isolation (yes vs. no). Health behaviours that had been impacted by caregiving (e.g., smoking, alcohol use, healthy eating, exercise) were also assessed.

Statistical analyses

All statistical analyses were conducted using the Statistical Analysis Software (SAS, version 9.4, Cary, NC). Descriptive analyses were first conducted to describe the study sample. We extended these analyses to compare the key characteristics (i.e., including age, income, relationship to primary care recipient, underlying condition of primary care recipient, number of people providing care for, and hours of providing care each week) across age groups. The likelihood ratio test was used to compare the distribution of these variables across five age groups of caregivers (15–34, 35–49, 50–64, 65–74, and 75 years of age and older). Similar descriptive analyses were performed to evaluate how caregiving impacted several health-related behaviours, by the age of the caregiver; these behaviours included changes in exercise, eating habits, alcohol consumption, and smoking.

Multiple logistic regression was then used to evaluate age-related differences in a variety of self-reported health and social outcomes due to caregiving. These included coping, feeling lonely or isolated, depression, experiencing financial hardship, seeking professional help for caregiving, and overall impact of caregiving on health. The odds ratios, and their corresponding 95 confidence intervals, were estimated and the youngest age group was set as the reference category (as they would conceivably be in the best overall health). Stratified analyses were done by household income category (< $40 000, $40 000–$99 999, and ≥ $100 000). The logistic regression models were adjusted for sex, the number of hours in a week the respondent provided care, and the number of individuals cared for.

Lastly, since a key objective of these analyses was to identify what factors among senior caregivers (e.g., sex, number of people cared for, and hours spent caregiving per week) were most predictive of adverse health impacts, we also fit logistic regression models to describe the impacts of sex and caring characteristics on those health impacts. We fit a separate model for each of the three income categories (as above).

Results

Descriptive characteristics of the participants of the General Social Survey are provided in Table 1. In total, 7082 respondents indicated that they provided care to someone with a chronic disease or disability, while 2470 indicated that they provided care for individuals with a problem related to aging. Subsequent analyses were undertaken with these 9552 caregivers as our primary sample.

As seen in Table 2, women accounted for approximately 60% of caregivers, and this was constant across the age groups. However, we observed other notable differences in several characteristics based on the age of the caregiver. A large proportion of caregivers had household incomes that exceeded $60 000 (46.1%), with younger caregivers (i.e., between 35 and 64) tending to have the highest household incomes. By far, the most commonly reported primary care recipient was the mother of the respondent (28.4%), followed by close friend (11.6%), father (10.7%) and spouse or partner (10.1%). As expected, the relationship with the primary care recipient varied by age. Among older caregivers (65 years +), the spouse or partner was the most common primary care recipient, while among younger caregivers it was their parents or (among the youngest age group) grandparents. Notably, 87% of the caregivers in our sample reported spending 21 hours or less on caregiving, with older caregivers tending to spend more time providing care than those who were younger. Specifically,

TABLE 1
Descriptive characteristics of participants of the 2012 General Social Survey

Characteristics		Participants	%
Sex	Men	9794	42.4
	Women	13 299	57.6
Age-group (y)	15–34	3756	16.3
	35–49	5351	23.2
	50–64	7395	32.0
	65–74	3589	15.5
	75+	3002	13.0
Total household income ($)	< 10 000	444	1.9
	10 000–29 999	3276	14.2
	30 000–59 999	4989	21.6
	60 000–99 999	4341	18.8
	≥ 100 000	4796	20.8
	Unknown	5247	22.7
Highest attained education	Under high school	4526	19.8
	High school or equivalent	6223	27.2
	Trade certificate	1149	5.0
	College or other non-university	4672	20.4
	University (below Bachelor's degree)	940	4.1
	University (Bachelor's degree)	3582	15.7
	University (above Bachelor's degree)	1769	7.7
Marital status	Married or common-law	13 509	58.6
	Widowed	2651	11.5
	Separated or divorced	2618	14.7
	Single or never married	4724	18.5
Main activity of participant	Working	11 383	49.4
	Retired	6923	30.0
	Student	1351	5.9
	Long-term illness	995	4.3
	Household work	871	3.8
	Caring for children	773	3.4
	Other	797	3.5
Provided care in last year	For individual with chronic disease/disability	7082	30.7
	For individual with problem related to aging	2470	10.7
Received care over last year	For a long-term health condition or disability	2859	12.4
Total participants		23 093	100.0

TABLE 2
Characteristics of participants of the Canadian 2012 General Social Survey who indicated they provided care over the past year to those with a chronic disease, disability, or problem related to aging, stratified by age-group

Characteristics		Age of caregiver (in years)												p^a
		15–34 *1476 caregivers*		35–49 *2336 caregivers*		50–64 *3822 caregivers*		65–74 *1316 caregivers*		75+ *602 caregivers*		Total *9552 caregivers*		
		n	%	n	%	n	%	n	%	n	%	n	%	
Sex	Men	586	39.7	979	41.9	1492	39.0	452	41.7	178	36.6	3837	40.2	0.09
	Women	890	60.3	1357	58.1	2330	61.0	631	58.3	308	63.4	5715	59.8	
Income ($)	< 30 000	146	13.6	213	10.8	441	11.5	250	19.0	155	25.8	1205	12.6	< 0.001
	30 000 - 59 999	238	22.2	393	19.9	843	22.1	415	31.5	194	32.2	2083	21.8	
	60 000 - 99 999	321	29.9	560	28.3	859	22.5	247	18.8	65	10.8	2052	21.5	
	≥ 100 000	369	34.4	811	41.0	998	26.1	141	10.7	27	4.5	2346	24.6	
	Unknown	402	–	359	–	681	–	263	–	161	–	1866	19.5	
Relationship to the primary care recipient	Spouse	27	1.9	115	5.1	320	8.7	256	20.4	208	38.2	926	10.1	< 0.001
	Mother	234	16.4	740	32.6	1404	38.0	223	17.9	8	1.5	2609	28.4	
	Father	150	10.5	374	16.5	427	11.6	31	2.5	0	0.0	982	10.7	
	Mother-in-law	50	3.5	152	6.7	303	8.2	62	4.9	5	0.9	572	6.2	
	Father-in-law	17	1.2	78	3.4	124	3.4	15	1.2	1	0.2	235	2.6	
	Grandparent	555	39.0	135	5.9	7	0.2	0	0.0	0	0	697	7.6	
	Sibling	65	4.6	75	3.3	182	5.0	109	8.7	54	9.9	485	5.3	
	Child	41	1.8	153	6.7	184	5.0	77	5.1	35	6.4	490	5.4	
	Neighbour	46	3.2	81	3.6	142	3.8	89	7.0	45	8.2	403	4.4	
	Close friend	117	8.2	191	8.4	367	9.9	253	20.2	142	26.1	1070	11.6	
	Other	122	8.6	178	7.8	235	6.4	139	11.1	47	8.6	721	7.8	
	Missing	52	–	64	–	127	–	62	–	57	–	362	–	
Hours per week	< 7	1004	72.2	1517	69.0	2288	64.4	726	52.5	274	55.5	5809	66.0	< 0.001
	7 to < 21	282	20.3	457	20.8	785	22.1	219	18.9	101	20.5	1844	21.0	
	21 to < 48	66	4.7	125	5.7	281	7.9	99	8.5	48	9.7	619	7.0	
	48 to < 96	30	2.2	48	2.2	95	2.7	46	4.0	33	6.7	252	2.9	
	96+	9	0.7	51	2.3	106	3.0	71	6.1	38	7.7	275	3.1	
	Missing	85	–	138	–	267	–	155	–	108	–	753	–	
Condition	Cancer	138	9.8	317	4.1	380	10.3	165	13.2	58	10.9	1058	11.6	< 0.001
	Cardiovascular	121	8.6	220	9.8	392	10.7	109	8.7	70	13.1	912	10.0	
	Diabetes	51	3.6	88	3.9	90	2.5	24	1.9	14	2.6	267	2.9	
	Mental Illness	109	7.7	180	8.0	205	5.6	165	13.2	24	4.5	599	6.6	
	Dementia	53	3.8	115	5.1	294	8.0	106	8.5	56	10.5	624	6.8	
	Neurological	88	6.2	114	5.1	159	4.3	81	6.5	24	4.5	446	4.9	
	Aging	396	28.1	586	26.0	1193	32.5	314	25.2	118	22.1	2607	28.6	
	Eye	27	1.9	40	1.8	92	2.5	40	3.2	27	5.1	226	2.5	
	Injury	74	5.3	68	3.0	122	3.3	48	3.9	18	3.4	330	3.6	
	Arthritis	50	3.6	86	3.8	152	4.1	52	4.2	24	4.5	367	4.0	
	Dev. delay	40	2.8	68	3.0	66	1.8	32	2.6	6	1.1	212	2.3	
	Other	163	11.6	373	16.5	529	14.4	111	8.9	65	12.2	1472	16.1	
	Missing	66	–	81	–	148	–	69	–	68	–	432	–	
Number of people providing care for	One	785	55.0	1239	54.2	2189	59.1	838	66.3	380	69.6	5426	58.5	< 0.001
	Two	385	27.0	696	30.5	984	26.6	241	19.2	85	15.5	2391	25.9	
	Three or more	258	18.1	351	15.4	532	14.4	182	14.5	81	14.8	1404	15.2	
	Missing	48	–	50	–	117	–	60	–	56	–	432	–	

[a] *p*-value testing for differences in distribution of classification variable across 5 age groups based on likelihood ratio chi-square statistic.

approximately 14% of caregivers who were 75 years of age and older reported spending at least 48 hours per week on caregiving activities. The corresponding percentage for those under 50 years of age was less than 5%. Younger caregivers (i.e., under 50), however, were more likely to provide care to more than one individual. Across all age groups, "aging" was the most common condition for which caregivers provided care, when compared to specific diseases or injury.

Caregivers indicated that providing care adversely impacted several of their health behaviours (Table 3). In general, these reported impacts were greater among middle-aged caregivers. For example, among those aged 35–49, 32.4% of caregivers indicated that their exercise had decreased due to caregiving, 19% indicated that their eating habits had become less healthy, and 5.3% had increased their alcohol consumption. In contrast, the corresponding estimates among those who were 65 years of age and older included that 20.8% had decreased exercise, 10.8% reported less healthy eating, and only 1.9% had increased their alcohol consumption due to caregiving. Changes in smoking behaviour (either increased or decreased) were relatively unchanged among all age groups.

In Table 4, we present the odds ratios to describe differences in the self-reported impacts of caregiving on social and health outcomes by age group and total household income. Given the aging demographic of caregivers, the health of the oldest caregivers—those over 75 years of age—was of particular interest. Overall, caregivers who were 75 years and older reported that they were coping 'very well' with caregiving when compared to the youngest age group—those under 35 years of age (OR = 1.47; 95% CI = 1.15–1.87). This pattern was observed across all income groups, though not statistically significant in all cases. Older caregivers were also less likely to experience financial hardships due to caregiving. Specifically, the odds ratio of reported financial hardship among caregivers 75 years of age and older relative those who were under 35 was 0.29 (95% CI = 0.16–0.50). However, the odds ratios in Table 4 also reveal differences across different income categories. Among older caregivers in the lowest income grouping (< $40000), caregivers who were 75 years of age or older were most likely to indicate that they felt depressed due to caregiving when compared to those under 35 years of age (OR = 1.56; 95% CI = 0.84–2.92), although this difference was not statistically significant.

Finally, we performed logistic regression analyses to better understand which characteristics, specifically among caregivers 65 years of age and older, were related to an increased likelihood that caregiving had impacted their overall health (Table 5). In all income groups, women were far more likely than males to have had their overall health impacted by caregiving. However, although not statistically significant, this was especially the case among those with household incomes of greater than $100 000. Specifically, the odds ratio for having overall health suffer due to caregiving among women was 2.67 (95% CI = 0.81–8.44) when compared to men. Finally, not surprisingly, the number of hours per week spent caregiving was also a very strong predictor of having overall health suffer across all income groups.

TABLE 3
Self-reported impacts of caregiving on health-related behaviours, by age-group, among participants of the 2012 General Social Survey

Has caregiving impacted the following characteristics?		Age of caregiver (in years)							
		15–34		35–49		50–64		≥ 65	
		n	%	n	%	n	%	n	%
Exercise	No change	752	78.9	1009	63.6	1795	66.2	957	75.8
	Increase in exercise	35	3.7	62	3.9	106	3.9	43	3.4
	Decrease in exercise	166	17.4	514	32.4	812	30.0	263	20.8
Eating habits	No change	792	83.1	1213	76.1	2123	77.7	1090	85.0
	More healthy eating	48	5.0	76	4.8	148	5.5	53	4.1
	Less healthy eating	113	11.9	305	19.1	462	17.0	139	10.8
Alcohol	No change	785	82.0	1253	78.3	2098	76.2	852	65.8
	Don't drink	122	12.7	231	14.4	516	18.8	404	31.2
	Increased drinking	28	2.9	85	5.3	101	3.7	25	1.9
	Decreased drinking	15	1.6	23	1.4	22	0.8	6	0.5
	Stopped use	6	0.1	4	0.2	12	0.4	4	0.3
	Started drinking	1	0.0	5	0.3	3	0.1	3	0.2
Smoking	No change	554	57.9	824	51.4	1223	44.4	349	27.0
	Don't smoke	341	36.0	681	42.5	1361	29.5	917	70.9
	Increased smoking	33	3.5	54	3.4	95	3.5	8	0.6
	Decreased smoking	11	1.2	25	1.6	40	1.5	12	0.9
	Stopped smoking	13	1.4	10	0.6	23	0.8	4	0.3
	Started smoking	4	0.4	8	0.5	10	0.4	3	0.2

Note: *p*-value testing for differences in distribution of classification variable across 4 age groups based on likelihood ratio chi-square statistic were all statistically significant ($p < 0.05$).

TABLE 4
Adjusted odds ratios in relation to self-reported impacts of caregiving on health, by age and total household income

Self-reported impact on health	Age group	Low income (< $40 000)		Middle income ($40 000–$99 999)		High income (> $100 000)		All caregivers	
		OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Coping 'very well' with caregiving	15–34	1.0		1.0		1.0		1.0	
	35–49	0.85	0.56–1.28	0.80	0.60–1.05	0.75	0.51–1.03	0.73	0.62–0.86
	50–64	0.84	0.58–1.21	0.93	0.72–1.20	0.69	0.51–0.94	0.80	0.69–0.93
	65–74	1.00	0.67–1.49	1.14	0.83–1.55	1.12	0.69–1.83	1.00	0.83–1.21
	75+	1.69	1.07–2.67	1.45	0.94–2.23	1.15	0.39–3.41	1.47	1.15–1.87
Overall health suffered from caregiving	15–34	1.0		1.0		1.0		1.0	
	35–49	1.62	0.91–2.88	2.56	1.69–3.85	2.79	1.63–4.78	2.73	2.12–3.51
	50–64	2.78	1.66–4.65	2.45	1.66–3.62	2.59	1.52–4.39	2.82	2.22–3.58
	65–74	1.98	1.14–3.45	1.81	1.15–2.87	1.48	0.67–3.28	2.06	1.55–2.72
	75+	1.20	0.63–2.72	1.52	0.81–2.84	1.63	0.30–8.93	1.66	1.17–2.35
Seek professional help for caregiving	15–34	1.0		1.0		1.0		1.0	
	35–49	1.78	1.03–3.08	1.07	0.73–1.56	1.42	0.87–2.34	1.25	1.00–1.57
	50–64	2.08	1.26–3.44	1.40	1.00–1.98	1.47	0.91–2.37	1.43	1.17–1.77
	65–74	1.51	0.87–2.60	0.90	0.58–1.38	0.98	0.46–2.10	1.12	0.87–1.45
	75+	0.68	0.35–1.33	1.08	0.61–1.93	0.92	0.17–4.94	0.85	0.61–1.20
Feel lonely or isolated from caregiving	15–34	1.0		1.0		1.0		1.0	
	35–49	1.84	1.08–3.16	1.90	1.28–2.82	2.09	1.24–3.52	2.36	1.85–3.01
	50–64	2.51	1.54–4.09	1.75	1.20–2.54	1.64	0.98–2.75	2.13	1.69–2.68
	65–74	1.57	0.92–2.67	1.06	0.67–1.68	0.83	0.35–1.94	1.46	1.10–1.93
	75+	1.34	0.73–2.46	1.64	0.91–2.94	0.80	0.09–6.77	1.83	1.30–2.57
Feel depressed from caregiving	15–34	1.0		1.0		1.0		1.0	
	35–49	0.69	0.41–1.14	0.61	0.42–0.89	0.57	0.35–0.94	0.57	0.45–0.71
	50–64	0.50	0.32–0.78	0.57	0.40–0.81	0.50	0.31–0.83	0.52	0.42–0.64
	65–74	0.77	0.47–1.28	0.74	0.48–1.13	0.80	0.38–1.70	0.70	0.54–0.90
	75+	1.56	0.84–2.92	0.54	0.32–0.93	n.e		0.81	0.58–1.13
Experience financial hardship due to caregiving	15–34	1.0		1.0		1.0		1.0	
	35–49	1.54	0.83–2.85	1.16	0.74–1.82	1.39	0.65–2.98	1.10	0.83–1.48
	50–64	1.45	0.83–2.56	0.71	0.46–1.10	1.05	0.49–2.24	0.91	0.83–1.48
	65–74	0.71	0.37–1.36	0.27	0.14–0.51	0.59	0.17–2.06	0.51	0.36–0.73
	75+	0.32	0.13–0.80	0.20	0.07–0.53	n.e.		0.29	0.16–0.50

Abbreviation: n.e., not estimable.
Note: Adjusted for sex, number of hours of caregiving, and number of individuals cared for.

Discussion

Our analyses of the 2012 General Social Survey (GSS) highlight important features of Canadian caregivers. They also extend previous analyses of the 2012 GSS by presenting more detailed data among older caregivers.[1] The data from the 2012 survey suggest that approximately 20% of Canadian caregivers are 65 years and older. Of these, approximately 31% are aged 75 years and older, approximately 30% of them provide care to a spouse, 32% provide care to more than one individual, and approximately 11% are spending at least 48 hours a week providing that care. Among caregivers 65 years of age and older, women and those who devoted a greater number of hours to caregiving were also most likely to report detrimental impacts on overall health. Given the projected increase in the Canadian population of older adults, coupled with anticipated increases in life expectancy, the associated impacts will grow substantially. A comparison with previous data presented by Cranswick and Dosnick using the 2007 GSS reveals how dramatic the shift in the age distribution of Canadian caregivers was in a 5-year interval.[19] In 2007, among caregivers 45 years of age and older, 24% of these individuals were 65 years of age and older. In contrast, in 2012, among caregivers 45 years of age and older, 41% of these individuals were 65 years of age and older. We can only expect this percentage to rise.

Importantly, the 2012 GSS also allowed us to examine the self-reported health impacts of caregiving itself. Previous research has reported differences in general self-reported

TABLE 5
Coefficients from logistic model with outcome "has overall health suffered as a result of caregiving?", among caregivers 65 years of age and older (n = 1918), by income

Covariate		Household income					
		< $40 000		$40 000–99 999		> $100 000	
		OR	95% CI	OR	95% CI	OR	95% CI
Sex	Male	1.0		1.0		1.0	
	Female	1.65	0.97–2.79	2.15	1.28–3.64	2.67	0.81–8.44
Individuals cared for	One	1.0		1.0		1.0	
	Two or more	0.93	0.55–1.83	1.20	0.72–2.04	1.03	0.07–2.63
Hours per week of providing care	2–6	1.0		1.0		1.0	
	7–20	1.85	1.01–3.38	3.36	1.81–6.24	1.11	0.27–5.21
	21–48	2.16	1.01–4.59	5.91	2.76–12.62	2.30	0.38–14.16
	48+	4.90	2.70–8.89	7.89	3.63–17.13	4.36	0.97–19.46

Note: *p*-value testing for differences in distribution of classification variable across the 3 income groups based on likelihood ratio chi-square statistic were all statistically significant.

physical and mental health between caregivers and non-caregivers who participated in the 2012 GSS.[20] For example, among those who provided care for someone with a problem related to aging, 24.8% reported being in excellent physical health compared to 21.6% who did not provide care. Conversely, 27% of caregivers reported that their mental health was excellent compared to 33% who did not provide care and reported excellent mental health. However, by looking at the overall health of caregivers we may miss important physical and mental health impacts that potentially result from stressors or fatigue associated with providing care itself. Our analyses suggest that the oldest caregivers were coping well with caregiving, perhaps due to less financial hardship and therefore the ability to pay for additional professional support. However, among the oldest caregivers in the lowest income category, mental health issues associated with caregiving—specifically, depression—may be of concern. Indeed, in every other age group (i.e., under 75) in this income category, the OR was < 1, which provided a striking contrast to those over 75 years of age (OR = 1.56). Of course, given that the sample size for this oldest age group was small compared to the others, further work should be done to provide additional evidence of this pattern.

Also, in line with earlier research,[21] all caregivers noted that they experienced social isolation or feelings of loneliness as a result of their caregiving responsibilities, although this appeared to be mitigated by both greater age and income. The inconsistencies between caregivers' reports of overall health in previous analyses of the 2012 GSS and the health-related impacts of caregiving highlighted here indicate the need for survey questions that specifically target impacts of the caregiving role. Alternatively, these findings might also suggest that the health-related impacts of caregiving can be distinct from overall health outcomes, perhaps due to other resources (e.g., income, social support) in caregiver's lives that have health-enhancing effects.[6]

In addition, we found that the impacts of caregiving on health behaviours differed by age group. Middle-aged caregivers (i.e., between 35 to 64 years of age) reported that caregiving adversely impacted their participation in physical activity, healthy eating, and alcohol consumption, to a greater extent than did younger or older caregivers. The differential impacts of caregiving on physical activity patterns by age may be a reflection, in part, of competing responsibilities including occupation and simultaneously caring for one's children—the "sandwich generation".[22] Other recent work has also found that caregiving negatively impacted participation in valued activities.[23] Specifically, caregivers providing substantial help with health care were 5 times more likely to experience participation restrictions in valued activities. Elsewhere, analyses of the 2009 US Behavioral Risk Factor Surveillance System found that caregiving was associated with increased smoking, obesity, and physical inactivity.[24] Like our analyses, they too found that impacts on physical activity were more pronounced among younger caregivers. Among those under 65 years of age, they found that those who were sedentary had an odds ratio of being a caregiver of 1.45 (95% CI = 1.09–1.94) when compared to those who were physically active. This odds ratio decreased to 1.03 (95% CI = 0.71–1.50) among individuals 65 years of age and older. In contrast, among those aged 65 and older they found that those who drank alcohol were less likely to be a caregiver (OR = 0.63; 95% CI = 0.44–0.90) relative to those who did not. However, these data are limited due to their cross-sectional nature, which does not allow for determination of whether these behaviours changed due to taking on caregiving responsibilities. The data from the 2012 General Social Survey are helpful in this regard, given questions highlighting change in health behaviours; for example, while relatively few respondents indicated that their smoking behaviours had changed because of caregiving, much of this change was increased use.

Strengths and limitations

There are several important strengths of the GSS that should be noted. The sampling scheme of GSS was designed to yield estimates that were representative of the Canadian population. As well, unlike previous surveys, the GSS specifically asked respondents to indicate to what extent caregiving itself impacted several different health conditions and behaviours, which may present differently than self-reported health in general. This is an important consideration to consider when framing similar future survey questionnaires for caregivers. The GSS also collected information on an extensive series of other socio-demographic characteristics including income, by which we were able to stratify some of the social and health impacts of caregiving to gain a clearer picture of the socio-economic toll of caregiving for the care providers themselves.

Despite these strengths, however, there are also limitations. It is possible that some of the presented findings may be biased due to participation rates and the reliance on a telephone sampling strategy. The tabulated participation rate was 65.7%[25] and as participation in telephone surveys is typically influenced by sociodemographic and lifestyle factors, it is not straightforward to generalize these findings to the Canadian population. Our analyses were also limited in some situations by a relatively small number of caregivers, particularly in the older age ranges. Although there were approximately 1900 caregivers who were 65 years of age and older, our analyses for some health measures that were less prevalent may have been limited by this sample size, and when stratified analyses were undertaken.

While this study demonstrates that caregiving is associated with several health behaviours and mental health outcomes, it is also important to acknowledge the limitations of cross-sectional studies. However, the questions that directly ask about whether caregiving has impacts on health outcomes provide a distinct advantage over other surveys that have examined these topics. Nonetheless, prospective cohort studies are ultimately needed to understand to what extent caregiving impacts the risk of developing chronic conditions over time. Record linkage processes will provide such an opportunity to examine these impacts among participants of the GSS and are recommended once sufficient follow-up time has accrued.

Conclusion

In conclusion, our findings show that various negative self-reported health outcomes are reported by caregivers, particularly by those under 65 years of age. Moreover, the social and health impacts of caregiving occurred across all income categories. Consistent with previous studies, providing care was found to have detrimental effects on health behaviours related to exercise, diet, and alcohol consumption. However, among caregivers 65 years of age and older, women and those who devoted a greater number of hours to caregiving were most likely to report detrimental impacts on overall health. Our findings should be interpreted cautiously due to the reliance on self-reported, cross-sectional data and participation bias. Nonetheless, the findings of our study are consistent with previous epidemiological investigations, and provide guidance for future research on caregiving, particularly regarding the health impacts of caregiving itself. Our analyses suggest that providing care impacts health behaviours and mental health regardless of age and income, with few exceptions. However, older caregivers (who are most often women), who provide the most hours of care and on reduced incomes relative to younger caregivers, appear to be less impacted in terms of health behaviours, perhaps as a result of fewer competing demands relative to younger caregivers (i.e., the sandwich generation) or due to cohort effects in which older adults may be less likely to be forthcoming with health concerns or simply less engaged with some health-related behaviours to begin with (e.g., frequency of smoking or alcohol consumption). Nonetheless, these findings suggest that support systems for caregivers must consider variations based on age, sex, and income.

Acknowledgements

The authors wish to thank Anna Tomczak, Kelly Biggs and Chantal Houser for their assistance with this paper.

Conflicts of interest

None to declare.

Authors' contributions and statement

Design and conceptualization: RY, PV, NK, SP.

Acquisition and analysis of data: PV; interpretation of data: PV, RY.

Drafting and revising paper: PV, RY, NK, SP.

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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https://doi.org/10.24095/hpcdp.39.5.02

Original quantitative research

Prostate cancer risk by occupation in the Occupational Disease Surveillance System (ODSS) in Ontario, Canada

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Abstract

Introduction: Previous Canadian epidemiologic studies have identified associations between occupations and prostate cancer risk, though evidence is limited. However, there are no well-established preventable risk factors for prostate cancer, which warrants the need for further investigation into occupational factors to strengthen existing evidence. This study uses occupation and prostate cancer information from a large surveillance cohort in Ontario that linked workers' compensation claim data to administrative health databases.

Methods: Occupations were examined using the Occupational Disease Surveillance System (ODSS). ODSS included 1 231 177 male workers for the 1983 to 2015 period, whose records were linked to the Ontario Cancer Registry (OCR) in order to identify and follow up on prostate cancer diagnoses. Cox proportional hazard models were used to calculate age-adjusted hazard ratios and 95% CI to estimate the risk of prostate cancer by occupation group.

Results: A total of 34 997 prostate cancer cases were diagnosed among workers in ODSS. Overall, elevated prostate cancer risk was observed for men employed in management/administration (HR 2.17, 95% CI = 1.98–2.38), teaching (HR 1.99, 95% CI = 1.79–2.21), transportation (HR 1.20, 95% CI = 1.16–1.24), construction (HR 1.09, 95% CI = 1.06–1.12), firefighting (HR 1.62, 95% CI = 1.47–1.78), and police work (HR 1.20, 95% CI = 1.10–1.32). Inconsistent findings were observed for clerical and farming occupations.

Conclusion: Associations observed in white collar, construction, transportation, and protective services occupations were consistent with previous Canadian studies. Findings emphasize the need to assess job-specific exposures, sedentary behaviour, psychological stress, and shift work. Understanding specific occupational risk factors can lead to better understanding of prostate cancer etiology and improve prevention strategies.

Keywords: *occupation, prostate cancer, surveillance, Ontario, cohort, compensation claims*

Highlights

- This is the first large occupational surveillance study in Ontario that links workers' compensation claims to administrative health data.
- We found increased risks of prostate cancer in white collar, transportation, construction, and protective services workers and mixed findings in clerical and farming workers.
- Findings are consistent with recent published Canadian studies on occupation and prostate cancer.
- Future studies need to address job-specific exposures and examine other factors of shift work, stress, sedentary behaviour, and screening patterns.

Introduction

In Canada, prostate cancer is the most commonly diagnosed cancer among men.[1,2] Aside from the few established non-modifiable risk factors of age, family history of prostate cancer, and ethnicity, there are no well-established modifiable risk factors for prostate cancer.[1,2] Prostate cancer risk increases with age, especially after the age of 50 years.[1] African American men are known to have the highest rates of prostate cancer and are more likely to be diagnosed at advanced stages of prostate cancer than other men.[3,4] Men with a family history of prostate cancer are also at an increased risk, and are more likely to seek out prostate cancer screening.[5] There is also growing evidence that men who are obese or overweight have an increased risk of prostate cancer and this may be related to dietary factors and physical inactivity.[6] There is also some evidence that consumption of processed or red meat may lead to an increased risk of prostate cancer.[7] Prostate-specific antigen (PSA) screening behaviours among men

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may also contribute to differences observed in prostate cancer risk.[8-10] As there continues to be limited understanding on modifiable risk factors for prostate cancer, there is a need to investigate other factors, like occupation.

Work-related risk factors for prostate cancer have been increasingly suggested as recent Canadian studies have shown consistent associations between employment in broad occupational groups and prostate cancer risk. Associations have been observed for management and administration, farming, construction, transportation, and protective services occupations.[5,11-14] It has been hypothesized that prostate cancer risk in these occupations is linked to factors such as sedentary behaviour, stress, shift work, whole body vibrations, and chemical exposures (ex. pesticides and diesel exhaust).[15-21] The International Agency for Research on Cancer (IARC) has reported that there is some limited evidence for associations between prostate cancer risk and rubber production industries, cadmium and arsenic metals, malathion, and x and gamma radiation exposures.[22]

Prostate cancer is expected to remain the most common cancer in Canadian men in the coming decades.[2] As working adult men spend a substantial part of their lives at work, occupational risk factors may be important determinants of prostate cancer risk. Improved occupational prostate cancer surveillance is crucial to identifying and reducing work-related risks for prostate cancer. The Occupational Disease Surveillance System (ODSS) was developed as the first surveillance system of its kind in Ontario to link worker compensation claims to administrative health databases to identify and monitor trends in work-related disease.[23,24] The ODSS linkage was developed for surveillance of multiple occupational diseases, including prostate cancer. Unlike previous population-level studies, ODSS narrows the focus to a large cohort of Ontario's working population.

The purpose of this study was to identify associations between occupation and prostate cancer in Ontario using ODSS. This study aims to determine whether previous findings from epidemiologic population studies in Canada are also observed in this study and to explore new associations.

Methods

ODSS was created through the linkage of multiple administrative health databases in Ontario. The system can be used to detect risk of disease, including cancers, among Ontario workers, which provides valuable information on work-related diseases.

Specifically, a cohort of Ontario workers was derived from Workplace Safety and Insurance Board (WSIB) accepted lost-time compensation claims data. The WSIB provides mandatory coverage to 70–76% of workers and provides workers' compensation to those with accepted occupational-related injury/illness claims.[25] The remaining workers who are not covered by WSIB are self-employed individuals not opting for coverage, financial and entertainment workers, and other groups.[25] WSIB records from 1983 to 2014 were eligible for linkage, and these records contained information specific to the claim (date of injury, occupation/industry at time of claim, nature of injury) and personal information (worker name, sex, date of birth, and death date (if applicable)). Occupation associated with the claim was coded by the WSIB according to the Canadian Classification Dictionary of Occupations (CCDO 1971).

WSIB records (n = 2 253 734 unique workers) were linked, through a series of deterministic and probabilistic linkages, to the Ontario Health Insurance Plan's (OHIP) Registered Persons Database (RPDB) (1990–2015) (n = 16 162 277), which contains information on sex, residence, birthdate, death date or emigration (if applicable), and health insurance number (HIN).[23,24] Records were excluded if they were missing sex or date of birth, were under the age of 15 years, had an invalid claim date, or were missing valid occupation or industry codes, resulting in a total of 2 190 246 unique workers in the cohort.[23,24] Workers were then deterministically linked to the Ontario Cancer Registry (OCR) using HINs where available (n = 1 796 731), but also probabilistically linked where no HIN was available, by use of name, sex, birthdate, and death date (n = 393 515).[24] The OCR provides information on Ontario incident cancer cases (1964–2016) collected from hospital records, pathology reports, cancer center records, and death certificates. As a result, 214 821 unique workers were linked to cancer diagnoses in the OCR.[23,24] Follow-up time commenced from the date of the first claim and for this analysis, ODSS cohort members were followed up in the OCR for diagnosis of prostate cancer (International Statistical Classification of Diseases and Related Health Problems, 10th revision, C61). Workers with a prostate cancer diagnosis in the OCR that preceded entry into the ODSS cohort were excluded to establish a prostate cancer free cohort. Workers were followed from cohort entry until prostate cancer diagnosis, emigration from Ontario, death, or the end of the study period (December 31, 2016).[23,24] A full description of the linkage methods can be found elsewhere.[24]

Cox proportional hazard models were used to calculate age-adjusted hazard ratios and 95% confidence intervals (CI) to estimate the risk of prostate cancer for each occupation. Workers with more than one claim record could appear in multiple occupation groups. For each analysis, the occupation group of interest was compared to all other workers in the cohort. Previously, different reference groups were considered (e.g., white-collar jobs) and analyses were restricted to specific age groups with increased prostate cancer development (> 50 years), however no significant changes were observed in the results (results not shown). The occupation groups (CCDO 1971) are presented at division (2-digit), major (3-digit), and minor (4-digit) levels. We conducted the analyses using statistical package SAS version 9.4 (SAS institute Inc., Cary, NC, USA).

In this analysis, occupation groups were examined based on *a priori* or suspected groups of interest stemming from the IARC evaluation and previous Canadian studies. These groups include agriculture and farming, management/administrative and related, transportation, construction, and protective services.[5,11-14] Since ODSS is a newly established system, testing its ability to detect consistent risks among the a priori or suspected groups supports its use as a reliable and valid surveillance system.

This study was approved by the University of Toronto Health Sciences Research Ethics Board (protocol reference #27513).

Results

The ODSS cohort consisted of 1 231 177 male workers with a mean age at cohort entry of 37.4 years. During the cohort time period, 70% had only one accepted time-loss claim. Prostate cancer was the most commonly diagnosed cancer in the ODSS cohort, with a total of 34 997 incident prostate cancer cases identified, as shown in Table 1. The average follow-up time for occupation by division, major, or minor levels was 261 person-months.

Table 2 presents the number of prostate cancer cases and risk estimates by occupation division. A priori and suspected occupation groups that showed elevated risks in the ODSS include management/administrative, teaching, construction trades, and transportation equipment operating. Decreased risks were observed among two suspected at-risk a priori groups, namely, agriculture and forestry/logging. Other associations were observed for natural sciences and engineering, medicine and health, service, mining and quarrying, processing, machining, product fabricating/assembling/repair, material handling, and other crafts/equipment operating occupation groups.

Table 3 reports the number of prostate cancer cases and risk estimates for major occupation groups (3-digit CCDO code) and some minor occupation groups (4-digit CCDO code) with a priori or suspected associations. Complete minor group-level results are presented in a supplementary Table (S1) available upon request from the authors.

Management and administration

Increased risks were observed across all major level management and administrative, teaching, and several non-managerial clerical occupation groups (Table 3). A more than 70% increased risk was observed for the major level teaching-related occupation, with the highest risk observed among university teachers at a minor level (S1).

Natural resources

An increased risk was observed in the overall major group of farmers and farm managers (Table 3), and at a minor level, this was specific to a small group of farmers (S1). However, a decreased risk was observed in the major group of farm, nursery, and related work (Table 3), and this was driven by farm workers (S1). Decreased risks in forestry and logging were primarily driven by workers employed in timber cutting and to a lesser

TABLE 1
ODSS cohort distribution by birth year

Year of birth	Males in the cohort		Prostate cancer cases	
	n (%)		n (%)	
< 1920	2357	(0.2)	328	(1.0)
1920–1929	40 973	(3.3)	5387	(15.4)
1930–1939	98 766	(8.0)	11 067	(31.6)
1940–1949	171 826	(14.0)	11 208	(32.0)
1950–1959	287 897	(23.4)	5883	(16.8)
1960–1969	345 476	(28.0)	1099	(3.1)
1970–1979	182 909	(14.9)	24	(0.1)
1980–1989	87 545	(7.1)	—	
≥ 1990	13 428	(1.1)	—	
Total	1 231 177	(100)	34 997	(100)

Abbreviation: ODSS, Occupational Disease Surveillance System.
Note: — indicate counts < 5.

TABLE 2
Risk of prostate cancer by occupation division group in ODSS

Occupation division (CCDO code)	Cases	Total workers	HR[a] (95% CI)
Managerial, administrative and related (11)[b]	464	14 228	2.17 (1.98–2.38)[c]
Natural sciences, engineering and mathematics (21)	538	20 814	1.30 (1.20–1.42)[c]
Social sciences and related fields (23)	128	6 834	1.10 (0.92–1.31)
Teaching and related (27)[b]	353	10 018	1.99 (1.79–2.21)[c]
Medicine and health (31)	362	17 068	1.14 (1.03–1.27)[c]
Artistic, literary, recreational and related (33)	156	8 400	1.11 (0.95–1.30)
Clerical and related (41)[b]	2133	96 316	1.00 (0.96–1.04)
Sales (51)	1163	71 727	0.88 (0.83–0.94)
Service (61)	4221	187 123	1.07 (1.04–1.11)[c]
Farming, horticultural and animal husbandry (71)[b]	586	39 236	0.68 (0.63–0.74)[d]
Fishing, hunting, trapping and related (73)	8	518	0.66 (0.33–1.33)
Forestry and logging(75)[b]	183	10 109	0.67 (0.58–0.77)[d]
Mining and quarrying including oil and gas field (77)	422	12 870	1.31 (1.19–1.44)[c]
Processing – metal/clay, glass, stone/chemicals (81)	1403	62 878	0.93 (0.88–0.98)[d]
Processing – food/wood/pulp/textile (82)	1372	67 325	0.87 (0.82–0.91)[d]
Machining and related (83)	4428	168 127	1.07 (1.04–1.11)[c]
Product fabricating, assembling and repairing (85)	7156	261 187	1.12 (1.09–1.14)[c]
Construction trades (87)[b]	5284	211 378	1.09 (1.06–1.12)[c]
Transport equipment operating (91)[b]	3998	153 882	1.20 (1.16–1.24)[c]
Materials handling and related (93)	2392	121 957	0.80 (0.76–0.83)[d]
Other crafts and equipment operating (95)	619	21 541	1.15 (1.06–1.24)[c]
Occupations not elsewhere classified (99)	3554	174 651	0.85 (0.82–0.88)[d]

Abbreviations: CCDO, Canadian Classification Dictionary of Occupations; HR, hazard ratio; ODSS, Occupational Disease Surveillance System.
[a] Adjusted for age and calendar year.
[b] A priori groups.
[c] Statistically significant increased risk.
[d] Statistically significant decreased risk.

TABLE 3
Risk of prostate cancer for selected a priori major occupation groups in ODSS

Occupation (CCDO code)	Cases	Total workers	HR[a] (95% CI)
Management & Administrative			
Officials and Administrators Unique to Government (111)	115	2 835	1.97 (1.64–2.37)[b]
Other Managers and Administrators (113)	240	7 150	2.43 (2.14–2.76)[b]
Occupation Related to Management and Administration (117)	116	4 422	1.96 (1.63–2.35)[b]
University Teaching and Related (271)	24	438	3.71 (2.48–5.53)[b]
Elementary and Secondary School Teaching and Related (273)	282	8 225	1.94 (1.72–2.18)[b]
Other Teaching and Related (279)	57	1 519	2.01 (1.55–2.60)[b]
Bookkeeping Account Recording and Related (413)	79	4 479	1.04 (0.84–1.30)
Office Machine and Electronic Data Processing Operators (414)	23	983	0.96 (0.64–1.44)
Material Recording Scheduling and Distributing (415)	1204	58 607	0.87 (0.82–0.92)[c]
Reception Information Mail and Message Distribution (417)	160	8 238	1.30 (1.11–1.52)[b]
Other Clerical and Related (419)	181	8 931	1.21 (1.05–1.40)[b]
Natural Resources			
Farmers and Farm Management (711/713)	112	3 528	1.72 (1.43–2.07)[b]
Farm, Nursery, and Related Workers (718/719)	468	34 920	0.61 (0.56–0.67)[c]
Other Farming Horticulture and Animal Husbandry (718)	37	1 834	0.75 (0.55–1.04)
Fishing Trapping and Related (731)	8	518	0.66 (0.33–1.33)
Forestry and Logging (751)	183	10 109	0.67 (0.58–0.77)[c]
Mining and Quarrying, Drilling and Blasting (7711)	135	3 473	1.28 (1.08–1.52)[b]
Other Mining and Quarrying Including Oil and Gas (7710)	326	10 365	1.36 (1.22–1.52)[b]
Construction & Trades			
Mineral Ore Treating (811)	40	948	1.38 (1.01–1.89)[b]
Metal Processing and Related (813)	681	26 178	1.09 (1.10–1.18)[b]
Clay, Glass, Stone Processing Forming and Related (815)	214	9 007	0.82 (0.71–0.94)[c]
Chemicals, Petroleum, Rubber, Plastic, and Related Processing (816)	493	28 227	0.79 (0.73–0.87)[c]
Food and Beverage and Related Processing (821)	962	45 030	0.89 (0.83–0.95)[c]
Wood Processing Occupations Except Paper Pulp (823)	106	5 923	0.70 (0.58–0.84)[c]
Pulp and Papermaking and Related (825)	145	4 879	1.12 (0.95–1.32)
Textile Processing (826)	99	5 362	0.74 (0.60–0.90)[c]
Other Processing (829)	74	7 141	0.83 (0.66–1.04)
Metal Machining (831)	1201	39 210	1.30 (1.22–1.37)[b]
Metal Shaping and Forming, Except Machining (833)	2990	118 192	1.04 (1.00–1.08)
Wood Machining (835)	135	7 550	0.81 (0.68–0.96)[c]
Clay, Glass, and Stone and Related Materials Machining (837)	372	12 678	1.06 (0.96–1.18)
Fabricating and Assembling Other Metal Products (851)	2036	67 413	1.17 (1.12–1.23)[b]
Fabricating Assembling, Installing, Repairing - Electrical/Electronic (853)	628	25 862	1.17 (1.08–1.27)[b]
Fabricating Assembling and Repairing - Wood (854)	391	21 627	0.68 (0.61–0.75)[c]
Fabricating Assembling and Repairing - Textile/Fur/Leather (855)	231	8 686	0.90 (0.79–1.02)

Continued on the following page

degree, workers in laboring and elemental work (S1). Increased risks in mining and quarrying related occupations were observed across all minor level mining and quarrying occupations (S1).

Construction and trades

Increased risks were observed for metal related occupations such as metal processing, metal machining, metal shaping and forming, and fabricating and assembling other metal products; all groups which had large numbers of prostate cancer cases at a major level (Table 3). At a minor level, a number of these metal related occupations with many prostate cancer cases were also elevated: metal processing foremen, metal rolling, metal machining foremen, tool and die making, machinists, metal shaping and forming foreman, forging, boil-makers, and sheet metal workers (S1). An increased risk was also observed in the major group of mechanics and repairers which had one of the highest numbers of prostate cancer cases among the construction occupations (Table 3). Almost all minor groups under mechanics and repairers showed increased risks for prostate cancer, primarily driven by many prostate cancer cases in motor vehicle and industrial/farm/construction machinery occupations (S1). Several construction occupations at a major level were also observed as decreased risks: non-metal product processing, food and beverage processing, wood processing, textile processing, wood machining, and fabricating/assembling/repair of wood, rubber, and plastic (Table 3).

Transportation

Multiple transportation occupations at a major level were observed to be associated to prostate cancer, with increased risks across railway transport operating, motor transport operating, other transport and related operating, and stationary engine and utilities operating (Table 3). For railway transport, all minor level groups demonstrated increased risks, however these groups had small numbers of prostate cancer cases. All minor level motor transport occupations also showed increased risks, primarily driven by many cases in truck and bus driving (S1).

Protective services

Increased risks of prostate cancer were observed across firefighters, policemen and detectives, and guards and watchmen (Table 3).

TABLE 3 (continued)
Risk of prostate cancer for selected a priori major occupation groups in ODSS

Occupation (CCDO code)	Cases	Total workers	HR[a] (95% CI)
Fabricating Assembling and Repairing - Rubber/Plastic (857)	225	11 006	0.65 (0.57–0.75)[c]
Mechanics and Repairers Except Electrical (858)	3382	110 106	1.30 (1.26–1.35)[b]
Other Product Fabricating Assembling and Repairing (859)	732	34 982	1.05 (0.98–1.13)
Excavating Grading Paving and Related (871)	600	17 912	1.51 (1.39–1.64)[b]
Electrical Power Lighting/Wire Communications Equipment (873)	1035	34 606	1.28 (1.21–1.36)[b]
Other Construction Trades (878)	3735	162 367	1.00 (0.97–1.03)
Transportation			
Air Transport Operating (911)	120	7 397	0.93 (0.78–1.11)
Railway Transport Operating (913)	159	3 825	1.85 (1.58–2.16)[b]
Water Transport Operating (915)	61	2 550	1.12 (0.87–1.44)
Motor Transport Operating (917)	548	20 733	1.45 (1.10–1.19)[b]
Other Transport and Related Equipment Operating (919)	275	12 166	2.16 (1.92–2.43)[b]
Stationary Engine and Utilities Equipment Operating and Related (953)	270	7 165	1.59 (1.41–1.79)[b]
Protective Services			
Fire-fighting (6111)	404	11 647	1.62 (1.47–1.78)[b]
Policemen and Detectives (6112)	501	19 448	1.20 (1.10–1.32)[b]
Guards and Watchmen (6115)	454	17 400	1.36 (1.24–1.49)[b]
Other Protective Services (6119)	15	617	1.01 (0.61–1.68)

Abbreviations: CCDO, Canadian Classification Dictionary of Occupations; HR, hazard ratio; ODSS, Occupational Disease Surveillance System.

[a] Adjusted for age and calendar year.

[b] Statistically significant increased risk.

[c] Statistically significant decreased risk.

Other occupations

Table 4 presents risk estimates for other major occupation groups where excesses were observed at the division level (Table 2) and were not considered a priori or suspected groups of interest. Mainly, men employed in major occupational groups related to science/engineering/social sciences (life sciences, architecture and engineering) and health services (health diagnosing, nursing, other health occupations) were observed to have increased risks of prostate cancer (Table 4).

Discussion

As in the general population, prostate cancer was the most common cancer diagnosed among men in the ODSS cohort. Consistent with a priori suspected associations and with recent published Canadian studies, this study observed an excess risk for prostate cancer among white collar, transportation, construction, and protective services occupations and for some clerical and farming occupations.[5,11-13] Findings from this large study of more than 1.2 million male workers in Ontario strengthen previous findings. Occupational associations observed in this study may be driven by several work-related factors such as sedentary behaviour/low physical activity, psychological stress, shift-work, whole-body vibrations, and specific chemical exposures.

Previous studies have suggested that sedentary behaviour or low occupational physical activity may be linked to increased prostate cancer risk.[26] A meta-analysis that included 19 cohort studies and 24 case-control studies observed a 19% reduction in prostate cancer risk related to occupational physical activity.[27] Although the biological mechanism linking physical inactivity to prostate cancer is not clear, it is speculated that decreased physical activity may influence prostate cancer risk through changes in testosterone levels, immune function, and insulin-like growth factors.[27] Increased prostate cancer risks previously observed among white collar and administrative occupations have been commonly attributed to sedentary behavior, as there are few hazardous chemical exposures involved in these occupations.[5,11-13] Our findings in managerial and administrative work may be explained by increased sedentary behaviour and low occupational physical activity. Men employed in managerial level positions are also likely to be older with higher education and experience, however we were able to adjust for age. Also, these workers tend to have a higher socioeconomic status (SES) when compared to blue collar workers, and a higher SES has been linked to increased use of health services and possible early diagnosis of prostate cancer (e.g., increased PSA screening), which may play a role in our findings.[5,28] On the other hand, decreased risks identified in blue collar workers (e.g., farming, forestry and logging, and some construction trades) in our study may be linked to the increased occupational physical activity in these workers, compared to white collar workers. Transportation workers, specifically truck and bus drivers identified in our study, may also experience long periods of sitting or sedentary behaviour. Previous studies in Ontario saw no association with physical activity level in these workers.[11,15] However, few studies in the literature have shown that increased occupational sedentary behaviour in transport drivers is also related to shift work, obesity, and low physical activity during non-work hours.[29,30]

Psychological stress has been found to have an important impact on health conditions, with increased risks for cardiovascular disease and mental illness, but there is growing interest for its role in cancer etiology.[31] Chronic stress may impact cancer development with activation of the sympathetic nervous system leading to downregulation of cellular immune response and promoting genomic instability. There is also some evidence that chronic stress can influence testosterone levels contributing to prostate cancer development.[31] The main source of stress in men is workplace stress, and few studies have been able to assess workplace stress and prostate cancer risk. Workplace stress is categorized by the balance of demand and control, with high stress environments involving high demand and low control.[31]

TABLE 4
Risk of prostate cancer for other major occupation groups in ODSS

Occupation (CCDO code)	Cases	Total workers	HR[a] (95% CI)
Science, Engineering, and Social Sciences			
Physical Sciences (211)	70	2491	1.13 (0.90–1.43)
Life Sciences (213)	49	1793	1.36 (1.02–1.79)[b]
Architects and Engineers (214)	128	3675	1.36 (1.02–1.79)[b]
Other Architecture and Engineering (216)	284	11 918	1.22 (1.09–1.38)[b]
Other Mathematics and Statistical Systems (218)	18	1361	1.03 (0.65–1.64)
Social Sciences (231)	46	1942	1.75 (1.31–2.34)[b]
Social Work and Related Fields (233)	88	5179	0.93 (0.75–1.14)
Health Services			
Health Diagnosing and Treating (311)	12	255	2.33 (1.33–4.10)[b]
Nursing Therapy and Related Assisting (313)	303	14 789	1.09 (0.97–1.22)
Other Occupations in Medicine and Health (315)	58	2317	1.58 (1.22–2.04)[b]
Other Occupations			
Fine and Commercial Art Photography (331)	38	1529	1.41 (1.03–1.94)[b]
Performing and Audiovisual Arts (333)	21	1628	0.93 (0.61–1.43)
Writing (335)	8	273	1.50 (0.75–3.00)
Sport and Recreation (337)	90	5009	1.05 (0.85–1.29)
Sales Commodities (513)	1029	66 747	0.86 (0.81–0.91)[c]
Food and Beverage Preparation and Related Services (612)	99	14 814	0.44 (0.36–0.53)[c]
Lodging and Other Accommodation (613)	61	2663	0.99 (0.77–1.27)
Printing and Related (951)	335	13 551	0.95 (0.85–1.05)

Abbreviations: CCDO, Canadian Classification Dictionary of Occupations; HR, hazard ratio; ODSS, Occupational Disease Surveillance System.

[a] Adjusted for age and calendar year.

[b] Statistically significant increased risk.

[c] Statistically significant decreased risk.

This is important in occupations identified in our study, such as firefighting and police work, which are recognized as high risk professions where workers are required to respond to a range of emergencies in consistent high stress environments.[32] But there is also the perception of stress, if the worker perceives their job to be of high stress compared to other workers. Some studies have reported that higher stress levels were often reported among white-collar workers when compared to blue collar workers.[31,33] Workplace stress may be a contributor to increased risks identified in white collar workers in our study. Workplace stress has also been associated to increased unhealthy lifestyle factors such as physical inactivity, obesity, increased alcohol use, and smoking.[7]

Recent meta-analyses on shift work and prostate cancer suggest that night and rotating shift work is associated with prostate cancer risk.[19,34,35] Shift work can lead to the suppression of melatonin synthesis which leads to the disruption of the circadian rhythm.[35-37] Melatonin is recognized as an important contributor to preventing cancer development,[19] but with the suppression of melatonin through increased shift work, there may be an increase in testosterone levels leading to increased prostate cancer risk.[19] This is relevant across some occupations identified in this study that involve shift work, such as transportation, protective services, and health care occupations. Transportation drivers, specifically truck drivers identified in our study, may be likely to work night shifts or irregular hours.[29,30] Shift work has also been shown among protective services occupations in firefighting and police work.[38,39] Increased prostate cancer risks observed in health care occupations, specifically in nursing occupations, could be related to shift work as previous studies have established an association between nursing occupations, shift work, and breast cancer risk.[36,37]

Whole body vibration (WBV) is a common exposure in occupations involving repetitive vehicle or machine use, such as in transportation and construction jobs. Exposure to WBV occurs when mechanical energy from vibrating surfaces is passed to the body either in standing or sitting positions.[40] Although the role of WBV in prostate cancer etiology remains unclear, other prostate conditions like prostatitis and increasing testosterone levels have been linked to WBV exposure.[40] Transportation workers in railway transportation, truck driving, motor transport operating, equipment operating, and stationary engine equipment operating had excess risks in our study similar to previous studies, which all involve WBV exposure.[10,15-17,40-42] Construction workers involved in machinery related work requiring the use of hand tools may be exposed to whole body vibrations as well, however it is unclear which construction occupations involve WBV in our study.

Our study findings may also be related to specific chemical exposures. An increased risk in farmers and farm management may be linked to pesticide exposure, which has been consistently shown in the previous literature.[43-45] Also, some agriculture studies have shown associations in men with a family history of prostate cancer and exposure to specific pesticides.[46,47] Farming workers may also be exposed to diesel exhaust, similar to workers in construction, transportation, mining, and protective services.[11-13,43-45,48] These workers may be exposed through the use of diesel emitting vehicles or by working near them for long periods of time.[43-45,48] Diesel exhaust exposure is also common in forestry and logging occupations, however decreased risks were observed for these groups in our study. There is evidence that cadmium and arsenic metal compounds are linked to prostate cancer risk based on IARC evaluations.[25] However, in this study it was not possible to narrow down occupations by specific metal exposures, though we observed increased risks across different construction metal–related occupations. Increased risks were also observed among mechanics and repairmen, and these workers may be exposed to chemical agents such as solvents, iron and steel metals, and welding equipment.[49]

Screening behaviours may also contribute to prostate cancer risk differences observed in occupation groups in our study. It is well known that the PSA test is the only available screening test for prostate cancer. However, it is non-specific and can lead to false-positives and additional unnecessary testing.[28,50] Routine prostate cancer screening is not recommended in Canada,[50] but there are screening related factors that may influence screening behaviours in men. Previous evidence has shown that men of older age, with higher SES, family history of prostate cancer, and those who are married are more likely to get screened than other men.[14,28,44] Also, men employed in white collar jobs have been shown to have better awareness, accessibility, and flexibility to seek out prostate cancer screening which may explain some of the increased risks identified in these occupations.[10,28] Decreased risks identified in blue collar jobs of construction, farming, forestry, and logging may be related to decreased prostate cancer screening, based on lower SES, less flexible working hours, and less awareness of screening resources.[10] Protective services workers, specifically firefighting, may have more frequent medical exams than other professions, given the nature of these occupations, resulting in increased screening behaviours.[51,52] Excess risks observed in engineering and social sciences in our study have also been reported in the literature with the suggestion that these men are more likely to get screened for prostate cancer when compared to other men.[5,10] Also, our findings in health care workers may indicate increased screening in these workers, as they are more likely to be informed on available medical tests.

There were limitations with this study. Although occupational information was collected at the time of claim, no lifetime work history was available. We also did not have the ability to examine occupation-related factors such as duration of employment. Only workers with a lost-time compensation claim were included in this cohort, which over represents workers in physically hazardous occupations compared to the broader workforce since most accepted claims are for workplace injuries. Although this cohort includes many Ontario workers, it may not represent all individuals in the identified occupations and this could lead to selection bias, if risk factors associated with prostate cancer are correlated with physical hazards. All analyses were conducted within the cohort, such that both the target group and reference are formerly injured workers, which may offset this bias. Workers in particularly high hazard occupations, may also have an increased risk of death, which could remove them from follow-up prior to the age when they are at high risk of prostate cancer. While adjusting for age may address this, its impact could only be fully assessed using a competing risk model.

Due to the nature of how the cohort is constructed, people in senior level positions may have a higher level of risk attributed to them because of exposure under prior work duties, such as a manager who was a former worker. This may also occur simply because people had to be older in order to achieve that position, such as judges, and prostate cancer is a disease of old age. All analyses were age adjusted, which should at least partially mitigate potential bias, but caution should be used in interpreting excess risks in these groups. Also, the administrative databases used in this study did not capture information on socioeconomic (e.g., income, education), lifestyle, or known prostate cancer risk factors, aside from age, which could act as potential confounders and could help to alleviate some of the selection bias. This study also uses multiple testing which can lead to chance findings, a common issue with occupational studies looking at multiple groups. However, our study results were quite similar to previous publications, providing confidence in our findings. A major strength of this study is that it uses a linkage-based approach with accurate and updated administrative health data. Another major strength is the use of compensation claims data which provided vital and accurate employment information. The linkage-based approach is efficient for identifying a large sample of prostate cancer cases with occupational information prior to diagnosis. Also, comparisons were restricted to a cohort of workers rather than the general population which reduces the potential impact of the healthy worker effect.

Conclusion

This study identified associations between occupation and prostate cancer risk similar to *a priori* or suspected associations recognized in previous Canadian studies. Findings included associations in management/administrative, construction, transportation, and protective services occupations and prostate cancer risk. There were also other associations that warrant further investigation. There is a continued need to examine potential job-specific exposures and other factors such as sedentary behaviour, stress, shift work, and screening patterns, among other non-occupational factors. Understanding specific work-related factors will help determine how the identified jobs are related to prostate cancer risk. This can lead to improved knowledge on prostate cancer risk factors and evidence-based prevention strategies.

Acknowledgements

This project was funded by the Ministry of Labour (No. 14-R-29) and the Public Health Agency of Canada (No. 1516-HQ-000066). The Occupational Cancer Research Centre is supported from core funding from Cancer Care Ontario, the Canadian Cancer Society and the Ontario Ministry of Labour.

Conflicts of interest

None to declare.

Authors' contributions and statement

JS, the primary author, contributed to the design and conceptualization of the work, data analysis, interpretation of the data, drafting and revising of the paper. JSM contributed to the acquisition of the data, design and conceptualization of the work, data analysis, and revising of the paper. CBM and AP contributed to the interpretation of the data and revising of the paper. PAD contributed to the acquisition of the data, design and conceptualization of the work, interpretation of the data, and revising of the paper.

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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https://doi.org/10.24095/hpcdp.39.5.03

Evidence synthesis

A scoping review on the relations between urban form and health: a focus on Canadian quantitative evidence

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Abstract

Introduction: Despite the accumulating Canadian evidence regarding the relations between urban form and health behaviours, less is known about the associations between urban form and health conditions. Our study aim was to undertake a scoping review to synthesize evidence from quantitative studies that have investigated the relationship between built environment and chronic health conditions, self-reported health and quality of life, and injuries in the Canadian adult population.

Methods: From January to March 2017, we searched 13 databases to identify peer-reviewed quantitative studies from all years that estimated associations between the objectively-measured built environment and health conditions in Canadian adults. Studies undertaken within urban settings only were included. Relevant studies were catalogued and synthesized in relation to their reported study and sample design, and health outcome and built environment features.

Results: Fifty-five articles met the inclusion criteria, 52 of which were published after 2008. Most single province studies were undertaken in Ontario (n = 22), Quebec (n = 12), and Alberta (n = 7). Associations between the built environment features and 11 broad health outcomes emerged from the review, including injury (n = 19), weight status (n = 19), cardiovascular disease (n = 5), depression/anxiety (n = 5), diabetes (n = 5), mortality (n = 4), self-rated health (n = 2), chronic conditions (n = 2), metabolic conditions (n = 2), quality of life (n = 1), and cancer (n = 1). Consistent evidence for associations between aggregate built environment indicators (e.g., walkability) and diabetes and weight and between connectivity and route features (e.g., transportation route, trails, pathways, sidewalks, street pattern, intersections, route characteristics) and injury were found. Evidence for greenspace, parks and recreation features impacting multiple health outcomes was also found.

Conclusion: Within the Canadian context, the built environment is associated with a range of chronic health conditions and injury in adults, but the evidence to date has limitations. More research on the built environment and health incorporating rigorous study designs are needed to provide stronger causal evidence to inform policy and practice.

Highlights

- The most frequently reported associations among Canadian studies on urban form and health outcomes were related to injury and weight status.
- Not all provinces and territories were represented in this review, with much of the evidence coming from studies in Ontario, Quebec, and Alberta.
- Objectively-measured aggregate built environment indicators, connectivity and route features, destinations, food environment, population density, and greenspace, parks and recreation features are associated with a range of modifiable health conditions and injury.
- This scoping review identifies that more Canadian research, with rigorous designs that allow for causal inference, is required to inform policy and practice.

Keywords: *disease, neighbourhood, built environment, injury, health, mental health*

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Introduction

The World Health Organization's 1986 Ottawa Charter for Health Promotion acknowledged the need to create health-supportive environments.[1] Health-supportive environments, whether on local or global scales are responsive to changes in energy production, technology, work, and urbanization, and positively support interrelationships between the environment and human health.[1] Creating such environments continues to be an important strategy for reducing the chronic disease risk and promoting health and wellbeing in Canada and globally.[2,3] Since the early 20th century, urban planning strategies in Canadian cities have contributed to poor health due to the rapid geographic expansion of metropolitan areas resulting in increased intra- and inter-neighbourhood distances between homes and destinations, lower city and neighbourhood population densities, disconnected regional and neighbourhood street patterns, and scattered suburban neighbourhood development.[4] Previous and often contemporary urban planning strategies continue to negatively impact transportation walking and cycling, encourage dependence on private motorized transportation, and contribute to increased obesity, pedestrian injury, and chronic disease risk.[4]

Neighbourhoods, which incorporate interrelated urban form and social characteristics, are important settings that positively and negatively influence the health and wellbeing of individuals and populations. Neighbourhood urban form or built environment – the human-modified physical surroundings and features such as parks, streets, buildings, destinations and land uses, connectivity, density, sidewalks and paths, lighting, aesthetics, and architecture – supports physical activity,[5,6] sedentary behaviour,[7,8] diet,[9] and socializing.[10,11] Informed by evidence, Northridge et al.'s[12] conceptual framework proposed links between urban form and population health, in particular positing land use (e.g., industrial, residential, mixed or single use), services (e.g., shopping, banking), transportation systems, public resources (e.g., parks), zoning regulations, and buildings as important broadly-defined community level determinants. Similarly, Frank et al.'s[13] conceptual framework links land use patterns (i.e., arrangement of destinations, mix of uses, distribution of parks and recreational opportunities), urban design characteristics (i.e., micro-scale characteristics influencing safety, aesthetics, friendliness, and vibrancy), and transportation systems (i.e., road, sidewalk/pathway and other transportation infrastructure, connections, and linkages) to the public health of communities and cities.

Systematic review findings, which are often based on a synthesis of studies from multiples countries, provide some evidence for associations between a variety of built environment features (e.g., food environment, walkability, greenery) and weight status,[14,15] blood pressure,[15] metabolic syndrome,[15] diabetes,[15,16] and major cardiovascular outcomes such as myocardial infarctions, coronary heart disease, congestive heart failure and stroke.[15] Further, built environment features are associated with motor vehicle-related bicyclist (e.g., presence of bike routes, lanes, and paths)[17] or pedestrian (e.g., traffic-calming infrastructure and roadway design)[18,19] injuries among adults, and associated with the risk of outdoor falls and fall-related injuries in older adults (e.g., perceived personal safety and neighbourhood disorder[20,21] and sidewalk quality[21]). In addition to associations with physical health, evidence also suggests that built environment features are associated with mental health (e.g., depression, anxiety, and distress)[11,22] and intervening variables such as stress, social support and social capital.[10,11,22-24] The built environment can affect the subjective experience of residents, for example through perceptions of safety and the stress process, which in turn can result in physical and mental health consequences.[22]

In Canada, approximately 34% of adults report having at least one of the five major chronic diseases (i.e., cancer, cardiovascular diseases, diabetes, chronic respiratory diseases, and mood/anxiety disorders).[25] Among those 12 years and older, at least one-quarter report less than very good mental health and approximately 13% report having a diagnosed mood or anxiety disorder.[25] Thus, a better understanding regarding the nature of the neighbourhood built environment for promoting health and wellbeing and preventing multiple chronic diseases in Canada is needed. Previous systematic reviews on built environment and health typically do not stratify their findings by country or geography, and the findings are often weighted towards US and European studies, which despite being informative, lack specificity, and potentially some relevance for aiding local decision-making. The climatic, cultural, political, legislative, and healthcare system differences between countries (among other differences) suggest that synthesizing findings from studies undertaken within a single country might be a better strategy for informing local urban planning strategies and policies that have the potential to impact health. While some findings support the generalizability of built environment and physical activity associations between countries,[26,27] country and regional differences in relations between built environment and rates of bicycling,[28-30] bicycling injuries and crashes,[17] transportation walking,[30] and obesity[31] found elsewhere exemplify the need for synthesis of local evidence. Country-specific literature reviews on the association between built environment and different health outcomes are scarce.[32]

Generating and sharing local evidence (e.g., via literature reviews) with stakeholders, practitioners, and decision-makers is identified as one of several vital approaches needed for the development and implementation of land use and transportation policies for a health-supportive environment within the Canadian context.[33] Thus, the aim of our study was to undertake a scoping review to synthesize and map evidence from quantitative studies that have investigated the built environment and its associations with modifiable health conditions, self-reported health, quality of life, and injuries in the Canadian adult population. Evidence from this review is intended to inform the direction of the Canadian research agenda by identifying knowledge gaps and to consolidate findings from existing studies investigating associations between urban form and health that could inform local policy and practice.

Methods

Overview

Our scoping review approach was informed by the steps proposed by Arksey and O'Malley.[34] Our review: 1) included a comprehensive systematic search of the peer-reviewed literature to identify health-focussed quantitative studies that included an objective measure of the built environment; 2) catalogued and mapped study characteristics (types of built environment exposures, types of chronic disease and injury outcomes, study populations, methods, geographical contexts, journal types, funding sources, and findings); 3) summarized the relationships between the built environment and health status and injury (e.g., cardiovascular-related diseases, diabetes, depression, weight status, quality of life, and injury); and 4) identified knowledge and evidence gaps.

Search strategy

In consultation with a Health Sciences librarian, we developed a preliminary list of search terms pertaining to built environment, health outcomes, and the Canadian context and identified relevant databases informed by the Public Health Agency of Canada's Chronic Disease Indicator Framework (CDIF).[35] This framework was developed as a reference tool for practitioners and policymakers to inform chronic disease surveillance in Canada. Despite updates to the framework—including the removal of injury as an indicator[25]—we report on injury in this scoping review. Studies estimating associations between the built environment and health behaviours (e.g., physical activity, diet, sedentary behaviour, socializing) were not included.

Thirteen scientific databases (CINAHL, EMBASE, Environment Complete, MEDLINE, PsycInfo, PubMed, Scopus, SocIndex, SportDiscus, TRID, Urban Studies, Web of Science, and CAB Abstracts) were identified as likely indexing journals and articles relevant for our review. A pilot test of our search strategy using Medline alone yielded over 80 000 titles. A preliminary check of these titles suggested that the initially included term "nature" was contributing many irrelevant titles, and thus this term was excluded. We also added "suburb" as a built environment term. A trained research assistant (RL) undertook the database search in March 2017 (Table 1). Separate title, abstract, and keywords searches were conducted for the built environment (n = 28), health (n = 29), and then Canadian geography (n = 14) terms. The results for the three separate search strings were combined to identify relevant titles. The database search resulted in 87 552 titles. These titles and abstracts were imported into the Endnote reference management software for further processing. After removal of duplicate titles and screening of title relevance, 1544 remained for full abstract screening. Following the detailed abstract screening and removal of conference proceedings, book reviews, commentaries, editorials, and non-peer reviewed articles, 232 titles were identified as relevant to undergo full-text assessment (i.e., whereby the abstract mentioned both the built environment and at least one health outcome).

RL and GRM independently reviewed the 232 full-text articles (percent of overall agreement = 84.7%; kappa = 0.68) against our review's inclusion criteria. A consensus was reached for those articles where RL and GRM disagreed regarding their inclusion. Studies included in the review were primary quantitative or mixed-methods studies, included adults (age ≥ 18 years) from a Canadian geographical location, and estimated and reported an association between an objective measure of the built environment (derived from geographical information systems or virtual or in-person audits) or neighbourhood type (e.g., expert-determined) and at least one relevant self-reported, clinically assessed, or administrative data determined outcome associated with either cancer, cardiovascular disease, aggregate chronic conditions, depression/anxiety, diabetes, injury, metabolic conditions, mortality, quality of life, self-rated health, and weight status.

Studies that recruited a rural sample only or compared rural to urban only, examined air or noise pollution as an exposure only, included road proximity or traffic volume as a proxy for pollution exposure, included a self-reported measure of the built environment only, or exclusively included children and/or adolescents were excluded. Upon checking the analysis and results of included studies, those which did not adjust for any covariates (i.e., via statistical controls, matching, or stratification) in estimated associations between the built environment and health were also excluded. The reference lists of articles meeting the inclusion criteria, similar literature reviews, and key Canadian peer-reviewed journals (*Canadian Journal of Public Health, Health Promotion and Chronic Disease Prevention in Canada, Canadian Medical Association Journal, and Canadian Journal of Urban Research*) were also screened for relevant articles. After full-text assessment, 55 were included in the review and underwent data extraction

TABLE 1
Study count by health outcomes and type of built environment characteristics examined

Built environment characteristic	Cancer	Cardiovascular disease	Weight status	Depression/ anxiety	diabetes	Injury	Metabolic conditions	Mortality	Quality of life	Self-rated health	Aggregate chronic conditions
Aggregate index (e.g. walkability)	0	1	8	0	3	1	0	0	1	0	0
Route characteristics	0	0	5	0	1	19	0	0	0	0	0
Traffic	0	3	0	1	0	4	0	0	0	0	0
Greenness, parks, recreation	1	2	2	4	1	2	1	1	0	1	1
Land use and destinations	0	1	4	4	1	4	0	1	0	1	1
Food environment	0	3	9	3	1	0	1	2	0	0	0
Population and dwellings	0	1	5	0	2	3	0	0	0	0	0

Note: A study can investigate more than one built environment characteristic and more than one health outcome.

and synthesis. We applied the PRISMA-ScR checklist[36] to guide reporting of article inclusion and exclusion for our scoping review and to improve rigor and replicability (Figure 1).

Data extraction and synthesis

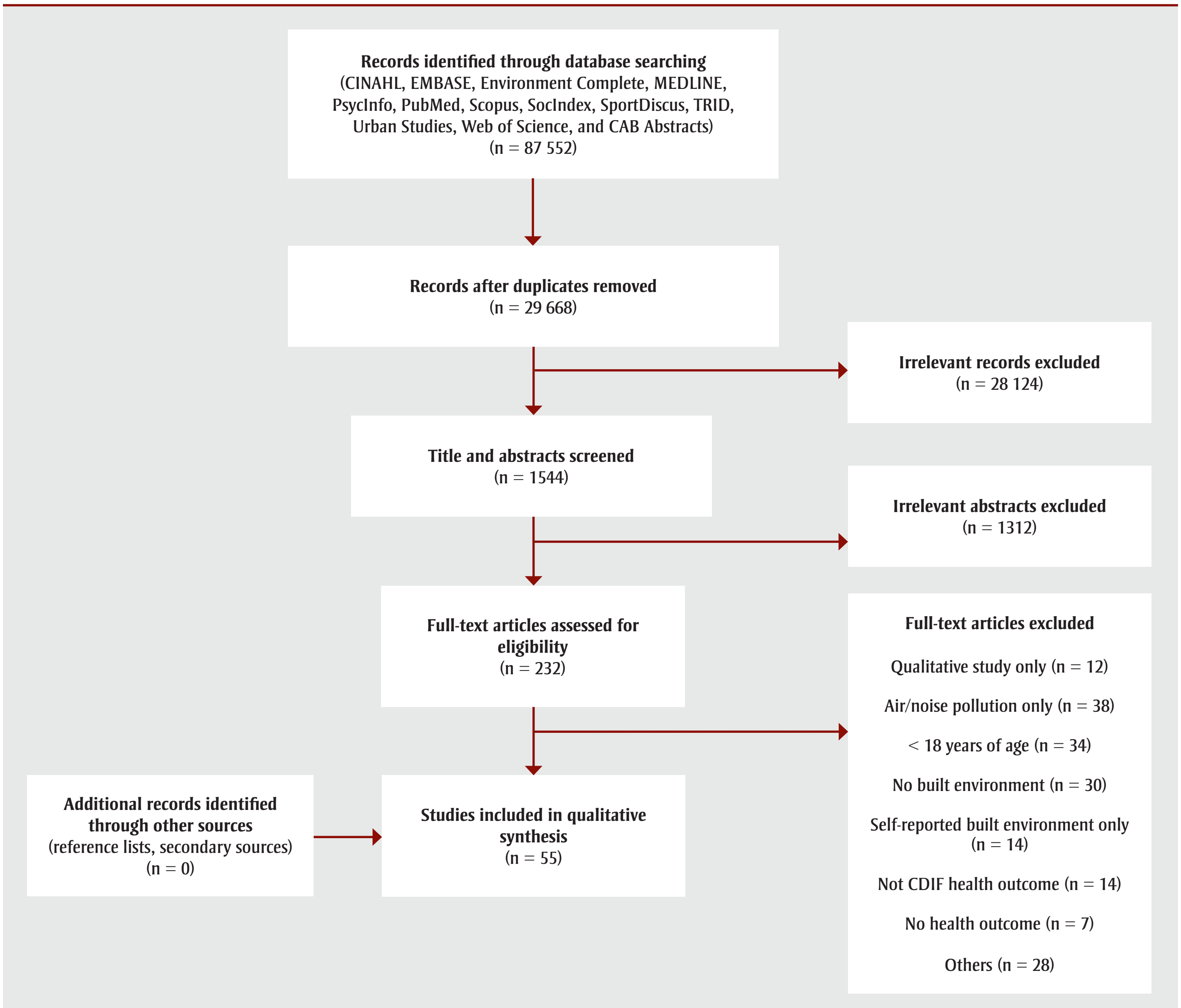
Relevant data extracted from reviewed articles included author, first-author institution, publication year, study design, geographical location, sample design, basic sample characteristics, data collection and measures (built environment and health), findings, and funding or sponsor details. One reviewer (RL) led article data extraction, tabulation, and synthesis, with a second (AB) and a third reviewer (GRM) tasked with ensuring the accuracy of the data extracted and summary of findings reported. We extracted and synthesized statistically significant positive and negative associations (based on either reported p-values or confidence intervals) from the most fully or final covariate-adjusted (including statistical controls, matching, or stratification) model reported in the study. Extracted article data were entered and organized in an electronic database (Microsoft Excel). Summaries of article findings were broadly categorized based on the eleven health outcomes informed by the CDIF and the broad groupings of conceptually similar built characteristics informed by previous frameworks.[12,13] We undertook a narrative qualitative description of study differences and similarities in terms of their types of built environment exposures, types of chronic disease and injury outcomes, study populations, methods, geographical contexts, journal types, funding sources, and findings.

Results

Study contexts

Fifty-five articles were included in this review. Articles were published between 1998 and 2017, although most (n = 52) were published after 2008. Eleven articles

FIGURE 1
PRISMA-ScR flow chart of included and excluded studies



included national or multi-province samples (e.g., Ontario and British Columbia). Most single province studies were undertaken in Ontario (n = 22) followed by Quebec (n = 12), Alberta (n = 7), British Columbia (n = 2), and Nova Scotia (n = 1). Notably, other Canadian provinces and territories were not represented in the included articles. Forty-six studies declared some type of research funding (program, project, or salary support), with most studies supported by funding from Canadian Institutes of Health Research (n = 32), provincial government (n = 26), national government (n = 13), and the Heart and Stroke Foundation (n = 11). All but 5 articles were principal authored by someone affiliated with a Canadian university, institute or other organization. Based on first-author affiliations, affiliation from which multiple articles were published included McGill University (n = 8), Li Ka Shing Knowledge Institute, Toronto (n = 5), University of Calgary (n = 4),University of Alberta (n = 3), Child Health Evaluative Sciences, Toronto (n = 3), Institute for Clinical Evaluative Sciences, Toronto (n = 3), University of Toronto (n = 3), University of British Columbia (n = 3), Université de Montreal (n = 3), University of Ottawa (n = 2), Simon Fraser University (n = 2), and University of Western Ontario (n = 2). Studies were typically published in international and national public health or medical journals (e.g., *British Medical Journal, BMC Public Health, Health Reports, Canadian Journal of Public Health, American Journal of Preventive Medicine, American Journal of Public Health*) environment and health journals (e.g., *Health and Place, Social Science and Medicine, Journal of Environmental and Public Health, International Journal of Environmental Research and Public Health, Journal of Epidemiology and Community Health, Geospatial Health),* injury-related journals (e.g., *Injury Prevention, Accident Analysis and Prevention, Traffic Injury Prevention*), or land use or transportation journals (e.g., *Land Use Policy, Transportation Research Board*).

Study and sample design

Cross-sectional studies (individual-level and ecological) were the most common study type (n = 36) with the remainder including a mix of prospective and retrospective cohort, longitudinal, case-control, case-crossover, time series, and quasi-experimental study designs. Twenty-nine studies reported using a probability sampling strategy to recruit participants. Among studies that reported sample size, samples ranged from 160 to over 1.4 million. Further, among studies providing response rates, rates were as low as 8% and as high as 94.4%. All but one study included men and women. Most studies included samples aged 18 to 64 years, although three included samples aged 30 to 64 years, and one study included a sample aged 60 years and older.

Twenty-seven studies included self-reported health outcomes alone or in combination with a clinician-diagnosed, administrative or other objective measure of health. Twenty-eight studies reported on clinician-diagnosed or administrative database reported health outcomes only. Among those studies reporting use of existing data, nineteen studies undertook secondary analysis using the National Population Health Survey or the Canadian Community Health Survey, ten studies used ambulance dispatch or hospital data, and the remainder used other sources (e.g., traffic data, police reports, disease registries and surveillance databases, municipal, provincial and other administrative databases) (summary of findings available on request).

Study approaches for measuring the health outcomes varied for injury (n = 19; 18 with objective and 1 with self-reported injury), weight status (n = 19; all self-reported), cardiovascular disease (n = 5; 3 with objective and 2 self-reported CVD), depression/anxiety (n = 5; all self-reported), diabetes (n = 5; all objectively measured), mortality (n = 4; all objectively measured), self-rated health (n = 2; all self-reported), metabolic conditions (n = 2; 1 with objectively measured and 1 self-reported conditions), quality of life (n = 1; self-reported), cancer (n = 1, objectively measured), and aggregate chronic conditions (n = 2; all self-reported). Two studies included “aggregate chronic conditions”, one combined cancer, migraines, asthma, and arthritis[37] and another[38] combined asthma, fibromyalgia, high blood pressure, migraines, chronic bronchitis, emphysema or chronic obstructive pulmonary disease, diabetes, heart disease, angina, cancer, ulcers, bowel disorders, and Alzheimer’s disease into a single health outcome, in addition to a separate measure of self-reported general health.

Measurement of urban form

Geographical information systems (GIS) with spatial databases represented the most common approach for estimating built environment characteristics (n = 37 studies), followed by use of Walk Score® (n = 4 studies), in-person or virtual (e.g., via Google Street View®) street audits (n = 4 studies), and other approaches (i.e., police reports, street classifications, census data). Studies evaluated the built environment characteristics at or within a specific distance of an intersection or collision site (e.g., between motor vehicle and pedestrian), along transportation routes and streets, within activity spaces (e.g., geographical areas estimated based on mobility, travel patterns, and origin and destination locations), within administrative boundaries (e.g., census tracts, dissemination areas or blocks, postal code polygons, neighbourhoods), and within researcher-defined buffers of various sizes (i.e., 150m to 1600m) and types (e.g., network, line-based, or radial) typically estimated in relation to a geo-located residential postal code or household address (summary of findings available on request).

Aggregate-built environment indicators and health

There was consistent support for an association between aggregate or overall built environment indicators (e.g., walkability, Walk Scores®, centrality, and sprawl), diabetes and weight status (Table 2). One study also found an increase in walkability to be associated with a decreased risk of hypertension.[39] All significant associations were in the expected direction (summary of findings available on request). The one study estimating the relation between walkability and quality of life reported a statistically non-significant association only.[40] No studies reviewed estimated associations between aggregate built environment indicators and depression/anxiety, self-rated health, cancer, metabolic or aggregate chronic conditions, or mortality.

Connectivity and route features and health

There was consistent evidence for an association between connectivity and route features (e.g., transportation route, traffic and pedestrian signals, tracks, trails, pathways, and sidewalks, street pattern, connectivity and intersections, road and path characteristics) and injury (Table 2). Connectivity and route features both increased and decreased the risk of pedestrian and cyclist injury (summary of

TABLE 2
Associations between objectively-measured built environment variables and health outcomes reported in Canadian quantitative studies published 1998-2017

Built environment	Health outcome	Statistical associations	
		Significant	Non-significant
Multi-component measures	Cardiovascular disease	Chiu et al. (2016)[39]	–
Walkability	Diabetes	Booth et al. (2013)[62]	–
Centrality		Creatore et al. (2016)[63]	
Urban sprawl		Glazier et al. (2014)[42]	
	Injury	Strauss et al. (2015)[64]	–
	Quality of life	–	Engel et al. (2016)[40]
	Weight status	Chiu et al. (2015)[65]	Berry et al. (2010)[69]
		Creatore et al. (2016)[63]	
		Glazier et al. (2014)[42]	
		Lebel et al. (2012)[66]	
		Pouliou and Elliott (2010)[41]	
		Ross et al. (2007)[67]	
		Wasfi et al. (2016)[68]	
Route characteristics	Diabetes	Glazier et al. (2014)[42]	–
Transportation route	Injury	Aultman-Hall and Kalteckner (1999)[70]	–
Traffic/pedestrian signals		Cripton et al. (2015)[71]	
Road crossings		Forbes and Habib (2015)[72]	
Railroad/streetcar tracks		Harris et al. (2013)[73]	
Sloped road/path		Klassen et al. (2014)[74]	
Sidewalk/path length		Miranda-Moreno et al. (2011)[75]	
Transit route/stop		Morency et al. (2012)[76]	
Street pattern		Morency et al. (2015)[77]	
Street connectivity		Richmond et al. (2014)[78]	
Intersection characteristics		Rifaat and Tay (2009)[79]	
Other road/path characteristics		Rifaat et al. (2011)[80]	
		Rifaat et al. (2011)[81]	
		Romanow et al. (2012)[82]	
		Rothman et al. (2010)[83]	
		Rothman et al. (2012)[84]	
		Strauss et al. (2015)[64]	
		Teschke et al. (2012)[85]	
		Teschke et al. (2016)[86]	
		Zahabi et al. (2011)[87]	
	Weight status	Pouliou and Elliott (2010)[41]	Glazier et al. (2014)[42]
			Pouliou et al. (2014)[46]
			Prince et al. (2011)[88]
			Prince et al. (2012)[89]

Continued on the following page

TABLE 2 (continued)
Associations between objectively-measured built environment variables and health outcomes reported in Canadian quantitative studies published 1998-2017

Built environment	Health outcome	Statistical associations	
		Significant	Non-significant
Traffic Traffic/road density Proximity to traffic/roads	Cardiovascular disease	Chum and O'Campo (2013)[43] Chum and O'Campo (2015)[44]	Ngom et al. (2016)[90]
	Depression/anxiety	–	Gariepy et al. (2015)[91]
	Injury	Miranda-Morena et al. (2011)[75] Morency et al. (2012)[76] Morency et al. (2015)[77]	Romanow et al. (2012)[82]
Greenness/parks Greenness Park density Presence of park Distance to park Recreation facilities	Cancer	Demoury et al. (2017)[92]	–
	Cardiovascular disease	Ngom et al. (2016)[90]	Chum and O'Campo (2015)[44]
	Aggregate chronic conditions	Kardan et al. (2015)[37]	–
	Depression/anxiety	Gariepy et al. (2014)[47] Gariepy et al. (2015)[48] Gariepy et al. (2015)[91] Kardan et al. (2015)[37]	–
	Diabetes	Ngom et al. (2016)[90]	–
	Injury	Zahabi et al. (2011)[87]	Romanow et al. (2012)[82]
	Metabolic conditions	Kardan et al. (2015)[37]	–
	Mortality	Villeneuve et al. (2012)[93]	–
	Self-rated health	Kardan et al. (2015)[37]	–
	Weight status	Prince et al. (2011)[88] Prince et al. (2012)[89]	–
Land use/destinations Land use mix Commercial use Building area Schools Health services Cultural services Community resources Alcohol focused destinations Number of destinations Dwellings in disrepair	Cardiovascular disease	–	Chum and O'Campo (2015)[44]
	Aggregate chronic conditions	O'Campo et al. (2015)[38]	–
	Depression/anxiety	Gariepy et al. (2014)[47] Gariepy et al. (2015)[48] Gariepy et al. (2015)[91]	O'Campo et al. (2015)[38]
	Diabetes	Glazier et al. (2014)[42]	–
	Injury	Forbes and Habib (2015)[72] Miranda-Moreno et al. (2011)[75] Romanow et al. (2012)[82] Zahabi et al. (2011)[87]	–
	Mortality	Matheson et al. (2014)[45]	–
	Self-rated health	–	O'Campo et al. (2015)[38]
	Weight status	Glazier et al. (2014)[42] O'Campo et al. (2015)[38] Pouliou and Elliott (2010)[41] Pouliou et al. (2014)[46]	–

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TABLE 2 (continued)
Associations between objectively-measured built environment variables and health outcomes reported in Canadian quantitative studies published 1998-2017

Built environment	Health outcome	Statistical associations	
		Significant	Non-significant
Food environment Fast food density Proximity to fast food Fast food proportion Grocery store density Proximity to grocery store Convenience store density Proximity to convenience store Full service restaurants Specialty stores	Cardiovascular disease	Alter and Eny (2005)[94] Chum and O'Campo (2013)[43]	Chum and O'Campo (2015)[44]
	Depression/anxiety	Gariepy et al. (2014)[47] Gariepy et al. (2015)[48]	Gariepy et al. (2015)[91]
	Diabetes	Polsky et al. (2016)[95]	–
	Metabolic conditions	Paquet et al. (2010)[96]	–
	Mortality	Alter and Eny (2005)[94] Daniel et al. (2010)[97]	–
	Weight status	Hollands et al. (2013)[98] Hollands et al. (2014)[99] Kestens et al. (2012)[100] Lebel et al. (2012)[66] Minaker et al. (2013)[101] Polsky et al. (2016)[102] Prince et al. (2011)[88] Prince et al. (2012)[89] Spence et al. (2009)[103]	–
Population/dwellings Population density Dwelling density	Cardiovascular disease	Ngom et al. (2016)[90]	–
	Diabetes	Glazier et al. (2014)[42] Ngom et al. (2016)[90]	–
	Injury	Morency et al. (2012)[76] Morency et al. (2015)[77]	Zahabi et al. (2011)[87]
	Weight status	Glazier et al. (2014)[42] Polliou and Elliot (2010)[41] Pouliou et al. (2014)[46]	Ross et al. (2007)[67] Schuurman et al. (2009)[104]

Note: If a study found a statistically significant association, regardless of the number of statistically non-significant associations, it was included in the "Significant" column. If a study found only non-significant associations, then the study was included in the "Non-significant" column. Direction of significant associations are available on request.

findings available on request). One study found higher street connectivity significantly associated with lower weight status;[41] however, four other studies reported no significant association. Higher street connectivity was also significantly associated with a decrease in diabetes risk in one study.[42] Among the studies reviewed, none estimated associations between connectivity or route features and cardiovascular conditions, metabolic and aggregate chronic conditions, cancer, depression/anxiety, self-rated health, or quality of life.

Traffic features and health

Five studies found significant associations between traffic features (e.g., traffic and road density, proximity to traffic) and cardiovascular conditions and injury (Table 2). For example, Chum and colleagues[43,44] found proximity to traffic to be positively associated with self-reported cardiovascular disease. Three studies also reported only statistically non-significant associations between traffic features and objectively determined cardiovascular disease, injury, and self-reported depression. Among the reviewed studies, associations between traffic features and other health outcomes were not estimated.

Green space, parks, and recreation features and health

Greenspace, parks and recreation features (e.g., park density, park proximity) were significantly associated with a range of health outcomes including cancer, depression/anxiety, metabolic conditions, self-rated health, weight status, cardiovascular related disease outcomes, aggregate chronic conditions, diabetes, injury, and mortality (Table 2). Notably, the direction of association (protective vs. risk factor) between greenspace, parks, and recreational facilities was mixed (summary of findings available on request). Among the studies that investigated greenspace and park features, none estimated the association with quality of life.

Land use and destination features and health

Non-food related land use and destination features (e.g., mix and proximity to general and specific land uses and destinations) were significantly associated with a range of health outcomes including aggregate chronic conditions, depression/anxiety, diabetes, injury, weight status, and mortality (Table 2). For example, increased access to alcohol outlets (among men and women) and cheque cashing destinations (among men only) increased the likelihood of all-cause mortality,[45] land use mix was associated with better weight status,[41,46] and access to health and cultural services was associated with lower odds of self-reported depression.[47,48] One study reported statistically non-significant associations between community resources and depression, anxiety, and self-rated health, but found significant associations between community resources and aggregate chronic conditions and weight status[38] (summary of findings available on request).

Food environment features and health

Food environment features, such as proximity to and density of healthy and unhealthy food destinations, were significantly associated with a range of health outcomes (Table 2). Proximity and access to fast food was associated with mortality, depression, cardiovascular conditions, and weight status. Access and proximity to grocery or healthy food stores were supportive of health (e.g., depression and weight status). Two studies only found no association between the food environment and cardiovascular conditions and anxiety and depression. Among the reviewed food environment studies, none investigated cancer, self-reported health, quality of life, aggregate chronic conditions, or injury.

Population and dwelling density and health

Eight studies reported significant associations between population and dwelling density and health outcomes (i.e., cardiovascular conditions, diabetes, injury, and weight status). Despite this, statistically non-significant associations between population/dwelling density and injury and weight status were also found (Table 2). None of the included population/dwelling density studies estimated associations with cancer, depression/anxiety, self-rated health, quality of life, mortality, metabolic or aggregate chronic conditions.

Discussion

Our scoping review findings support those of previous systematic reviews that suggest urban form is associated with weight status,[14,15] blood pressure,[15] metabolic syndrome,[15] diabetes,[15,16] cardiovascular outcomes,[15] injury risk[17-19] and mental health.[11,22] Built characteristics related to land use patterns, urban design features, and transportation systems were found to be important correlates of chronic health conditions and injury in the Canadian context. Moreover, among Canadian studies on urban form and health, most have focussed on injury (primarily transport-related) and weight status outcomes. This focus may reflect the significant preventable burden both transport-related injury[49] and excess weight[50] place on the Canadian healthcare system. Despite some evidence elsewhere showing relations between the urban form or built environment and falls in the older adult population,[20,21] this evidence appears to be scant within the Canadian context. There is a recognized need for evidence in relation to the impact of urban form on the health of older Canadian adults, including the enablers and barriers to ‘aging in place’.[51,52] This context-specific understanding of the relationship between urban form and health is needed to develop and expand policy and interventions that can promote well-being and accommodate the health and social needs of adults, including infrastructure that allows adults to remain mobile and active across the life-span.[53]

Our study is novel, as previously no single source had attempted to systematically review and articulate all Canadian evidence on urban form and chronic health outcomes and injury. Thus, the findings of this review are specific and relevant to the current Canadian research and policy context. As suggested from our review findings, there are built environment features that might be important for specific health outcomes that have yet to be studied. For instance, published studies have not provided evidence about the associations between objectively-measured walkability indices and mental health and pedestrian or cyclist injury outcomes, although components of walkability have been found to be important correlates. Similarly, there is still a range of built environment features (e.g., aesthetics and appeal, personal safety and incivilities) to be examined even for the most investigated health outcomes in this literature (e.g., weight status, injury, and cardiovascular outcomes). The findings from the review suggest more research, especially longitudinal and quasi-experiment studies, is needed in relation to urban form, mental health and quality of life. Despite its subjectivity, health related quality of life (HRQOL) is strongly associated with the type, number, and pattern of physical and mental health conditions[54,55] as well as mortality risk.[56] Only two Canadian studies have examined the relationship between quality of life and urban form; however, because HRQOL summarises a wide range of health states into a comprehensive measure, future research on the built environment and its impact on HRQOL would be useful.

Based on the published scientific literature, there has been a steady increase in Canadian studies on urban form and health outcomes since 2008. Notably, not all provinces or territories were represented in the studies reviewed and those included were heterogeneous in terms of their methodology, thus making direct comparison of results impossible. While this increase in the quantity of studies is encouraging, more causal evidence is needed to better inform local policy and urban planning decisions in all Canadian provinces and territories. Within the Canadian context, associations between some built environment characteristics and health outcomes have been established; however, some of this evidence is mixed. Further, the few studies published reporting statistically non-significant associations only could suggest publication bias, thus overemphasizing the apparent impact of the built environment might have on health. Notably, statistical significance is affected by other factors (e.g., aggregation of data, delay between exposure and health outcome, reliability of measures, sample exposure and outcome variation) and may not necessarily mean no actual association exists. Future high-quality primary studies and systematic reviews investigating urban form and health should consider in more detail (beyond this scoping review) the reasons for these non-significant associations. Most of the evidence to date has been derived from observational, primarily cross-sectional, studies that allow only weak causal inferences to be drawn. Given the large amount of resources and time and the potential short- and long-term social and economic impact associated with urban planning decisions, rigorous evidence from scientifically robust study designs (e.g., longitudinal studies, natural and quasi-experiments, cluster randomized designs where feasible) is desperately needed. Increasing the use of existing Canadian longitudinal data sources, such as the National Population Health Survey (1994 to 2010)[57] and the Canadian Longitudinal Study on Aging,[58] and longitudinal linked health administrative data,[59] can contribute to enhancing the evidence base in a timely manner. In addition to the mostly cross-sectional nature of the current Canadian evidence, studies in our review typically did not take into consideration the intensity and duration of built environment exposure needed to result in a clinically relevant influence on health.

We acknowledge several limitations with our review that impact the findings. Our scoping review allowed for a large body of evidence to be synthesized; however, given the breadth of urban form and health outcomes, we did not formally critique the scientific quality, and internal and external validity of individual studies—a strategy typically used in systematic reviews. The implicit aim of our scoping review was to identify knowledge trends and gaps that could inform future primary studies and systemic reviews and to provide an overview of the research on this topic. Our inclusion of published peer-review evidence only could mean that relevant, yet unpublished findings are missing from our review. Despite scanning the reference lists of the included studies to identify other additional sources, it is possible that peer-reviewed studies not indexed in our search databases may have been omitted. Several health studies were excluded as they did not include health outcomes in alignment with the CDIF.[60] For example, one excluded study found associations between satellite-determined greenery (i.e., Normalized Difference Vegetation Index) and indicators of perinatal health (such as birth weight, likelihood of preterm birth).[60] Hence, we acknowledge that the effect of the built environment on health likely goes beyond the specific health outcomes presented in this scoping review. Furthermore, our inclusion of studies that undertook steps to control for confounding could have resulted in the exclusion of relevant descriptive studies, including those exploring relations between spatial variation in urban form and health.

Conclusion

It is important for practitioners and policymakers to use the best available evidence. Evidence elsewhere demonstrating plausible pathways linking urban form with health (e.g., via physical activity, sedentary behaviour, diet, the stress process[61] and social interactions)[5-11] support our findings. Notably, not all statistically significant associations between the built environment and health outcomes were in an expected harm-reducing or health-promoting direction. Health promotion strategies might be required where urban form has some unavoidable negative impact on a health outcome. Our review findings show that in Canada, associations exist between urban form and health outcomes, but causal evidence is lacking.

Acknowledgements

Funding supporting this study was obtained from a makeCalgary Network pilot grant (University of Calgary), the Public Health Agency of Canada, and a Canadian Institutes for Health Research (CIHR) Foundations Scheme Grant. Gavin McCormack was supported by a CIHR New Investigator Award (MSH-130162). We appreciate the guidance provided by Lorraine Toews (Health Sciences Librarian, University of Calgary).

Conflicts of interest

Heather Orpana is affiliated with the Public Health Agency of Canada, which oversees the production and publication of the Health Promotion and Chronic Disease Prevention in Canada (HPCDPIC). Gavin McCormack and Heather Orpana are Associate Scientific Editors for HPCDPIC. Orpana and McCormack were blinded from the peer review process and editorial decision-making associated with the publication of this manuscript. The Public Health Agency of Canada provided funding support to undertake the scoping review. The authors declare there are no other conflicts of interest regarding the publication of this article.

Authors' contributions and statement

GRM, NK, and JC conceived the study aim and overall design. All authors contributed to the method design and the review and interpretation of results. GRM, RL, and AB conducted the scoping review with input from NK, JC, HO, and SG. All authors contributed to the manuscript drafting and approved the final manuscript.

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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https://doi.org/10.24095/hpcdp.39.5.04

At-a-glance

Conceptualizing a framework for the surveillance of physical activity, sedentary behaviour and sleep in Canada

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Abstract

The Public Health Agency of Canada (PHAC) has modernized its approach to physical activity surveillance by broadening its scope to include sedentary behaviour and sleep. The first step was to develop a conceptual framework which covers the full spectrum of physical movement from moderate-to-vigorous intensity physical activity (MVPA) and light intensity physical activity (LPA) to sedentary behaviour and sleep. The framework accounts for the environments in which these behaviours take place (home, work/school, transportation, and community), and applies a socioecological approach to incorporate individual factors and broader built, social, and societal environmental indicators. A visual model of the conceptual framework was created to aid dissemination.

Keywords: *motor activity, sedentary behaviour, sleep, framework*

Highlights

- The Public Health Agency of Canada (PHAC) has modernized its approach to physical activity surveillance to include all aspects of daily movement from moderate-to-vigorous intensity physical activity (MVPA) and light intensity physical activity (LPA) to sedentary behaviour and sleep.
- The new approach accounts for the environments where these behaviours take place (home, work/school, transportation, and community) and the socioecological model.
- To guide this process, the PHAC has developed a conceptual framework and visual model.

Canada has a long series of physical activity surveillance data[1] which have received international recognition.[2] Canada's physical activity surveillance system has traditionally focused on measures of leisure-time physical activity. In recent years, there has been a growth in research identifying the independent effects of prolonged sedentary behaviour (e.g., time spent sitting, lying or reclining while awake at a low energy expenditure)[3] and inadequate sleep[4,5] on chronic disease.[6,7] Further, at the international level, there has been a move away from measuring physical activity through the single lens of leisure-time physical activity and instead examining physical activity behaviours/indicators from across domains of physical activity, such as home, work/school, transportation, and community.[8] Finally, a number of scientific systematic reviews and key research papers have been published outlining a broad range of individual, social and environmental correlates or dimensions for physical activity, sedentary behaviour and sleep that were important for consideration with an evidence based surveillance system.[9-17] Drawing on these developments, the Public Health Agency of Canada (PHAC) modernized its physical activity surveillance system.

To support the identification and selection of a set of surveillance indicators that would form the foundation of the PHAC's Physical Activity, Sedentary behaviour and Sleep (PASS) surveillance system, a conceptual framework was developed.[18] The conceptual framework included three core components (i.e., behaviours, settings, socioecological approach) and the 24-hour movement spectrum (i.e., physical activity [light, moderate and vigorous], sedentary behaviour and sleep). The first component identified the behaviours of interest: moderate-to-vigorous intensity physical activity (MVPA), light intensity physical activity (LPA), sedentary behaviour, and sleep. The second component looked to incorporate a domain approach to the conceptual framework[8] by recognizing the settings in which these behaviours take place including: home; work/school; transportation; and, community. The final component is the use of a socioecological approach recognizing the importance of indicators across multiple levels of influence including: the individual (e.g., age,

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sex, ethnicity, socioeconomic status); the family/social environment (e.g., intrapersonal relationships, social norms, crime, neighbourhood demographics); and, the built environment (e.g., roadways, buildings, parks, playgrounds, public transit).

To quickly and easily describe the components of the conceptual framework, a visual model was created (Figure 1). This initial visual model, which displayed the components of the conceptual framework using a pyramid format, was presented to experts in the fields of physical activity, sedentary behaviour and sleep, who broadly agreed that it was consistent with current knowledge, and it was used during the selection of the PASS surveillance indicators at a meeting in Ottawa on June 24, 2014.[18] This initial framework lacked descriptions of the types of activities which the indicators were intended to illustrate. Further, the sense of hierarchy in the outcomes implied by the use of a pyramid was not its intended purpose. As a result, a second, visual model (Figure 2) was developed and has been adopted for use alongside the PASS Indicators.[18] The revised visual model includes illustrative examples of the components of the PASS Indicators.

The visual model illustrates the proposed depth and breadth of the PHAC's modernized PASS surveillance system. Work to ensure data development and reporting are undertaken in such a way that all areas of the conceptual framework are meaningfully represented is part of the PHAC's ongoing surveillance activities. In addition, both the visual model and the conceptual framework communicate the PHAC's approach to PASS surveillance to other international and domestic governmental partners working in surveillance and policy, and to researchers for their contribution and critical appraisal.

Conflicts of interest

The authors declare no conflicts of interest.

Authors' contributions and statement

GB, KR, EK, DR and GJ developed the concepts in the paper and GB and KR wrote the paper. BB, SP and WT reviewed the paper and offered advice, comments or refinements. The study was carried out under the management of WT and GJ.

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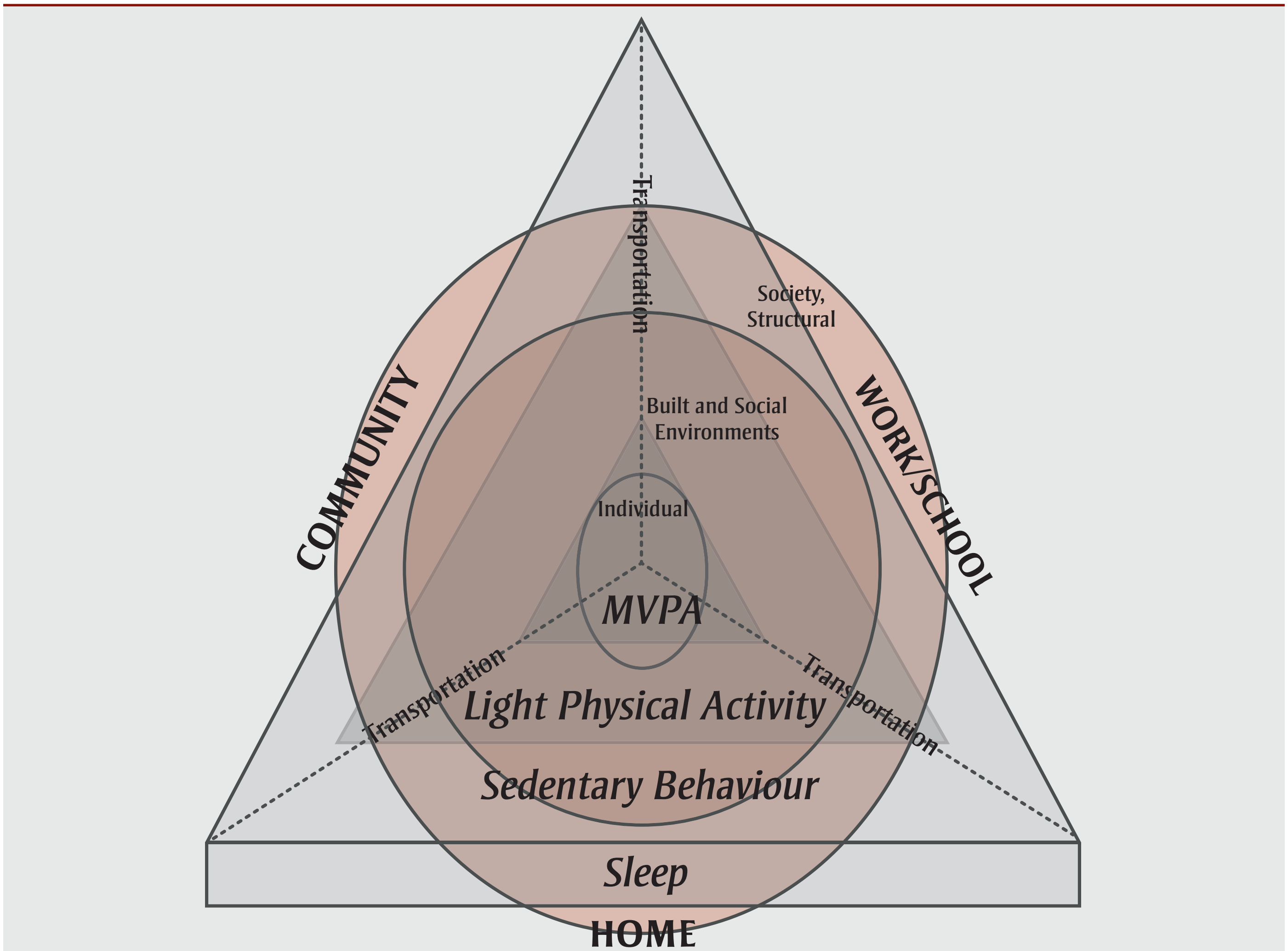
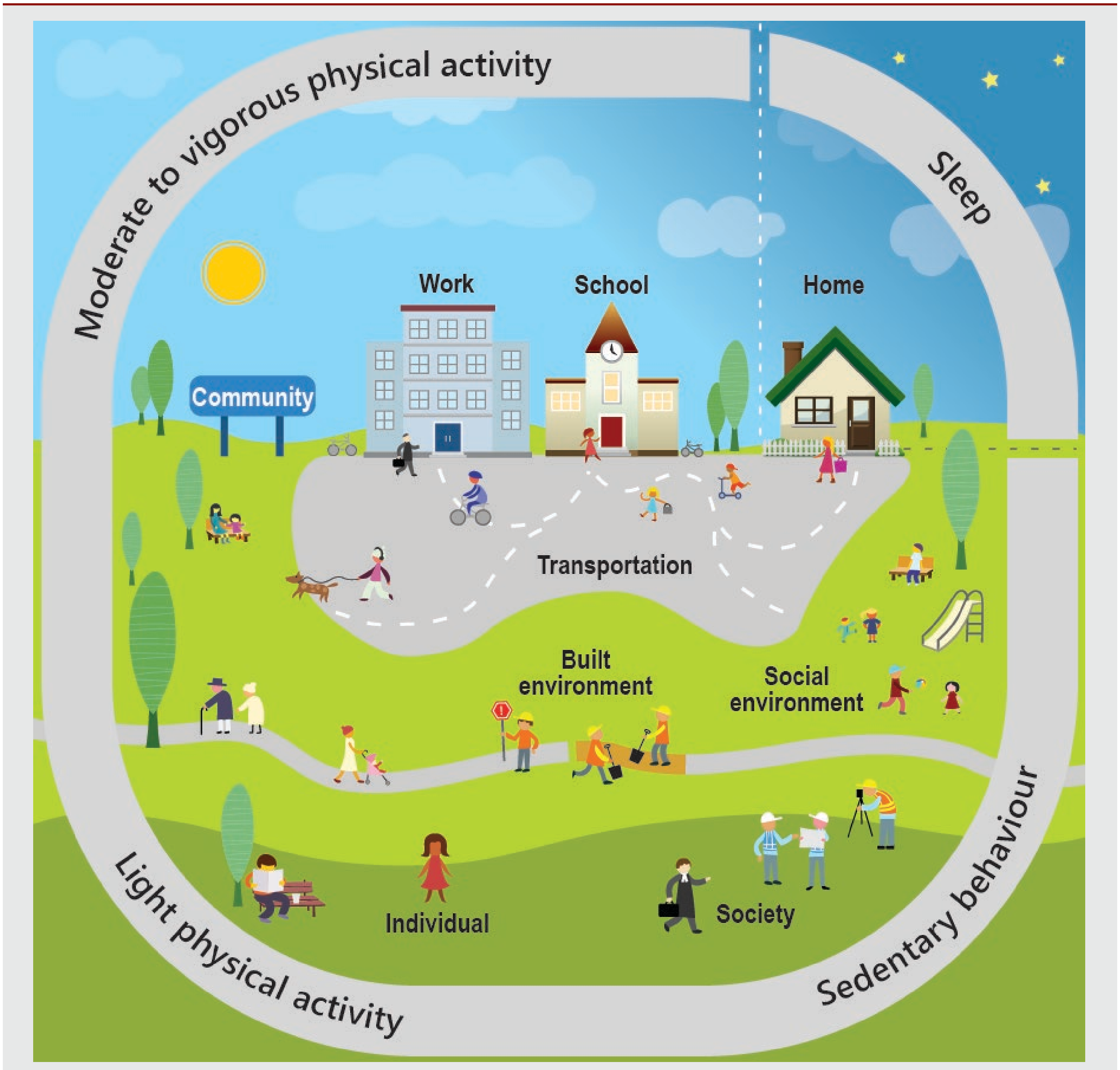
FIGURE 1
Initial visual model of the conceptual framework



Abbreviation: MVPA, moderate-to-vigorous intensity physical activity.

FIGURE 2
Current physical activity, sedentary behaviour and sleep (PASS) visual model of the conceptual framework for surveillance in Canada



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