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Risk Factors and Inequities in Transportation Injury and Mortality in the Canadian Census Health and Environment Cohorts (CanCHECs)

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Background: Road traffic injury contributes substantially to morbidity and mortality. Canada stands out among developed countries in not conducting a national household travel survey, leading to a dearth of national transportation mode data and risk calculations that have appropriate denominators. Since traffic injuries are specific to the mode of travel used, these risk calculations should consider travel mode.

Methods: Census data on mode of commute is one of the few sources of these data for persons aged 15 and over. This study leveraged a national data linkage cohort, the Canadian Census Health and Environment Cohorts, that connects census sociodemographic and commute mode data with records of deaths and hospitalizations, enabling assessment of road traffic injury associations by indicators of mode of travel (commuter mode). We examined longitudinal (1996–2019) bicyclist, pedestrian, and motor vehicle occupant injury and fatality risk in the Canadian Census Health and Environment Cohorts by commuter mode and sociodemographic characteristics using Cox proportional hazards models within the working adult population.

Results: We estimated positive associations between commute mode and same mode injury and fatality, particularly for bicycle commuters (hazard ratios for bicycling injury was 9.1 and for bicycling fatality was 11). Low-income populations and Indigenous people had increased injury risk across all modes.

Conclusions: This study shows inequities in transportation injury risk in Canada and underscores the importance of adjusting for mode of travel when examining differences between population groups.

Keywords: Active transport, CanCHEC, Cyclists, Inequity, Motor vehicle collisions, Pedestrians, Road safety

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Road traffic injury imposes a yearly global burden of morbidity and mortality of approximately 1.35 million fatalities and 50 million injuries.[1] In Canada, road traffic injury caused over 1800 fatalities and 10,000 serious injuries annually over the last decade,[2] each of which incurs health and economic costs.[3] As with many health outcomes in Canada, there is evidence indicating that marginalized populations bear a disproportionate burden of these injuries and fatalities.[4–8] Data limitations impede risk disparity measurement. These limitations include the systemic underreporting of injuries involving active transportation modes, the limited collection of sociodemographic variables, and an absence of travel data to account for exposure to risk (e.g., time or distance traveled by a specific transport mode).

In Canada, as in much of the industrialized world, the data that are typically used to estimate population-level traffic injury are derived from police-reported collision data.[2,9] Police data underreport bicycling and pedestrian injury, disproportionately comprise incidents involving motor vehicles, report mostly on those collisions of greatest severity due to policies related to when they attend a collision, and tend to contain only a few basic sociodemographic variables that limit comparisons of injuries between population groups.[10–12] Hospital records of treated injuries present an alternative, but these also have limited sociodemographic data and, historically, are difficult to access at a national level.[13] Previous research into differences in transportation injury risk between sociodemographic groups in Canada has generally been characterized by use of area-level indicators,[5] which has been shown to have

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The Statistics Canada microdata files used in this study contain sensitive information that cannot be shared publicly or outside of the secure physical location provided by the Research Data Centre (RDC) program. Approved researchers who need to access the data must comply with strict confidentiality guidelines and carry out their research within the secure physical location of the RDC. These measures ensure that the privacy of individuals and organizations included in the data is protected while allowing researchers to analyze it securely.

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low agreement with individual-level indicators.[14] Moreover, these sources only count the number of traffic injuries and therefore do not measure risk of injury.

To compare risk of injury between different travel modes and population groups, counts of injury must be adjusted by measurements of exposure to risk within these populations (e.g., time, distance, or number of trips by mode). However, Canada lacks a national household travel survey, such as those conducted in the US, UK, and other developed countries.[15] As a result, Canadian research is limited in comparing transportation injury risks across sociodemographic groups and travel modes and understanding risk inequities.[15]

The Canadian Census Health and Environment Cohorts (CanCHECs) are a series of population-based cohorts that probabilistically link detailed sociodemographic and commute mode data from the Canadian Census to health administrative databases, including hospitalization records and mortality data. Previously, these linked data have been used to examine the relationship between sociodemographic groups[16,17] and environmental factors[18,19] with health outcomes such as mortality and cancer diagnoses. The CanCHECs provide a unique opportunity to enable investigation into differences between sociodemographic groups using individual-level census data. Nationally, census data on the journey to work is one of few population-based data sources on use of active transportation among Canadians. The journey to work census module captures the main mode of commute for Canadians during the week of the census for the working adult population.[20,21] The CanCHECs, by linking census data to hospitalization and mortality data, address traditional data limitations associated with the use of police reports, hospital, and mortality records.

Our goal is to quantify differences in risk of injury resulting in hospitalization or death for adult bicyclists, pedestrians, and motor vehicle occupants who commute to work in Canada, across sociodemographic groups and accounting for an indicator of use of different modes of transportation, represented by the participants' primary mode of commute. We pool multiple waves of the CanCHECs linked to hospitalizations and deaths and construct cohorts to examine these separately. We use survival analysis to compare injury risks and identify sociodemographic groups at higher risk of hospitalization and death as a bicyclist, pedestrian, or motor vehicle occupant.

METHODS

Data and Cohort Construction

The CanCHECs are probabilistically linked individual-level long-form census data (and the 2011 equivalent National Household Survey) to nationally compiled hospitalization and mortality databases. The CanCHECs are accessed in Canada via the Canadian Research Data Centre Network. The analyses presented here were conducted at the Vancouver Research Data Centre. All research results from Canadian Research Data Centre Network projects are subject to disclosure guidelines including random rounding of hospitalization and fatality counts. This project received approval by the Toronto Metropolitan University Research Ethics Board (TMU REB # 2020-136).

The Canadian census is conducted every 5 years in early May. The long-form component of the census corresponds to a 20% sample of the population in the 1996, 2001, and 2006 cycles with a nearly complete response rate (93.8% in 2006). In 2011, the long-form census was replaced with a voluntary National Household Survey, which sampled 30% of the population but had a response rate of 68.6%.[22] Hospitalization data is from the Discharge Abstract Database (DAD, compiled by the Canadian Institute for Health Information). The DAD captures all hospitalizations from acute care facilities in all provinces and territories, with the exception of Quebec.[23] Mortality data is from the Canadian Vital Statistics Death Database (CVSD). The CVSD collects mortality data from each province and territory's vital statistics agencies and captures all deaths that occur in Canada.[24] The CanCHECs are only linked to CVSD for the population aged 19+, while the linkage to DAD data spans all ages.

Census long-form data linked to DAD and CVSD enable stratification of transportation injuries by work commute mode data and sociodemographic information captured in the census.[25] We conducted analysis of hospitalizations and fatalities separately and create two analytic samples of commuting adults that we will refer to as the hospitalization cohort and the fatality cohort. The construction of each cohort was predicated on the criteria for being included in the linkage to either DAD or CVSD as well as the criteria for inclusion in the census data we examined including commute modes and basic sociodemographic indicators. Only respondents that had employment between 1 January and the week of the census were asked questions regarding commute modes and are included in our analysis. The fatality cohort consisted of persons aged 19 and over who completed the long-form census in 1996, 2001, 2006, or 2011, resided in a Canadian province, and had a regular place of employment at some point since 1 January of that year they completed the census (Figure 1). The hospitalization cohort consisted of persons aged 15 and over who completed the long-form census in either 2006 or 2011, resided in a Canadian province other than Quebec, and had a regular place of employment at some point since 1 January of that year they completed the census (Figure 2). Participants in both cohorts enter on the census day corresponding to their completed census cycle: 14 May (1996), 15 May (2001), 16 May (2006), and 10 May (2011).

Outcome Ascertainment

For both cohorts, we identified three types of injury outcomes within the DAD and CVSD respectively, including hospitalizations and/or deaths as a (1) bicyclist; (2) pedestrian; or (3) motor vehicle occupant. In the fatality cohort, bicyclist deaths were identified using International Classification

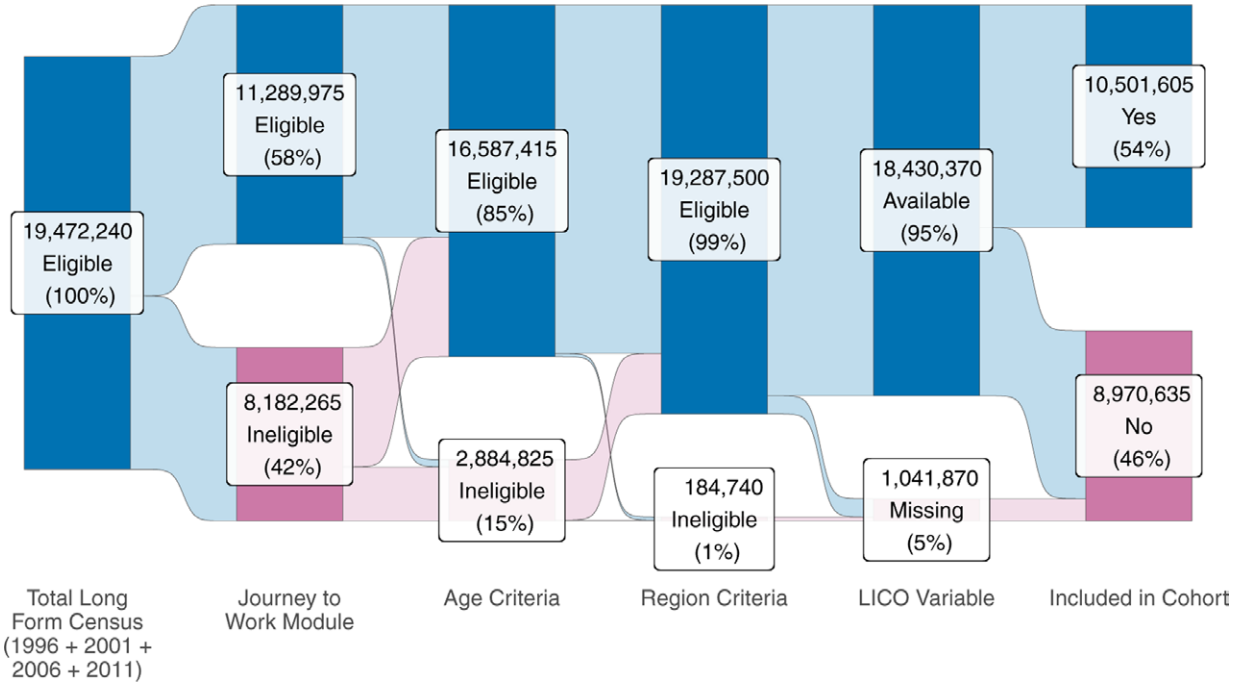

Figure 1. Fatality cohort construction.

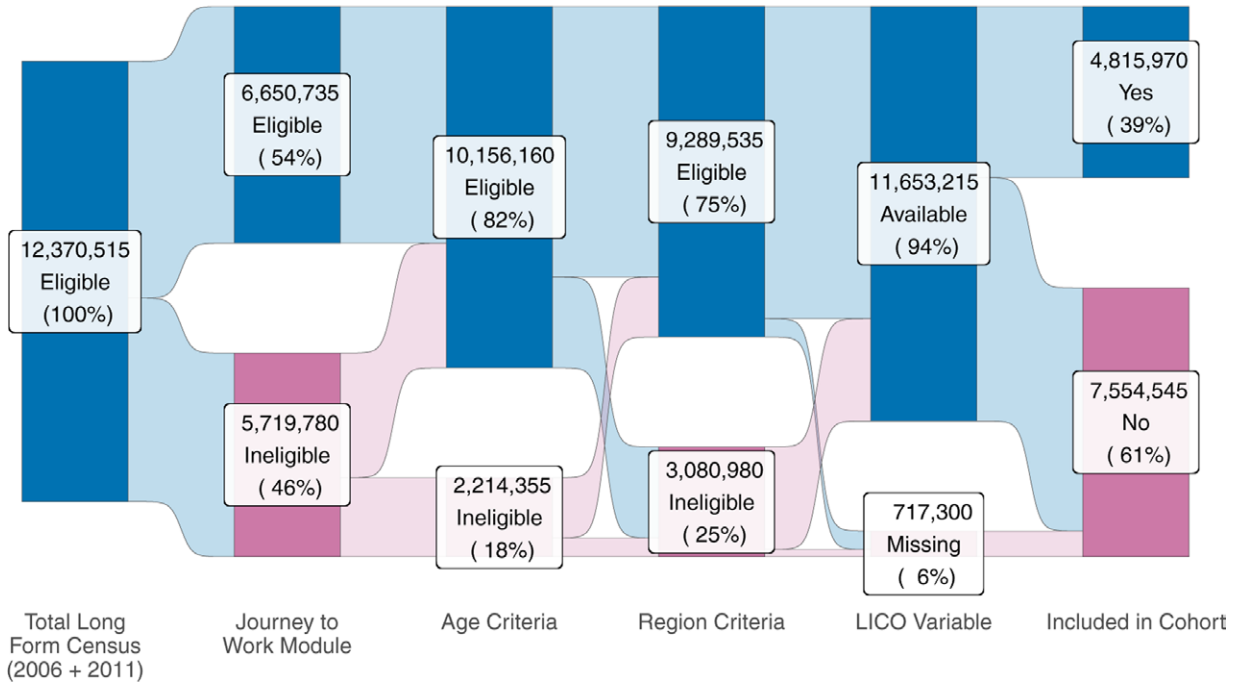

Figure 2. Hospitalization cohort construction.

of Diseases 10th revision external cause codes V100–V199, pedestrian deaths using V010–V099, and motor vehicle occupant deaths using V400–V699 (but only including codes that specified the victim as a driver, passenger, or unspecified). Deaths that occurred between 1996 and 2000 were identified using International Classification of Diseases 9th revision external cause codes (eTable 1, http://links.lww.com/EDE/C96).

We identified bicyclist, pedestrian, and motor vehicle occupant hospitalizations using the same International Classification of Diseases 10th revision external cause codes as in the fatality cohort. Deaths as a bicyclist, pedestrian, or

motor vehicle occupant not associated with a hospitalization were also identified using these International Classification of Diseases 10th revision codes. We included repeat hospitalizations if the subsequent injury occurred after a period of 30 days.

Travel Mode

We measured a participant's use of different modes of travel using a categorical variable that describes the participant's main mode of transport they used for commuting to work. This variable is derived from the journey to work module in the long-form census.[15] Since 1996, the long-form census queries respondents on the "main mode of commuting," which refers to the main mode of transportation used to travel to and from their home and workplace.[15] This question is restricted to the population in private households with employment and applies to the job held the week of the census (early May) or – if not working at the time of the census – the job held for the longest period since 1 January of that year. If a person used more than one mode, they were asked to choose the mode they used for the greatest distance. Respondents could select from several options, some of which have changed from 1996 to 2011 (Table 1). We simplified the census variable to categories of commuting modes as (1) car, truck, or van; (2) bicycle; (3) walking; or (4) other (Table 1). We use "motorized vehicle" to refer to car, truck, or van modes.

Covariates

To examine injury risk across basic sociodemographic characteristics, we included the following covariates: (1) age at baseline; (2) gender; (3) low-income cutoff (LICO) (after tax); (4) self-identified racialization; and (5) recent immigration status. LICOs are based on a threshold set by Statistics Canada where an individual spends 20% points more than average of their after-tax income on necessities of life (food, shelter clothing).[26] This threshold varies for an individual based on their family size and the population characteristics of the area they live in.[26] Since 1996, Statistics Canada has collected information on racialized population groups based on the framework of belonging to a visible minority, Indigenous, or White population group. Visible minorities are defined by Statistics Canada as a person identifying as non-Caucasian in race or nonwhite in color.[27] Between 1996 and 2011, Statistics Canada used the term *Aboriginal* but has since been replaced and we will use Indigenous as the current terminology. Indigeneity is self-identified as belonging to at least one Indigenous group including First Nations (North American Indian), Métis, or Inuk (Inuit). The census also collects information on the year a person immigrated to Canada. Recent immigration was originally defined as settlement in Canada less than 5 years before census date, but due to small cell sizes, we expanded this definition to include settlement less than 10 years before census date.

Table 1. Main Mode of Commute Variable and Its Corresponding Categories From the Census

Main Mode of Commute	Census Main Mode of Commute	Years Applicable
Car, truck, or van	Car, truck, or van – as a driver	1996, 2001, 2006, 2011
	Car, truck, or van – as a passenger	1996, 2001, 2006, 2011
Bicycle	Bicycle	1996, 2001, 2006, 2011
Walking	Walked to work	1996, 2001, 2006, 2011
Other	Public transit	1996, 2001, 2006
	Motorcycle	1996, 2001, 2006
	Taxicab	1996, 2001, 2006
	Subway or elevated rail	2011
	Passenger ferry	2011
	Light rail, streetcar, or commuter train	2011
	Motorcycle, scooter or moped	2011
	Other	1996, 2001, 2006, 2011

Statistical Analysis

To examine associations among exposure, covariates, and hospitalizations or fatal injuries, we fit a series of Cox proportional hazards models that estimated risk for bicycling, pedestrian, and motor vehicle occupant injury separately. For each covariate we estimated hazard ratios (HR) and 95% confidence intervals (CIs) for time to: (1) bicycling hospitalization; (2) bicycling fatality; (3) pedestrian hospitalization; (4) pedestrian fatality; (5) motor vehicle occupant hospitalization; and (6) motor vehicle occupant fatality. For each outcome, participants were censored at the end of the follow-up period (Table 2) or upon the date of death from any cause. In the hospitalization analysis, we modeled repeated events using a counting process marginal rates approach.[28] Analyses are unweighted. Given the complex interplay among sociodemographic indicators and transportation injury in the prior literature, we modeled injury against mode of travel mutually adjusted for all sociodemographic indicators. Because age and sex have particular bearing on mode of travel related injuries, we also included a minimally adjusted model with only age and sex as covariates. Finally, we include unadjusted results in eTables 2–4, http://links.lww.com/EDE/C96. Analyses were conducted in R version 3.5.3 http://links.lww.com/EDE/C97; http://links.lww.com/EDE/C98.

RESULTS

The hospitalization cohort included 4,815,970 persons who contributed 39.3 million person years between 2006 and 2018 follow-up period (Table 3). The fatality cohort included 10,501,605 persons and 129.4 million person years between

Table 2. Follow-up Periods for Health Outcome Data by Canadian Census Health and Environment Cohort

CanCHEC	Ages Included	CVSD	DAD
1996 (version 3)	19+	14 May 1996–31 December 2016	n/a
2001 (version 3)	19+	15 May 2001–31 December 2016	n/a
2006 (version 1.1)	0+	16 May 2006–31 December 2019	16 May 2006–31 March 2017
2011 (version 2)	0+	10 May 2011–31 December 2018	10 May 2011–31 March 2017

CanCHEC indicates Canadian Census Health and Environment Cohort; CVSD, Canadian Vital Statistics Death Database; DAD, Discharge Abstract Database; n/a, not available.

the 1996 and 2018 follow-up period (Table 4). Most members of both cohorts reported using a car, truck, or van (as driver or passenger) as their main mode of commute were White, were long-term residents or Canadian born, and were not low income (Tables 3 and 4). Most members of both cohorts were under the age of 65, reflecting our inclusion of only participants who were working outside the home at baseline (Tables 3 and 4).

During the follow-up period, there were 4560 hospitalizations (Table 3) and 239 deaths due to bicyclist-related injuries (Table 4) and 2270 hospitalizations (Table 3) and 960 deaths for pedestrian-related injuries (Table 4). For motor vehicle occupant injuries, there were 10,325 hospitalizations (Table 3) and 3170 deaths (Table 4).

In our mutually adjusted models, primary mode of commute was strongly related to injury risk occurring in corresponding modes (Tables 5–7). This was most strongly observed for people whose primary mode of transportation to work was bicycle and who had increased risk for bicycle hospitalization (HR = 9.1; 95% CI = 8.3, 10) and fatality (HR = 11; 95% CI = 7.5, 17), compared with people whose primary mode of transportation to work was motor vehicle (Table 5). Those who walked to work experienced higher risk of pedestrian injury hospitalization (HR = 2.1; 95% CI = 1.8, 2.4) and fatality (HR = 1.5; 95% CI = 1.2, 1.9) (Table 6). By contrast, people who bicycled or walked, along with people who used "other" transportation modes (which includes public transport) had lower risk of motor vehicle-based hospitalization and fatality, as compared with people who mainly commuted by motor vehicle (Table 7). Collectively, these patterns suggest that mode of commute is a relevant indicator of exposure to risk. This finding is nuanced because bicyclists and users of "other" modes, including public

Table 3. Sociodemographic and Injury Characteristics of the CanCHEC Hospitalization Cohort

				Hospitalization			Incidence Rate Per Million Person Years		
Variable	Level	Participants (%)	Million Person Years (%)	Bicyclist; N (%)	Pedestrian; N (%)	Motor Vehicle; N (%)	Bicyclist	Pedestrian	Motor Vehicle
Total		4,815,970 (100.0)	39.3 (100.0)	4,560 (100)	2,270 (100)	10,325 (100)	116.0	57.7	262.6
Main commute mode	Car, truck, van	3,852,730 (80.0)	31.5 (80.1)	3,085 (68)	1,430 (63)	8,815 (85)	97.9	45.4	279.8
	Bicycle	62,990 (1.3)	0.5 (1.3)	535 (12)	35 (2)	110 (1)	1,028.8	67.3	211.5
	Walking	288,055 (6.0)	2.4 (6.1)	345 (8)	245 (11)	555 (5)	143.8	102.1	231.2
	Other mode	612,195 (12.7)	4.9 (12.5)	595 (13)	565 (25)	845 (8)	121.4	115.3	172.4
Age at baseline	15–24	813,505 (16.9)	6.8 (17.3)	850 (19)	495 (22)	2,605 (25)	124.6	72.6	382.0
	25–34	937,810 (19.5)	7.7 (19.6)	810 (18)	280 (12)	1,710 (17)	105.1	36.3	221.8
	35–44	1,066,740 (22.2)	8.9 (22.7)	1,000 (22)	360 (16)	1,860 (18)	112.1	40.4	208.5
	45–54	1,150,535 (23.9)	9.3 (23.8)	1,170 (26)	540 (24)	2,075 (20)	125.1	57.8	221.9
	55–64	690,635 (14.3)	5.4 (13.7)	595 (13)	435 (19)	1,530 (15)	110.4	80.7	283.9
	65+	156,745 (3.3)	1.1 (2.9)	130 (3)	155 (7)	545 (5)	114.0	136.0	478.1
Gender[a]	Women	2,329,990 (48.4)	19.0 (48.4)	1,270 (28)	1,035 (46)	4,080 (40)	66.7	54.4	214.3
	Men	2,485,980 (51.6)	20.3 (51.6)	3,290 (72)	1,235 (54)	6,245 (60)	162.2	60.9	307.9
LICO	Non-low income	4,474,220 (92.9)	36.5 (92.9)	4,210 (92)	1,955 (86)	9,495 (92)	115.3	53.5	260.1
	Low income	341,750 (7.1)	2.8 (7.1)	350 (8)	315 (14)	830 (8)	124.6	112.1	295.4
Racialization	Not visible minority	3,755,900 (78.0)	30.8 (78.4)	4,035 (88)	1,665 (73)	8,340 (81)	130.8	54.0	270.4
	Visible minority	909,820 (18.9)	7.3 (18.5)	370 (8)	465 (20)	1,365 (13)	51.0	64.0	188.0
	Indigenous[b]	150,250 (3.1)	1.2 (3.1)	155 (3)	140 (6)	620 (6)	127.0	114.8	508.2
Recent immigrant at baseline	No	4,472,620 (92.9)	36.5 (92.9)	4,380 (96)	2,090 (92)	9,850 (95)	119.9	57.2	269.6
	Yes	343,350 (7.1)	2.8 (7.1)	180 (4)	180 (8)	475 (5)	64.5	64.5	170.3

[a]Statistics Canada collects "sex" without information on nonbinary gender in these census years.
[b]Statistics Canada uses the term "Aboriginal" in these census years.
LICO indicates low-income cut-off.

Table 4. Sociodemographic and Injury Characteristics of the CanCHEC Fatality Cohort

				Deaths			Incidence Rate Per Million Person Years		
Variable	**Level**	**Participants (%)**	**Million Person Years (%)**	**Bicyclist; N (%)**	**Pedestrian; N (%)**	**Motor Vehicle; N (%)**	**Bicyclist**	**Pedestrian**	**Motor Vehicle**
Total		10,501,605 (100)	129.4 (100)	240 (100)	960 (100)	3,170 (100)	1.9	7.4	24.5
Main commute mode	Car, truck, van	8,500,560 (80.9)	105.2 (81.3)	155 (65)	700 (73)	2,770 (87)	1.5	6.7	26.3
	Bicycle	119,135 (1.1)	1.4 (1.1)	25 (10)	15 (2)	35 (1)	17.6	10.6	24.6
	Walking	617,255 (5.9)	7.8 (6.0)	20 (8)	80 (8)	155 (5)	2.6	10.3	19.9
	Other mode	1,264,655 (12.0)	15.0 (11.6)	35 (15)	165 (17)	210 (7)	2.3	11.0	14.0
Age at baseline	15–24	1,256,860 (12.0)	15.6 (12.0)	25 (10)	100 (10)	550 (17)	1.6	6.4	35.3
	25–34	2,291,655 (21.8)	29.5 (22.8)	35 (15)	135 (14)	610 (19)	1.2	4.6	20.7
	35–44	2,719,145 (25.9)	35.6 (27.5)	60 (25)	230 (24)	790 (25)	1.7	6.5	22.2
	45–54	2,590,830 (24.7)	31.2 (24.1)	75 (31)	225 (23)	730 (23)	2.4	7.2	23.4
	55–64	1,362,570 (13.0)	14.8 (11.5)	35 (15)	185 (19)	380 (12)	2.4	12.5	25.6
	65+	280,545 (2.7)	2.7 (2.1)	10 (4)	80 (8)	115 (4)	3.7	29.7	42.8
Gender[a]	Women	5,008,325 (47.7)	61.7 (47.7)	45 (19)	340 (35)	950 (30)	0.7	5.5	15.4
	Men	5,493,285 (52.3)	67.7 (52.3)	195 (81)	620 (65)	2,220 (70)	2.9	9.2	32.8
LICO	Non-low income	9,641,015 (91.8)	118.1 (91.3)	210 (88)	820 (85)	2,825 (89)	1.8	6.9	23.9
	Low income	860,590 (8.2)	11.3 (8.7)	30 (12)	140 (15)	345 (11)	2.7	12.4	30.6
Racialization	Not visible minority	8,769,890 (83.5)	109.7 (84.8)	225 (94)	770 (80)	2,840 (90)	2.1	7.0	25.9
	Visible minority	1,493,360 (14.2)	17.0 (13.1)	5 (2)	120 (12)	220 (7)	0.3	7.1	13.0
	Indigenous[b]	238,350 (2.3)	2.7 (2.1)	10 (4)	70 (7)	110 (3)	3.7	25.7	40.4
Recent immigrant at baseline	No	9,845,210 (93.7)	121.4 (93.8)	235 (98)	895 (93)	3,075 (97)	1.9	7.4	25.3
	Yes	656,395 (6.3)	8.0 (6.2)	5 (2)	65 (7)	100 (3)	0.6	8.2	12.5

[a]Statistics Canada collects "sex" without information on nonbinary gender in these census years.
[b]Statistics Canada uses the term "Aboriginal" in these census years.
LICO indicates low-income cut-off.

Table 5. Hazard Ratio for Hospitalization and Death as a Bicyclist Within the Hospitalization and Fatality Cohorts

		Hospitalization (CanCHEC 2006, 2011)		Fatality (CanCHEC 1996, 2001, 2006, 2011)	
Variable	**Level**	**Minimally Adjusted (95% CI)[a]**	**Mutually Adjusted (95% CI)[b]**	**Minimally Adjusted (95% CI)**	**Mutually Adjusted (95% CI)**
Main commute mode	Car, truck, or van	Reference			
	Bicycle	9.5 (8.6, 11)	9.1 (8.3, 10)	12 (8.1, 19)	11 (7.5, 17)
	Walking	1.6 (1.5, 1.8)	1.6 (1.4, 1.8)	2.3 (1.5, 3.6)	2.2 (1.4, 3.4)
	Other mode	1.4 (1.3, 1.5)	1.6 (1.4, 1.7)	2.0 (1.4, 2.9)	2.2 (1.5, 3.3)
Age at baseline	15/19–24[c]	Reference			
	25–34	0.84 (0.76, 0.93)	0.95 (0.86, 1.1)	0.69 (0.42, 1.1)	0.81 (0.49, 1.3)
	35–44	0.90 (0.82, 0.99)	1.1 (0.96, 1.2)	0.92 (0.58, 1.4)	1.1 (0.72, 1.8)
	45–54	1.0 (0.92, 1.1)	1.2 (1.1, 1.3)	1.3 (0.86, 2.1)	1.7 (1.1, 2.7)
	55–64	0.87 (0.78, 0.97)	1.0 (0.91, 1.1)	1.3 (0.82, 2.2)	1.7 (1, 2.9)
	65+	0.84 (0.7, 1.0)	0.99 (0.82, 1.2)	1.9 (0.93, 4.0)	2.5 (1.2, 5.2)
Gender[d]	Women	Reference			
	Men	2.4 (2.3, 2.6)	2.3 (2.2, 2.5)	4.0 (2.9, 5.5)	4.0 (2.9, 5.6)
LICO	Non-low income	Reference			
	Low income	1.1 (0.97, 1.2)	1.1 (0.96, 1.2)	1.6 (1.1, 2.4)	1.6 (1.1, 2.3)
Racialization	Nonvisible minority	Reference			
	Visible minority	0.39 (0.35, 0.44)	0.41 (0.36, 0.46)	0.21 (0.10, 0.45)	0.21 (0.093, 0.46)
	Indigenous[e]	0.98 (0.83, 1.2)	0.95 (0.8, 1.1)	1.6 (0.78, 3.2)	1.4 (0.68, 2.8)
Recent immigrant at baseline	No	Reference			
	Yes	0.54 (0.46, 0.63)	0.85 (0.72, 1.0)	0.69 (0.22, 2.2)	0.78 (0.33, 1.8)

[a]Adjusted for age and gender.
[b]Adjusted for all other variables.
[c]Reference category for age at baseline is 15–24 for hospitalization cohort and 19–24 for fatality cohort.
[d]Statistics Canada collects "sex" without information on nonbinary gender in these census years.
[e]Statistics Canada uses the term "Aboriginal" in these census years.
CanCHEC indicates Canadian Census Health and Environment Cohort; CI, confidence interval; LICO, low-income cut-off.

Table 6. Hazard Ratio for Hospitalization and Death as a Pedestrian Within the Hospitalization and Fatality Cohorts

		Hospitalization (CanCHEC 2006, 2011)		Fatality (CanCHEC 1996, 2001, 2006, 2011)	
Variable	Level	Minimally Adjusted (95% CI)[a]	Mutually Adjusted (95% CI)[b]	Minimally Adjusted (95% CI)	Mutually Adjusted (95% CI)
Main commute mode	Car, truck, or van	Reference			
	Bicycle	1.4 (0.99, 2.1)	1.4 (0.95, 2.0)	1.8 (1.1, 3)	1.7 (1.0, 2.8)
	Walking	2.2 (1.9, 2.6)	2.1 (1.8, 2.4)	1.7 (1.3, 2.1)	1.5 (1.2, 1.9)
	Other mode	2.7 (2.4, 2.9)	2.5 (2.2, 2.8)	1.9 (1.6, 2.2)	1.8 (1.5, 2.1)
Age at baseline	15/19–24[c]	Reference			
	25–34	0.50 (0.43, 0.59)	0.56 (0.48, 0.65)	0.71 (0.55, 0.92)	0.76 (0.59, 0.99)
	35–44	0.56 (0.49, 0.64)	0.67 (0.58, 0.77)	0.99 (0.78, 1.3)	1.1 (0.89, 1.4)
	45–54	0.80 (0.70, 0.90)	0.99 (0.87, 1.1)	1.1 (0.9, 1.4)	1.3 (1.1, 1.7)
	55–64	1.1 (0.97, 1.3)	1.4 (1.2, 1.6)	2.0 (1.5, 2.5)	2.3 (1.8, 3.0)
	65+	1.9 (1.5, 2.3)	2.3 (1.9, 2.9)	4.6 (3.5, 6.2)	5.6 (4.1, 7.5)
Gender[d]	Women	Reference			
	Men	1.1 (1.0, 1.2)	1.2 (1.1, 1.3)	1.6 (1.4, 1.8)	1.7 (1.5, 1.9)
LICO	Non-low income	Reference			
	Low income	2.2 (1.9, 2.5)	1.8 (1.6, 2.1)	1.9 (1.6, 2.3)	1.7 (1.4, 2.1)
Racialization	Nonvisible minority	Reference			
	Visible minority	1.3 (1.1, 1.4)	1.0 (0.91, 1.2)	1.1 (0.92, 1.3)	0.91 (0.73, 1.1)
	Indigenous[e]	2.3 (1.9, 2.7)	2.0 (1.7, 2.5)	4.1 (3.2, 5.2)	3.7 (2.9, 4.7)
Recent immigrant at baseline	No	Reference			
	Yes	1.3 (1.1, 1.5)	1.0 (0.86, 1.2)	1.3 (1.0, 1.7)	1.2 (0.88, 1.6)

[a]Adjusted for age and gender.
[b]Adjusted for all other variables.
[c]Reference category for age at baseline is 15–24 for hospitalization cohort and 19–24 for fatality cohort.
[d]Statistics Canada collects "sex" without information on nonbinary gender in these census years.
[e]Statistics Canada uses the term "Aboriginal" in these census years.
CanCHEC indicates Canadian Census Health and Environment Cohort; CI, confidence interval; LICO, low-income cut-off.

transport, had elevated risks for both bicycling and pedestrian injury, suggesting that these commute modes may correlate to overall nonmotor vehicle transportation exposure. Unadjusted results (eTables 2–4, http://links.lww.com/EDE/C96) showed broad similarity in these patterns to minimally adjusted results.

Relative to women, and adjusting for other covariates, men were at increased risk of bicycle, pedestrian, and motor vehicle occupant injuries resulting in either hospitalization or death (Tables 5–7), a pattern most pronounced in bicyclist hospitalizations (HR = 2.3; 95% CI = 2.2, 2.5) and fatalities (HR = 4.0, 95% CI = 2.9, 5.6). Adjusted for other covariates, the youngest age group (15 or 19 to 24) was at highest risk for bicycle and motor vehicle occupant injuries, whereas the oldest age group (65+) was at the highest risk for pedestrian injuries (Tables 5–7).

After adjustment, we estimated that people who identified as a visible minority were at lower risk for bicyclist injury resulting in hospitalization (HR = 0.41; 95% CI = 0.36, 0.46) or fatality (HR = 0.21; 95% CI = 0.093, 0.46), as well as for a motor vehicle occupant hospitalization (HR = 0.78; 95% CI = 0.73, 0.83) or fatality (HR = 0.57; 95% CI = 0.49, 0.66), compared with people who were not visible minorities. However, persons who self-identified as Indigenous were at higher risk for pedestrian hospitalization (HR = 2.0; 95% CI = 1.7, 2.5) and fatalities (HR = 3.7; 95% CI = 2.9, 4.7) and motor vehicle hospitalization (HR = 1.9; 95% CI = 1.7, 2.0) and fatalities (HR = 1.5; 95% CI = 1.3, 1.8). There were variable patterns between recent immigration and injury and fatality risk by mode (Tables 5–7). The observed associations for recent immigration were, however, attenuated when adjusted for all covariates including main mode of commute (Tables 5–7). Relative to those with higher incomes, people with low incomes (as defined by LICO) were at higher risk for hospitalization and fatality for all modes, except for bicycling hospitalization.

DISCUSSION

The CanCHECs provide a unique and rich dataset that mitigates some of the major limitations of traditional traffic injury datasets in Canada and enable the comparison of mode-specific traffic injury risks between more detailed sociodemographic groups than previously possible. We estimated strong associations among bicyclist, pedestrian, and motor vehicle occupant injuries for those who reported each mode, respectively, as their main mode of commute (e.g., strong associations between bicyclist injury and using a bicycle as a main mode of commute). We suggest that the commute mode variable is capturing a substantial difference in mode-specific exposure between commute modes. After adjustment for main mode of commute and other covariates, we estimated

Table 7. Hazard Ratio for Hospitalization and Death as a Motor Vehicle Occupant Within the Hospitalization and Fatality Cohorts

		Hospitalization (CanCHEC 2006, 2011)		Fatality (CanCHEC 1996, 2001, 2006, 2011)	
Variable	**Level**	**Minimally Adjusted (95% CI)[a]**	**Mutually Adjusted (95% CI)[b]**	**Minimally Adjusted (95% CI)**	**Mutually Adjusted (95% CI)**
Main commute mode	Car, truck, or van	Reference			
	Bicycle	0.67 (0.55, 0.81)	0.65 (0.54, 0.79)	0.83 (0.60, 1.2)	0.79 (0.57, 1.1)
	Walking	0.77 (0.71, 0.84)	0.75 (0.68, 0.81)	0.79 (0.68, 0.93)	0.75 (0.64, 0.88)
	Other mode	0.60 (0.56, 0.65)	0.63 (0.59, 0.68)	0.56 (0.48, 0.64)	0.60 (0.52, 0.69)
Age at baseline	15/19–24[c]	Reference			
	25–34	0.58 (0.55, 0.62)	0.58 (0.54, 0.62)	0.58 (0.52, 0.66)	0.58 (0.52, 0.65)
	35–44	0.54 (0.51, 0.58)	0.53 (0.5, 0.57)	0.62 (0.56, 0.69)	0.61 (0.55, 0.68)
	45–54	0.58 (0.55, 0.62)	0.56 (0.53, 0.6)	0.65 (0.58, 0.73)	0.64 (0.57, 0.71)
	55–64	0.73 (0.69, 0.78)	0.71 (0.66, 0.75)	0.69 (0.60, 0.78)	0.67 (0.58, 0.76)
	65+	1.2 (1.1, 1.3)	1.2 (1.1, 1.3)	1.1 (0.87, 1.3)	1.1 (0.86, 1.3)
Gender[d]	Women	Reference			
	Men	1.4 (1.4, 1.5)	1.4 (1.3, 1.5)	2.1 (2.0, 2.3)	2.1 (1.9, 2.2)
LICO	Non-low income	Reference			
	Low income	1.1 (1.0, 1.2)	1.2 (1.1, 1.3)	1.3 (1.2, 1.4)	1.5 (1.3, 1.6)
Racialization	Nonvisible minority	Reference			
	Visible minority	0.71 (0.67, 0.76)	0.78 (0.73, 0.83)	0.51 (0.44, 0.58)	0.57 (0.49, 0.66)
	Indigenous[e]	1.9 (1.7, 2.0)	1.9 (1.7, 2.0)	1.5 (1.3, 1.9)	1.5 (1.3, 1.8)
Recent immigrant at baseline	No	Reference			
	Yes	0.67 (0.61, 0.73)	0.84 (0.76, 0.93)	0.50 (0.41, 0.61)	0.70 (0.57, 0.88)

[a]Adjusted for age and gender.
[b]Adjusted for all other variables.
[c]Reference category for age at baseline is 15–24 for hospitalization cohort and 19–24 for fatality cohort.
[d]Statistics Canada collects "sex" without information on nonbinary gender in these census years.
[e]Statistics Canada uses the term "Aboriginal" in these census years.
CanCHEC indicates Canadian Census Health and Environment Cohort; CI, confidence interval; LICO, low-income cut-off.

transportation injury occurs disproportionately within historically marginalized populations, including low-income populations and Indigenous people. Negative associations between injury risk amongst immigrant populations and injury as bicyclist, pedestrian, or motor vehicle occupant were attenuated by adjustment for other covariates. These results highlight the importance of accounting for exposure when examining risk differences between population groups and indicate inequities in transportation injury risk in Canada.

Although main mode of commute is a crude measure of total usage of different transportation modes, this represents one of the few sources of population-based data on transportation mode exposure in Canada. The census journey to work module is the only dataset available to measure transportation behavior and mode choice nationally that is consistently collected over time.[15,29] The strong association between main mode of commute and risk of an injury of the corresponding mode suggests that it is capturing meaningful differences in exposure between different modes of transportation. Our results consistently showed a strong association between risk of injury as a bicyclist or pedestrian and using modes other than motor vehicles as main mode of commute. We estimated similar associations between pedestrian injury and nonmotor vehicle-commuting modes (walking, bicycling, and other). We suggest that this is likely partially due to the fact that walking is often an overlooked secondary transportation choice particularly for trips that involve bicycling, and "other" modes such as public transportation,[30] and is not well captured in "main mode of commute" that excludes supporting incidental modes of transportation.

We estimated elevated risks of hospitalization and death for men across all modes, as well as for our youngest age group (15–24 for hospitalizations, 19–24 for deaths). Men and younger age groups are consistently estimated to be at higher risk for road traffic injury across transportation modes.[15,31–36] Men and younger people tend to travel longer distances than women and older adults.[37] Men also tend to have higher rates of risk-taking behavior such as traveling at higher speeds or having a weaker preference for safer route choices.[38,39] In our research, we also find the oldest age groups at highest risk for bicycling fatality and pedestrian hospitalization and death. For older age groups, the increased risk of hospitalization and fatality for most modes and outcomes may be due to increased fragility in addition to increased risk of involvement in a crash.[40]

Our research estimated an increased risk of hospitalization and mortality for both low-income populations and Indigenous persons for all modes (except for bicycling hospitalizations), consistent with previous Canadian research.[4–8] The higher risk observed in these population groups likely reflects an unequal distribution of risk factors

that can influence both the likelihood and severity of injury. Built environment and traffic-related conditions are different in neighborhoods that are lower income and with higher populations of racialized groups (e.g., higher speeds, larger roads, less safe infrastructure for cyclists and pedestrians, and poor surface maintenance).[5,8,41,42] Other potential risk factors for low-income groups include exposure-related factors (e.g., more time/distance traveled due to living further away from city centers), vehicular factors (e.g., more likely to have older, less safe vehicles), and more difficulties accessing critical care.[43–46] Interpretation of the association of Indigenous identity with increased risk of injury and death from traffic should consider the specific historical, social, and economic determinants of Indigenous people's health in Canada, which are rooted in generations of colonial oppression and continued systematic discrimination.[47,48] The economic, built environment, and social conditions of Indigenous people that result from these power structures result in inequities across a multitude of different health outcomes.[6,8,47–50]

Visible minorities cohort members were at lower risk of injury and death relative to nonminorities when they were motor vehicle occupants or bicyclists but had similar risks as pedestrians. In the US, racialized people have been estimated to be at higher risk of transportation injury, especially for walking and bicycling.[51,52] The Canadian census category of "visible minority" encompasses a variety of racial identities.[53]

We estimated that newer Canadians (immigrated within the past 10 years) had significantly lower risk of injury and death by motor vehicle and a similar risk for bicyclist and pedestrian injury and death. Previous analyses of individual-level data for adults in Canada show a similar inverse risk for newer immigrants.[54–56] Our definition of "recent" in immigration status (10 years or less) is long and was required to create a large enough category for analyses. We note our initial analyses with a more stringent (5 years or less) definition showed similar patterns of inverse risk. The literature suggests inverse relationships may not be consistent across age groups and settings. For example, a study of child injuries in Toronto, Canada estimated neighborhoods with a higher proportion of recent immigrants and visible minorities were associated with higher per capita rates of traffic injury for child pedestrian and child bicyclists.[57] Lower risk for immigrant populations may in part be attributable to exposure to risk, with new immigrants more likely to use modes of transport at lowest risk for injury (particularly public transit),[58,59] and/or the result of the mechanisms leading to better health outcomes across many diseases and injuries for immigrants in Canada; mechanisms such as a requirement of good health to be able to immigrate to Canada, the maintenance of ethnic traditions, and more robust social networks.[56] That immigrants may be using lower risk modes more often is partly supported by our finding that adjusting for main mode of commute attenuated the observed inverse risks for recent immigrants' hospitalization and fatalities across all modes. Therefore, when considering interventions in terms of policy changes, it is important to consider the target setting and population.

Our analysis has limitations. We have only primary mode of commute at the time of the census, whereas travel behavior may change over the follow-up period. The main mode of commute variable only captures a narrow aspect of transportation (one mode most often used for commuting) and excludes children commutes and the nonworking adult (15+) population. As such our results are limited in their generalizability outside of the working adult population in Canada. Data from the Canadian Community Health Survey suggest that there are nearly seven times more bicycling trips for leisure than for commuting.[29] Administrative data can be challenging for identifying injury circumstances specific to commute modes, and our study does not differentiate between injuries incurred while commuting versus other types of travel. The ideal measurement of transportation mode would be for each individual to have estimates of the time or distance traveled for all modes and have this captured throughout the follow-up period.[60,61] We also are unable to account for hospitalizations that may have occurred prior to baseline, meaning that individuals in the analytic cohorts could have different baseline risks for future injury, particularly if prior injury impacted physical abilities to use different travel modes. Adjustment for commute mode at baseline may therefore partly address any ongoing impacts of preascertainment injury history that had ongoing impacts on travel behavior and opportunity to incur injury risk over follow-up.

This study is the first to examine traffic injury risks for multiple transportation modes using injuries at an individual level using national Canadian data. We used an unprecedented linked database for road injury research that enabled the examination of differences in injury risk between previously unexplored sociodemographic characteristics such as income, racialization, and recent immigrant status, while also being able to account for a measure of exposure through main mode of commute. Our analysis is descriptive in nature, and the mutually adjusted model results presented represent independent associations rather than causal relationships. However, such analyses are important to identifying inequities in road traffic injury and understanding which populations are more likely to benefit from effective interventions improving road safety (particularly infrastructural improvements and speed reduction[62]) and help set priorities for interventions. Future work can examine risk differences by environmental and built environment conditions by linking participants to their place of residence through postal codes. Ultimately traffic injury research that seeks to compare groups (particularly for active transport injuries) would greatly benefit from more detailed exposure data to better compare risks in Canada.[15] A national household travel survey, which could then be linked to health outcomes, would provide not only unique and important opportunities for traffic injury research but also a wide array

of epidemiological questions about travel and health outcomes in Canada.

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