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Social Disparities in the Risk of Potentially Avoidable Hospitalization for Diabetes Mellitus: an Analysis with Linked Census and Hospital Data

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Abstract

There is an increasing recognition of the value of linked administrative data sets for applied demographic and health research. We use a prospective population-based cohort approach to take advantage of the 2006 Canadian Census data linked to 3 years of hospital records in order to investigate the social determinants of diabetes hospitalizations. We offer compelling evidence of the social gradient in health, with results highlighting decreasing risk of potentially avoidable hospitalization associated with increasing household income. We also found consistently higher risks of hospitalization and 6-month rehospitalization among persons of Aboriginal identity, after controlling for many individual and community-level factors.

Résumé

On reconnaît de plus en plus la valeur de l'appariement de données administratives pour la recherche appliquée en démographie et en santé. Nous utilisons dans cet article une approche de cohorte prospective, qui tire parti de l'appariement des données du Recensement canadien de 2006 et de trois années d'enregistrements d'hospitalisation pour étudier les déterminants sociaux des hospitalisations liées au diabète. Nous offrons des preuves convaincantes des inégalités sociales en matière de santé, avec des résultats soulignant le risque décroissant d'hospitalisation potentiellement évitable suivant l'augmentation progressive du quintile de revenu du ménage. Des risques toujours plus élevés d'hospitalisation et de réadmission durant les six mois suivant l'hospitalisation initiale ont été aussi constatés chez les personnes d'identité autochtone, après avoir tenu compte de nombreux facteurs individuels et communautaires.

Keywords Population health · Administrative data · Hospitalization · Diabetes mellitus · Health inequalities

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Mots clés Santé de la population · données administratives · hospitalisation · diabète sucré · inégalités en santé

1 Introduction

The prevalence of diabetes mellitus and many other chronic non-communicable diseases is increasing rapidly across Canada, a trend attributed in large part to population aging and rising rates of obesity (Public Health Agency of Canada 2011). Equitable accessibility and sustainability of healthcare services at the appropriate level of care are essential to achieving clinical and public health goals for chronic disease prevention and management. Medical advances and changing demographic and epidemiological patterns mean that health system priorities are increasingly focusing on primary and community care, rather than on episodic and responsive hospital care. In particular, hospitalizations for diabetes are often referred to as "ambulatory care sensitive", that is, preventable and potentially avoidable through appropriate management in primary care (Bennett et al. 2011; Billings et al. 1993; Gibson et al. 2013; Pappas et al. 1997; Sanmartin et al. 2011). Common relevant metrics for health system performance assessment include hospitalizations for diabetes and other ambulatory care sensitive conditions (typically excluding the older population), and readmissions within 30 days of hospital discharge. These outcomes offer the advantage of being able to be measured using data readily available in most health services settings. However, research relying on administrative health data has been hindered in the ability to provide comprehensive contextual information (aside from patients' age, sex, and geographic location) to inform health and social policy options from a population health perspective.

Optimal use and reuse of existing health-related data are critical to support evidence-informed decisions to reduce the population and health system impacts of diabetes and other high-burden chronic diseases (Jones et al. 2017). There is increasing recognition of the value of administrative data sets for social science research to inform policy options (Connelly et al. 2016). An important benefit compared with social surveys is the large sizes of many administrative data resources, which offer the opportunity to study population sub-groups. Even more valuable for novel research opportunities is the increasing availability of provincially managed administrative health databases linked with traditional sources of social science data, such as general household surveys and censuses (Connelly et al. 2016; Doiron et al. 2013).

Previous analyses have demonstrated independent influences of sociodemographic characteristics such as low income on the odds of hospitalization for diabetes and other ambulatory care sensitive conditions at the national level, drawing on linked hospital and survey data sets (Sanmartin et al. 2011). However, survey sample size limitations have, so far, precluded a detailed investigation at the disease-specific and sub-national levels. In their study of the associations between income and chronic disease–related health indicators, Pichora et al. (2018) concluded that the measure of income used, notably whether it was individual- or area -based, led to differential categorization of survey respondents.

We take advantage of the unique large-scale resource of the 2006 Canadian Census linked to the 2006/2007–2008/2009 Discharge Abstract Database (DAD) to support investigations of hospital use by sub-groups and socioeconomic status. We use a

whole-population prospective cohort approach to provide the first comprehensive national assessment of the social determinants of potentially avoidable diabetes hospitalization and rehospitalization, using both individual and geospatial measures of income inequality. We hypothesize that rural residence, low household income, low community income, and Aboriginal identity are independently associated with increased risk of diabetes-related hospitalization among Canadian adults. We further hypothesize that these same mediating factors influence the risk of diabetes rehospitalization, thus presenting the "low-hanging fruit" for diabetes-related population health strategies to enhance equity and efficiency in the healthcare system in managing chronic conditions (Gupta et al. 2018).

2 Data and Methods

2.1 Data sources

This study makes use of data from the 2006 Census (mandatory long-form) linked to standardized data on inpatient care for the fiscal years 2006/2007–2008/2009 obtained from the hospital Discharge Abstract Database (Canadian Institute for Health Information 2019; Statistics Canada 2006). Pseudonymization of all data for research use by Statistics Canada ensured that personally identifiable information was eliminated or transformed. Details of the dataset linkage process have been described elsewhere (Rotermann et al. 2015). Briefly, the 2006 long-form Census questionnaire was distributed to one in five Canadian households (approximately 4.65 million respondents) representing 95–97% of the population across provinces, and includes content on income, ethnicity, and employment, among other topics. The DAD contains annual information from approximately 3 million records, each corresponding to one hospital stay with basic demographic, administrative, and clinical data for virtually all acute-care and some psychiatric, chronic, rehabilitation, and day-surgery discharges in nine of the ten provinces (except Quebec).

Approximately 5.3% of the census respondents were linked to at least one DAD record occurring between May 16, 2006 (the census date), and March 31, 2009 (the end of the 2008/2009 fiscal year) (Rotermann et al. 2015). Hierarchical deterministic exact matching was employed to link census with hospital data, based on linkage keys derived from three variables common to both data sources: sex, date of birth, and postal code. Since each DAD record corresponds to one hospitalization, individuals with multiple hospitalizations will have multiple records. Although there was information specific to each hospitalization over the 3-year period considered, all individual and contextual socioeconomic covariates were available only at baseline (2006).

The target population for this study are adults aged 30–69 years living in private households at the time of the census. This delineation yielded a sample size of 2,413,560 individuals who completed the long-form questionnaire and for whom a linkage key to the DAD could be identified (Rotermann et al. 2015). The confidential linked microdata used for the analysis were accessed through the secure setting of the New Brunswick Research Data Centre (NB-RDC), located at the University of New Brunswick in Fredericton, Canada.

2.2 Outcome Measures

Our two outcomes of interest are hospitalizations and rehospitalizations with complications of type 1 or type 2 diabetes mellitus, as defined by the International Statistical Classification of Diseases and Related Health Problems, 10th Revision–Canada (ICD-10-CA), codes E10–E14 (Canadian Institute for Health Information 2006). For our first outcome measure, we searched hospital records prospectively over the 3-year period to identify each individual with either of the following: (i) a primary diagnosis of diabetes, that is, with the condition being considered most responsible for the patient's hospital stay (i.e., listed first of the potential 25 diagnostic codes in the record); or (ii) a secondary diagnosis of diabetes, that is, for which the patient may or may not have received treatment, but which was assigned a diagnostic code (i.e., diagnostic fields 2 through 25). These cases are referred here as a hospitalization *with* diabetes.

For our second outcome measure, we tracked those individuals with a first hospitalization with identified diabetes (flagged as the index admission) by whether or not they were readmitted to any hospital at least once within 6 months during the study period with diabetes as primary diagnosis, referred to as a rehospitalization *for* diabetes. We adopted this approach to better emphasize the role of primary care in potentially avoidable hospitalizations among adults with chronic disease. Previous research has found that, compared with 30-day rehospitalization measures, the use of a longer post-discharge duration is less sensitive to shorter-term hospital-level quality of care concerns, more likely to capture readmissions due to disease progression, more complete by including patients admitted to the same or a different hospital, more likely to reflect post-discharge follow-up including home visits and telephone contacts, and more reflective of care continuity regardless of whether the patient sees the same or a different practitioner (Adib-Hajbaghery et al. 2013; Fischer et al. 2014; van Servellen et al. 2006). Patients who died during the first hospital stay were excluded from the analysis since they would not be exposed to the risk of a readmission.

2.3 Covariates

We examined the relationship between our two outcomes of interest and a number of key social and demographic predictors of health disparities as measured in the census: age, sex, urban/rural place of residence, household income quintile, community income status, and Aboriginal identity. Urban and rural areas were distinguished in the 2006 Census in terms of population concentration and density (Statistics Canada 2011). Geographic residence as well as income level have been attributed to observed variations in potentially avoidable hospitalizations in Canada, a pattern related to both patient and health system characteristics (Sanchez et al. 2008). In particular, Sanmartin et al. (2011) found that individuals hospitalized for an ambulatory care sensitive condition were more likely to be in the lowest household income quintile. At the same time, few studies have examined jointly the relation of individual and community low-income (poverty) measures with chronic disease outcomes (Crews et al. 2014). We ranked all census respondents in our target population by household income quintile based on total after-tax income, adjusted for household size. We further derived an indicator of community poverty using a dichotomized community income variable, defining

low-income communities as those in which 30% or more residents fell below the after-tax Low-Income Measure (LIM), a relative measure of low income for private households of Canada (Murphy et al. 2010; Statistics Canada 2013). Communities were defined according to census subdivisions, given the evidence that pre-defined census geostatistical units make good proxies for "natural" neighborhood boundaries in studies of areal effects on health (Ross et al. 2004).

Aboriginal identity was captured in the census in terms of whether or not a person self-identified as First Nations, Métis, or Inuit. In Canada, the major administrative health data sets do not consistently capture Aboriginal status, and previous analyses have largely addressed this information gap only indirectly through proportional area-based measures (Carrière et al. 2010, 2016; North East Local Health Integration Network 2011).

We further controlled for other potential confounding factors widely identified in the literature, including educational attainment, visible minority status (measured in the census as whether or not the person identified as non-Caucasian in race or non-white in color, other than Aboriginal, as defined in federal employment equity legislation), immigrant status, family/marital status, and labor force status.

Province of residence was included as a proxy for unobserved influences on healthcare utilization patterns, such as jurisdiction-specific health policy, organization of health services delivery, or social welfare programs. For our analysis, the territories were excluded to meet Statistics Canada's data quality and confidentiality standards due to small numbers of diabetes hospitalizations. The provinces of Prince Edward Island and New Brunswick were grouped together to ensure adequate sample sizes of diabetes rehospitalizations. Given the many similarities in demographics and the collaborative approaches to healthcare delivery to residents of these two small neighboring provinces (Horizon Health Network 2019), we do not believe serious bias would have arisen from this constraint.

2.4 Statistical Analysis

We used multiple logistic regression analysis to better understand individual and social correlates associated with the risk of being hospitalized with, and rehospitalized for, diabetes. To test for effect modification by community income, we ran separate models for residents of low-income communities. Analyses were conducted using SAS 9.4 and Stata 15. Individual census weights were employed to ensure population-level representation, with results expressed in terms of odds ratios (OR) for each covariate of interest. We estimated 95% confidence intervals (CIs) using bootstrap replications and cluster-robust standard errors (Rogers 1993). Population counts were rounded to a base of 5, and adjusted to reinforce the confidential nature of the data using Statistics Canada control algorithms.

3 Results

3.1 Cohort Description

Our cohorts included 41,290 adults 30–69 years admitted to a hospital at least once with diabetes, and 510 readmitted for diabetes within 6 months of the index hospitalization. This translates to a rate of 1.71% ever-hospitalized with diabetes (primary or secondary diagnosis) over the 3-year period of observation and, in

turn, 1.24% rehospitalized primarily for diabetes (representing 0.02% of the total adult population). By definition, 20% of the target population were in the lowest household income group, whereas 6.1% resided in low-income communities at the time of the census (Table 1).

Persons in the older age groups and males were over-represented among those ever-hospitalized with diabetes during the study period compared with the general population (Table 1). This generally reflects established epidemiological patterns of disease prevalence: diabetes is more common with advancing age and among males. For example, in 2008/2009, males represented 52.5% of the total 2.4 million Canadians living with diabetes (Public Health Agency of Canada 2011). Our results show that more than half (55.6%) of adults hospitalized with diagnosed diabetes were men, and nearly two-thirds (63.7%) of those rehospitalized were also men.

As expected, persons living in rural areas, in lower income households, in low-income communities, and of Aboriginal identity were disproportionately represented among those hospitalized with or rehospitalized for diabetes. Higher age-adjusted hospitalization rates and other adverse health outcomes have previously been found in Canada among Aboriginal people than among non-Aboriginal people, possibly related to their socioeconomic disadvantage or other underlying health determinants (Carrière et al. 2016; Greenwood and de Leeuw 2012).

Consistently with other studies, we also observed that preventable hospitalizations were relatively less frequent among those with a university degree, who were employed, and who were foreign-born. The latter pattern may be attributed to the well-documented "healthy immigrant effect" (Kennedy et al. 2015; Newbold 2005; Ng 2011). Immigrants, especially those who have immigrated recently, are less likely to have chronic health conditions or disabilities than the native-born population, in part due to selection processes that screen potential immigrants by health status, education and skills, and other unobserved self-selection effects.

3.2 Risk of Hospitalization with Diagnosed Diabetes

As seen in Table 2, the odds of hospitalization with diagnosed diabetes increase with increasing years of age (OR, 1.08; 95% CI, 1.07–1.08), after controlling for a wide range of demographic and socio-environmental factors. Among the total community-dwelling adult population, being female was strongly and significantly protective against risk of hospitalization (OR, 0.69; 95% CI, 0.68–0.70) (Model 1). However, this gendered association did not hold when limiting the analysis to those living in low-income communities (OR, 1.03; 95% CI, 0.97–1.08) (Model 2).

Urban residence was not significantly associated with differential risk of preventable hospitalization compared with rural residence (OR, 0.97; 95% CI, 0.95–1.00), regardless of community low-income status (OR, 0.94; 95% CI, 0.84–1.04).

We observed a classic socioeconomic gradient of decreasing odds of hospitalization associated with increasing household income. Compared with adults in the middle household income quintile, those in the lowest quintile were significantly more likely to be hospitalized (OR, 1.22; 95% CI, 1.18–1.26), whereas those in the highest quintile were significantly less likely to be hospitalized (OR, 0.78; 95% CI, 0.75–0.81).

Table 1 Percentage distribution (%) of the population 30–69 years hospitalized and rehospitalized for diabetes, by sociodemographic characteristics, 2006–2008

Characteristic	Total population (N = 2,413,560)	Hospitalized at least once with diabetes (N = 41,290)	Rehospitalized for diabetes within 6 months (N = 510)
Age (years)			
30–39	25.8	6.2	12.8
40–49	31.4	15.9	23.5
50–59	26.3	33.4	29.4
60–69	16.5	44.5	34.3
Sex			
Female	51.1	44.4	36.3
Male	48.9	55.6	63.7
Place of residence			
Urban	76.8	66.1	54.9
Rural	23.2	33.9	45.1
Household income quintile			
Lowest	20.0	34.5	43.1
Lower–middle	20.0	23.5	22.6
Middle	20.0	17.6	15.7
Middle–upper	20.0	13.7	10.8
Highest	20.0	10.7	7.8
Community income level			
Low-income communities	6.1	16.0	28.4
Other communities	93.9	84.0	71.6
Aboriginal identity			
No	93.6	82.0	66.7
Yes	6.4	18.0	33.3
Highest level of education			
Did not complete high school	18.0	36.3	42.2
High school diploma	24.0	21.3	21.6
Postsecondary diploma	31.4	28.8	28.4
University degree	26.6	13.6	7.8
Visible minority			
No	83.3	88.8	87.3
Yes	16.7	11.2	12.7
Immigrant status			
No	72.1	78.1	93.1
Yes	27.9	21.9	6.9
Marital status			
Currently married or in union	66.3	62.2	50.0
Formerly married or in union	17.0	23.5	24.5
Never married or in union	16.7	14.3	25.5

Table 1 (continued)

Characteristic	Total population (N = 2,413,560)	Hospitalized at least once with diabetes (N = 41,290)	Rehospitalized for diabetes within 6 months (N = 510)
Labor force status			
Employed	71.5	42.8	36.3
Unemployed	4.0	4.0	7.8
Not in labor force	24.5	53.2	55.9

Sample sizes are control rounded, based on the population 30–69 years in the 2006 Census. Characteristics are those at the time of the census. Hospitalizations include inpatient stays with a discharge date between May 16, 2006, and March 31, 2009. Data exclude Quebec and the territories

Significantly higher odds of hospitalization were found among those living in low-income communities compared with their counterparts in other communities (OR, 1.40; 95% CI, 1.34–1.45). Focusing on those residing in low-income communities (Model 2), a certain pattern of socioeconomic gradient for household income quintile was suggested, although results were less pronounced compared with the general population. There was no statistically significant difference in the odds of hospitalization among those in the highest versus middle-income quintiles (OR, 0.98; 95% CI, 0.85–1.14).

Consistently with research elsewhere (e.g., Carrière et al. 2016), persons of Aboriginal identity presented significantly higher odds of hospitalization, after controlling for age and other individual characteristics (OR, 2.56; 95% CI, 2.47–2.64) and additional community-level socioeconomics (OR, 3.48; 95% CI, 3.26–3.72).

Some differences were found by province (excluding residents of Quebec). Compared with those living in Ontario, and regardless of community income status, persons living in Newfoundland and Labrador, Alberta, and British Columbia tended to have reduced odds of hospitalization, while those living in Saskatchewan had significantly higher odds. Patterns were inconsistent by community income status for residents of New Brunswick/Prince Edward Island and Manitoba.

3.3 Risk of 6-Month Diabetes Rehospitalization

Similar to our results for the risk of being ever-hospitalized with diabetes over the study period, as seen in Table 3, we observed significantly decreased odds of diabetes-attributable rehospitalization among women, both among the total community-dwelling adult population (OR, 0.60; 95% CI, 0.50–0.73) (Model 1) and when limiting the analysis to those residing in low-income communities (OR, 0.57; 95% CI, 0.41–0.80) (Model 2).

Rural residence, household income group, and community low-income status were not found to be significant predictors of the risk of 6-month rehospitalization, after controlling for other factors. It should be noted that diabetes rehospitalizations are a relatively rare event, statistically speaking. Even when using large national data sets, numbers were small (510 patients rehospitalized for diabetes as measured here, of whom 145 were living in low-income communities at the time of the census). Despite the small numbers, a significantly higher risk of rehospitalization was found among adults of Aboriginal identity (OR, 1.37; 95% CI, 1.01–1.85).

Table 2 Adjusted odds ratios (and 95% confidence intervals) from the multiple logistic regression models for the risk of diabetes hospitalization among the population 30–69 years, by community income level

Characteristic	(1) All communities (N = 2,413,560)	(2) Low-income communities (N = 146,300)
Age		
Years (continuous)	1.08 (1.07–1.08)	1.07 (1.07–1.07)
Sex		
Female	0.69 (0.68–0.70)	1.03 (0.97–1.08)
Male (ref)	1.00	1.00
Place of residence		
Urban	0.97 (0.94–1.00)	0.94 (0.84–1.04)
Rural (ref)	1.00	1.00
Household income quintile		
Lowest	1.22 (1.18–1.26)	1.12 (1.05–1.20)
Lower–middle	1.06 (1.03–1.10)	1.07 (0.99–1.16)
Middle (ref)	1.00	1.00
Middle–upper	0.92 (0.89–0.95)	0.93 (0.83–1.04)
Highest	0.78 (0.75–0.81)	0.98 (0.85–1.14)
Community income level		
Low-income communities	1.40 (1.34–1.45)	--
Other communities (ref)	1.00	--
Aboriginal identity		
No (ref)	1.00	1.00
Yes	2.56 (2.47–2.64)	3.48 (3.26–3.72)
Highest level of education		
Did not complete high school	1.26 (1.23–1.29)	1.11 (1.03–1.20)
High school diploma (ref)	1.00	1.00
Postsecondary diploma	1.03 (1.01–1.06)	1.03 (0.96–1.12)
University degree	0.72 (0.69–0.74)	0.99 (0.88–1.12)
Visible minority		
No (ref)	1.00	1.00
Yes	1.23 (1.17–1.28)	1.74 (1.17–2.57)
Immigrant status		
No (ref)	1.00	1.00
Yes	0.77 (0.75–0.78)	0.82 (0.66–1.01)
Marital status		
Currently married or in union (ref)	1.00	1.00
Formerly married or in union	1.09 (1.07–1.11)	0.98 (0.92–1.05)
Never married or in union	1.06 (1.04–1.09)	0.93 (0.86–1.00)
Labor force status		
Employed (ref)	1.00	1.00
Unemployed	1.22 (1.16–1.29)	1.13 (1.04–1.22)
Not in labor force	1.70 (1.66–1.74)	1.49 (1.41–1.57)

Table 2 (continued)

Characteristic	(1) All communities (N = 2,413,560)	(2) Low-income communities (N = 146,300)
Province of residence		
Newfoundland and Labrador	0.91 (0.85–0.97)	0.65 (0.56–0.76)
Nova Scotia	1.03 (0.98–1.08)	0.99 (0.86–1.14)
New Brunswick and Prince Edward Island	1.17 (1.13–1.22)	0.81 (0.72–0.91)
Ontario (ref)	1.00	1.00
Manitoba	1.10 (1.06–1.13)	0.99 (0.92–1.07)
Saskatchewan	1.11 (1.06–1.17)	0.86 (0.79–0.93)
Alberta	0.97 (0.94–1.01)	0.75 (0.68–0.82)
British Columbia	0.78 (0.75–0.80)	0.44 (0.41–0.48)

Sample sizes are control rounded, based on the population 30–69 years in the census. Hospitalizations include any inpatient stays over the 3-year period with a primary or secondary diagnosis of diabetes. Confidence intervals are estimated using 50 bootstrap replications

Model 1, total community-dwelling adult population

Model 2, adult population living in communities (based on census subdivisions) where a substantial proportion live below an income threshold that is typical in society (based on low income measure)

4 Discussion

In this national-level cohort study drawing on linked administrative and census data, we provide detailed information on the socioeconomic characteristics of Canadian adults aged 30–69 years who experienced a hospitalization with diabetes, and a diabetes-attributable rehospitalization, over a 3-year period. We found compelling evidence of the social gradient in health, which refers to individuals of lower socioeconomic position tending to have poorer health outcomes than others. In particular, we found incremental increases in risk of hospitalization (and, to some extent, 6-month rehospitalization) associated with decreasing household income.

Social gradients in health have been observed for many different chronic diseases across the developed world, using different measures of deprivation or socioeconomic position (Wilkinson and Marmot 2003). The use of clinical diagnostic data linked to census data offered innovative analytical options for research on population health and health equity. We leveraged the new microdata resource made available through Statistics Canada's Social Data Linkage Environment to take into account both individual-level and geospatial socioeconomic indicators, thereby enhancing the robustness of the results. Our results were consistent with previous investigations in specific Canadian contexts suggesting socioeconomic disadvantage is associated with increased risk of hospitalization, but which relied on area-based gauges of deprivation (Agha et al. 2007; Glazier et al. 2004). We also found some indications of a social gradient in health outcomes among residents of low-income communities, signifying these communities themselves are not a homogeneous group.

The evidence base on Aboriginal health in Canada has been weak due to fragmented data sources that do not comprehensively capture social determinants. Previous studies have documented health disparities by distinguishing areas with a relatively high

Table 3 Adjusted odds ratios (and 95% confidence intervals) for the risk of 6-month diabetes rehospitalization among the population 30–69 years, by community income level

Characteristic	(1) All communities (N = 41,290)	(2) Low-income communities (N = 6480)
Age		
Years (continuous)	0.97 (0.96–0.98)	0.99 (0.97–1.01)
Sex		
Female	0.60 (0.50–0.73)	0.57 (0.41–0.80)
Male (ref)	1.00	1.00
Place of residence		
Urban	1.15 (0.92–1.43)	1.58 (0.65–3.87)
Rural (ref)	1.00	1.00
Household income quintile		
Lowest	1.09 (0.83–1.42)	1.08 (0.61–1.88)
Lower–middle	1.03 (0.78–1.35)	0.74 (0.36–1.51)
Middle (ref)	1.00	1.00
Middle–upper	0.90 (0.67–1.22)	0.68 (0.23–2.04)
Highest	0.91 (0.61–1.36)	1.43 (0.48–4.29)
Community income level		
Low-income communities	0.99 (0.72–1.37)	--
Other communities (ref)	1.00	--
Aboriginal identity		
No (ref)	1.00	1.00
Yes	1.37 (1.01–1.85)	1.54 (0.80–2.95)
Province of residence		
Newfoundland and Labrador	0.85 (0.52–1.39)	0.75 (0.19–2.89)
Nova Scotia	0.78 (0.50–1.20)	0.85 (0.22–3.36)
New Brunswick and Prince Edward Island	0.62 (0.37–1.03)	0.83 (0.22–3.10)
Ontario (ref)	1.00	1.00
Manitoba	1.38 (1.05–1.82)	1.34 (0.82–2.18)
Saskatchewan	0.96 (0.71–1.30)	0.88 (0.50–1.55)
Alberta	1.03 (0.79–1.34)	0.73 (0.33–1.62)
British Columbia	1.16 (0.86–1.56)	1.03 (0.53–2.00)

Sample sizes are control rounded, based on the population 30–69 years hospitalized at least once over the 3-year period with a primary or secondary diagnosis of diabetes. Models are further adjusted for educational attainment, visible minority status, immigrant status, marital status, and labor force status (results not shown)

Model 1, total community-dwelling adult population

Model 2, adult population living in communities (based on census subdivisions) where a substantial proportion live below an income threshold that is typical in society (based on low income measure)

percentage of Aboriginal residents, but community low-income status is likely to be collinear with Aboriginal status since Aboriginal communities tend to experience a disproportionate deficiency in economic and material structures (Greenwood and de

Leeuw 2012). We still found a consistently higher risk of hospitalization among adults of Aboriginal identity, and this after controlling for residence in a low-income community.

A limitation of our analysis is that we had no information on individuals' general health status, health-related behaviors such as physical inactivity and smoking, or measures of obesity, all of which may increase risk of diabetes hospitalization, but none of which were collected in the Census long-form questionnaire. While we were unable to identify whether patients had been diagnosed with diabetes in primary care, we accounted for disease progression through examination of diabetes-attributable rehospitalization over a longer 6-month duration.

Another potential limitation is that we only had information on personal and contextual characteristics at the time of the Census. We lacked continuous socioeconomic measures over the 3-year study period and across the life span. Patients may have changed residence (and potentially, community poverty category) during the period of observation. It is also possible that some patients with late-stage complications of diabetes could have been required to stop working at a given point during adulthood and experienced economic disadvantage due to the disease, potentially biasing our results (reverse causality).

It is possible that we underestimated the number of readmissions. Diabetes is a complex group of metabolic disorders, associated with a large number of long-term complications including heart disease, eye disease, kidney failure, pregnancy complications, and lower-limb amputations. We attempted to compensate for diabetes not always being recognized as the cause of hospitalization by including cases where diabetes diagnosis was recorded as a secondary reason for the initial hospital stay. We chose to measure readmissions dichotomously based on an index hospitalization, thereby excluding non-successive and repeat diabetes-related admissions over the 3 years. In addition, 6-month readmissions would have been right-censored in the last months of the 3 years of data.

The linked Census-DAD data sets, as used here, remain the only Canadian information source that offers the statistical power to conduct an investigation such as this, with the ability to disentangle relatively rare events, such as diabetes readmissions. Despite the limitations noted above, this study represents, to the best of our knowledge, the first national-level assessment of a wide range of demographic and socioeconomic factors associated with preventable diabetes hospitalizations and rehospitalizations. A key strength of our study is the large, broadly nationally representative nature of our cohort (representative of the population for nine of ten provinces, except Quebec). We were able to tap into the rich personal-level information available uniquely through the Census long-form linked to cause-specific data on hospital stays. This approach overcomes limitations of working with either administrative health data alone or census data alone.

Given that diabetes hospitalizations are typically seen as a measure of access to primary care and the capacity of the healthcare system to manage chronic conditions, our findings reinforce the premise that social policy is good health policy (Raphael 2003). In other words, despite the Canadian context of universal healthcare coverage, the persistence of disparities by socioeconomic and ancestry status fuelling excess hospitalizations reinforces the importance of integrating social and economic policies within health policy and planning. We added substantive information to the growing evidence base on the social determinants of health and diabetes. Strategies for reducing

the numbers of hospitalizations and rehospitalizations, which are both costly to the public system and detrimental to patient quality of life, should imperatively integrate social science research and approaches to consider a person's sociocultural environment as a driver of health.

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Compliance with Ethical Standards

The views expressed in this paper are those of the authors alone. The funders and partners had no role in study design, decision to publish, or preparation of the manuscript. The study complied with the University of New Brunswick's Research Ethics Board, which does not require an internal institutional review for research projects using data accessed through the NB-RDC.

Conflict of Interest The authors declare that they have no conflicts of interest.

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