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Multimorbidity prevalence in Canada: a comparison of Northern Territories with Provinces, 2013/14

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ABSTRACT
Rapid social, economic, and environmental changes in the northern territories of Canada have raised concerns about potentially increasing levels of chronic disease. This concern prompted us to compare multimorbidity prevalence in Canada between the territories and provinces. We analyzed Canadian Community Health Survey data for 2013/14. We defined multimorbidity, the outcome, as having 3 or more chronic conditions and used survey-weighted multivariable logistic regression for comparisons between territories and provinces. We found a prevalence of multimorbidity in Canada of 14.0% (95% CI: 13.6, 14.3). We could not find significant difference in multimorbidity prevalence between the territories and provinces of Canada overall; however, the territories tended to have lower prevalence estimates than provinces for multimorbidity (adj-OR = 0.88; 95% CI: 0.74–1.04). Sensitivity analyses from propensity score analyses had similar conclusions. Effect modification analyses identified lower multimorbidity in territories versus provinces among households without a post-secondary graduate (adj-OR = 0.46; 95% CI: 0.34–0.61 for northern residence), males (adj-OR = 0.71; 95% CI: 0.54–0.93), and ages 12–29 years (adj-OR = 0.63; 95% CI: 0.39–0.99). Caution is needed in interpreting the results in light of representativeness of CCHS in northern populations of Canada.

Introduction

Multimorbidity is defined as two or more co-occurring chronic conditions without an index condition[1]. Multimorbidity is common among adults, with a general population prevalence estimated to be between 17.3 5 to 71.8%[2]. Multimorbidity reduces physical and social functioning, increases utilization of healthcare services, and leads to higher personal and social costs [3–6]. In Ontario, multimorbidity was estimated to account for 86% of healthcare spending totalling over $26B annually[7]. Healthcare policy and practice are rapidly shifting to patient-centred and coordinated care approaches, in part prompted by the challenges of multimorbidity [2,8–10]. Many unanswered questions about incidence, prevalence, prevention, and intervention remain [2,8,10,11]. However, core risk factors for multimorbidity have been identified, including advanced age, lower socioeconomic status, and female sex[10]. Other risk factors, such as tobacco use, physical inactivity, alcohol consumption, and urban living have also been described in various populations with mixed results[2]. Canadian studies have produced evidence regarding these risk factors for multimorbidity, and have highlighted the role of socioeconomic disparities in

multimorbidity [3,11–13]. Other circumpolar countries have investigated multimorbidity prevalence, patterns, predictors, and prescribing practices, with varying results, and prevalence estimates ranging from 21.6% to 55%, depending on participants, data source, and included conditions [14–17].

Northern Canada, which includes the Northwest Territories (NWT), Yukon Territory (YT), and Nunavut (NU), has experienced a slower epidemiological transition from infectious to chronic disease than the rest of Canada [18,19]. However, a higher prevalence of risk factors for chronic disease in northern Canada suggests that multimorbidity may be an emerging phenomenon [18,20–22]. Estimates of the burden of multimorbidity and the factors associated with this burden can help inform needed primary care reform in northern Canada [23]. Two studies to date have included comparisons of multimorbidity between Canadian provinces and territories [18,24]. Deering et al. found a higher prevalence of risk factors for chronic disease in northern compared to southern Canada, although at the time of their study (years 2000/01 and 2005) the higher prevalence of risk factors may not have translated to higher prevalence of chronic disease in northern Canada[18].

Their analysis was adjusted for age and sex yet did not consider risk factors for multimorbidity such as smoking, diet, physical activity, or socioeconomic status [18]. Deering *et al*. predicted a rise in chronic disease in northern Canada, with implications for care, and called for continued monitoring [18]. Feely *et al*. used the Canadian Chronic Disease Surveillance System (populated by administrative hospital discharge and physician claims data) to analyze multimorbidity across Canadian provinces and territories. They found slightly higher age-standardized rates of three or more chronic conditions in the Yukon and Nunavut compared to Canada overall with higher than average increases in all three territories between 2001/02 and 2011/12[24]. However, their estimates are were also not adjusted for risk factors such as smoking, diet, physical activity, or socioeconomic status[24].

The equivocacy of findings coupled with predictions of epidemiological change and known disparities in healthcare access, warrant research into multimorbidity in northern Canada. Recent CCHS data for 2013/14 enables an updated analysis of chronic disease burden between the territories and provinces of Canada. The primary aim of this study was to answer the following question: What is the prevalence of multimorbidity in northern compared to southern Canada? A higher prevalence of multimorbidity in northern Canada, after adjustment for known risk factors, was hypothesized. This study describes multimorbidity prevalence and associated factors in the general Canadian population using nationally representative data and modern regression methods appropriate for complex surveys to compare territories and provinces in terms of multimorbidity prevalence.

Methods

Data source, design, and study population

Data from the Canadian Community Health Survey (CCHS) 2013/14 Public Use Microdata File (PUMF) was used for this cross-sectional study. The study population for CCHS includes Canadians age ≥12 years through a multistage stratified cluster random sampling strategy[25]. Survey weights are provided with the PUMF to produce accurate point estimates based on the complex survey design. However, bootstrap weights and necessary design information (strata and primary sampling units) are not provided with the CCHS PUMF for privacy reasons, potentially reducing users' ability to estimate variance precisely.[25]

Analytic sample and study variables

All CCHS participants were included. The primary outcome, multimorbidity, was derived from 14 chronic condition questions ("do you have <condition>?") asked of all participants. Chronic conditions included in the definition of multimorbidity: asthma, arthritis (excluding fibromyalgia), back problems (excluding fibromyalgia/arthritis), high blood pressure, migraine headaches, chronic obstructive pulmonary disorder (COPD), diabetes, heart disease, cancer, stomach or intestinal ulcers, urinary incontinence, bowel disorder, as well as two mental health conditions (mood disorder and anxiety disorder). These conditions fit with the literature and the recommendation by Fortin *et al*. to use at least 12 candidate conditions [8,9]. Indicator variables for each question were set to 1:("yes") and 0: ("no", "don't know", "not applicable", "not stated", "refused"). The sum of these indicator variables was dichotomized into the *outcome variable*: "< 3 conditions" versus "3+ conditions"[26].

The dichotomous *exposure variable* for this study was residence in northern Canada during data collection: residence in a *territory* of Canada (Yukon, Northwest Territories, or Nunavut; north = 1) or in a *province* of Canada (north = 0). *Covariates* were identified based on Canadian literature examining chronic disease using CCHS data [3,12,18,20,21]. Covariates that potentially confound the relationship between residence in northern Canada and multimorbidity were grouped as follows: age group (12–17, 18–24, 25–34, 35–44, 45–54, 55–64, 65–74, 75+), sex (male, female), leisure physical activity index (active/moderately active, inactive), total household annual income (<$20,000, $20,000–39,999. $40,000–59,999, $60,000–79,999, $80,000+), type of smoker (current, former, never), highest household education (post-secondary graduate, non-post-secondary graduate), alcohol consumption (regular, occasional, not in the last 12 months), and daily consumption of fruits and vegetable (<5 servings, 5+ servings)[27]. Participants with invalid covariate values ("don't know", "refused", "not stated", or "not applicable") were excluded from the analytic sample. Figure 1 displays participant flow in/out of the analytic sample (*n* = 110,924).

Statistical analysis

Descriptive analysis

Analytic sample characteristics are described through frequency and percent of participants in the covariate
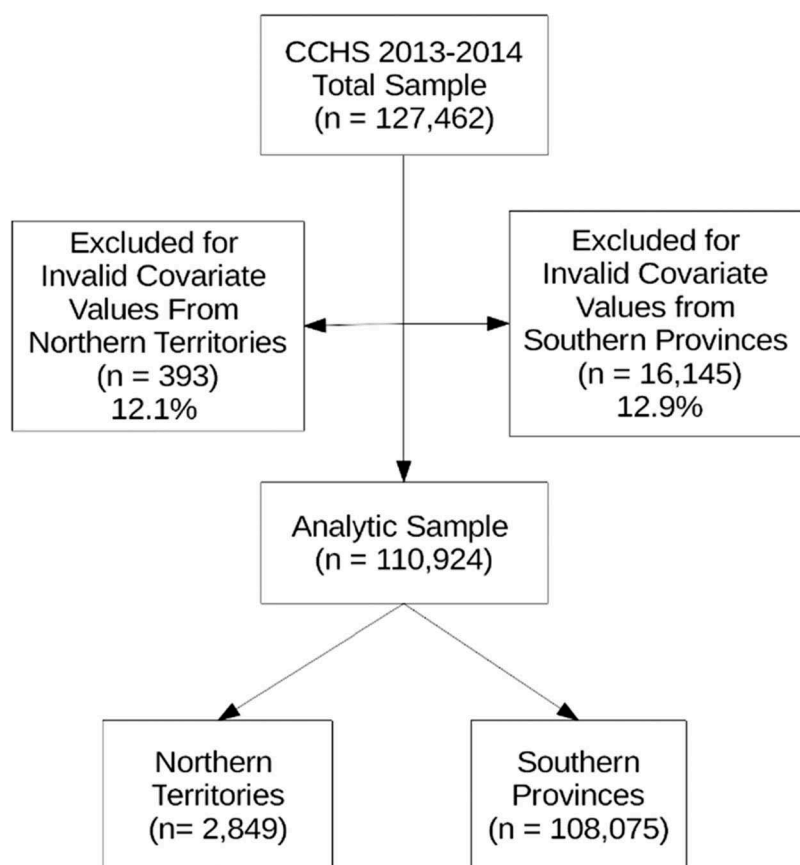
Figure 1. Flow diagram of analytic sample inclusion and exclusion by residence North (Territories) and South (Provinces).
Excluded persons with invalid responses for one or more covariates, as well as the regular medical doctor variable ($n = 232$) that was considered for secondary analysis. Most exclusions ($n = 10,798$; 8.49%) made for missing values were for fruit and vegetable consumption.

groups stratified by residence in territories or provinces and compared using the standardized mean difference (SMD) to assess covariate balance[28]. Analytic sample characteristics were also stratified by the outcome variable, multimorbidity status, and their statistical association with the outcome assessed through the Rao-Scott Chi-square test[29].

Statistical inference

Survey-weighted multivariable logistic regression estimated differences in multimorbidity prevalence after adjusting for confounding, with results presented as odds ratios (OR) and confidence intervals (CI). All covariates were entered into the main effects model simultaneously based on their presumed effect. All covariates were significant, hence none were removed. Potential effect modification of northern residence by age, sex, income, or education was explored. Interactions between covariates that might better explain the relationship between exposure and outcome were considered, with a focus on sex-based interactions. As recommended, male and female subgroups were analyzed separately to identify differences in

factors associated with multimorbidity[8]. The main effects model was evaluated through the weighted area under the receiver operating characteristics curve (AUC) and the Archer-Lemeshow goodness-of-fit test[30].

Sensitivity analyses

First, two age-restricted samples (age 18 years and over and age 35 years and over) were used to account for low cell counts among ages 12–17 years (see Table 2) and because urinary incontinence and COPD were not measured for those under 25 years and 35 years, respectively. Next, a series of interaction models assessed covariate interactions that may alter the adjusted odds ratio for northern residence from the main effects model.

Third, propensity score (PS) methods were employed to balance the exposure and control groups through (a) PS matching and (b) PS weighting of the analytic sample [28,31]. All covariates were used to create propensity scores in both cases. The PS for this study was the predicted probability of being a resident of the northern territories based on the covariates in main analysis. Improvements in the balance of treatment and

exposure groups on covariates was assessed through the reduction in SMD between the unmatched and PS-matched samples[28]. For the matching approach, a 1:10 nearest neighbour (logit distance)-matched-with-replacement analytic sample was assembled for territorial and provincial residents[32]. Two propensity score estimation methods were used for the weighting approach: logistic regression and ensembling through a 5-fold cross-validated super learner[33]. In the logistic regression PS model, all variables used in the main effects analysis were included. In the super learning PS method, all covariates were entered into the ensembling algorithm with three candidate algorithms: generalized linear model (GLM) (main effects only), GLM stepwise interaction, and recursive partitioning with pruned regression trees using cross-validated mean square error (CV-MSE) to evaluate predictive performance[34].

Finally, a multiple imputation analysis was conducted using a larger set of observations where participants with missing covariate values who were removed from the previous analysis were included. Missing covariate values for six covariates were multiply imputed in 20 datasets, and analyzed using appropriate methods[35]. Data analyses were conducted in R v.3.4.4[36].

Results

Descriptive analysis: study population characteristics and multimorbidity

Bivariable comparisons of the exposure and covariates with the outcome suggest that all study variables are significantly associated with multimorbidity (Table 1). The estimated prevalence of multimorbidity in Canada during 2013/14 was 14% ($N = 3,732,160$ people): 14% ($N = 3,722,786$) in the provinces, and 12% ($N = 9,374$) in the territories (Table 1). A higher proportion of persons with multimorbidity are female, older, consuming less than 5 servings of fruits and vegetables per day, consuming alcohol occasionally or not in the last 12 months, current and former smokers, and physically active (Table 1). A large proportion (80%) of the population without multimorbidity report "post-secondary graduate" as highest household education level and

Table 1. Study sample characteristics stratified by multimorbidity status with survey-weighted proportions and associations: Canadian Community Health Survey, 2013/14.

Characteristic	Group	Overall N (%)[a]	MM (3+ Conditions) N (%)[a,b]	Non-MM (< 3 Conditions) N (%)[a]
Total		110,924	21,909	89,015
Residence	Provinces	108,075	21,550 (99.7)	86,525 (99.7)
	Territories	2,849 (0.3)	359 (0.3)	2,490 (0.3)
Sex	Male	49,071 (48.9)	7,726 (38.9)	41,291 (50.6)
	Female	61,907 (51.1)	14,183 (61.1)	47,724 (49.4)
Age Group	12-17 years	8,435 (7.6)	160 (0.9)	8,275 (8.7)
	18-24 years	8,699 (11.0)	419 (3.1)	8,280 (12.2)
	25-34 years	12,994 (16.3)	884 (6.6)	12,110 (17.9)
	35-44 years	13,670 (16.3)	1,305 (10.0)	12,365 (17.3)
	45-54 years	14,410 (17.2)	2,624 (17.8)	11,786 (17.1)
	55-64 years	21,978 (15.9)	5,436 (24.0)	16,542 (14.5)
	65-74 years	18,122 (10.0)	5,856 (21.5)	12,266 (8.1)
	75+ years	12,616 (5.8)	5,225 (16.1)	7,391 (4.1)
Fruit & Vegetable Consumption	< 5 servings	66,358 (59.7)	14,076 (63.6)	52,282 (59.0)
	5+ servings	44,566 (40.3)	7,833 (36.4)	36,733 (41.0)
Alcohol Consumption	Regular	64,929 (60.5)	10280 (49.8)	54,649 (62.3)
	Occasional	19,417 (16.6)	4876 (22.1)	14,541 (15.7)
	Not in 12 months	26,578 (22.9)	6753 (28.1)	19,825 (22.1)
Household Income	<$20,000	1,1307 (7.2)	4398 (15.2)	6,909 (5.9)
	$20,000 to $39,999	22,784 (16.5)	6642 (26.3)	16,142 (14.9)
	$40,000 to $59,999	19,925 (17.2)	4150 (18.3)	15,775 (17.0)
	$60,000 to $79,999	16,198 (14.9)	2593 (13.5)	13,605 (15.1)
	$80,000+	40,710 (44.2)	4126 (26.7)	36,584 (47.0)
Smoker Type	Never	43,023 (43.7)	5888 (29.6)	37,135 (46.0)
	Current	20,641 (18.7)	4780 (24.1)	15,861 (17.8)
	Former	47,260 (37.6)	11241 (46.2)	36,019 (36.2)
Physical Activity	Inactive	49,965 (55.1)	13,136 (58.4)	36,829 (42.7)
	Active / Moderately	60,959 (48.9)	8,773 (41.6)	52,186 (57.3)
Education	Non-graduate	31,604 (21.8)	9,004 (34.3)	22,600 (19.8)
	Post-secondary graduate	79,320 (78.2)	12,905 (65.7)	66,415 (80.2)

MM = multimorbidity, N = number of persons in the analytic sample.
[a] All percentages are weighted to the Canadian population.
[b] P-value from Rao-Scott modified Pearson chi-square test for multiway contingency tables with proportions estimated from complex survey data. All were significant ($p < 0.05$) so p-value omitted.

approximately half (47%) report household income over $80,000/year (Table 1).

Main analyses: survey-weighted logistic regression

The crude odds of multimorbidity was 18% lower among residents of territories than provinces (OR = 0.82, 95% CI: 0.70–0.96). After adjusting for numerous risk factors for multimorbidity there appeared to be a lower prevalence of multimorbidity in territories than provinces, although not statistically significant (aOR = 0.88, 95% CI: 0.74–1.04) (Table 2). Females, older persons, current or former smokers, the physically active, and those who consume alcohol occasionally or not in the last year had higher odds of multimorbidity after adjusting for covariates (Table 2). Eating five or more servings of fruits/vegetables, having higher levels of household income, or having highest household education of post-secondary graduate, were all associated with lower odds of multimorbidity after adjusting for covariates (Table 2). The final model discriminated between persons with and without multimorbidity 28% better than chance (AUC = 0.78). Archer-Lemeshow goodness-of-fit test did not show evidence of lack of model fit ($p = 0.3$).

Effect modification, interaction, and sub-group analyses

Effect modification models showed lower odds of multimorbidity in territories than provinces for ages 12–-29 years (aOR = 0.63; 95% CI: 0.39–0.99), males (aOR = 0.71; 95% CI: 0.54–0.93), and people in households with a post-secondary graduate (aOR = 0.46; 95% CI: 0.34–0.61) (Table 3). Females had larger aOR in the territories (aOR = 2.17, 95% CI: 1.54–3.05) than the provinces (aOR = 1.51, 95% CI: 1.41–1.62) (Table 4). The increased odds of multimorbidity for females compared to males was larger in younger years and became smaller at older ages (Table 4). Sex-specific models showed differences in adjusted odds ratios between males and females for effects of northern residence and age group, with slight differences for household education, physical activity, alcohol consumption, smoker type and fruit & vegetable consumption (Table 4).

Sensitivity analyses

Models including interaction terms for sex by age, sex by smoking, age by alcohol consumption, age by

Table 2. Model estimates from survey-weighted logistic regression of multimorbidity prevalence (3+ conditions): Canadian Community Health Survey, 2013/14.

Variable	Unadjusted OR (95%CI)	Adjusted OR (95%CI)
Residence (Provinces)	Ref	Ref
Territories	0.82 (0.70 − 0.96)	0.88 (0.74 − 1.04)
Sex (Male)	Ref	Ref
Female	1.61 (1.51 − 1.71)	1.52 (1.41 − 1.62)
Age Group (12-17 years)	N/A	N/A
18-24 years	0.06 (0.05 −0.08)	0.08 (0.07 − 0.10)
25-34 years	0.09 (0.08 − 0.11)	0.12 (0.11 − 0.14)
35-44 years	0.15 (0.13 − 0.17)	0.19 (0.17 − 0.22)
45-54 years	0.27 (0.24 − 0.30)	0.34 (0.30 − 0.39)
55-64 years	0.42 (0.39 − 0.46)	0.52 (0.47 − 0.57)
65-74 years	0.68 (0.62 − 0.73)	0.76 (0.70 − 0.84)
75+ years	Ref	Ref
Household Income (<$20,000)	Ref	Ref
$20,000 to $39,999	0.69 (0.63 − 0.76)	0.66 (0.60 − 0.74)
$40,000 to $59,999	0.42 (0.38 − 0.46)	0.49 (0.44 − 0.55)
$60,000 to $79,999	0.35 (0.31 − 0.39)	0.48 (0.42 − 0.54)
$80,000 or more	0.22 (0.20 − 0.24)	0.39 (0.35 − 0.44)
Highest Household Education (non-post-secondary)	Ref	Ref
Post-secondary graduate	0.47 (0.44 − 0.50)	0.92 (0.86 − 0.99)
Leisure Physical Activity (Inactive)	Ref	Ref
Active/Moderately Active	1.88 (1.77 − 2.00)	1.40 (1.31 − 1.50)
Alcohol Consumption (Regular)		
Occasional	1.77 (1.63 − 1.91)	1.62 (1.48 − 1.77)
Not in last 12 months	1.60 (1.49 − 1.71)	1.54 (1.42 − 1.68)
Fruit and Vegetable Consumption (<5 services/day)	Ref	Ref
Five (5) or more servings per day	0.82 (0.78 − 0.88)	0.92 (0.85 − 0.99)
Smoker Type (never)	Ref	Ref
Current Smoker	2.11 (1.94 − 2.30)	2.20 (2.00 − 2.42)
Former Smoker	1.98 (1.85 − 2.13)	1.60 (1.47 − 1.73)

OR = odds ratio, CI = confidence interval, N/A = cell count too low to report.

Table 3. Effect modification, covariate interaction, and sub-group model effect estimates for northern residence on multimorbidity prevalence (3+ Conditions): Canadian Community Health Survey, 2013/14.

Interaction / Sub-Group	Level	Adjusted OR for Northern Residence	95% CI
Effect Modifiers			
Sex	Male	0.71*	(0.54 – 0.93)
	Female	1.02	(0.81 – 1.28)
Age Group	12- 29 years	0.63*	(0.39 – 0.99)
	30 – 49 years	1.06	(0.76 – 1.47)
	50 – 64 years	0.73	(0.55 – 0.95)
	≥ 65 years	1.02	(0.70 – 1.49)
Household Income	<$60,000/year	0.88	(0.69 – 1.13)
	$60,000+/year	0.88	(0.70 – 1.12)
Household Education	<Post-Secondary	0.46*	(0.34 – 0.61)
	Post-Secondary Graduate	0.92	(0.76 – 1.12)
Covariate Interactions			
Sex by Age		0.87	(0.73 – 1.04)
Sex by Smoking		0.86	(0.72 – 1.03)
Age by Alcohol		0.88	(0.74 – 1.04)
Age by Income		0.86	(0.72 – 1.03)
Alcohol by Smoking		0.86	(0.72 – 1.03)
Sub-Group Analysis			
Age ≥ 18 years		0.80	(0.50 – 1.27)
Age ≥ 35 years		0.89	(0.59 – 1.35)

OR = odds ratio, CI = confidence interval. *p < 0.05.

Table 4. Sex-specific and modified sex effect model estimates from survey-weighted logistic regression of multimorbidity prevalence (3+ chronic conditions): Canadian Community Health Survey, 2013/14.

Variable / Effect Modifier	Females Adjusted OR (95%CI)	Males Adjusted OR (95%CI)	Female vs Male Adjusted OR (95% CI)
Residence (Provinces)	Ref	Ref	1.51 (1.41 – 1.62]
Territories	0.97 (0.77 – 1.21)	0.74 (0.56 – 0.98)	2.17 (1.54 – 3.05]
Age Group (12-17 years)	N/A	N/A	2.56 (1.61 – 4.05)
18-24 years	0.11 (0.09 – 0.13)	0.06 (0.04 – 0.08)	2.28 (1.65 – 3.15)
25-34 years	0.14 (0.12 – 0.16)	0.10 (0.07 – 0.13)	1.78 (1.33 – 2.37)
35-44 years	0.24 (0.20 – 0.28)	0.14 (0.12 – 0.17)	2.03 (1.65 – 2.49)
45-54 years	0.40 (0.34 – 0.47)	0.27 (0.22 – 0.33)	1.78 (1.46 – 2.18)
55-64 years	0.55 (0.49 – 0.62)	0.47 (0.41 – 0.54)	1.41 (1.24 – 1.59)
65-74 years	0.75 (0.67 – 0.84)	0.77 (0.67 – 0.89)	1.16 (1.02 – 1.31)
75+ years	Ref	Ref	1.18 (1.03 – 1.34)
Household Income (<$20,000)	Ref	Ref	1.54 (1.27 – 1.86)
$20,000 to $39,999	0.66 (0.58 – 0.75)	0.66 (0.54 – 0.82)	1.43 (1.24 – 1.65)
$40,000 to $59,999	0.49 (0.42 – 0.56)	0.50 (0.41 – 0.61)	1.45 (1.26 – 1.66)
$60,000 to $79,999	0.52 (0.44 – 0.61)	0.42 (0.34 – 0.52)	1.88 (1.59 – 2.22)
$80,000 or more	0.37 (0.32 – 0.43)	0.41 (0.33 – 0.50)	1.47 (1.29 – 1.67)
Highest Household Education (non-post-secondary)	Ref	Ref	1.43 (1.28 – 1.59)
Post-secondary graduate	0.94 (0.86 – 1.03)	0.88 (0.78, 0.99)	1.56 (1.43 – 1.70)
Leisure Physical Activity (Inactive)	Ref	Ref	1.44 (1.31 – 1.59)
Active/Moderately Active	1.44 (1.32 – 1.57)	1.35 (1.22 – 1.51)	1.58 (1.44 – 1.74)
Alcohol Consumption (Regular)	Ref	Ref	1.50 (1.38 – 1.64)
Occasional	1.57 (1.42 – 1.74)	1.71 (1.44 – 2.02)	1.44 (1.20 – 1.72)
Not in last 12 months	1.58 (1.42 – 1.76)	1.46 (1.28 – 1.66)	1.61 (1.40 – 1.85)
Fruit and Vegetable Consumption (<5 servings/day)	Ref	Ref	1.35 (1.19 – 1.52)
Five (5) or more servings per day	0.88 (0.80 – 0.95)	1.01 (0.89 – 1.15)	1.62 (1.49 – 1.75)
Smoker Type (never)	Ref	Ref	1.51 (1.32 – 1.74)
Current Smoker	2.33 (2.06 – 2.62)	2.06 (1.75 – 2.43)	1.80 (1.56 – 2.07)
Former Smoker	1.58 (1.42 – 1.75)	1.56 (1.36 – 1.80)	1.39 (1.27 – 1.52)

OR = odds ratio, CI = confidence interval. In the unadjusted models all variables were significant at α = 0.05, N/A = cell count too low to report.
Note: Each effect modification model was run separately and adjusted for all covariates.

Table 5. Propensity score-adjusted analyses of multimorbidity prevalence (3+ Conditions) between Territories and Provinces: Canadian Community Health Survey, 2013/14.

Propensity Score Method	Inverse Probability of Treatment Weights Mean (Min, Max)	Outcome Analysis	PS-Adjusted OR	95% CI
PS Matched (1:10 nearest neighbour with replacement)	1.00 (0.01, 83.45)	Survey-weighted logistic regression of matched sample using scaled matching and survey weights.	1.01[a]	0.86 – 1.20
Weights calculated by logistic regression	1.00 (0.01, 89.24)	Survey-weighted logistic regression with scaled PS and survey weights.	0.83[a]	0.67 – 1.03
	0.93 (0.02, 9.81)	Survey-weighted logistic regression with scaled PS and survey weights, truncated at one percent.	0.82[a]	0.67 – 1.01
Weights calculated by SuperLearner	1.00 (0.01, 120.24)	Survey-weighted logistic regression with scaled PS and survey weights.	0.74[b]	0.58 – 0.95
	0.93 (0.02, 10.10)	Survey-weighted logistic regression with scaled PS and survey weights, truncated at one percent.	0.73[b]	0.57 – 0.93

CI = confidence interval, IPTW = inverse probability of treatment weights, OR = odds ratio, PS = propensity score.
Notes: IPTW defined as 1.0 for territorial residents, and PS/(1-PS) for provincial residents.
[a] adjusted for main effects of covariates.
[b] adjusted for main effects and statistically significant interactions of covariates as determined by the step.interaction algorithm in the SuperLearner library.

household income, and alcohol by smoking, all returned northern residence estimates similar to the main analysis (Table 3). Restricting the analysis to ages ≥ 35 years yielded the same northern residence adjusted OR of 0.88 (95% CI: 0.59–1.35) as the main analysis (aOR = 0.88), as did restricting to ages ≥ 18 years with aOR = 0.80 (95% CI: 0.50–1.27) (Table 3.).

Propensity score analyses

A substantial improvement was observed in covariate balance in the PS-matched sample (all SMD<0.1) compared to the original analytic sample (several SMD>0.25). PS-adjusted effect estimates for residence in territories on odds of multimorbidity varied slightly from the main analysis, depending on PS and outcome analysis methods, although the conclusion from these models did not change (Table 5).

Missing data analysis

Six covariates were subject to multiple imputation leaving an analytic sample of n = 127,230 . After imputation, the covariate-adjusted odds of multimorbidity was significantly lower within territories compared to the provinces (aOR = 0.83; 95% CI: 0.71–0.98) (results not shown).

Discussion

This study hypothesized a higher prevalence of multimorbidity in northern Canada. Instead, lower prevalence of multimorbidity in the territories compared to provinces is apparent, although not statistically significant (Table 2). The matched analysis suggested no difference between territorial and provincial residents. The logistic regression PS analysis confirmed the results from the main analysis (Table 5). The super learner-based PS analysis found a significantly lower prevalence of multimorbidity in territories than provinces, which may be owing to better covariate balance between territories and provinces, although the upper confidence limit was close to null (Table 5). A series of covariate interaction terms, when individually added to the final model, did not alter the main conclusion of no significant difference between territories and provinces (Table 3) The missing data analysis further confirmed the results from the main analysis (results not shown). The results are in relative harmony that there is no difference in the prevalence of multimorbidity between territories and provinces.

To compare our Canadian prevalence estimate of 14% to other circumpolar states we provide a brief selection of prevalence estimates below. In Iceland, multimorbidity (2+ conditions) prevalence was estimated at 35% using primary care data (n = 221,822) [14]. Analysis of a prospective rural northern cohort in Norway identified multimorbidity (2+ conditions) prevalence of 30.8% (n = 20,365)[15]. In Sweden, a study including people ages 77 to 100 years (n = 1,099) found a prevalence of multimorbidity (2+ conditions) of 55%. based on medical records[16]. In Denmark, a cross-sectional study of capital region residents (n = 1,397,173) found a prevalence of multimorbidity (2+ conditions) of 20.6%[17]. These studies used a less strict definition of multimorbidity (2+ conditions) than our study (3+ conditions), which is the most obvious reason our prevalence estimates are lower; other reasons being differences in data source, participants, and conditions considered.

Demographic factors: age and sex

As expected, a strong relationship between age and multimorbidity was observed (Table 2). Finer age groups were retained to produce a more complete picture of the increasing prevalence of multimorbidity with advancing age, as recommended[8]. For females, 52% higher adjusted odds of multimorbidity is consistent with the literature [3,10,11]. Higher age-specific adjusted OR of multimorbidity for females compared to males at younger ages (Table 4) is a novel finding and may be related to higher prevalence of mood and anxiety disorders among females in at those ages in Canada[37]. The finding of lower multimorbidity prevalence among males in territories compared to males in provinces is also a new finding. Similarly, higher adjusted odds ratios for females compared to males in territories than provinces is also a novel finding (Table 4). These findings require more in-depth exploration of specific conditions involved

Socioeconomic status (SES): household income and household education

This study found a linear relationship between increasing income and lower prevalence of multimorbidity after adjusting for other factors (Tables 2 and 4), which agrees with existing research [3,8,11,38]. How income affects multimorbidity is unclear, involving multiple potential pathways [2,9]. One Canadian study suggests that the effect of income inequality can be attributed primarily to income itself, as opposed to the risk factors mentioned previously[3]. Those findings contradict the argument that behind socioeconomic gradients in health are a higher prevalence of risky health behaviours among the poor, such as smoking and alcohol consumption, which are posited as the actual cause of the socioeconomic gradient observed in social epidemiological studies[39].

Behavioural risk factors: smoking, alcohol consumption, and physical activity

Smoking was strongly associated with multimorbidity, whether current or former (Table 2). Physical inactivity, which is generally associated with a higher prevalence of multimorbidity, was related to lower multimorbidity in our study (Table 2). However, only leisure physical activity was examined, which limits the generalizability of these results to leisure physical activity. For alcohol consumption, occasional and abstention (not in the last 12 months) both had higher adjusted odds of multimorbidity when compared to those with regular alcohol consumption (Table 2). This result aligns with an analysis of the Twenty-07 cohort, which also found an increased risk among non-drinkers compared to regular and excess drinkers [40]. Han et al. (2012), noted a lower prevalence of multimorbidity among binge compared to non-binge drinkers age≥50, describing the "sick-quitter" hypothesis and survivor bias as selecting out unhealthy binge drinkers over time, leaving a group of healthy drinkers compared with unhealthy non-drinkers [41], which may be the case in our study.

Strengths and limitations

Previous analyses showing lower but increasing chronic disease prevalence in northern Canada were not adjusted for known risk factors beyond age and sex [18,21,24]. Our results contradict predictions of rising chronic disease among northern populations made in previous studies; however, we did not use a longitudinal design so could not test for trend. We found a higher proportion of the population with 3 + chronic conditions (14%) than Roberts et al. (3.9%) using CCHS data, although they included fewer chronic conditions [12]. Different age inclusion, outcome definition, and analysis methods preclude direct comparison with previous studies. This study has specific strengths, such as the use of a prospective statistical analysis plan [42], with a directed acyclic graph (DAG) to select analysis variables grounded in the literature and a priori assumptions [2,43]. As recommended for multimorbidity prevalence studies [8]: our data source was the general population, more than 12 chronic conditions were considered, fine age bands were employed, and we reported sex-specific results. The application of survey-weighted multivariable logistic regression to a large sample with adjustment for individual risk factors provide a solid foundation for study results. The main analysis conclusion was robust to multiple sensitivity analyses including PS as an alternative method for adjustment for confounding [28]. The super learning approach to PS estimation enabled construction of a better prediction model for the PS [44], with a very low CV-MSE of 0.025 (SE = 0.0004). Multiple imputation demonstrated that the main analysis results were not sensitive to missing covariate data. The low cell count for ages 12–17 in the north with multimorbidity was a concern (Table 2). We conducted a sensitivity analysis removing this age group (Table 3; Sub-Group Analysis), and the conclusion remained unchanged compared to the main analysis. Another limitation is the small cell sizes in northern territories for some covariates.

In addition to standard limitations for cross-sectional health surveys, this study has particular limitations

related to the representativeness of CCHS for territories, related to phone coverage and language[45]. Explicitly, 2% of the Canadian population is not represented in the CCHS, including persons living in First Nations communities; however this number grows in the north[45]. Language barriers may create selection bias in a study of multimorbidity, which generally occurs among older persons, particularly among northern residents, whose elders may be more likely to speak Indigenous languages not used by CCHS interviewers[25]. Moreover, access to physicians to diagnose conditions may also create a case-ascertainment bias where those in provinces are more likely to be diagnosed with a condition. We could not address these problems analytically so results must be interpreted with caution. Finally, because prevalence measures both the incidence and duration of disease, there is a possibility that differences in survival between the territories and the provinces influence our estimates, with known higher age-standardized mortality in the territories[46]. However, for Nunavut the leading cause of death is suicide, which would not be captured by our estimates, and injury also contributes a greater proportion to the causes of mortality in northern territories [46,47]. How different mortality patterns may affect multimorbidity estimates was beyond the scope of our project, but should be considered in future research.

Conclusion

This study found a prevalence of multimorbidity (3 + conditions) of 14% in Canada (over 3.7 M people). Northern Canada did not have a higher prevalence of multimorbidity than the provinces in our main analysis, which was confirmed through multiple sensitivity analyses. However, lower prevalence of multimorbidity in the territories compared to provinces among those in households with less than post-secondary education, males, and youth are novel findings.

Other circumpolar states expecting an epidemiological transition to chronic disease in their northern-most populations may find these estimates and our methodology of interest. While multimorbidity prevalence estimates are not directly comparable with other circumpolar countries, given variations in data sources, conditions considered, and definitions of multimorbidity, our methods may be of particular interest to researchers investigating multimorbidity prevalence using survey data. Use of a larger sample by combining several CCHS cycles, and using the confidential CCHS microdata file, including population origin and specific territory, rather than PUMF, would enrich future analyses based on our preliminary findings.

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