Diabetes and Adverse Outcomes in a First Nations Population: Associations With Healthcare Access, and Socioeconomic and Geographical Factors

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ABSTRACT

OBJECTIVE

For Aboriginal on-reserve First Nations populations of Manitoba, Canada, this study explores (i) diabetes and amputation patterns; and (ii) their ecologic associations with geography, income and access to healthcare.

RESEARCH DESIGN AND METHODS

De-identified administrative claims data in the Population Health Research Data Repository were linked to federal Status Verification System files for 1995 to 1999 (n=48 036 First Nations; 1 054 422 other Manitobans). Directly standardized rates were determined for ages 20 to 79 using International Classification of Diseases, 9th Revision, Clinical Modification codings: (i) *treatment prevalence of diabetes*, using physician and hospital billing claims with diagnosis 250; (ii) *lower limb amputation with diabetes comorbidity* (diagnosis 250) using hospitalization procedure codes 84.40 and 84.45 to 84.48. Ecologic correlations at the tribal council level, consisting of 9 First Nations on-reserve groupings, examined associations of diabetes indicators, average household income

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RÉSUMÉ

OBJECTIF

Cette étude, menée chez des Autochtones des Premières nations qui habitent dans une réserve du Manitoba, au Canada, explore (i) le diabète et l'amputation et (ii) leur association écologique à la géographie, au revenu et à l'accès aux soins de santé.

PLAN ET MÉTHODES

On a fait un rapprochement entre les données sur les demandes administratives dépersonnalisées tirées du registre *Population Health Research Data Repository* du Manitoba et celles du registre fédéral des Premières nations *Status Verification System* des années 1995 à 1999 (n = 48 036 Autochtones; 1 054 422 autres Manitobains). Des taux directement normalisés ont été déterminés pour les personnes de 20 à 79 ans à partir des codes de la Classification internationale des mala-dies (*International Classification of Diseases, 9th Revision, Clinical Modification* [ICD-9-CM]) : (i) *traitement et prévalence du diabète* à partir des factures des médecins et des hôpitaux et du diagnostic 250; (ii) *amputation d'un membre inférieur chez une personne diabétique* (diagnostic 250) à partir des codes d'intervention des hôpitaux 84.40 et 84.45 à 84.48. Les corrélations écologiques au niveau du Conseil tribal, composé de neuf groupes d'Autochtones des Premières nations, ont porté sur les liens entre les indicateurs du diabète, le revenu familial moyen (recensement de 1996 de Statistique Canada), les taux de consultation ambulatoire et la géographie (nord vs sud).

RÉSULTATS

La comparaison entre les Autochtones des Premières nations et les autres Manitobains a révélé que la fréquence du diabète (203 par rapport à 45 pour 1000) et des amputations (3,39

(1996 Statistics Canada census), ambulatory consult rates and geography (north vs. south).

RESULTS

Comparing First Nations with other Manitobans, rates of diabetes (203 vs. 45 per thousand) and amputation (3.39 vs. 0.19 per thousand) were higher. For on-reserve First Nations, diabetes varied by tribal council (149 to 249 per thousand) and was associated with income (r=–0.82, p=0.007) and geography (north 186.8, south 227.9, p<0.04), but not consult rates. First Nations amputation rates varied by tribal council (1.19 to 6.16 per thousand) and were associated with consult rates (r=–0.73, p=0.025), but not with income or geography.

CONCLUSION

Among First Nations, diabetes prevalence is associated with socioeconomic (income) and geographic gradients, whereas the adverse outcome of amputation is associated with healthcare access (consult rates). Even within universally insured industrialized countries, First Nations barriers to healthcare must be addressed.

KEYWORDS

Aboriginal, diabetes complications, First Nations, health inequalities, health services research, health status indicators, primary care, specialist care

par rapport à 0,19 pour 1000) était plus éleves chez les Autochtones. Chez les Autochtones habitant dans une réserve, la fréquence du diabète variait d'un Conseil tribal à l'autre (149 à 249 pour 1000) et était associée au revenu (r = -0,82; p = 0,007) et à la géographie (nord : 186,8; sud : 227,9; p < 0,04), mais ne variait pas en fonction des taux de consultation. Les taux d'amputation chez les Autochtones variaient d'un Conseil tribal à l'autre (1,19 à 6,16 pour 1000) et étaient associés aux taux de consultation (r = -0,73; p = 0,025), mais non au revenu ni à la géographie.

CONCLUSION

Chez les Autochtones des Premières nations, la prévalence du diabète est associée à des facteurs socio-économiques (revenu) et géographiques, tandis que les amputations sont associées au manque d'accès aux soins de santé (taux de consultation). Même dans les pays industrialisés où l'assurance est universelle, les problèmes d'accès aux soins de santé des Autochtones doivent être réglés.

MOTS CLÉS

Autochtones, complications du diabète, Premières nations, inégalités dans le domaine de la santé, recherche sur les services de santé, indicateurs de l'état de santé, soins primaires, soins de spécialistes

INTRODUCTION

Inequalities in health status of Aboriginal peoples are well documented throughout the world (1) and are also mirrored in population-based comparisons in the province of Manitoba, Canada. Manitoba First Nations people have a life expectancy that is 8 years lower than other Manitobans, both for males (68.4 vs. 76.1 years) and females (73.2 vs. 81.4 years) (2). One of the major health concerns of Canadian First Nations people is type 2 diabetes (also known as adult-onset or non-insulin-dependent diabetes mellitus). The complications of type 2 diabetes can include ischemic heart disease and stroke; nephropathy leading to renal failure; retinopathy leading to blindness; and neuropathy leading to foot ulcers, infections, gangrene and, potentially, limb amputations. Amputation of a lower limb is heavily associated with diabetes; patients with diabetes have 10 times the risk compared to those without diabetes (3). However, other factors associated with amputation include hypertension, heart disease, smoking and low income (possibly through delayed diagnosis or lack of access to adequate care) (3-5). There is conflicting information about the contribution of smoking to amputation, with 1 study showing that smoking is contributory only for people without diabetes (6). Models of care have been related to lower amputation rates, with 1 cross-sectional study showing lower rates associated with better programmatic coordination of care (electronic medical records, policies, protocols, educational seminars and reminders) and feedback (for example, quality of care initiatives for healthcare providers and discharge planning) (7).

Research (4-9) shows that Canadian First Nations people are at much higher risk for type 2 diabetes and its risk factors than the overall Canadian adult population (15 vs. 5%, respectively) (8-13). Moreover, provincial costing estimates demonstrate that type 2 diabetes accounted for 18% of the total health budget a decade ago in the 1995/1996 fiscal year, with costs expected to escalate as prevalence increases (14). Previous studies have identified a north/south gradient in diabetes prevalence for First Nations in Canada, attributable mostly to acculturation and length of contact with Western influences (15,16).

Given the importance of understanding the epidemiology of diabetes in First Nations people of Manitoba, the purpose of this paper is: (a) to describe the prevalence of diabetes and the rates of lower limb amputation with diabetes comorbidity in Manitoba First Nations tribal councils and for other Manitobans overall; and (b) to determine "within First Nations" ecologic associations of diabetes indicators with measures of income, access to specialist care and geography. Ecologic (or ecological) studies are those in which the units

of analysis are groups of people or populations rather than individuals. Caution must be taken with any ecologic study, since an association observed between variables at the group or population level may not necessarily hold true at the individual level. Knowing that ecologic studies are hypothesis-generating, this study is not intended to imply causation. Rather, the findings are proposed to spur further person-based studies with methods that have stronger internal validity (that is, more likely to point out causal relationships rather than simply associations).

The Manitoba context

The province of Manitoba is centrally located in Canada's prairie region. In the 1996 census, 11.7% of the province's 1.14 million people were Aboriginal, the highest percentage of any Canadian province (17). The Canadian Constitution Act, 1982, recognizes 3 Aboriginal groups in Canada: First Nations (sometimes referred to as Native American or Indian), Inuit (northern Aboriginal people) and Métis (distinct Aboriginal people of mixed heritage—First Nations and European—who also associate themselves with a distinctive culture). Of Aboriginal Manitobans, 63.5% are Registered First Nations, 4.0% are Non-Registered First Nations, 31.9% are Métis and 0.6% are Inuit/Other (0.6%) (18). "Registered" (also called "Status") refers to First Nations people entitled to treaty rights under Canada's Indian Act, and thus registered as a member of a band community governed by the elected chief and band councillors. Provincially, 58% of Registered First Nations people live "on-reserve" (i.e. in a band community), but this proportion is higher in the north (83%) (17). In June 2001, there were 62 First Nations communities in Manitoba, 54 of these affiliated with 1 of the 7 tribal councils (ranging from 4 to 11 communities each) and 8 being independent or unaffiliated.

Most Manitobans reside in the southern part of the province, including over half (643 789) in Winnipeg, the provincial capital. As well, tertiary care hospitals and specialist physicians are located mainly in the south, with the majority in Winnipeg. Only 6% of Manitobans live in the north; in contrast, 39% of Registered First Nations people live in the north (18). The northern part of the province has many remote communities accessible only by airplane or winter road.

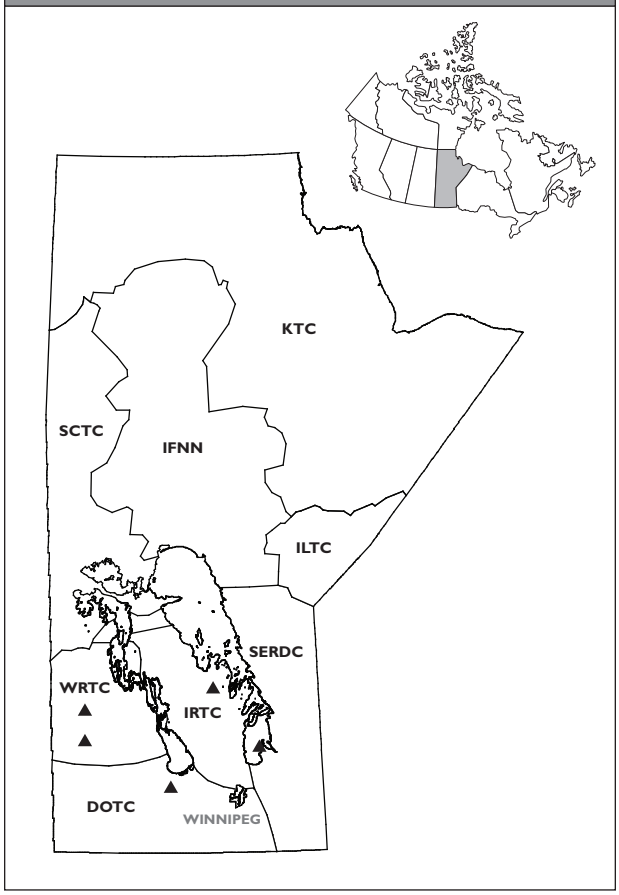
RESEARCH DESIGN AND METHODS

Geographical regions and population counts

In this study, diabetes-related indicators are compared by the 9 tribal council areas (see Figure 1 for location and population size—7 political tribal council geographical areas, plus 2 virtual tribal council areas: "Independent First Nations North" (a contingent geographical area of 3 northern independent/unaffiliated First Nations band communities); and "Independent First Nations South" (a non-contingent virtual "area" of 5 First Nations communities found within other southern tribal council geographical boundaries) (see Figure 1). In all tables, these areas are ordered to represent north vs. south as determined generally by the 53rd parallel of latitude, with the 4 northern tribal council areas (Keewatin Tribal Council, Independent First Nations North, Swampy Cree Tribal Council, Island Lake Tribal Council) listed first, followed by the 5 southern areas.

As determined by matching individual band-affiliation postal code with residential postal code, Registered First Nations people living in or near their band-affiliated First Nations community were assigned to that particular community (i.e. a proxy for "on-reserve") and hence to a larger

Figure 1. Map of the province of Manitoba (Canada) showing the tribal council areas as of June 2001 and the provincial capital city of Winnipeg



▲ = the 5 non-contingent First Nations Communities in the virtual Independent First Nations South tribal council area (n=4262)
*All n = represent the population as of December 31, 1998
DOTC = Dakota Ojibway Tribal Council (n=5227*)
IFNN = Independent First Nations North (n=9187)
ILTC = Island Lake Tribal Council (n=5568)
IRTC = Interlake Reserves Tribal Council (n=4155)
KTC = Keewatin Tribal Council (n=6982)
SCTC = Swampy Cree Tribal Council (n=6285)
SERDC = South-East Resource Development Council (n=3646)
WRTC = West Region Tribal Council (n=2724)

geographical tribal council area. All healthcare use was attributed back to the tribal council area where the person resided, regardless of where the service took place.

Sources of data for the research

The Population Health Research Data Repository (housed at the Manitoba Centre for Health Policy [MCHP] at the University of Manitoba) contains de-identified records for physician and hospital billing claims in the universal-coverage provincial healthcare system. The federal department of Indian and Northern Affairs Canada (INAC) maintains the Status Verification System (SVS) files of all Registered First Nations for purposes of entitlements. After receiving permission from INAC, as well as the Assembly of Manitoba Chiefs, the First Nations and Inuit Health Branch of Health Canada and Manitoba Health, a de-identified linkage between the SVS files and the repository was created for the years 1995 to 1999. Details on the linkage have been reported elsewhere (19). Ethical approval was obtained from the University of Manitoba's Faculty of Medicine Research Ethics Board.

Diabetes indicators, health/health service indicators and statistical considerations

In this study, determination of diabetes prevalence is based solely on physician and hospital billing claims, rather than on diabetes surveillance registries. It is really physician-diagnosed diabetes prevalence—i.e. the diagnosis relies upon contact with the healthcare system. This does not include those who have diabetes but have not obtained a diagnosis in the administrative claims data used for the study. If within 3 years a person had at least 2 ambulatory visits to physicians primarily for diabetes (International Classification of Diseases, 9th Revisions, Clinical Modification [ICD-9-CM] 250), or at least 1 hospitalization with a diagnostic coding for diabetes, the person was considered a diabetes case (this definition excludes gestational diabetes, which is coded 648.8). This definition has been validated using self-reported diabetes in a First Nations survey (19), with 76.0% sensitivity, 91.9% specificity and a moderate to substantial agreement as shown by a kappa reliability score of 0.6038. This definition has also been validated for the entire population of Manitoba using the Canadian Community Health Survey linked to the repository housed at the MCHP, with a sensitivity of 84.9% and specificity of 99.0% (20). The rate of lower limb amputation with diabetes comorbidity was calculated as the rate per thousand population (including people with and without diabetes). This was defined as hospitalization for a lower limb amputation (ICD-9-CM 84.40 or 84.45 to 84.48 present in any procedure field) where the ICD-9-CM diagnosis was 250 in any diagnostic field (i.e. diabetes comorbidity). Excluded were those records where amputation resulted from accidental injury and records of those who were being fitted with a prosthesis. To obtain a stable rate, 5 years of data were required (1994/95 to 1998/99). Both diabetes indicators were directly standardized (age and sex) to the 1996 Manitoba population and included only those aged 20 to 79 years.

A second means of calculating this indicator was considered: taking the amputation rate per diabetes case. However, knowing that the diabetes prevalence could be somewhat biased through undercounting (see subsequent description of salaried physician and nurse practitioner service provision), whereas the amputation rates would not be undercounted because they were in-hospital services, the overestimation of amputation rates in areas at greater risk of undercounting would have been possible. Thus, the population-based amputation rate was deemed preferable to a diabetes-based rate. To ensure face validity of this choice, correlations were also reported for diabetes-based amputation rates in the table footnotes, with statistically significant findings similar to those derived from population-based rates.

Ecologic-level correlations (i.e. by the 9 tribal council areas) were performed between the 2 diabetes indicators and 3 other measures: a socioeconomic indicator (average household income); access to health services (consults to specialist care); and a geographical measure (north vs. south). Average household income, derived from the Statistics Canada 1996 Census (21), is based on the sum of all incomes of persons who live within the same dwelling, regardless of their relationship to one another.

As an indicator of access to healthcare services, the ambulatory (i.e. nonhospitalized) consult visit rate was used. A consult occurs when a client is referred by 1 physician to another because of the complexity, obscurity or seriousness of a patient's illness, or because of a request for a second opinion, with the majority of consults being provided by specialists. This is considered the best overall indicator of access to specialist care (22), rather than the overall specialist visit rate, which is highly dependent on differing patterns for urban vs. rural residents with respect to the way specialists are used in Manitoba (23). Using the repository claims data, general practitioner visit rates are underestimated for the north. Many northern communities employ salaried (rather than fee-for-service) physicians, and it has been estimated that the repository claims data includes only about 80% of those visits (23). Moreover, many northern communities rely on nurse practitioners for primary care, and these visits are not captured in the repository. In contrast, virtually all specialist visits are recorded in administrative claims data; thus, a consult rate is considered a more valid measure of healthcare services access for this particular ecologic study.

Rates were age- and sex-adjusted to the Manitoba population at December 31, 1996, using the direct method of standardization. Statistical comparison tests of age- and sex-standardized rates/prevalence used Hotelling's T^2 statistic as described by Carriere and Roos (24), with appropriate confidence limits to maintain an acceptable overall type I error of 0.05 when doing multiple comparisons. Data management, programming and analyses were performed using SAS

Table 1. Tribal council area diabetes prevalence, amputation rates, average household income and consult rates, including correlations with diabetes indicators, for on-reserve Registered First Nations in Manitoba

	Age- and sex-standardized diabetes prevalence, per 1000 1996/97–1998/99	*Age- and sex-standardized annual lower limb amputation rates per 1000, 1994/95–1998/99*	*Average household income, 1996, $*	*Age- and sex-standardized ambulatory consult rate (visits per person per year), 1998/99*
Keewatin Tribal Council	149*	1.37	30 730	0.303
Independent First Nations North	173*	2.20	31 842	0.277
Swampy Cree Tribal Council	205	5.03	29 891	0.259
Island Lake Tribal Council	220	3.77	28 132	0.323
South-East Resource Development Council	219	5.07	24 428	0.276
West Region Tribal Council	231*	3.85	22 607	0.277
Interlake Reserves Tribal Council	207	3.95	22 751	0.272
Independent First Nations South	234*	1.19	23 719	0.312
Dakota Ojibway Tribal Council	249*	6.16*	20 503	0.208
Correlations†				
Age- and sex-standardized diabetes prevalence, 1996/97–1998/99	–	0.55 (p=0.12, NS)	–0.82* (p=0.007)	–0.34 (p=0.37, NS)
Age- and sex-standardized lower limb amputation with diabetes comorbidity,‡ 1994/95–1998/99	–	–	–0.45 (p=0.22, NS)	–0.73* (p=0.025)

*Statistically significant (i.e. $p<0.05$). In the case of diabetes prevalence and amputation rates, * means statistically different than the overall Manitoba on-reserve value, which is 203 per thousand for diabetes, 3.39 per thousand for amputation.

†Pearson's correlation, 2-tailed, 7 df (for the 9 tribal council areas).

‡Amputation rate correlations using a denominator of number of diabetes cases (not the population) did not change statistical significance (i.e. whether the relationship was significant or nonsignificant). Correlations were as follows: income, r=–0.28, p=0.47, NS; consult rates, r=–0.70, p=0.04*; diabetes, r=0.37, p=0.32, NS.

NS = not significant

software (SAS Institute Inc., Cary, North Carolina, United States). Two-tailed Pearson's correlation tests and unpaired 2-tailed t tests were used for ecologic associations, since all variables conformed to test assumptions.

RESULTS

Diabetes prevalence

The overall age- and sex-adjusted diabetes prevalence for Manitoba Registered First Nations people living on-reserve was 203 per thousand (i.e. 20.3% of the population aged 20 to 79). The crude, unadjusted rate was 150 per thousand, translating to 3582 people with diabetes out of a total Registered First Nations population of 23 844. Age- and sex-adjusted diabetes prevalence varied from 149 per thousand in Keewatin Tribal Council to 249 per thousand in the southern Dakota Ojibway Tribal Council (Table 1). Overall prevalence for all other Manitobans (i.e. all Manitobans who were not classified as Registered First Nations) was 45 per thousand (4.5%), less than one-quarter of the prevalence of on-reserve Registered First Nations. As illustrated in Tables 1 and 2, diabetes prevalence was highly associated with income (r=–0.82, p=0.007) and geography, with prevalence in the north being lower than in the south (186.8 vs. 227.9 per thousand, respectively; p=0.038).

Table 2. Tribal council area values of income, consult rates and diabetes indicators comparing north and south areas for on-reserve Registered First Nations in Manitoba*

	North tribal council areas (SD)	*South tribal council areas (SD)*	*Test of difference between north and south†*
Average household income, 1996, $	30 149 (1564)	22 801 (1484)	T=7.2 p=0.0002‡
Age- and sex-standardized ambulatory consult rate (visits per person per year), 1998/99	0.29 (0.03)	0.27 (0.04)	T=0.94 p=0.38, NS
Age- and sex-standardized diabetes prevalence per thousand, 1996/97 to 1998/99	186.8 (31.6)	227.9 (16.1)	T=–2.55 p=0.038‡
Age- and sex-standardized lower-limb amputation with diabetes comorbidity§ per thousand, 1994/95 to 1998/99	3.09 (1.63)	4.05 (1.85)	T=–0.82 p=0.44, NS

*North includes the tribal council areas of Keewatin Tribal Council, Independent First Nations North, Swampy Cree Tribal Council, and Island Lake Tribal Council. South includes South-East Resource Development Council, West Region Tribal Council, Interlake Reserves Tribal Council, Independent First Nations South and Dakota Ojibway Tribal Council.

†Unpaired 2-tailed t tests, 7 df.

‡Statistically significant (i.e. p<0.05).

§Using a denominator of number of diabetes cases (not the population) did not change statistical significance (i.e. whether the relationship was significant or nonsignificant). T-test results were as follows: north=15.9 (SD 6.6), south=17.8 (SD 7.8); t=–0.38, p=0.71, NS.

NS = not significant
SD = standard deviation

Rate of lower-limb amputation with diabetes comorbidity

The overall age- and sex-adjusted rate of lower limb amputation with diabetes comorbidity (herein referred to as "amputation") among on-reserve Registered First Nations people aged 20 to 79 years was 3.39 per thousand, varying from 1.19 in Independent First Nations South to 6.16 in Dakota Ojibway Tribal Council (see Table 1). The crude, unadjusted rate was 2.02 per thousand, translating into 234 amputations out of a total of 116 071 Registered First Nations people over the 5 year period. There was no significant difference between rates in the north compared to the south (see Table 2). The age- and sex-adjusted rate of amputations for Registered First Nations living on-reserve was approximately 18 times higher than for all other Manitobans (3.39 vs. 0.19 per thousand).

Correlations of diabetes indicators with average household income and consult rates

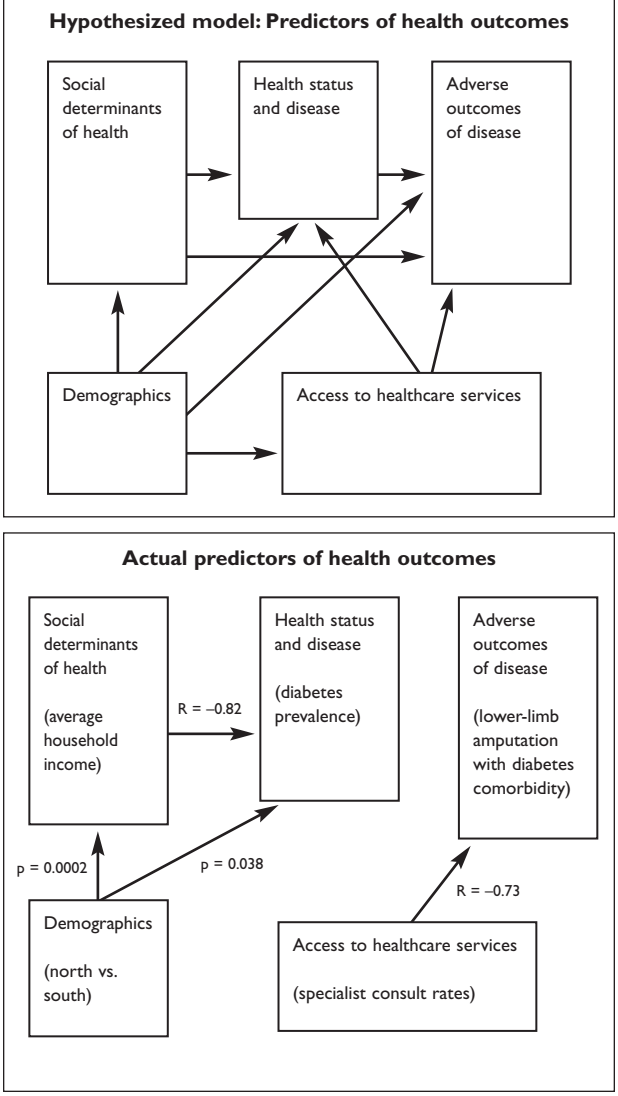
As illustrated in Table 1, there was a significant negative relationship (r=–0.82, 7 df, p=0.007) between diabetes prevalence and average household income: the higher the income of the tribal council area, the lower the diabetes prevalence. However, the relationship was not statistically significant between amputation rates and income (r=–0.45, 7 df, p=0.22, NS). Consult rates were not associated with diabetes prevalence (r=–0.34, 7 df, p=0.37, NS), but there was a strong negative relationship with amputation rates (r=–0.73, 7 df, p=0.025), where regions with lower consult rates showed higher amputation rates. The north had lower diabetes prevalence and higher average household income, but similar amputation and consult rates compared with the south (Table 1, Table 2).

DISCUSSION

This study had 2 objectives: namely, to determine prevalence of diabetes and rates of lower limb amputation with diabetes comorbidity, and to determine associations between these 2 outcomes and various determinants of health and healthcare access. For the second objective, the limitations of using ecologic data must be underscored. Aggregate group rates, not individual outcomes, have been used to calculate the hypothesized associations, and therefore extreme caution must be exercised in making statements that imply that 1 variable caused another variable in the model. Moreover, unmeasurable variables such as smoking rates, hypertension rates or heart disease were not included.

The extremely elevated prevalence of diabetes within First Nations populations has been previously documented. Studies report the prevalence in Aboriginal populations to be 2 to 5 times higher than for non-Aboriginals (16,25,26). Very few studies provide a population rate of amputation, but Ephraim and colleagues (27) found that all-cause amputation

Figure 2. Hypothesized and actual determinants of disease and adverse outcomes model, with observed ecologic correlations using Manitoba tribal council areas of on-reserve Registered First Nations populations*



*Solid lines in the "Actual Predictors" model indicate a statistically significant correlation coefficient "r" at $p<0.05$ using ecologic associations with data from the 9 tribal council area levels. For measures of geography (north vs. south), p values are shown since these are derived from t-tests, not correlations.

rates ranged from 0.12 per thousand for Japanese women up to 0.44 per thousand for United States Navajo men, with elevated rates for people with diabetes. Thus, it is not surprising in this study to find over 4-fold differences in diabetes prevalence between on-reserve Registered First Nations and all other Manitobans (203 vs. 45 per thousand). However, 4 times the population prevalence of diabetes could potentially translate into a 4-fold difference in population-based amputation rates, assuming similar risk factors (such as smoking or hypertension rates) in the 2 populations. Even given variation in smoking and heart-related conditions, diabetes is one of the largest risk factors for amputation (3). The 18-fold difference (3.39 vs. 0.19 per thousand) is extremely high and may indicate potentially earlier onset or more severe type 2 diabetes in First Nations populations, or possibly less self-regulation of diabetes or less coordinated primary care monitoring.

The compelling aspect of this study is the observed differences among on-reserve First Nations groups within Manitoba and the associations of diabetes and amputation with such variables as income, geography and access to specialist care services in this supposedly homogeneous group. Reported differences often focus on Aboriginal vs. non-Aboriginal comparisons, yet this study lends itself to a first look at variations among First Nations living on-reserve and the underlying relationships to determinants of health. However, knowing the limitations of a small ecologic study such as this, it must be underscored that these are simply hypothesis-generating associations requiring further study.

A model of the associations and interrelationships of diabetes outcomes with determinants of health is shown in Figure 2. First, the hypothesized model is displayed, followed by the findings of the current study for on-reserve Registered First Nations. For Manitoba tribal council areas, significant correlations (explaining more than half the variance) exist between the following: (i) geography (north vs. south) and disease (diabetes prevalence); (ii) income and disease (diabetes prevalence); and (iii) access to specialist care (consult rates) and adverse outcomes of a disease (amputation rates).

What factors could potentially explain the association of geography and diabetes prevalence, with the south experiencing higher rates? Previous studies have pointed to the strong association between diabetes prevalence and acculturation, with higher prevalence among First Nations people living in eastern and southern regions of Canada (16). Others have argued that duration of contact with Western influences alone is an insufficient explanation for these gradients, suggesting that the intergenerational effects of colonization play an important role. Colonization serves to disrupt an individual's sense of continuity with his or her cultural traditions and has been shown to be strongly associated with poor health and youth suicide in First Nations communities in British Columbia (28,29). In addition to a greater loss of cultural activities, less access to traditional foods and less physical work activities, colonization could lead to greater experience of chronic psychosocial stress and, hence, greater risk for type 2 diabetes (30,31).

Within tribal council areas, higher average household income is associated with lower diabetes prevalence, demonstrating the importance of social determinants of health underscored in literature-based explanations of health status gradients (32,33). Given the constraints of this study and its

small sample size, it is impossible to untangle the unique effects of geography and income (the north has higher incomes, and both are related to lower diabetes prevalence), but it is important to note that the inverse relationship of income and diabetes is actually stronger than that between geography and diabetes. Continued efforts at reducing economic disparities must be supported.

Interestingly enough, neither geography nor income is associated with amputation rates, the adverse outcome of disease. Rather, amputation rates are inversely associated with access to specialist care; those tribal council areas with lower consult rates also experienced higher amputation rates. One limitation of the current study is the use of a consult rate as a surrogate for overall access to healthcare. This is in no way intended to imply that specialists are required for care—rather, the limitations of using administrative claims data meant that the best indicator or surrogate of access to healthcare was the consult rate (given the problems of undercounting primary care from nurse practitioners and some salaried physicians). If the consult rate is indeed a surrogate for different models of service provision or barriers to receiving services in various geographical locations, application of successful models of care must be adopted to reduce the disparities in healthcare service provision.

Under a supposedly universal healthcare system in Canada, it is troublesome to think that people who may be in need of care may not be able to access it. The intuitive guess would be that the most remote, northern, isolated First Nations communities would have difficulties accessing appropriate care. In Manitoba, this is not necessarily the case; it may be more related to models of health service provision, which can vary substantially throughout the province. Effective linkages with urban centres were advocated by the 2001 Romanow Commission (34), echoing similar recommendations in the 1965 Hall Commission (35), which established the foundation for Canada's universal healthcare system. Specific to the latter study, the J.A. Hildes Northern Medical Unit of the University of Manitoba, founded in 1970, established a system of integrating community-based health providers, visiting medical specialists and urban tertiary care supports under contractual agreements. The outcome of the formal linkages is reflected by higher consult rates than expected in selected remote areas (Keewatin Tribal Council 0.30 consult visits per person per year; Island Lake Tribal Council 0.32), and lower rates in the southern tribal council of Dakota Ojibway Tribal Council (0.21) despite proximity to urban-based specialists.

What are the barriers in the south? Are people not being referred to specialist care, or are they unable to find transportation to urban specialists? Are they hesitant to use a medical system that may not be as "in tune" with the needs of First Nations people as the system in the north (where the majority of clients are First Nations people)? Or has federal policy, through the FNIHB Health Transfer Policy, directly influenced access to services and models of care? FNIHB has transferred health services to local control to some degree in the majority of southern First Nation communities, whereas FNIHB maintains responsibility for primary care services in the majority of Keewatin Tribal Council and other northern communities. In the north, nurses are the primary caregivers working in an extended scope of practice, and client care is centrally coordinated by nurses working within interdisciplinary teams. In contrast, transferred communities in the south often work within a public health model: the community health nurse does not work as the primary caregiver and is not responsible for ongoing coordination of primary and secondary care, but rather works with limited scope of practice and professional autonomy. These healthcare model differences could potentially affect access to and coordination of diabetes treatment.

This ecologic study points to the necessity of further research to understand barriers and propose models of care or policy that are causally related to better health outcomes. Further studies could incorporate methodologies similar to qualitative continuity of care research in northern Ontario First Nations communities (36) and quantitative assessments (7) in which standardized tools assess the primary care protocols, policies and management information systems that are related to better outcomes. Study designs to assess causation should be considered at the onset of program or policy interventions.

Models that include the social determinants of health remind us of the importance of underlying social conditions and their effects on health outcomes. However, the fact that a serious adverse effect of diabetes such as lower-limb amputation is not correlated with income but rather with access to health service care brings us back to the importance of an accessible healthcare system as a basic determinant of adverse outcomes, even in a supposedly industrialized nation with universal healthcare insurance such as Canada.

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AUTHOR CONTRIBUTIONS

PJM was principal investigator, overseeing the conceptualization and design of the study, data acquisition, and analysis and interpretation of the data, as well as being the primary author of the manuscript. JO contributed to the acquisition of data, and MM contributed to the writing of the draft article. BM, JO and MM contributed to the analysis and interpretation of data and to the revision of the draft article for important intellectual content. All authors have seen and approved the final version.

AUTHOR DISCLOSURES

No dualities of interest declared.

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