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Does First Nations ancestry modify the association between gestational diabetes and subsequent diabetes: a historical prospective cohort study among women in Manitoba, Canada

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Abstract

Background Over the past 30 years, the prevalence of diabetes has steadily increased among Canadians, and is particularly evident among First Nations (FN) women. The interplay between FN ancestry, gestational diabetes and the development of subsequent diabetes among mothers remains unclear.

Methods After excluding known pre-existing diabetes, we explored whether FN ancestry may modify the association between gestational diabetes and post-partum diabetes among women in Manitoba (1981–2011) via a historical prospective cohort database study. We analysed administrative data in the Population Health Research Data Repository using Kaplan–Meier survival analysis and Cox proportional hazards regression.

Results Gestational diabetes was diagnosed in 11 906 of 404 736 deliveries (2.9%), 6.7% of FN and 2.2% of non-FN pregnant women ($P < 0.0001$). Post-partum diabetes during ≤ 30 years follow-up was more than three times higher among FN women than among non-FN women ($P < 0.0001$). Diabetes developed in 76.0% of FN and 56.2% of non-FN women with gestational diabetes within the follow-up period. The hazard ratio of gestational diabetes for post-partum diabetes was 10.6 among non-FN women and 5.4 among FN women. Other factors associated with a higher risk of diabetes included lower family income among FN and non-FN women and rural/remote residences among FN women. Among non-FN women, urban residence was associated with a higher risk of diabetes.

Conclusion Gestational diabetes increases post-partum diabetes in FN and non-FN women. FN women had substantially more gestational diabetes or post-partum diabetes than non-FN women, partially due to socio-economic and environmental barriers. Reductions in gestational diabetes and socio-economic inequalities are required to prevent diabetes in women, particularly in FN population.

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Introduction

Type 2 diabetes is one of the fastest growing chronic diseases and is the cause of serious health and economic concerns worldwide [1]. Indigenous people around the world are disproportionally affected by Type 2 diabetes [2]. First Nations (FN) people are the largest Indigenous group in Manitoba [3]. FN women have a higher prevalence of both diabetes and obesity than FN men in rural/remote communities in Manitoba [4].

Gestational diabetes is a condition in which pregnant women without previous diabetes exhibit glucose intolerance during late pregnancy [5,6]. The prevalence of gestational diabetes varies among groups of Indigenous North Americans. Native Americans and Canadian FN women have both been identified as having higher rates of gestational diabetes [7–10]. Results from previous prospective [11,12] and retrospective [13,14] cohorts suggest that

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What's new?

- This historical cohort study examined the impact of gestational diabetes after excluding pre-existing diabetes in mothers who delivered between 1981 and 2011 in Manitoba, Canada.
- First Nations (FN) women had two times more gestational diabetes and were three times more likely to develop post-partum diabetes than non-FN women.
- Post-partum diabetes in both FN and non-FN mothers was affected by gestational diabetes, lower family income and rural residence.
- The relative risk of developing post-partum diabetes in non-FN women was higher than in FN women.
- The findings suggest that reductions in gestational diabetes and socio-economic inequities are required to prevent post-partum diabetes in FN and non-FN women.

gestational diabetes increases the risk for subsequent development of diabetes in mothers. A meta-analysis in 2009 that summarized 20 qualified studies indicated that gestational diabetes may increase the risk of Type 2 diabetes by up to sevenfold compared with those without gestational diabetes after an average of 8.3 years of follow-up [15]. However, gestational diabetes is not easy to distinguish from pre-existing diabetes in population-based database studies. Glucose intolerance detected during early pregnancy may result from pre-existing diabetes. The degree to which FN ancestry may modify the association between gestational diabetes and post-partum diabetes has not been studied in Canada.

To address these knowledge gaps, we conducted a large population-based historical prospective cohort database study using an administrative database that included all pregnancies delivered in hospitals within the province of Manitoba between 1981 and 2011 to explore the impact of gestational diabetes on the development of diabetes after excluding pre-existing diabetes in FN and non-FN women during up to 30 years of follow-up.

Methods

Study design and databases

Since 1970, Manitoba Health has collected a complete standardized obstetric hospital abstract form from all women who give birth in hospitals in the Province. Information from the abstracts was incorporated into the Population Health Research Data Repository (Repository) at the Manitoba Centre for Health Policy (MCHP) in the University of Manitoba. The Repository contains linkable administrative databases, including physician claims, hospital discharge abstracts, vital statistics and pharmaceutical prescriptions of all registered residents in the province using scrambled personal health identification numbers.

Ethics

The Research Ethics Board at the University of Manitoba and the provincial Health Information Privacy Committee approved the study protocol. Permission was obtained from the Health Information Research Governance Committee of the Assembly of Manitoba Chiefs and the Department of Aboriginal and Northern Affairs Canada's National Indian Registry System (IRS) to link the FN identifier in the Status Verification System in the Repository to identify FN women.

Exposures of interest

The primary exposure of interest was gestational diabetes. To avoid confounding the effects of gestational diabetes and pre-existing diabetes on the outcome of incident diabetes after pregnancy, gestational diabetes was defined as a diagnosis of diabetes (through hospital abstract) at $\geq$ 21 weeks of gestation or any first-time incident diagnosis of diabetes (through hospital or physician claims data) at $\geq$ 21 weeks of gestation [16]. Women with a diagnosis of gestational diabetes or any type of diabetes at $\leq$ 20 weeks of gestation were excluded from the study with pre-existing diabetes.

FN status was verified in the database through an approved linkage with the IRS database (99% reliability) for FN people living in Manitoba between 1984 and 2011 [17], and municipal codes (70% reliability) were used for those before 1984 [10]. However, non-status FN and Métis people (representing ~ 30% of total 'Aboriginal' people in the Province) [3] were not identified in the linked file.

Outcomes of interest

Incident diabetes among women was defined as one hospitalization or two physicians' diagnoses of diabetes within a 3–year period [18] following pregnancy. We used the International Classification of Diseases codes (ICD)-10-CA codes after 1 April 2004 or ICD-9-CM code prior to that date on all outpatient physician claims to define gestational diabetes. Outpatient claims are only available at the three-digit level in the Repository. The dataset was unable to differentiate Type 1 diabetes from Type 2 diabetes in women. In an effort to control for the potential confounding effect of Type 1 diabetes, women diagnosed with diabetes prior to pregnancy were excluded from analyses. Women who were not diagnosed with diabetes after pregnancy were censored on the date they left the province, died, conceived a new pregnancy, or the end of the study period, whichever came first.

Secondary factors controlled for in analysis

Hypertension in pregnancy was defined as: any hospitalization or physician visit for essential hypertension in the year prior to birth; or any hospitalization or physician visit for gestational hypertension (including hypertension complicating pregnancy, pre-eclampsia and eclampsia) in the gestation period.

Socio-economic status is available in the Repository at a small-area aggregate level using the Canada Census, and attributed through postal code and municipal code to individuals living within the small areas. Income quintiles (five groupings of 20% of the population each) were defined as described previously [18]. Rural or urban residence was identified from postal codes.

Statistical methods

Differences in the proportion of pregnancies with a gestational diabetes diagnosis were determined using Fisher exact tests. Kaplan–Meier survival analysis was used to calculate the cumulative incidence rate for diabetes after delivery. Risk factors associated with diabetes after delivery were assessed using a Cox proportional hazards regression model. Multiple deliveries per woman were accounted for with a frailty parameter. All analyses were performed using SAS© v. 9.3.

Results

Descriptive background

We identified 404 736 deliveries with a live birth from 214 028 women who delivered in hospitals in Manitoba between 1 April 1981 and 31 March 2011 (Fig. 1). Among FN women, nearly three-quarters of the deliveries (70.5%) were to women who resided in rural or remote communities (Table 1). FN women were 3.3 times more likely than non-FN women to be from families in the lowest income quintile in the Province (60.0% vs. 17.9%). FN women were four times more likely to develop diabetes during up to 30 years of follow-up after delivery than non-FN women (14.2% vs. 3.5%). In total, 2.9% of pregnancies (n = 11 906) were complicated with gestational diabetes, which did not include the 6141 deliveries from women with pre-existing diabetes. FN women had three times more gestational diabetes than non-FN women (6.7% vs. 2.2%, Table 1). Women with pre-existing diabetes were excluded from the study.

Descriptive background by gestational diabetes diagnosis

A pregnancy complicated by gestational diabetes was nearly 0.63 and 0.79 times more likely to have Caesarean section among FN or non-FN women, respectively, compared with those without gestational diabetes (Table 2). Women with gestational diabetes were more likely to be in the lowest income quintile compared with those without gestational diabetes (65.5% vs. 59.9% in FN, 21.9% vs. 17.8% in non-FN, $P < 0.0001$). Although FN women had more gestational diabetes than non-FN women, the relative increase in diabetes subsequent to delivery (gestational diabetes vs. non-gestational diabetes) in non-FN women (27.6% vs. 3.0%) was 2.41 times of that in FN women (45.5% vs. 11.9%, $P < 0.0001$).

Associations between gestational diabetes, FN status and Type 2 diabetes

In pooled Cox proportional hazards analysis (data not shown), we found that the hazard radio (HR) of gestational diabetes for the development of subsequent diabetes was 7.97 [95% confidence interval (CI) 7.58 to 8.38], whereas the HR of FN status was 3.51 (95% CI 3.34 to 3.70). When exploring the impact of gestational diabetes and FN status on Type 2 diabetes among women, significant interactions between gestational diabetes and FN were detected ($P < 0.0001$) using the Cox proportional hazards model. This indicates that the association between gestational diabetes and subsequent Type 2 diabetes may differ, depending on whether the woman is of FN ancestry or not. We therefore stratified our survival analysis and Cox proportional hazards model by FN status (Fig. 2, Table 3). The per cent of accumulated incidence of diabetes in non-FN women with gestational diabetes was 16.5% at 5 years after delivery compared with 0.4% among those without gestational diabetes ($P < 0.0001$). Among FN women, 22.2% with gestational diabetes had developed diabetes by 5 years after delivery compared with 1.5% among those without gestational diabetes ($P < 0.0001$). At 10 years after delivery, the incidence of diabetes among FN women with gestational diabetes was 47.2% compared with 5.5% among those without gestational diabetes ($P < 0.0001$). The trend for an increased incidence of diabetes among women with gestational diabetes was sustained and remained significant at 10–25 years following their first pregnancy in the cohort. Diabetes was estimated to develop in 76.0% of FN women and 56.2% of non-FN women who had gestational diabetes within 25 years after pregnancy ($P < 0.0001$), which is 2.46 and 6.46 times higher than the risk of diabetes among FN or non-FN women without gestational diabetes (30.9% and 8.7%). Regardless of gestational diabetes status, the cumulative incidence of diabetes among FN women was higher than that among non-FN women at all time points (Fig. 2). The patterns of the survival curves for the development of diabetes after the second, third and fourth pregnancies were similar to that after the first pregnancy (data not shown).

In multivariate survival analyses (Cox proportional hazards model, Table 3), the association between gestational diabetes and subsequent diabetes was stronger among non-FN women (HR 10.61) than among FN women (HR 5.36) ($P < 0.0001$, assessed through model with interaction). In

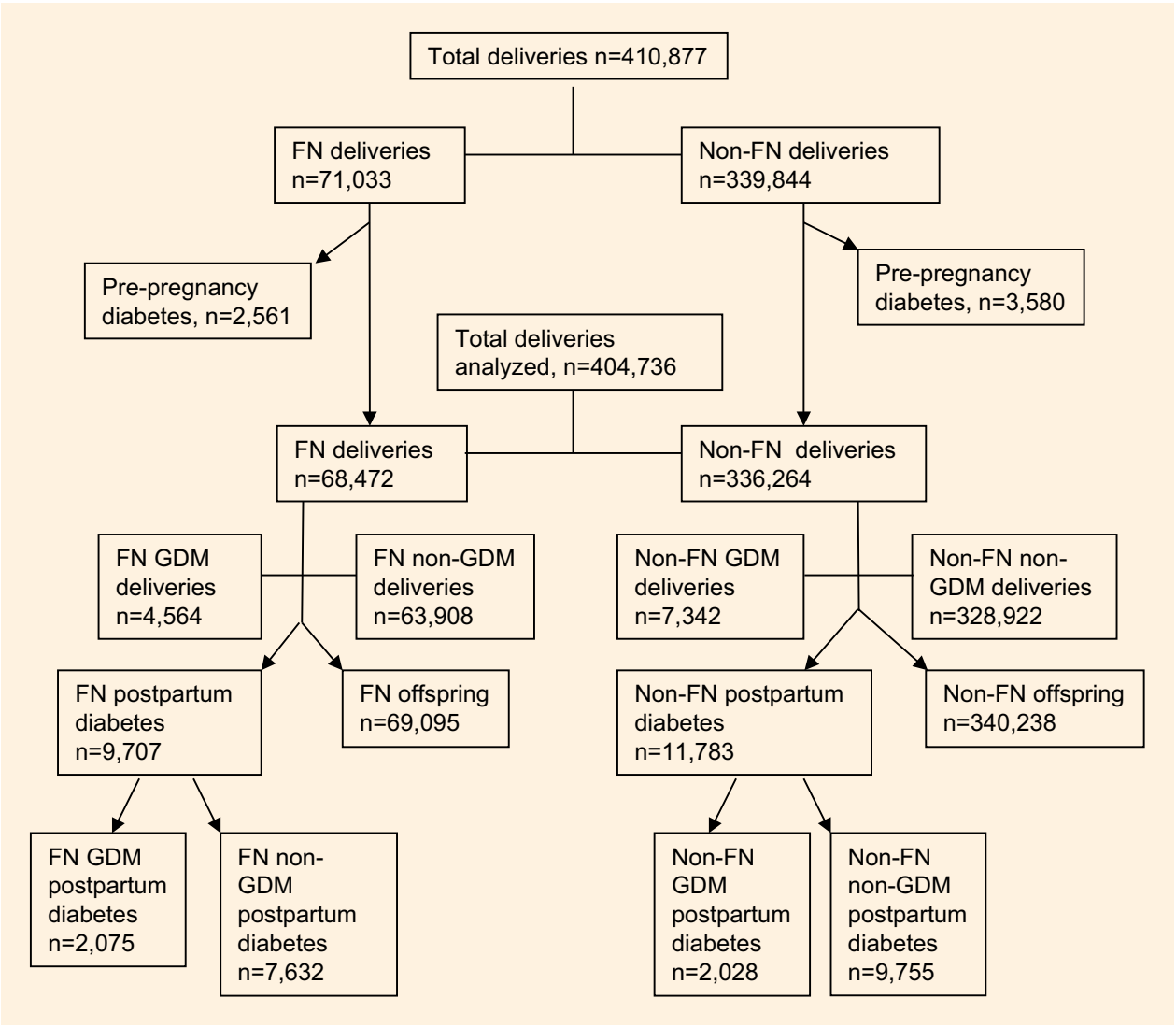

FIGURE 1 Cohort chart. FN, First Nations; GDM, gestational diabetes.

multivariate analyses, we controlled for factors other than our primary inputs (FN and gestational diabetes) of interest. For example, the strength of the association between hypertension during pregnancy on subsequent diabetes among non-FN women (HR 1.89, $P < 0.0001$) was moderately greater than that among FN women (HR 1.64, $P < 0.0001$). Each additional year of age was associated with a 1.021 times higher risk over time of diabetes among FN women and 1.024 times higher risk among non-FN women, $P < 0.0001$. For example, the HR of subsequent diabetes after delivery for a FN woman who is 15 years older than another is 1.37 ($1.021^{15} = 1.37$). Lower income was associated with an increased risk of developing diabetes among both FN (HR 1.28, $P = 0.0014$) and non-FN women (HR 1.87, $P < 0.0001$). Rural residence was also associated with an increased risk of developing diabetes among FN women (HR 1.16, $P = 0.0001$), but a decreased risk among non-FN women (HR 0.76, $P < 0.0001$) (Table 3).

Conclusions

In this large-scale, population-based cohort database study, we explored the possible impact that gestational diabetes may have on the subsequent risk of developing diabetes among women in Manitoba over a 30-year period. We specifically evaluated the role that FN ancestry may have on modifying the gestational diabetes/Type 2 diabetes association. The unique linkage of large population-based administrative and clinical datasets, as well as the careful epidemiological definition of gestational diabetes in this study allowed us to estimate the association between gestational diabetes and the development of subsequent diabetes among women after excluding known pre-existing diabetes. The results suggest that gestational diabetes alone is a strong and independent risk factor for developing diabetes after pregnancy. More than three-quarters of FN women and more than half of non-FN women with gestational diabetes

Table 1 Demographic data for women at time of delivery*

Outcome/factor	Non-First Nations (n = 336 264)	First Nations (*n* = 68 472)
Age of women at birth (years, mean ± SD)	27.85 ± 5.34	23.71 ± 5.53†
Gestational weeks (weeks, mean ± sd)	39.23 ± 1.97	39.05 ± 2.07
Parity†		
Parity 0 (%, no previous delivery)	137 396 (40.86)	19 702 (28.77)
Parity 1 (%)	118 587 (35.27)	16 487 (24.08)
Parity 2 + (%)	80 243 (23.86)	32 252 (47.10)
Missing data	38 (0.01)	31 (0.05)
Gestational diabetes	7 342 (2.18)	4 564 (6.67)†
Gestational hypertension	26 013 (7.74)	5 248 (7.66)
Caesarean section	59 091 (17.57)	8,910 (13.01)†
Diabetes (subsequent to delivery)	11 783 (3.50)	9 707 (14.18)†
Rural residence	125 805 (37.41)	48 302 (70.54)†
Income quintile (based on 2006 Census)†		
Quintile 1 (%, lowest)	60 195 (17.90)	41 097 (60.02)
Quintile 2 (%)	68 884 (20.49)	13 799 (20.15)
Quintile 3 (%)	70 659 (21.01)	6 222 (9.09)
Quintile 4 (%)	72 008 (21.41)	3 937 (5.75)
Quintile 5 (%, highest, reference)	63 762 (18.96)	3 160 (4.62)

*Women with multiple deliveries during the study period are represented multiple times in the table.
†$P < 0.0001$ vs. non-First Nations group.

Table 2 Comparison of outcomes and contributing factors for pregnant women with and without gestational diabetes

	Non-First Nations		First Nations	
Outcome/factor	Gestational diabetes (*n* = 7 337)	No gestational diabetes (*n* = 328 732)	Gestational diabetes (*n* = 4 558)	No gestational diabetes (*n* = 63 752)
Age of mothers at birth (years, mean ± SD)	30.22 ± 5.64	27.80 ± 5.32*	26.62 ± 6.10	23.50 ± 5.42*
Parity*				
Parity 0 (no previous delivery) (%)	36.92	40.95	20.78	29.37
Parity 1 (%)	34.05	35.30	20.38	24.36
Parity 2 + (%)	29.03	23.74	58.84	46.22
Missing data (%)	0.00	0.01	0.00	0.05
Caesarean section (%)	28.34	17.33†	22.14	12.36*
Diabetes subsequent to delivery (%)†	27.61	2.96*	45.41	11.94*
Gestational hypertension (%)	19.26	7.48*	16.28	7.00*
Rural residence (%)	31.44	7.55*	77.51	70.12*
Income quintile*				
Quintile 1 (%, lowest)	21.93	17.84	65.56	59.85
Quintile 2 (%)	21.69	20.51	17.58	20.42
Quintile 3 (%)	20.40	21.08	9.09	9.12
Quintile 4 (%)	20.12	21.50	4.20	5.89
Quintile 5 (%) (highest, reference)	15.86	19.08	3.57	4.72

*$P < 0.0001$ vs. Gestational diabetes.
†Cumulative incidence

were estimated to develop diabetes within 30 years after index delivery in Manitoba.

Importantly, we found that gestational diabetes may be a relatively stronger risk factor for the development of diabetes after pregnancy among non-FN women than among FN women. Although FN women have a higher rate of diabetes than non-FN women, the HR of gestational diabetes on subsequent diabetes among non-FN women was almost double that among FN women. This is possibly due to the lower proportion of non-FN women without gestational diabetes who developed subsequent diabetes (2.96%) compared with FN women without gestational diabetes who developed subsequent diabetes (11.94%, Table 2). Our study suggests that lower family income increases the risk of diabetes after pregnancy among FN and non-FN women. Rural/remote residence was associated with an increased risk of diabetes among FN women in this study. Approximately 60% of FN people in Manitoba live in rural communities and the majority of families in rural FN communities have annual incomes that are lower than the national average [19]. Many FN women live in inadequate housing conditions, and are dealing with present, chronic

and historical stress [20]. Although the HR for income or rural residence among FN women in this study are moderate (1.28, 1.16) compared with that of gestational diabetes (5.36), the combination of the impact of the socio-economic disparities and geographical barriers may play a substantial role in the increased risk of diabetes after pregnancy among FN women in rural communities. The health and social disparities between FN and the general Canadian population are well known [20]. This reality is reflected in current guidelines of the Society of Obstetricians and Gynecologists of Canada, which recognized the social determinants of health and historical factors as a root cause of poorer health outcomes in Indigenous women [21]. The contextual realities, including geographical isolation, lack of regular prenatal/postnatal healthcare providers and language barriers to communicate with health professionals, in rural and remote FN communities in Manitoba resulting from detrimental colonial policies, and the influence of the social determinants of health on well-being must be considered when assessing potential mechanisms for the development and the prevention of common chronic diseases, such as diabetes.

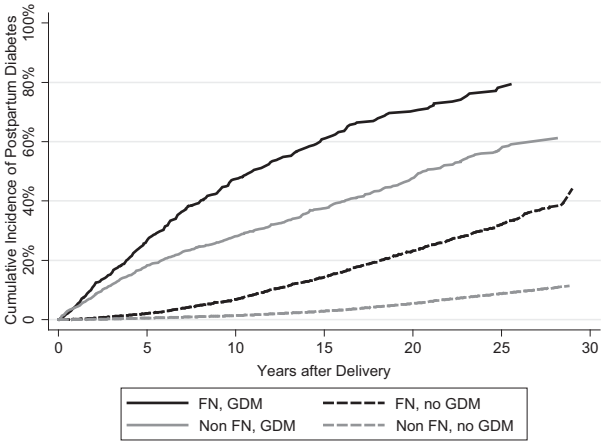

FIGURE 2 Accumulated incidence of post-partum diabetes in mothers analysed using Kaplan–Meier survival analysis. Solid black line: First Nations (FN) women with gestational diabetes (GDM); solid grey line: non-FN women with gestational diabetes; dashed black line: FN women without gestational diabetes (non-GDM); dashed grey line: non-FN and non-GDM.

Our findings of a high prevalence of gestational diabetes and incidence of diabetes among Canadian FN women are consistent with previous studies by our or other groups [10,13]. Both genetic and environmental factors may contribute to the susceptibility of FN women to both gestational and Type 2 diabetes [22,23]. A recent qualitative study demonstrated that gestational diabetes care among Indigenous women, including FN women living in urban or rural communities in Manitoba, is influenced by access to the healthcare system, culture, attitude and messages from healthcare providers, and trust between care providers and patients [24]. Randomized controlled trials from our group and others suggested that lifestyle interventions decreased the rate of excessive gestational weight gain in pregnant women [25,26], which reduced the risk for gestational diabetes and post-partum diabetes. Our recent studies suggested that pregnant women living in FN rural communities tend to have less access to healthy diets and lower physical activity than non-FN women in urban communities, but the pre-pregnancy BMI between groups was not significantly different [27]. Socio-economic factors and lower utilization of

Table 3 Risk factors for post-partum diabetes among women in Manitoba

	First Nations		Non-First Nations	
Predictors	HR (95% CI)	*P*	HR (95% CI)	*P*
Birth year 1982–1989 (reference):				
Birth year 1990–1994	1.03 (0.94–1.13)	0.5272	1.03 (0.96–1.10)	0.4073
Birth year 1995–1999	1.14 (1.04–1.26)	0.0080	1.22 (1.12–1.32)	< 0.0001
Birth year 2000–2004	1.08 (0.96–1.21)	0.1897	1.34 (1.22–1.48)	< 0.0001
Birth year 2005–2011	1.13 (0.99–1.30)	0.0792	1.41 (1.24–1.60)	< 0.0001
Gestational diabetes	5.36 (4.96–5.78)	< 0.0001	10.61 (9.84–11.31)	< 0.0001
Hypertension (gestational)	1.64 (1.51–1.79)	< 0.0001	1.89 (1.77–2.02)	< 0.0001
Caesarean section	1.38 (1.28–1.49)	< 0.0001	1.44 (1.36–1.52)	< 0.0001
Rural residence	1.16 (1.08–1.25)	0.0001	0.76 (0.72–0.80)	< 0.0001
Income quintile:				
Income quintile 1 (lowest)	1.28 (1.10–1.50)	0.0014	1.87 (1.73–2.03)	< 0.0001
Income quintile 2	1.06 (0.89–1.25)	0.5285	1.51 (1.39–1.63)	< 0.0001
Income quintile 3	1.08 (0.90–1.30)	0.4055	1.34 (1.24–1.46)	< 0.0001
Income quintile 4	1.11 (0.91–1.36)	0.2878	1.22 (1.12–1.32)	< 0.0001
Income quintile 5 (highest, reference)				
History of gestational diabetes	2.11 (1.91–2.32)	< 0.0001	2.27 (2.04–2.53)	< 0.0001
Mother's age (each year)	1.021 (1.015–1.027)	< 0.0001	1.024 (1.019–1.029)	< 0.0001
Parity 0 (reference)				
Parity 1	1.01 (0.90–1.13)	0.9148	0.87 (0.91–0.93)	< 0.0001
Parity 2+	1.18 (1.06–1.31)	0.0028	1.08 (1.01–1.16)	0.0245

HR, hazard ratio; CI, confidential interval; Parity 0, first parity; Parity 1, second parity; Parity 2 + , third parity or more.

prenatal/postnatal care may contribute to the increased risk of gestational diabetes and subsequent diabetes among rural-living FN women. The lower risk of diabetes after pregnancy by rural residence among non-FM women may be partially related to the lower prevalence of gestational diabetes among rural-living non-FN women compared with FN women as described previously [10]. Our current findings provide additional evidence that socio-economic and geographical factors contribute to the development of incident diabetes among FN and non-FN women.

Any type of hypertension is more frequent in diabetic pregnancies [28]. This study suggested that hypertension during pregnancy may significantly increase the hazard of subsequent diabetes in women with a 60% increase in the risk of subsequent diabetes (HR 1.64) among FN women and 90% increase of the risk among non-FN women (HR 1.89). This finding reflects an association between hypertension and post-partum diabetes, which is consistent with the results from previous prospective or population-based cohort where pre-eclampsia or hypertensive disorder during pregnancy may increase the risk of diabetes after pregnancy [29]. The underlying mechanism for the relatively higher risk of diabetes in non-FN women with gestational hypertension remains to be investigated.

Limitations

This study has several limitations. First, the Repository does not contain information on maternal height or pre-pregnancy weight or maternal weight gain during pregnancy. Obesity is a known risk factor for both gestational and Type 2 diabetes. However, we were unable to assess the impact of pre-pregnancy BMI or gestational weight gain on post-partum diabetes in mothers. Second, coding of outpatient data for post-partum diabetes in women did not distinguish between Type 2 and Type 1 diabetes, although the vast majority is Type 2 diabetes as expected [1]. Third, non-status FN and Métis people (this may account for over 30% of total Indigenous people) [3] are not registered as FN people in the administrative databases in Manitoba. Therefore, the results of this study may somewhat underestimate the impact of factors associated with FN ancestry. Fourth, although 6141 deliveries or 3948 pregnant women (1488 FN and 2460 non-FN women) with known pre-existing diabetes were excluded from the analysis in this study, we cannot be certain that all other women with gestational diabetes in the database did not have pre-existing diabetes. Some of them may never have been screened for diabetes before late pregnancy. This may somewhat overestimate the impact of gestational diabetes.

In conclusion, our results suggest that gestational diabetes, after excluding known pre-existing diabetes, increases the risk of diabetes after delivery among both non-FN and FN women in Manitoba. FN women have a higher prevalence of gestational diabetes and subsequent development of diabetes. In Manitoba, 70% of FN pregnant women live in rural areas (Table 1). Rural or remote residency and socio-economic inequalities contribute to the development of diabetes after gestational diabetes among FN women living in rural or remote communities. Socio-economic inequalities, such as poverty and difficulty accessing health care and other social services may also contribute to post-partum diabetes for off-reserve FN women due to in part to low employment rates, as well as more difficult access to health care and other social services. This study demonstrates for the first time that gestational diabetes is a stronger relative risk factor for subsequent diabetes among non-FN women than among FN women. Lower family income appears to be associated with diabetes among both FN and non-FN women. In addition, our results indicate that rural residence may be associated with an increased risk of diabetes after delivery among FN women, but a decreased risk of diabetes among non-FN women. The findings of this study may help to develop population-specific strategies for preventing diabetes after pregnancy and improving the long-term health of FN and non-FN women. The results also suggest the importance of the prevention and management of gestational diabetes, screening for diabetes in women with a history of gestational diabetes and post-partum care of women with a history of gestational diabetes. A recent review suggested that lifestyle intervention and breastfeeding ($\geq$ 3 months) reduced the risk of diabetes in women with gestational diabetes [30]. For FN and non-FN women recently diagnosed with gestational diabetes, health professionals should inform patients about the risk of post-partum diabetes to women and potential risk to offspring, and educate women on the importance of post-partum screening for diabetes, healthy eating, physical activity and breastfeeding for at least 3 months. Implementing policies to reduce socio-economic inequalities and strategies to reduce geographic barriers for access to prenatal/postnatal care are required for improving the outcomes of gestational diabetes patients in terms of subsequent diabetes at population level, particularly in FN women living in rural or urban areas. Although the study was conducted in Manitoba, we believe that the results are generalizable to other provinces in Canada in a public healthcare system, and may have international implications.

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Competing interests

None declared.

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References

1 World Health Organization. Diabetes programme. Available at http://www.who.int/diabetes/en/ Last accessed 22 March 2014.
2 Hanley AJ.Diabetes in Indigenous peoples. *Medscape Today*. Release 25 July 2007. Available at http://www.medscape.org/viewarticle/540921
3 Manitoba Aboriginal and Northern Affairs. *Aboriginal people in Manitoba 2000*. Available at http://www.gov.mb.ca/ana/apm2000/1/c.html Last accessed 24 November 2014.
4 Bruce SG, Riediger ND, Zacharias JM, Young TK. Obesity and obesity-related comorbidities in a Canadian First Nation population. *Prev Chronic Dis* 2011; **8**: A03.
5 Weinert LS. International Association of Diabetes and Pregnancy Study Groups recommendations on the diagnosis and classification of hyperglycemia in pregnancy: comment to the International Association of Diabetes and Pregnancy Study Groups Consensus Panel. *Diabetes Care* 2010; **33**: e97–98.
6 Thompson D, Berger H, Feig D, Gagnon R, Kader T, Keely E *et al*. Canadian Diabetes Association 2013 clinical practice guidelines for the prevention and management of diabetes in Canada: diabetes and pregnancy. *Can J Diabetes* 2013; **37**(Suppl. 1): S168–S183.
7 Dabelea D, Snell-Bergeon JK, Hartsfield CL, Bischoff KJ, Hamman RF, McDuffie RS. Increasing prevalence of gestational diabetes mellitus (GDM) over time and by birth cohort: Kaiser Permanente of Colorado GDM screening program. *Diabetes Care* 2005; **28**: 579–584.
8 Lawrence JM, Contreras R, Chen W, Sacks DA. Trends in the prevalence of preexisting diabetes and gestational diabetes mellitus among a racially/ethnically diverse population of pregnant women, 1999–2005. *Diabetes Care* 2008; **31**: 899–904.
9 Hedderson MM, Darbinian JA, Ferrara A. Disparities in the risk of gestational diabetes by race–ethnicity and country of birth. *Paediatr Perinat Epidemiol* 2010; **24**: 441–448.
10 Aljohani N, Rempel BM, Ludwig S, Morris M, McQuillen K, Cheang M *et al*. Gestational diabetes in Manitoba during a twenty-year period. *Clin Invest Med* 2008; **31**: E131–E137.
11 Steinhart JR, Sugarman JR, Connell FA. Gestational diabetes is a herald of NIDDM in Navajo women. High rate of abnormal glucose tolerance after GDM. *Diabetes Care* 1997; **20**: 943–947.
12 Lee H, Jang HC, Park HK, Metzger BE, Cho NH. Prevalence of type 2 diabetes among women with a previous history of gestational diabetes mellitus. *Diabetes Res Clin Pract* 2008; **81**: 124–129.
13 Feig DS, Zinman B, Wang X, Hux JE. Risk of development of diabetes mellitus after diagnosis of gestational diabetes. *Can Med Assoc J* 2008; **179**: 229–234.
14 Lee AJ, Hiscock RJ, Wein P, Walker SP, Permezel M. Gestational diabetes mellitus: clinical predictors and long-term risk of developing type 2 diabetes: a retrospective cohort study using survival analysis. *Diabetes Care* 2007; **30**: 878–883.
15 Bellamy L, Casas JP, Hingorani AD, Williams D. Type 2 diabetes mellitus after gestational diabetes: a systematic review and meta-analysis. *Lancet* 2009; **373**: 1773–1779.
16 Dart AB, Ruth CA, Sellers EA, Au W, Dean HJ. Maternal diabetes mellitus and congenital anomalies of the kidney and urinary tract (CAKUT) in the child. *Am J Kidney Dis* 2015; **65**: 684–691.
17 Jebamani LS, Burchill CA, Martens PJ. Using data linkage to identify First Nations Manitobans: technical, ethical, and political issues. *Can J Public Health* 2005; **96**(Suppl. 1): S28–S32.
18 Lix L, Yogendran M, Burchill C, Metge C, McKeen N, Moore D *et al*. *Defining and Validating Chronic Diseases: An Administrative Data Approach*. Winnipeg: Manitoba Centre for Health Policy, July 2006.
19 Wilson D, Macdonald D. *The income gap between Aboriginal peoples and the rest of Canada*. April 2000. Availale at http://www.policyalternatives.ca/sites/default/files/uploads/publications/reports/docs/ Aboriginal%20Income%20Gap.pdf Last accessed 30 November 2014.
20 Richmond CA, Ross NA, Egeland GM. Social support and thriving health: a new approach to understanding the health of indigenous Canadians. *Am J Public Health* 2007; **97**: 1827–1833.
21 Society of Obstetricians and Gynecologists in Canada. *SOGC Guideline Will Improve Aboriginal Women's Health Care*. Available at http://sogc.org/?s=Will+Improve+Aboriginal+Women%E2%80%99s+Health+Care. Last accessed 24 November 2014.
22 Sellers EA, Triggs-Raine B, Rockman-Greenberg C, Dean HJ. The prevalence of the HNF–1alpha G319S mutation in Canadian aboriginal youth with type 2 diabetes. *Diabetes Care* 2002; **25**: 2202–2206.
23 DyckFehderau D, Holt NL, Ball GD; Alexander First Nation Community, Willows ND. Feasibility study of asset mapping with children: identifying how the community environment shapes activity and food choices in Alexander First Nation. *Rural Remote Health* 2013; **13**: 2289.
24 Tait Neufeld H. Patient and caregiver perspectives of health provision practices for First Nations and Métis women with gestational diabetes mellitus accessing care in Winnipeg, Manitoba. *BMC Health Serv Res* 2014; **14**: 440.
25 Asbee SM, Jenkins TR, Butler JR, White J, Elliot M, Rutledge A. Preventing excessive weight gain during pregnancy through dietary and lifestyle counseling: a randomized controlled trial. *Obstet Gynecol* 2009; **113**: 305–312.
26 Hui A, Back L, Ludwig S, Gardiner P, Sevenhuysen G, Dean H *et al*. Lifestyle intervention on diet and exercise reduced excessive gestational weight gain in pregnant women under a randomized controlled trial. *Br J Obstetr Gynecol* 2012; **119**: 70–77.
27 Back L, Hui A, Reid A, Reid A, Sevenhuysen G, Gardiner P *et al*. Comparison of physical activity and nutritional intake in First Nations pregnant women in remote communities and urban-living pregnant women. *Can J Diabetes* 2012; **36**: 64–67.
28 Colatrella A, Loguercio V, Mattei L, Trappolini M, Festa C, Stoppo M *et al*. Hypertension in diabetic pregnancy: impact and long-term outlook. *Best Pract Res Clin Endocrinol Metab* 2010; **24**: 635–651.
29 Wang IK, Tsai IJ, Chen PC, Liang CC, Chou CY, Chang CT *et al*. Hypertensive disorders in pregnancy and subsequent diabetes mellitus: a retrospective cohort study. *Am J Med* 2012; **125**: 251–257.
30 Morton S, Kirkwood S, Thangaratinam S. Interventions to modify the progression to type 2 diabetes mellitus in women with gestational diabetes: a systematic review of literature. *Curr Opin Obstet Gynecol* 2014; **26**: 476–486.