



# Prevalence of diabetes in pregnancy among Indigenous women in Australia, Canada, New Zealand, and the USA: a systematic review and meta-analysis

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## Summary

**Background** Indigenous peoples in countries with similar colonial histories have disproportionate burdens of disease compared with non-Indigenous peoples. We aimed to systematically identify and collate studies describing the prevalence of pre-existing diabetes and gestational diabetes, and compare the prevalence of these conditions between Indigenous and non-Indigenous pregnant women in Australia, Canada, New Zealand, and the USA.

**Methods** For this systematic review and meta-analysis, an information specialist did a comprehensive search of eight databases (Ovid MEDLINE, Ovid Embase, Ovid Global Health, CINAHL [EBSCO], Scopus, ProQuest Dissertations and Theses Global, PROSPERO, and the Wiley Cochrane Library) in June, 2019, for studies published between inception and June 25, 2019, without restrictions on language, publication type, or year of publication. Database searches were supplemented by grey literature searches of the Bielefeld Academic Search Engine and Google Scholar, and the reference lists of relevant articles were also manually searched. We included observational epidemiological studies comparing the prevalence of pre-existing diabetes or gestational diabetes in Indigenous and non-Indigenous pregnant women in Australia, Canada, New Zealand, and the USA. Two independent reviewers assessed study eligibility and risk of bias. We used a standardised data extraction form to collect information from the published reports of eligible studies, and, if needed, we contacted authors for further information. We did a Mantel-Haenszel random-effects meta-analysis to obtain the pooled unadjusted prevalence odds ratios (PORs) of pre-existing diabetes and gestational diabetes in Indigenous women compared with non-Indigenous women. We stratified meta-analyses by country and type of diabetes. The study is registered with PROSPERO, number CRD42018095971.

**Findings** Our search identified 1348 studies, of which 43 studies with 32 952 441 participants from Australia, Canada, New Zealand, and the USA were included in the systematic review, and 39 of these studies were included in the meta-analysis. 40 of the included studies used a cohort design. Pre-existing diabetes was more prevalent in Indigenous women than in non-Indigenous women, with pooled PORs ranging from 1.81 (95% CI 1.53–2.13) for women in the USA to 3.63 (2.35–5.62) for women in Australia. Similarly, gestational diabetes was more prevalent in Indigenous women than in non-Indigenous women, with PORs ranging from 1.42 (1.24–1.63) for women in Australia to 2.04 (1.46–2.84) for women in Canada. Risk of bias was low in 37.2% of studies, unclear in 34.8% of studies, and high in 27.9% of studies. Heterogeneity between studies was predominantly high ( $P=97-100\%$ ), with one exception of moderate heterogeneity ( $P=48\%$ ); however, the magnitude and direction of the PORs from individual studies indicated an association between pre-existing diabetes or gestational diabetes and indigeneity among pregnant women.

**Interpretation** The prevalence of pre-existing diabetes and gestational diabetes was higher in Indigenous pregnant women than in non-Indigenous pregnant women in four countries (Australia, Canada, New Zealand and the USA) with similar histories of colonialism. These findings have implications for prenatal care services and the monitoring of Indigenous women in industrialised countries.

**Funding** Canadian Institute of Health Research and the Women's and Children's Health Research Institute.

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## Introduction

Diabetes during pregnancy, including both pre-existing diabetes (type 1 or type 2 diabetes) and gestational diabetes, are associated with adverse pregnancy outcomes,<sup>1-3</sup> poor maternal outcomes (caesarean section, pre-eclampsia, postpartum haemorrhage, and gestational hypertension), and poor perinatal outcomes (macrosomia, preterm birth, a large-for-gestational age birth, congenital

anomalies, stillbirth, injury during birth, neonatal death, and neonatal admission to an intensive care unit).<sup>3-5</sup> Gestational diabetes is associated with an increased risk of type 2 diabetes in the mother and an increased risk of early-onset type 2 diabetes in the child.<sup>6-9</sup>

The risk of having diabetes during pregnancy varies across different populations, with a prevalence of 2–5% in low-risk ethnic groups.<sup>10</sup> One population of individuals

*Lancet Glob Health* 2020;

8: e681–98

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### Research in context

#### Evidence before this study

Before this study, we searched MEDLINE and Google Scholar on Feb 20, 2018 to identify systematic reviews on the prevalence of pre-existing diabetes and gestational diabetes that had been done previously. Three previous systematic reviews have provided important data on this topic. The first study assessed the prevalence of diabetes in pregnancy and the maternal and infant outcomes of diabetes in pregnancy in Indigenous women from multiple countries. In the same review, the authors combined the prevalence of diabetes in pregnancy into one estimate, with a subcategory for gestational diabetes, and comparison groups consisted of either non-Indigenous women or national estimates for non-Indigenous women. To our knowledge, no meta-analysis comparing the prevalence of diabetes in pregnancy in Indigenous women with that in non-Indigenous women has been done. The second study examined the prevalence of gestational diabetes among Indigenous women in Australia. Although a meta-analysis was done, the prevalence of pre-existing diabetes was not analysed, and an analysis of the prevalence of diabetes during pregnancy in Indigenous women from countries other than Australia was not done. The third study examined the evidence for early screening for diabetes in Indigenous pregnant women in Australia, Canada, New Zealand, and the USA. This study summarised a large amount of data but it did not systematically compare the prevalence of pre-existing diabetes and gestational diabetes between Indigenous and non-Indigenous women. Our systematic review and meta-analysis focused on the comparing the prevalence of pre-existing diabetes and gestational diabetes in Indigenous women with that in non-Indigenous women in Australia, Canada, New Zealand, and the USA. These four countries are all industrialised and share a similar history of colonialism.

#### Added value of this study

We collated data on the prevalence of pre-existing diabetes and gestational diabetes and did a meta-analysis to compare the prevalence of these conditions in Indigenous women and non-Indigenous women from four countries with similar histories of colonialism. The pooled prevalence odds ratio (POR) of pre-existing diabetes mellitus indicated that the prevalence of this condition was higher in Indigenous women than in non-Indigenous women in Australia, Canada, and in the USA. Heterogeneity between studies done in Australia and

Canada was high, but when examining the magnitude and direction of the PORs from individual studies, there was an association between indigeneity and pre-existing diabetes during pregnancy. We were not able to derive a POR of pre-existing diabetes in Maori women in New Zealand because none of the studies included this information. The pooled POR of gestational diabetes suggested that the prevalence of this condition was higher in Indigenous women than in non-Indigenous women, indicating an association between indigeneity and gestational diabetes. In the meta-analysis of the prevalence of gestational diabetes across all included studies, high heterogeneity was observed between studies in Australia, Canada, and USA. However, the magnitude and direction of the PORs from individual studies indicated that there was an association between indigeneity and gestational diabetes during pregnancy. We estimated the PORs of pre-existing and gestational diabetes in studies grouped by screening criteria, diagnostic criteria, risk of bias assessment, and by the race or ethnicity of the comparison group; however, none of these subgroup analyses were able to meaningfully reduce the degree of heterogeneity between studies. The results of our study indicate that the prevalence of pre-existing diabetes and gestational diabetes is higher in Indigenous women than in non-Indigenous women in four different countries with similar histories of colonialism.

#### Implications of all the available evidence

Future research should focus on targeting important risk factors to prevent pre-existing diabetes and gestational diabetes in Indigenous women, and this research should be done in partnership with Indigenous peoples and communities. Given the higher prevalence of diabetes in Indigenous women than in non-Indigenous women during pregnancy in Australia, Canada, New Zealand and the USA, policy makers in these countries should consider implementing policies that aim to reduce this disparity between Indigenous and non-Indigenous pregnant women in terms of the prevalence and outcomes of maternal diabetes. Health practitioners need to be aware of the increased likelihood of having pre-existing diabetes and gestational diabetes in Indigenous pregnant women, so that they can better support these women before pregnancy, prenatally and postnatally.

who are at a high risk for developing diabetes during pregnancy are Indigenous women.<sup>11,12</sup> A previous systematic review<sup>13</sup> of the prevalence and effect of diabetes in pregnancy among Indigenous women from multiple countries found that the prevalence of diabetes during pregnancy was not the same for all Indigenous peoples. 65% of studies included in the review<sup>13</sup> estimated that the prevalence of diabetes was higher in Indigenous women than in non-Indigenous women. However, this review<sup>13</sup> did not consider pre-existing

diabetes and gestational diabetes separately, nor did it focus on Indigenous women from countries with a similar history of colonialism.

Colonialism has been identified as a crucial determinant of the health of Indigenous peoples.<sup>14</sup> The effects of colonialism include systematic discrimination, poverty, racism, and a rapid transition to a so-called western lifestyle. Indigenous women in Australia, Canada, New Zealand, and the USA have similar experiences of colonialism, and health outcomes have been compared in

previous systematic reviews.<sup>12,15</sup> The purpose of this systematic review is to compare the prevalence of pre-existing diabetes and gestational diabetes between Indigenous women and non-Indigenous women in countries with similar colonial histories: Australia (Aboriginal and Torres Strait Islander), Canada (First Nations, Inuit, and Métis), New Zealand (Maori), and the USA (Native American and Alaska Natives). To our knowledge, this systematic review is the first to systematically identify and collate studies that have compared the prevalence of pre-existing diabetes and gestational diabetes in Indigenous women with that in non-Indigenous women in these four countries.

## Methods

### Search strategy and selection criteria

We did this systematic review and meta-analysis in accordance with PRISMA guidelines.<sup>16</sup>

An information specialist (SC) did a comprehensive literature search in June 25, 2019, for relevant articles published from inception to June 25, 2019, in the following databases: Ovid MEDLINE, Ovid Embase, Ovid Global Health, CINAHL (EBSCO), Scopus, ProQuest Dissertations and Theses Global, PROSPERO, and the Wiley Cochrane Library. Controlled vocabulary terms (ie, Medical Subject Heading terms) and key words for Indigenous peoples, diabetes in pregnancy, and the included countries (Australia, Canada, New Zealand, and the USA) were used in the searches (see appendix 1 pp 1–8 for a list of the search terms used).<sup>17</sup> BV and SC also searched the grey literature for relevant studies using the Bielefeld Academic Search Engine and Google Scholar. Lastly, BV manually searched the reference lists of relevant articles. No limits on publication type, language of publication, and year of publication were applied. The detailed search strategies are available in appendix 1 (pp 1–8).

Studies were included if they were epidemiological observational studies comparing the prevalence estimates of either pre-existing diabetes (type 1 or type 2 diabetes, or both) or gestational diabetes among Indigenous women in Australia, Canada, New Zealand, or the USA with the prevalence of the same condition in a group of non-Indigenous women in the same country. We excluded non-primary research articles, letters to the editor, case reports or case series, studies that only provided combined estimates of diabetes in pregnancy by grouping pre-existing diabetes and gestational diabetes together, studies in which participants were not Indigenous women, studies in which the comparison group did not include non-Indigenous women, and studies in which Indigenous women from countries other than Australia, Canada, New Zealand, and the USA were included.

Two independent reviewers (BV and SR or BV and OS) screened all titles and abstracts identified from the database search. The full-texts of studies identified as potentially relevant were reviewed in duplicate by two independent investigators (BV and SR or BV and OS).

Disagreements about study selection were resolved by discussion, and if consensus could not be reached, a third reviewer (MBO or DE) made the final decision.

### Data extraction and quality assessment

Two independent reviewers (BV and SR or BV and OS) assessed the risk of bias of all included studies, and any disagreements were resolved by discussion until a consensus was reached. Cohort studies were assessed by use of the Newcastle-Ottawa Quality Assessment Scale for cohort studies.<sup>18</sup> This scale assesses three main sources of bias, including the selection of study cohorts, comparability of cohorts, and outcome assessment. Studies were classified as having a low risk of bias if they had a score of 3–4 for study selection, 1–2 for comparability, and 2–3 for outcome assessment; studies were classified as having an unclear risk of bias if they had a score of 2–3 for study selection, 1–2 for comparability, and 1–2 for outcome assessment; and studies were classified as having a high risk of bias if they had a score of 0–1 for study selection, a score of 0 for comparability, and a score of 0–1 for outcome assessment.<sup>18</sup> We assessed the risk of bias of cross-sectional studies using a nine-item scale, developed by Hoy and colleagues,<sup>19</sup> that included the domains of sample selection, non-response bias, data collection, and measurement reliability and validity. A low risk of bias was defined as a high risk classification in 0–3 categories, an unclear risk of bias was defined as a high risk classification in 4–6 categories, and a high risk of bias was defined as a high risk classification in 7–9 categories.<sup>19</sup>

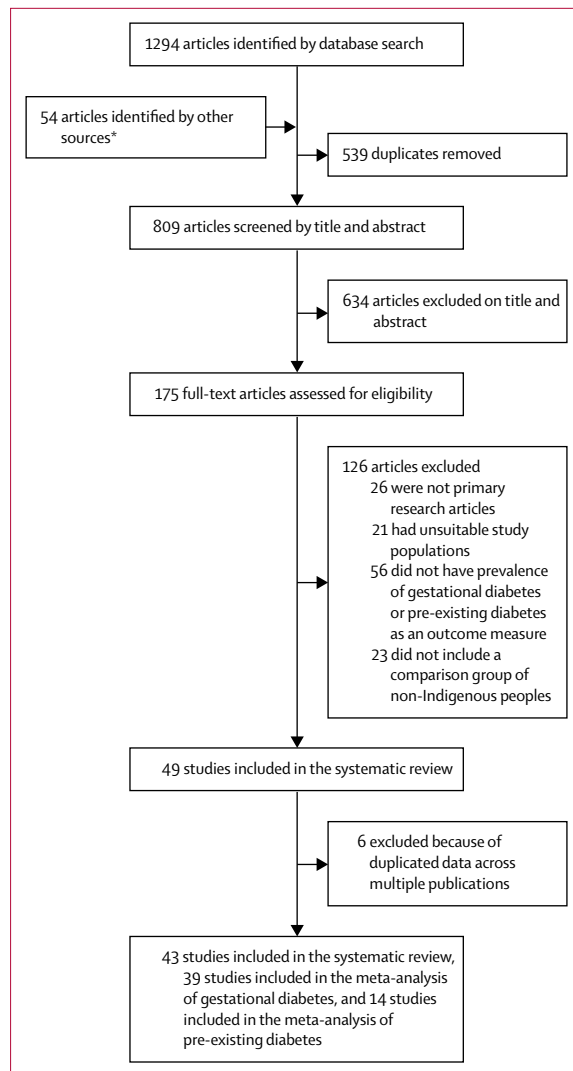
One independent reviewer (BV) extracted data using a standardised data collection form, and data from the published reports were verified by a second reviewer (OS) for accuracy (appendix 2 pp 1–2). From all included studies, we extracted information about study design, setting, Indigenous and comparison groups, data sources for exposure and the definition of outcomes, study sample size, screening guidelines and the diagnostic criteria for pre-existing diabetes and gestational diabetes, and data on the number of Indigenous and non-Indigenous women with pre-existing diabetes and gestational diabetes, and on the total number of Indigenous and non-Indigenous women, to estimate the prevalence of pre-existing diabetes and gestational diabetes.

### Data analysis

We used a Mantel-Haenszel random-effects meta-analysis to combine data from individual studies comparing the prevalence of pre-existing diabetes and gestational diabetes between groups of Indigenous and non-Indigenous women and to calculate crude prevalence odds ratios (PORs).<sup>20</sup> Because of the unique identities and singularities of Indigenous peoples around the world, only studies done in the same country were pooled so that a pan-Indigenous analysis approach was avoided during data synthesis. The summary measures

See Online for appendix 1

See Online for appendix 2



**Figure 1: Flow chart of study selection**

\*Additional articles identified by searching grey literature and reviewing relevant reference lists

were the pooled unadjusted PORs with 95% CIs. Statistical heterogeneity across the studies was assessed by use of the  $I^2$  statistic, with an  $I^2$  of less than 25% indicating low heterogeneity, an  $I^2$  of 26–74% indicating moderate heterogeneity, and an  $I^2$  of greater than 75% indicating high heterogeneity.<sup>21</sup> The summary measures and results for statistical heterogeneity are reported separately for each group of Indigenous peoples. Subgroup analyses were done by study design, screening guidelines, diagnostic criteria, and risk of bias.<sup>22</sup> A narrative synthesis of results was done to describe study populations and to explore both clinical and methodological heterogeneity across the included studies. Funnel plots were used to assess publication bias.<sup>23</sup> We used Review Manager (version 5.3) to do the meta-analysis, assess heterogeneity across the studies, and generate the funnel plots.<sup>24</sup>

This study is registered with PROSPERO, number CRD42018095971.

### Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

### Results

Electronic database searches identified 1294 titles and abstracts. The grey literature search and the review of relevant reference lists identified a further 54 titles and abstracts. After removal of duplicates, 809 articles were screened by title and abstract, resulting in 175 potential articles to be included. After reviewing the full texts of these articles, 43 unique studies were included in the systematic review and 39 studies were included in the meta-analysis (figure 1).

Of all 43 unique studies identified,<sup>25–66</sup> 19 studies<sup>25–28,30–43,65</sup> were done in Australia, eight studies<sup>8,44–49,66</sup> in Canada, one study<sup>50</sup> in New Zealand, and 15 studies<sup>29,51–64</sup> in the USA (table 1). Among the included studies, 39 were retrospective cohort studies,<sup>8,25,27–43,45–50,53–66</sup> one was a prospective cohort study,<sup>26</sup> and three were cross-sectional studies.<sup>44,51,52</sup> All 43 of the included studies reported the prevalence of gestational diabetes, and 14 studies<sup>8,25,27,31,43,45,46,53,54,65,66</sup> reported the prevalence of pre-existing diabetes, which included both type 1 and type 2 diabetes. Table 1 summarises the characteristics of individual studies.

Studies involving populations of Indigenous women in Australia identified women as either Indigenous Australian<sup>25–28,33,35–41,65</sup> or as Aboriginal and Torres Strait Islanders.<sup>30,31,34,43</sup> Studies in Canada identified Indigenous women as First Nation women<sup>8,45–49,66</sup> or as a group comprising First Nation, Métis, and Inuit women.<sup>44</sup> The study<sup>50</sup> in New Zealand identified women as Maori, and studies done in the USA identified Indigenous women as either Native American<sup>29,51,54–58,61–63</sup> or Native American and Alaska Native (including Yupik and Inupiat).<sup>52,53,59,60,62,64</sup> Most studies involving Indigenous women in Australia included a comparison group of non-Indigenous women, but some studies also included non-Indigenous women separated into subgroups of Australasian,<sup>26,34,42</sup> European,<sup>26,43</sup> Caucasian,<sup>27,37,41</sup> African women,<sup>42</sup> Asian (usually grouped by region),<sup>26,27,34,37,41,42</sup> Pacific Islanders,<sup>26,34</sup> and women from the Americas.<sup>34</sup> Studies involving Indigenous women in Canada included comparison groups of non-Indigenous women identified as either non-First Nation women,<sup>8,45–48</sup> non-Indigenous women,<sup>44,66</sup> or as a group of Caucasian, south east Asian and Chinese women.<sup>49</sup> The study<sup>50</sup> in New Zealand included a comparison group of non-Indigenous Pacific Islander and European women. Finally, studies involving Indigenous women in the USA included comparison groups of non-Indigenous women

identified as non-Native Americans,<sup>55</sup> Caucasian,<sup>29,51–54,56–64</sup> African American,<sup>29,51–54,56–58,60–64</sup> Hispanic,<sup>29,52–54,56–58,60,62–64</sup> or as Asian or Pacific Islander.<sup>29,52–54,56–58,60,62,63</sup>

Indigenous ancestry (exposure) was determined by self-reporting in studies done in Australia, New Zealand, and in the USA. In studies involving Indigenous women in Canada, Indigenous ancestry was determined by self-reporting,<sup>8,44,47</sup> place of residence,<sup>46,48,66</sup> language spoken,<sup>66</sup> or

by the health-care insurance Indian status identifier,<sup>45,49,66</sup> although Métis and non-status Indigenous peoples (ie, those who are not eligible to be registered with the federal government) could not be identified from health insurance records. For the assessment of outcomes, studies done in Australia used national perinatal data sources,<sup>30,32</sup> state or region data,<sup>25,27,28,31,33–35,40,41,65</sup> or clinic or hospital data.<sup>26,36–39,42</sup> Studies done in the USA used national data sources,<sup>53,60,62,64</sup>

Region	Total number of women included in the study	Screening or diagnostic criteria	Mean age (SD) of the mother when giving birth	Number of women with pre-existing diabetes	Number of women with GDM	Adjusted odds ratio (95% CI)
<b>Australia</b>						
Bower et al (1992) <sup>65</sup>	Western Australia 111 019 (5481 Aboriginal women and 105 538 non-Aboriginal women)	Pre-existing diabetes=NR; GDM=NR	NR	25 (0.5%) of 5481 Aboriginal women and 116 (0.1%) of 105 538 non-Aboriginal women	73 (1.3%) of 5481 Aboriginal women and 213 (0.2%) of 105 538 non-Aboriginal women	NR
Chamberlain et al (2014) <sup>32</sup>	Australia 3 555 575 (121 736 Indigenous women and 3 433 839 non-Indigenous women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	6121 (5.0%) of 121 736 Indigenous women and 142 689 (4.2%) of 3 433 839 non-Indigenous women	NR
Porter et al (2011) <sup>65</sup>	Western Australia 81 617 (4966 Aboriginal women and 76 651 Caucasian women)	Pre-existing diabetes=NR; GDM=NR	Aboriginal women: pre-existing DM 30.3 years (6.4), GDM 28.0 years (6.0); Caucasian women: pre-existing DM 31.1 years (5.0), GDM 31.7 years (5.2)	113 (2.3%) of 4966 Aboriginal women and 541 (0.7%) of 76 651 Caucasian women	418 (8.4%) of 4966 Aboriginal women and 4915 (6.4%) of 76 651 Caucasian women	NR
Krikham et al (2017) <sup>63</sup>	Northern Territory 7708 (2581 Aboriginal and Torres Strait Islander women, and 5127 non-Indigenous women)	Pre-existing diabetes=NR; GDM=guidelines were changed during the study period, but GDM was diagnosed with either: (1) a screening test at 26–28 weeks' gestation with a 50 g or 75 g GCT, and if glucose was $\geq 7.8$ mmol/L or 8.0 mmol/L at 1 h, then a follow-up 75 g OGTT was done, and GDM was diagnosed if FBG was $\geq 5.5$ mmol/L or if glucose was $\geq 8.0$ mmol/L at 2 h; or (2) a 75 g OGTT at 24–28 weeks' gestation, and GDM was diagnosed if FBG was $\geq 5.1$ mmol/L, glucose was $\geq 10.0$ mmol/L at 1 h, or if glucose was $\geq 8.5$ mmol/L at 2 h (or if patients had two or more of these results)	NR	104 (4.0%) of 2581 Aboriginal and Torres Strait Islander women, and 26 (0.5%) of 5127 non-Indigenous women	311 (12.0%) of 2581 Aboriginal and Torres Strait Islander women and 417 (8.1%) of 5127 non-Indigenous women	NR
Australian Institute of Health and Welfare (2010) <sup>30</sup>	Australia 832 693 (30 518 Aboriginal and Torres Strait Islander women, and 802 175 non-Indigenous women)	Pre-existing diabetes: patients were diagnosed if type 1 or type 2 diabetes was diagnosed before pregnancy or if a 75 g OGTT indicated a FBG concentration of $\geq 7.0$ mmol/L or a glucose concentration of $\geq 11.1$ mmol/L at 2 h; GDM=patients were screened at 26–30 weeks' gestation with a 50 g GCT, and if glucose was $\geq 7.8$ mmol/L at 1 h, then a 75 g OGTT was done and GDM was diagnosed if FBG was $\geq 5.5$ mmol/L, or if glucose was $\geq 10.0$ mmol/L at 1 h, or $\geq 8.0$ mmol/L at 2 h	NR	443 (1.5%) of 30 518 Aboriginal and Torres Strait Islander women, and 4501 (0.6%) of 802 175 non-Indigenous women	1562 (5.1%) of 30 518 Aboriginal and Torres Strait Islander women and 37 539 (4.7%) of 802 175 non-Indigenous women	NR
Thrift and Callaway (2014) <sup>33</sup>	Queensland 265 848 (13 582 Aboriginal women and 241 270 non-Aboriginal women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	883 (6.5%) of 13 582 Aboriginal women and 13 270 (5.5%) of 241 270 non-Aboriginal women	NR

(Table 1 continues on next page)

Region	Total number of women included in the study	Screening or diagnostic criteria	Mean age (SD) of the mother when giving birth	Number of women with pre-existing diabetes	Number of women with GDM	Adjusted odds ratio (95% CI)
(Continued from previous page)						
Abouzeid et al (2015) <sup>34</sup>	Victoria 269 682 (1555 Aboriginal women and 268 127 non-Aboriginal women [grouped by race or ethnicity])	Pre-existing diabetes=NR; GDM=screening was recommended at 26–28 weeks' gestation with a 50 g GCT, and if glucose was $\geq 7.8$ mmol/L at 1 h or if glucose was 8.0 mmol/L at 1 h with a 75 g GCT, then a 75 g OGTT was done, and GDM was diagnosed if fasting glucose was $\geq 5.5$ mmol/L or if glucose was $\geq 8.0$ mmol/L at 2 h	Aboriginal women: GDM 25.9 years (6.0); non-indigenous women: Australian, GDM 30.5 years (5.1); Oceania, GDM 30.8 years (5.7); north west Europe, GDM 33.1 years (4.6); southern and eastern Europe, GDM 31.8 years (5.4); north Africa and Middle East, GDM 29.6 years (6.0); south east Asia, GDM 31.0 years (4.9); north east Asia, GDM 32.5 years (4.3); southern and central Asia, GDM 29.9 years (4.3); Americas, GDM 32.0 years (4.9); and sub-Saharan Africa, GDM 30.3 years (4.6)	NR	41 (2.6%) of 1555 Aboriginal women, 11 708 (4.4%) of all 268 127 non-Indigenous women, 6970 (3.4%) of 202 374 non-Indigenous Australian women, 267 (4.3%) of 6197 Oceania women, 371 (4.0%) of 9352 north west European women, 371 (5.8%) of 6443 southern and eastern European women, 266 (5.1%) of 5204 north African and Middle Eastern women, 1438 (9.2%) of 15 585 south east Asian women, 733 (11.2%) of 6573 north east Asian women, 903 (10.7%) of 8435 southern and central Asian women, 150 (4.5%) of 3322 Americas women, and 206 (5.9%) of 3489 sub-Saharan African women	Aboriginal vs non-Aboriginal women: GDM 1.11 (0.81–1.52)
Ishak and Petocz (2003) <sup>38</sup>	South Australia 230 011 (4843 Aboriginal women and 225 168 non-Aboriginal women)	Pre-existing diabetes=NR; GDM=diagnosed if a 75 g OGTT showed FBG concentrations of $\geq 5.5$ mmol/L, or if glucose was $\geq 8.0$ mmol/L at 2 h, or if a 75 g OGTT results of 2 h glucose was $\geq 11.0$ mmol/L, but if glucose was 7.8–11.0 mmol/L then the patient was considered to be glucose intolerant.	NR	86 (1.8%) of 4843 Aboriginal women and 743 (0.3%) of 225 168 non-Aboriginal women	208 (4.3%) of 4843 Aboriginal women and 5472 (2.4%) of 225 168 non-Aboriginal women	Pre-existing DM 5.54 (5.40–5.69); GDM 1.83 (1.81–1.84)
Stone et al (2002) <sup>35</sup>	Victoria 60 400 (438 Aboriginal women and 59 962 non-Aboriginal women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	19 (4.3%) of 438 Aboriginal women and 2159 (3.6%) of 59 962 non-Aboriginal women	GDM 2.5 (1.54–4.06)
Simmons et al (2005) <sup>36</sup>	Victoria 140 (28 Aboriginal women and 114 non-Aboriginal women from four rural hospitals)	Pre-existing diabetes=NR; GDM=screening recommended at 26–28 weeks' gestation with a 50 g GCT, and if glucose was $\geq 7.8$ mmol/L at 1 h, or glucose was 8.0 mmol/L at 1 h with a 75 g GCT, then a 75g OGTT was done, and GDM diagnosed if fasting glucose was $\geq 5.5$ mmol/L or if glucose was $\geq 8.0$ mmol/L at 2 h	NR	NR	3 (10.7%) of 24 Aboriginal women and 4 (4.5%) of 75 non-Aboriginal women	NR
Yue et al (1996) <sup>37</sup>	New South Wales 3814 (89 Aboriginal women and 3718 non-Aboriginal women [grouped by race or ethnicity] from one antenatal clinic)	Pre-existing diabetes=NR; GDM=patients underwent universal screening at 24–28 weeks' gestation with a 50 g GCT, and if the results were positive, then a 75 g OGTT was done, and GDM was diagnosed if fasting glucose was $\geq 5.5$ mmol/L or if glucose was $\geq 8.0$ mmol/L at 2 h	Aboriginal women: GDM 28.8 years (4.8); non-indigenous women: Anglo-Celtic, GDM 30.5 years (6.4); Chinese, GDM 33.0 years (4.1); Vietnamese, GDM 32.0 years (5.7); Indian, GDM 31.8 years (4.1); Arab, GDM 30.5 years (4.4)	NR	9 (10.1%) of 89 Aboriginal women, 232 (6.2%) of all 3718 non-Aboriginal women, 72 (3.0%) of 2412 Anglo Celtic women, 71 (15.0%) of 474 Chinese women, 37 (9.5%) of 386 Vietnamese women, 19 (16.7%) of 114 Indian women, and 24 (7.4%) of 332 Arab women	NR
DeCosta and Child (1996) <sup>38</sup>	New South Wales 9179 (180 Aboriginal and 8999 Non-Aboriginal)	Pre-existing diabetes=NR; GDM=NR	NR	NR	3 (1.6%) of 180 Aboriginal women and 332 (3.7%) of 8999 non-Aboriginal women	NR

(Table 1 continues on next page)

Region	Total number of women included in the study	Screening or diagnostic criteria	Mean age (SD) of the mother when giving birth	Number of women with pre-existing diabetes	Number of women with GDM	Adjusted odds ratio (95% CI)	
(Continued from previous page)							
Moses et al (1994) <sup>26</sup>	New South Wales	1829 (12 Aboriginal women and 1702 non-Aboriginal women [grouped by race or ethnicity])	Pre-existing diabetes=NR; GDM=patients were tested at the start of the third trimester, whereby patients were diagnosed with GDM if a 75 g OGTT indicated FBG concentrations of $\geq 5.5$ mmol/L or glucose was $\geq 8.8$ mmol/L at 2 h, or both	NR	NR	0 of 12 Aboriginal women, 125 (7.3%) of all 1702 non-Aboriginal women, 92 (7.1%) of 1299 Australasian women, 12 (6.3%) of 191 northern European women, 14 (9.2%) of 153 southern European women, and 7 (11.9%) of 59 Asian women	NR
Powell and Dugdale (1999) <sup>29</sup>	Queensland	285 (132 rural Aboriginal women and 137 rural non-Aboriginal women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	2 (1.5%) of 132 rural Aboriginal women and 3 (2.2%) of 137 rural non-Aboriginal women	NR
New South Wales Government <sup>31*</sup>	New South Wales	1 900 947 (58 158 Aboriginal women and 1 842 789 non-Aboriginal women)	Pre-existing diabetes=NR; GDM=NR	NR	563 (1.0%) of 58 158 Aboriginal women and 12 817 (0.7%) of 1 842 789 non-Aboriginal women	3093 (5.3%) of 58 158 Aboriginal women and 107 342 (5.8%) of 1 842 789 non-Aboriginal women	NR
Sharpe et al (2005) <sup>27</sup>	South Australia	282 260 (7542 Aboriginal women and 274 008 non-Aboriginal women [grouped by race or ethnicity])	Pre-existing diabetes=NR; GDM=NR	NR	98 (1.3%) of 7542 Aboriginal women, 848 (0.3%) of all 274 008 non-Aboriginal women, 828 (3.1%) of 264 121 Caucasian women, and 15 (0.2%) of 9887 Asian women	334 (2.4%) of 7542 Aboriginal women, 6370 (5.6%) of all 274 008 non-Aboriginal women, 5821 (2.2%) of 264 121 Caucasian women, and 549 (5.6%) of 9887 Asian women	NR
Teh et al (2011) <sup>42</sup>	Victoria	2880 (21 urban Aboriginal women and 2852 urban non-Aboriginal women)	Pre-existing diabetes=NR; GDM=screening at 26–28 weeks' gestation was done with a 75 g GCT, and if glucose was $\geq 8.0$ mmol/L at 1 h, then a 75 g OGTT was done and GDM was diagnosed if fasting glucose was $\geq 5.5$ mmol/L or if glucose was $\geq 8.8$ mmol/L at 2 h	NR	NR	1 (4.8%) of 21 urban Aboriginal women, 250 (8.8%) of all 2852 urban non-Aboriginal women, 66 (5.4%) of 1213 non-Indigenous Australian women, 9 (18.0%) of 50 Polynesian women, 46 (15.6%) of 295 women from mainland south east Asia, 14 (12.8%) of 117 women from maritime south east Asia, 22 (11.6%) of 189 Chinese Asian women, 42 (12.3%) of 341 southern Asian women, and 13 (9.6%) of 135 African women	Urban Aboriginal women vs urban non-Aboriginal women: GDM 1.1 (0.1, 9.3)
Zhang et al (2010) <sup>40</sup>	Northern Territory	42 440 (18 614 Aboriginal women and 23 826 non-Aboriginal women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	1173 (6.3%) of 18 614 Aboriginal women and 994 (4.2%) of 23 826 non-Aboriginal women	NR
Markey et al (1996) <sup>41</sup>	Northern Territory	14 138 (4937 Aboriginal women and 9201 non-Aboriginal women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	311 (6.3%) of 4937 Aboriginal women, 370 (4.0%) of 9201 non-Aboriginal women, 273 (3.4%) of 8039 European women, and 76 (9.9%) of 768 Asian women	NR

(Table 1 continues on next page)

state-level data,<sup>29,51,52,54–58,61</sup> or hospital data.<sup>63</sup> Studies done in Canada used databases at the provincial,<sup>8,45–47,49,66</sup> regional,<sup>48</sup> or hospital levels.<sup>44</sup>

The risk of bias assessment indicated that 75% of studies had an unclear or low risk of bias (figure 2). 16 studies<sup>8,27,29,34–37,42,45,49,54,61–63,66</sup> had a low risk of bias,

Region	Total number of women included in the study	Screening or diagnostic criteria	Mean age (SD) of the mother when giving birth	Number of women with pre-existing diabetes	Number of women with GDM	Adjusted odds ratio (95% CI)
(Continued from previous page)						
<b>Canada</b>						
Aljohani et al (2008) <sup>47</sup>	Manitoba 324 605 (39 820 First Nation women and 284 785 non-First Nation women)	Pre-existing diabetes=NR; GDM=there were no guidelines before 1992, but after 1992, screening was recommended at 24 weeks' gestation with a 50 g GTT, and if glucose was $\geq 7.8$ mmol/L at 1 h, then a 100 g OGTT was done and GDM was diagnosed if two or more results were abnormal (FBG concentration of $\geq 5.8$ mmol/L, glucose concentration of $\geq 10.6$ mmol/L at 1 h, glucose concentration of $\geq 9.2$ mmol/L at 2 h, or glucose concentration of $\geq 8.1$ mmol/L at 3 h); after 1998, patients were screened at 24–28 weeks' gestation with a 50 g GTT, and if glucose was $\geq 10.2$ mmol/L at 1 h, then GDM was diagnosed, but if glucose was $\geq 7.8$ mmol/L and $\leq 10.2$ mmol/L, then a 75 g OGTT was done, and GDM was diagnosed with two or more abnormal results (fasting blood glucose concentration of $\geq 5.8$ mmol/L, glucose concentration of $\geq 10.6$ mmol/L at 1 h, glucose concentration of $\geq 9.2$ mmol/L at 2 h, or glucose concentration of $\geq 8.1$ mmol/L at 3 h)	NR	NR	2764 (6.9%) of 39 820 First Nation women and 6708 (2.4%) of 284 785 non-First Nation women	GDM 2.20 (2.00–2.42)
Dyck et al (2002) <sup>44</sup>	Saskatchewan 1612 (252 First Nation and Métis women, and 1360 non-Indigenous women)	Pre-existing diabetes=NR; GDM=women were diagnosed if they met one of the following three criteria: (1) they had two or more abnormal values from a 100 g OGTT; (2) a 50 g oral GCT showed glucose concentrations of $\geq 7.8$ mmol/L at 1 h and a physician had confirmed the diagnosis; or (3) they required treatment with insulin or were given a specific diet for high blood glucose concentrations during pregnancy	NR	NR	29 (11.5%) of 252 First Nation and Métis women and 48 (3.5%) of 1360 non-Indigenous women	GDM 1.98 (1.06–3.96)
Liu et al (2012) <sup>46</sup>	Ontario 487 368 (2465 First Nations women living on reserves and 484 903 non-First Nation women)	Pre-existing diabetes=NR; GDM=NR	First Nation women: pre-existing DM 30.6 years (7.4), GDM 28.8 years (7.0); non-First Nation women: pre-existing DM 32.7 years (5.5), GDM 32.8 years (5.4)	96 (3.9%) of 2465 First Nations women living on reserves and 8728 (1.8%) of 484 903 non-First Nation women	160 (6.5%) of 2465 First Nation women and 20 366 (4.2%) of 484 903 non-First Nation women	NR
Oster et al (2014) <sup>45</sup>	Alberta 427 058 (28 306 First Nation women and 398 752 non-First Nation women)	Pre-existing diabetes=diagnoses were made on the basis of the patient's history, a review of patient's chart, their medication record, and if an OGTT was done in the first trimester and there was a positive result; GDM=patients were screened at 24–28 weeks' gestation with a 50 g oral GCT, and GDM was diagnosed if glucose was $\geq 10.3$ mmol/L, but if they were $\geq 7.8$ mmol and $< 10.2$ mmol/L then a 75 g OGTT was done, and GDM was diagnosed if two results were abnormal (FBG concentration of $\geq 5.3$ mmol/L, a glucose concentration of $> 10.3$ mmol/L at 1 h, or a glucose concentration of $\geq 8.9$ mmol/L at 2 h)	First Nation women with pre-existing DM, GDM 28.9 years (6.2); non-First Nation women with pre-existing DM and GDM 31.6 years (5.3)	283 (1.0%) of 28 306 First Nation women and 2393 (0.6%) of 398 752 non-First Nation women	1217 (4.3%) of 28 306 First Nation women and 15 153 (3.8%) of 398 752 non-First Nation women	Pre-existing DM 1.73 (1.52–1.96); GDM 1.47 (1.38–1.57)

(Table 1 continues on next page)

Region	Total number of women included in the study	Screening or diagnostic criteria	Mean age (SD) of the mother when giving birth	Number of women with pre-existing diabetes	Number of women with GDM	Adjusted odds ratio (95% CI)	
(Continued from previous page)							
Rodrigues et al (1999) <sup>48</sup>	Quebec and Montreal	8120 (402 Cree First Nation women living on reserve in Quebec and 7718 non-First Nation women living in Montreal)	Pre-existing diabetes=NR; GDM=patients were screened at 24–30 weeks' gestation with a 50 g GCT, and if glucose was $\geq 7.8$ mmol/L at 1 h, then a 100 g OGTT was done, and GDM was diagnosed if two results were abnormal (FBG concentration of $\geq 5.8$ mmol/L, a glucose concentration of 10.6 mmol/L at 1 h, a glucose concentration of $\geq 9.2$ mmol/L at 2 h, or a glucose concentration of $\geq 8.1$ mmol/L at 3 h)	NR	NR	46 (11.4%) of 402 Cree First Nation women living on reserve in Quebec and 178 (2.3%) of 7718 non-First Nation women living in Montreal	NR
Shen et al (2015) <sup>8</sup>	Manitoba	410 877 (71 033 First Nation women and 339 844 non-First Nation women)	Pre-existing diabetes=NR; GDM=NR	First Nation women: 26.6 years (6.1); non-First Nation women: 30.2 years (5.6)	2561 (6.3%) of 71 033 First Nation women and 3580 (1.1%) of 339 844 non-First Nation women	4564 (6.6%) of 71 033 First Nation women and 7342 (2.2%) of 339 844 non-First Nation women	NR
Yeung et al (2015) <sup>49</sup>	Alberta	248 525 (14 967 First Nation women and 233 558 Chinese, South Asian, and Caucasian women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	748 (5.0%) of 14 967 First Nation women, 11 169 (5.2%) of all 233 558 non-First Nation women, 8309 (4.1%) of 202 661 Caucasian women, 916 (11.8%) of 7759 Chinese women, and 1944 (8.4%) of 23 138 south east Asian women	First Nation women vs Caucasian women: GDM 1.80 (1.60–2.00)
Chen et al (2019) <sup>66</sup>	Quebec	234 850 (17 090 First Nation women and 217 760 non-Indigenous women)	Pre-existing diabetes=NR; GDM=patients underwent universal screening at 24–28 weeks' gestation with a 50 g GCT, and if blood glucose was $\geq 7.8$ mmol/L, then a 75 g OGTT was done and GDM was diagnosed if two results were abnormal (FBG concentration of $\geq 5.3$ mmol/L, a glucose concentration of $\geq 10.0$ mmol/L at 1 h, or a glucose concentration of $\geq 8.6$ mmol/L at 2 h)	NR	667 (3.9%) of 17 090 First Nation women and 2395 (1.1%) of 217 760 non-First Nation women	1829 (10.7%) of 17 090 First Nation women and 10 453 (4.8%) of 217 760 non-First Nation women	NR
<b>New Zealand</b>							
Yapa and Simmons (2000) <sup>50</sup>	South Auckland	2523 (613 Maori women and 1910 European, Pacific Islander, and other women)	Pre-existing diabetes=NR; GDM=patients were screened at 24–28 weeks' gestation with a 50 g GCT, and if glucose was $\geq 7.8$ mmol/L at 1 h, then a 75g OGTT was done and GDM was diagnosed if fasting glucose was $\geq 5.5$ mmol/L or if glucose was $\geq 9.0$ mmol/L at 2 h	NR	NR	35 (5.7%) of 613 Maori women, 92 (4.8%) of 1910 non-Indigenous women, 15 (2.5%) of 597 European women, and 68 (6.6%) of 1036 Pacific Islander women	NR

(Table 1 continues on next page)

15 studies<sup>28,32,33,41,47,48,51–53,55,56,58–60</sup> had an unclear risk of bias, and 12 studies<sup>25,26,30,31,38–40,43,44,50,64,65</sup> had a high risk of bias. Cohort studies received the lowest risk of bias scores in the following categories: representativeness of the exposed cohorts, selection of the non-exposed cohorts, assessment of the outcome, length of follow-up, and adequacy of follow-up.<sup>18</sup> Cohort studies received high risk of bias scores in the following categories: ascertainment of exposure, demonstration that the outcome of interest was not present before the study, and comparability of cohorts.<sup>18</sup> All cross-sectional studies<sup>44,51,52</sup> had an unclear risk of bias. Cross-sectional studies received high risk

of bias scores in the following categories: whether the study instrument showed validity or reliability, whether the same mode of data collection was used for all study participants, and whether the study population was a close representation of the national population.<sup>19</sup>

The pooled POR of pre-existing diabetes in Indigenous women compared with non-Indigenous women in Australia was 3.63 (95% CI 2.35–5.62), and heterogeneity across studies was high ( $I^2=98\%$ ,  $p<0.00001$ ; figure 3). The PORs of pre-existing diabetes in individual studies done in Australia ranged from 1.40 (1.28–1.52) to 8.24 (5.35–12.69). In Canada, the pooled POR

	Region	Total number of women included in the study	Screening or diagnostic criteria	Mean age (SD) of the mother when giving birth	Number of women with pre-existing diabetes	Number of women with GDM	Adjusted odds ratio (95% CI)
(Continued from previous page)							
<b>USA</b>							
Anderson et al (2016) <sup>53</sup>	USA	5 193 586 (44 570 American Indian and Alaska Native women, and 5 148 816 non-Indigenous women)	Pre-existing diabetes=NR; GDM=NR	NR	499 (1.1%) of 44 570 American Indian and Alaska Native women, 32 191 (0.6%) of all 5 148 816 non-Indigenous women, 19 349 (0.6%) of 3 182 835 white women, 6060 (0.8%) of 742 387 African American women, and 6782 (0.6%) of 1 223 594 Hispanic women	1932 (4.3%) of 44 570 American Indian and Alaska Native women, 195 504 (3.8%) of all 5 148 816 non-Indigenous women, 127 485 (4.0%) of 3 182 835 white women, 25 149 (3.4%) of 742 387 African American women, and 42 870 (3.5%) of 1 223 594 Hispanic women	NR
Ralls et al (2007) <sup>55</sup>	Utah	228 680 (2567 Native American women and 226 113 non-Native American women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	149 (5.6%) of 2657 Native American women and 5201 (2.3%) of 226 113 non-Native American women	GDM 2.10 (NR)
Cabacungan et al (2012) <sup>56</sup>	Wisconsin	197 253 (2216 Native American women and 195 037 non-Indigenous women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	151 (6.8%) of 2216 Native American women, 8176 (4.19%) of all 195 037 non-Native American women, 5810 (3.9%) of 148 967 white women, 686 (3.5%) of 19 587 African American women, 1083 (6.4%) of 16 926 Hispanic women, and 359 (6.1%) of 5884 Asian or Pacific Islander women	Native American women vs white women: GDM 2.27 (1.90-2.70)
Dennis (2019) <sup>64</sup>	USA	2 730 146 (23 926 American Indian and Alaska Native women, and 2 706 220 non-Indigenous women [excluding those who were not born in the USA])	Pre-existing diabetes=NR; GDM=NR	NR	NR	1563 (6.5%) of 23 926 American Indian and Alaska Native women, 109 575 (4.0%) of all 2 706 220 non-Indigenous women, 79 393 (4.3%) of 1 847 838 white women, 12 798 (3.3%) of 394 545 African American women, and 17 384 (3.8%) of 463 837 Hispanic women	NR
Fridman et al (2014) <sup>39</sup>	California	1 551 017 (6787 Native American women and 1 544 230 non-Indigenous women [grouped by race or ethnicity])	Pre-existing diabetes=NR; GDM=NR	NR	82 (1.2%) of 6787 Native American women, 11 807 (0.7%) of all 1 544 230 non-Indigenous women, 3057 (0.6%) of 518 113 white women, 855 (1.0%) of 85 510 African American women, 6318 (0.9%) of 718 003 Hispanic women, and 1125 (0.7%) of 152 099 Asian or Pacific Islander women	357 (5.3%) of 6787 Native American women, 75 769 (4.9%) of all 1 544 230 non-Indigenous women, 19 585 (3.8%) of 518 113 white women, 3172 (3.7%) of 85 510 African American women, 37 982 (5.3%) of 718 003 Hispanic women, and 11 681 (7.7%) of 152 099 Asian or Pacific Islander women	Native American women vs Caucasian women: pre-existing DM 1.01 (1.01-1.01); GDM 1.02 (1.02-1.03)

(Table 1 continues on next page)

Region	Total number of women included in the study	Screening or diagnostic criteria	Mean age (SD) of the mother when giving birth	Number of women with pre-existing diabetes	Number of women with GDM	Adjusted odds ratio (95% CI)
(Continued from previous page)						
Hunsberger et al (2010) <sup>27</sup>	Oklahoma 3767 (493 American Indian and Alaska Native women, and 3274 non-Native American and Alaska Native women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	39 (7.9%) of 493 American Indian and Alaska Native women, 318 (9.7%) of all 3274 non-Native American and Alaska Native women, 94 (6.9%) of 1354 white women, 93 (11.3%) of 824 Hispanic women, 92 (14.8%) of 617 Asian or Pacific Islander women, and 38 (8.1%) of 471 black women	American Indian and Alaska Native women vs white women: GDM 1.17 (0.71-1.95)
Kim et al (2012) <sup>27</sup>	Florida 641 697 (1211 American Indian women and 640 486 non-Indigenous women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	79 (6.5%) of 1211 American Indian women, 30 376 (4.6%) of all 640 486 non-Indigenous women, 15 456 (4.7%) of 331 126 of white women, 5522 (4.0%) of 138 844 black women, 1608 (9.9%) of 16 228 Asian or Pacific Islander women, and 7502 (4.9%) of 148 375 Hispanic women	NR
Kim et al (2013) <sup>28</sup>	California 1 228 265 (4134 American Indian women and 1 224 131 non-Indigenous women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	316 (7.6%) of 4134 of American Indian women, 96 045 (7.8%) of all 1 224 131 non-Indigenous women, 18 806 (5.4%) of 350 697 white women, 3371 (5.6%) of 60 685 black women, 20 129 (11.9%) of 168 933 Asian or Pacific Islander women, and 52 255 (8.4%) of 621 187 Hispanic women	NR
Pearson et al (2016) <sup>29</sup>	California 544 743 (35 792 American Indian and Alaska Native women, and 508 951 white women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	2004 (5.6%) of 35 792 American Indian and Alaska Native women and 22 597 (4.4%) of 508 951 white women	GDM 1.34 (1.28-1.41)
Singh et al (2018) <sup>30</sup>	USA 7 480 879 (14 497 American Indian and Alaska Native women, and 7 466 382 non-American Indian or Alaska Native women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	1420 (9.8%) of 14 497 of American Indian and Alaska Native women, 470 049 (6.3%) of all 7 466 382 non-American Indian and Alaska Native women, 246 365 (5.7%) of 4 322 169 white women, 66 529 (5.6%) of 1 188 014 African American women, 17 502 (13.3%) of 131 594 Asian Indian women, 7516 (11.9%) of 63 160 Filipino women, 4896 (11.6%) of 41 211 Vietnamese women, 436 (10.1%) of 4316 Samoan women, 11 062 (9.5%) of 116 439 Chinese women, 879 (6.2%) of 14 177 Japanese women, 2401 (7.9%) of 30 390 Korean women, 143 (8.3%) of 1725 Hawaiian women, 83 003 (7.6%) of 1 092 146 Mexican women, 9438 (6.7%) of 140 866 Puerto Rican women, 2146 (5.2%) of 41 270 Cuban women, and 17 849 (6.4%) of 278 905 Central or South American women	NR

(Table 1 continues on next page)

	Region	Total number of women included in the study	Screening or diagnostic criteria	Mean age (SD) of the mother when giving birth	Number of women with pre-existing diabetes	Number of women with GDM	Adjusted odds ratio (95% CI)
(Continued from previous page)							
Hegwood et al (2015) <sup>51</sup>	Oklahoma	21 143 (2451 Native American women and 18 692 white and black women)	Pre-existing diabetes=NR; GDM=postpartum women self-report by use of the Pregnancy Risk Assessment Monitoring System survey	NR	NR	215 (8.8%) of 2449 Native American women, 1304 (7.0%) of all 18 692 white and black women, 1304 (7.2%) of 15 927 white women, and 163 (5.9%) of 2765 African American women	NR
Williams et al (1999) <sup>61</sup>	Washington	41 839 (7456 Native American women and 34 383 non-Indigenous women)	Pre-existing diabetes=NR; GDM=NR	NR	NR	201 (2.7%) of 7456 of Native American women, 962 (2.8%) of all 34 383 non-Indigenous women, 602 (2.8%) of 21 528 white women, 165 (2.6%) of 6359 African American women, and 195 (3.0%) of 6495 Hispanic women	NR
Caughey et al (2010) <sup>63</sup>	Northern California	139 853 (800 Native American women and 139 053 non-Indigenous women)	Pre-existing diabetes=NR; GD=NR	NR	NR	45 (5.6%) of 800 Native American women, 6133 (6.8%) of all 139 053 non-Indigenous women, 2136 (3.4%) of 62 823 white women, 450 (3.2%) of 14 069 African American women, 1754 (4.9%) of 35 786 Latino women, and 1793 (6.8%) of 26 370 Asian women	Native American women vs white women: GDM 1.31 (0.85–2.01)
Chu et al (2009) <sup>62</sup>	Florida, Idaho, Kansas, Kentucky, Nebraska, New Hampshire, New York, Pennsylvania, South Dakota, Delaware, North Dakota, South Dakota, Ohio, Vermont, Wyoming, and California	3 108 877 (14 617 American Indian and Alaska Native women, and 3 094 260 non-American Indian or Alaska Native women)	Pre-existing diabetes=NR; GD=NR	NR	NR	750 (5.1%) of 14 617 American Indian and Alaska Native women, 119 473 (3.9%) of all 3 094 260 non-American Indian or Alaska Native women, 13 951 (3.8%) of 1873 925 white women, 13 951 (3.5%) of 394 081 African American women, 24 589 (3.6%) of 677 392 Hispanic women, and 9349 (6.3%) of 148 862 Asian or Pacific Islander women	NR
Moum et al (2004) <sup>54</sup>	Montana and North Dakota	22 746 (2664 American Indian women and 20 082 white women)	Pre-existing diabetes=NR; GD=NR	NR	27 (1.0%) of 2664 American Indian women and 80 (0.4%) of 20 082 white women	103 (3.9%) of 2 644 American Indian women and 562 (2.8%) of 20 082 white women	NR

All studies apart from those by Moses and colleagues (prospective cohort),<sup>26</sup> Dyck and colleagues (cross-sectional),<sup>44</sup> Hunsberger and colleagues (cross-sectional),<sup>52</sup> and Hegwood and colleagues (cross-sectional)<sup>51</sup> were retrospective cohort studies. The GCT was a non-fasted test and the OGTT was a fasted test. GD=gestational diabetes. GCT=glucose challenge test. NR=not reported. OGTT=oral glucose challenge test. FBG=fasting blood glucose. \*Includes mothers and babies reports from 1996–2010 and 2012–2017.

**Table 1: Summary of included studies**

estimate of pre-existing diabetes in First Nation women compared with non-First Nation women was 2.66 (1.92–3.67); however, heterogeneity between studies was also high ( $I^2=98%$ ,  $p<0.00001$ ; figure 4). The PORs of pre-existing diabetes in individual studies done in Canada ranged from 1.71 (1.51–1.93) to 3.65 (3.35–3.99). In the USA, the pooled POR of pre-existing diabetes in Native American or Alaska Native women compared with non-Indigenous women was 1.81 (1.53–2.13), with moderate heterogeneity between

studies ( $I^2=48%$ ,  $p=0.15$ ; figure 5). The PORs of pre-existing diabetes in individual studies done in the USA ranged from 1.59 (95% CI: 1.28–1.97) to 2.58 (1.66–4.00). We did not identify studies that estimated the prevalence of pre-existing diabetes among Maori women in New Zealand.

14 studies<sup>8,25,27–31,43,45,46,53,54,66</sup> on pre-existing diabetes reported crude PORs indicating that the odds of having pre-existing diabetes was higher in Indigenous women than in non-Indigenous women (table 2), with POR

values ranging from 1.40 (95% CI 1.28–1.52) to 8.24 (5.35–12.69). The pooled POR estimates from the meta-analysis of studies done in Australia and Canada should

be interpreted with caution because of the high heterogeneity between studies. However, the direction and magnitude of individual study PORs indicated that there was an association between indigeneity and pre-existing diabetes. No obvious publication bias was evident from the funnel plots (appendix 3 pp 6–7).

The pooled POR of gestational diabetes in Indigenous women compared with non-Indigenous women in Australia was 1.42 (95% CI 1.24–1.63), with high heterogeneity observed between studies ( $I^2=97%$ ,  $p<0.00001$ ; figure 3). The PORs of gestational diabetes in individual studies done in Australia ranged from 0.44 (0.14–1.39) to 6.67 (5.11–8.72). The pooled POR of

See Online for appendix 3

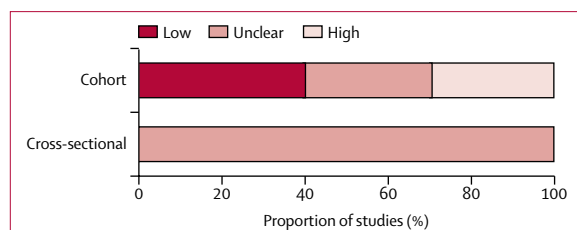


Figure 2: Risk of bias of included studies

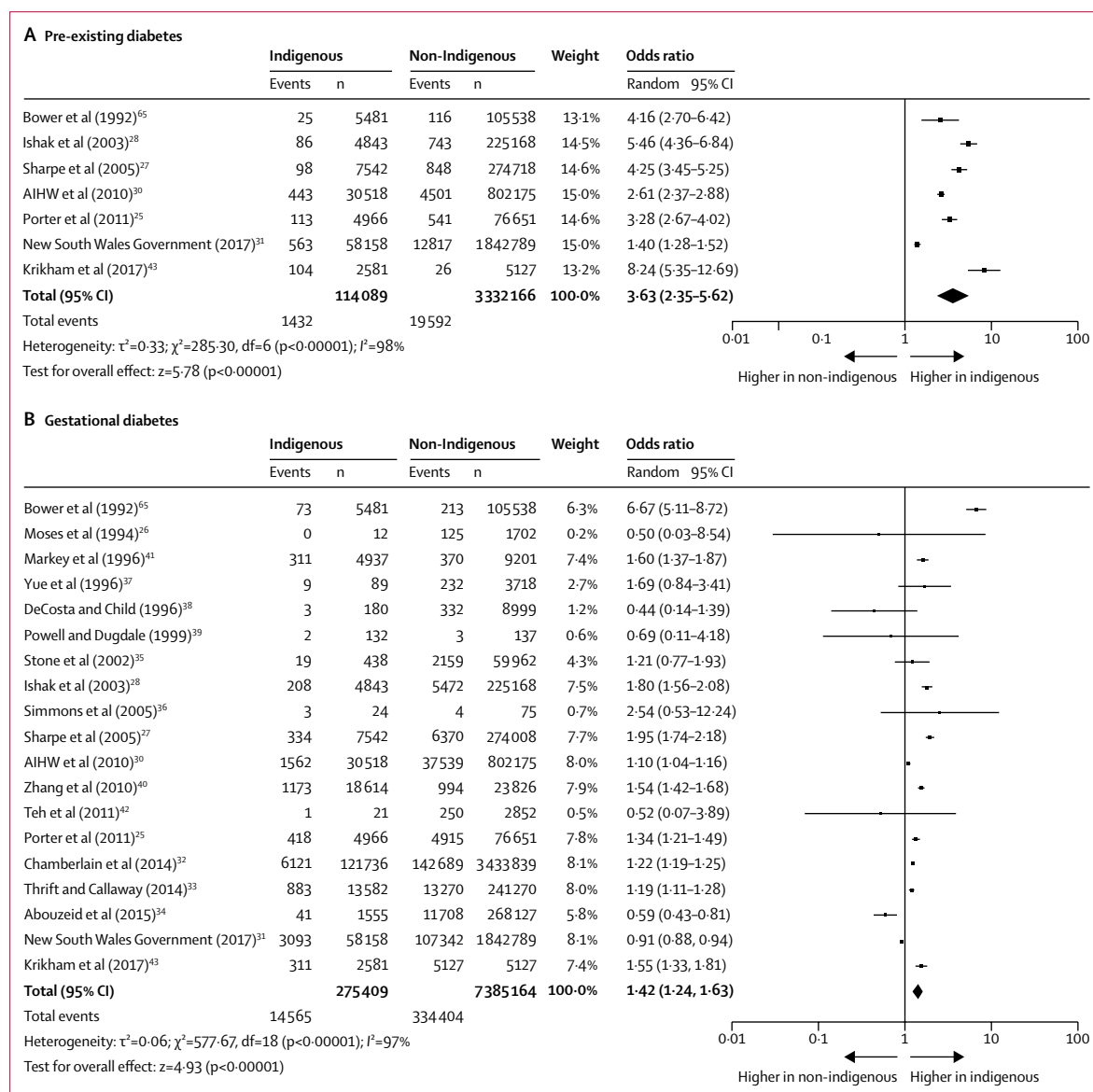
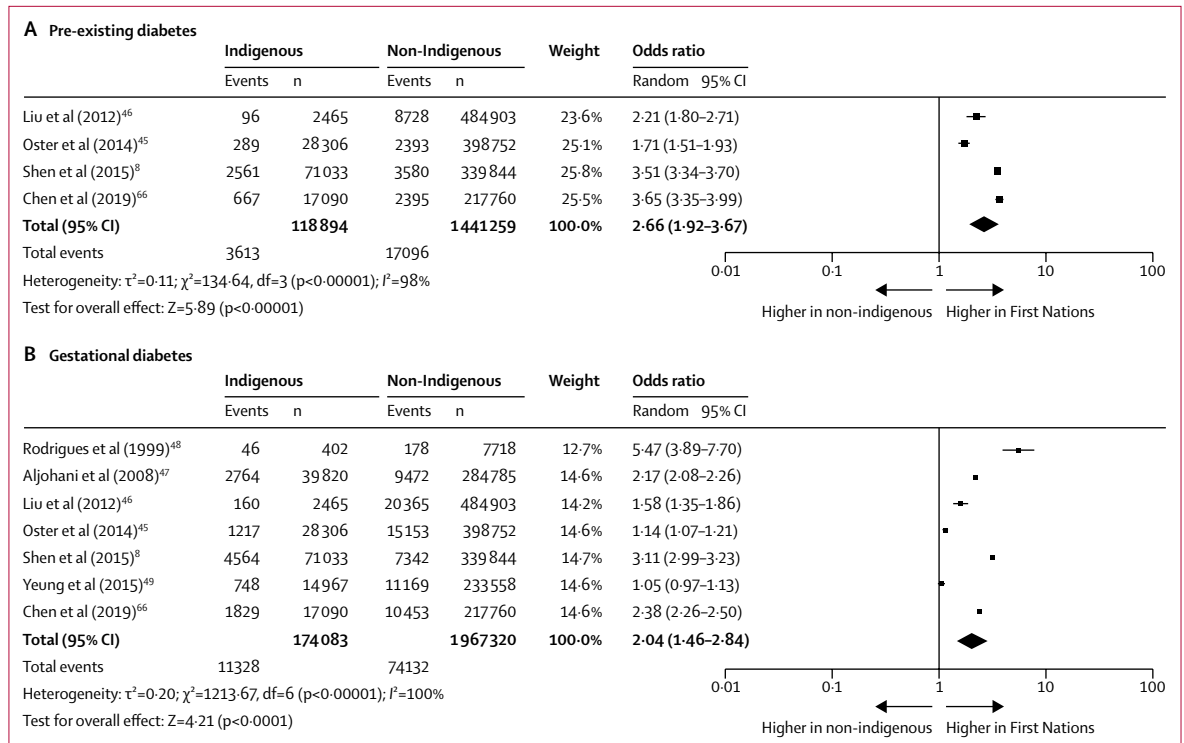


Figure 3: Mantel-Haenszel random-effects meta-analysis results showing the pooled prevalence of (A) pre-existing diabetes and (B) gestational diabetes in observational studies comparing Aboriginal or Torres Strait Islander women to Non-Indigenous women in Australia. Events are defined as the number of participants in the study with pre-existing diabetes or gestational diabetes, and n is the total number of participants in the study. AIHW=Australian Institute of Health and Welfare. df=degrees of freedom.

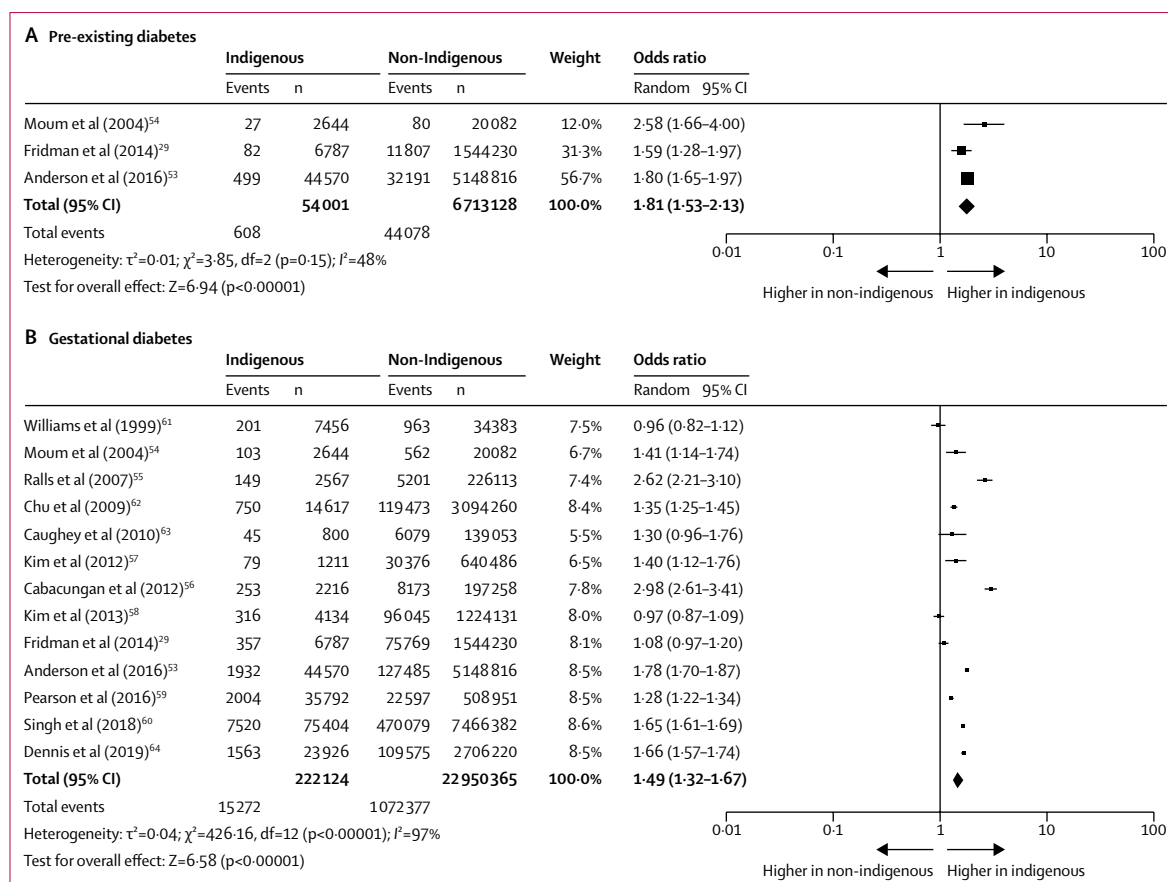


**Figure 4: Mantel-Haenszel random-effects meta-analysis results showing the pooled prevalence of (A) pre-existing diabetes and (B) gestational diabetes in observational studies comparing First Nation women to non-Indigenous women in Canada**  
 Events are defined as the number of participants in the study with pre-existing diabetes or gestational diabetes, and n is the total number of participants in the study. AIHW=Australian Institute of Health and Welfare. df=degrees of freedom.

gestational diabetes in First Nation women compared with non-First Nation women in studies done in Canada was 2.04 (1.46–2.84), with high heterogeneity observed between studies ( $I^2=100\%$ ,  $p<0.00001$ ; figure 4). The PORs of gestational diabetes in individual studies done in Canada ranged from 1.05 (0.97–1.13) to 5.47 (3.89–7.70). In the USA, the pooled POR of gestational diabetes in Native American or Alaska Native women compared with non-Indigenous women was 1.49 (1.32–1.67), with high heterogeneity observed between studies ( $I^2=97\%$ ,  $p<0.00001$ ; figure 5). The PORs of gestational diabetes in individual studies done in the USA ranged from 0.96 (0.82–1.12) to 2.98 (2.61–3.41).

Of all 39 studies<sup>8,25-43,45-50,53-56</sup> on gestational diabetes included in the meta-analysis, 25 (64%) studies<sup>8,25,27,28,30,32,33,40,41,43,45-48,53-57,59,60,62,64-66</sup> reported crude PORs indicating that the odds of having gestational diabetes in pregnancy were higher among Indigenous women than non-Indigenous women (table 2), with PORs ranging from 1.10 (95% CI 1.04–1.16) to 6.67 (5.11–8.72). 12 (31%) of these studies<sup>26,29,35-39,42,49,58,61,63</sup> indicated that the odds of having gestational diabetes in pregnancy were no different between Indigenous and non-Indigenous women, with PORs ranging from 0.44 (0.14–1.39) to 2.54 (0.53–12.24). Two (5%) studies<sup>31,34</sup> showed that the odds of having gestational diabetes in pregnancy were lower among Indigenous women, with PORs of 0.59

(0.48–0.72) and 0.91 (0.88–0.94). The pooled PORs of studies done in Australia, Canada, and the USA should be interpreted with caution because of the high heterogeneity between studies. However, the magnitude and direction of the PORs from individual studies suggest that there is an association between indigeneity and gestational diabetes that is not as consistent as the association between pre-existing diabetes and indigeneity. Heterogeneity between studies was explored by subgroup analyses. Studies done in different time periods were assessed separately because of changing screening and diagnostic criteria (appendix 3 pp 1–3). In addition, studies that used different sources of data were grouped and analysed separately (appendix 3 pp 3–5). Low, unclear, and high risk of bias categories were also pooled separately. In addition, we analysed pre-existing diabetes and gestational diabetes in Indigenous women compared with white women (low risk) in the USA and Australia, for studies in which these data were reported (appendix 3 p 5). Although heterogeneity between studies was not meaningfully reduced, the magnitude of the pooled POR for both pre-existing diabetes and gestational diabetes in the USA and Australia was found to increase. Subgroup analysis of cohort studies in Australia that used hospital data showed low heterogeneity between studies ( $I^2=22\%$ ,  $p=0.27$ ; appendix 3 p 4).



**Figure 5:** Mantel-Haenszel random-effects meta-analysis results showing the pooled prevalence of (A) pre-existing diabetes and (B) gestational diabetes in observational studies comparing Native America or Alaska Native women to non-Indigenous women in the USA. Events are defined as the number of participants in the study with pre-existing diabetes or gestational diabetes, and n is the total number of participants in the study. df=degrees of freedom.

**Discussion**

This systematic review and meta-analysis provided a comprehensive assessment of the prevalence of diabetes in pregnancy among Indigenous women in Australia, Canada, New Zealand, and the USA. We found a large variation in the prevalence estimates of pre-existing diabetes and gestational diabetes among Indigenous women in these four countries. Predominantly, the odds of having pre-existing diabetes or gestational diabetes are greater in Indigenous pregnant women than in non-Indigenous pregnant women.

The crude POR estimates of pre-existing diabetes and gestational diabetes in individual studies showed that both types of diabetes appear to be strongly associated with Indigenous ancestry in pregnant women, but the magnitude of this association varies across studies and by type of diabetes. The association between indigeneity and the prevalence of pre-existing diabetes was consistently stronger than the association between indigeneity and the prevalence of gestational diabetes. Pre-existing diabetes primarily consists of type 1 and type 2 diabetes, diagnosed before pregnancy, and overt

	Pre-existing diabetes (n=14)	Gestational diabetes (n=39)
Number of studies with a greater POR among Indigenous women	14	25
Number of studies with a POR that was no different between Indigenous and non-Indigenous women	0	12
Number of studies with a lower POR among Indigenous women	0	2

POR=prevalence odds ratio.

**Table 2:** Number of studies showing higher, no different, or lower prevalence odds ratios of pre-existing diabetes and gestational diabetes among Indigenous women

diabetes, identified at the beginning of pregnancy.<sup>67,68</sup> The higher prevalence of pre-existing diabetes among Indigenous women compared with non-Indigenous women is likely to be because there are a higher number of Indigenous women with type 2 diabetes than non-Indigenous women. Although this analysis was not done in our study, it is likely to be the case because the prevalence of type 2 diabetes has been reported to be higher among Indigenous peoples than in non-Indigenous peoples.<sup>69</sup> The results of our

systematic review and meta-analysis are similar to those of other reviews done in this field.<sup>11,13</sup> One previous systematic review<sup>11</sup> that assessed the prevalence of gestational diabetes among Indigenous women in Australia found substantial heterogeneity in the prevalence estimates across the included studies.

Compared with previous studies,<sup>11–13</sup> our review adds a systematic comparison between the prevalence of pre-existing diabetes and gestational diabetes in Indigenous women and non-Indigenous women from four countries (Australia, Canada, New Zealand and the USA) with similar histories of colonialism. The Indigenous people's experience of colonialism is an important factor contributing to loss of identity, language, culture, the rapid transition to industrialisation, as well as ongoing oppression and discrimination.<sup>70–72</sup> Increased exposure to unfavourable social determinants of health (ie, income, education, and employment) among Indigenous peoples is also a consequence of colonialism.<sup>14</sup> Social inequalities and colonialism have been recognised as important contributors for the development of diabetes in Indigenous peoples.<sup>73</sup> These factors also create barriers to the effective management of diabetes in Indigenous peoples (eg, increasing physical activity, consuming balanced meals, monitoring blood sugar concentrations, and injecting insulin).<sup>73,74</sup> Alternatively, the high prevalence of diabetes among Indigenous peoples has been proposed to be because of genetic susceptibility, but research has yet to find a strong causative gene.<sup>69</sup>

Clinical care and public health interventions designed for Indigenous women to prevent diabetes in pregnancy and to reduce the negative effects of this condition should be led by Indigenous women at the community level. Incorporating the culture, traditional practices, and the world views of Indigenous peoples in the design of prevention strategies at the community level will ensure local needs are met. Care for Indigenous women also needs to be equitable to ensure that social inequalities are not preventing them from achieving the same health status as non-Indigenous women. Two previous reviews<sup>75,76</sup> suggest that the results are promising when Indigenous self-determination is incorporated into primary care and maternal child health programmes. The prevalence of pre-existing diabetes is greater in Indigenous women than in non-Indigenous women, therefore, early screening of Indigenous women during pregnancy should be prioritised to identify previously undiagnosed type 1 or type 2 diabetes. Clinicians should be aware that Indigenous women are more likely to have pre-existing diabetes and gestational diabetes in pregnancy, and they should adjust their practice accordingly when treating Indigenous women.

Future research should focus on both prevention of diabetes in pregnancy and adapting clinical care so that it is more meaningful and effective for Indigenous women. Research on innovative solutions to improve social inequalities should be done in partnership with

Indigenous communities. Evaluations of adapted care for Indigenous women should focus on improving outcomes and decreasing the effect of pre-existing diabetes and gestational diabetes on their health and the health of their child. Continued surveillance of the prevalence of gestational diabetes and pre-existing diabetes among Indigenous women, by either health-care systems, governments, or Indigenous communities, is necessary; but future studies should clearly report the screening and diagnostic criteria that are used to diagnose both types of diabetes so that the interpretation of study results can be improved.

The strengths of our systematic review and meta-analysis include the use of a rigorous methodological approach that followed a pre-defined protocol, which was registered before the beginning of the study. We used validated search terms to do a comprehensive database search,<sup>17</sup> and we searched the grey literature and relevant reference lists to reduce selection bias by decreasing the chance of missing potentially relevant studies. The risk of bias assessment and data extraction were done in duplicate to minimise assessor bias.

However, there are several limitations of our study. Included studies were from a wide range of time periods, over which the screening guidelines and diagnostic criteria for pre-existing diabetes and gestational diabetes had changed. The screening and diagnostic criteria for pre-existing diabetes and gestational diabetes, and the characteristics of comparison groups, were not always reported in the included studies, which prevented meaningful subgroup analyses. Other reasons for the high heterogeneity between studies could be because of underlying differences in study participants. One could argue that the high heterogeneity across the included studies might make the pooled POR estimates less useful; however, high heterogeneity could also indicate that there is a wide variation in the prevalence of pre-existing diabetes and gestational diabetes across a range of different Indigenous groups. Finally, no formal evaluation of the effect of colonialism and the social determinants of health among Indigenous and non-Indigenous women in this study was done, therefore, a causal association cannot be inferred.

To the best of our knowledge, there are no cohort studies done in New Zealand that have compared the prevalence of pre-existing diabetes in Indigenous women with that in non-Indigenous women. In Canada, available data from cross-sectional studies<sup>77</sup> have shown that 4·0% of all cases of diabetes among Inuit people are gestational diabetes, and among Métis people, 2·2% of all cases of diabetes are gestational diabetes. The generalisability of our results to other Indigenous peoples should be interpreted with caution, until such a time when those studies have been produced, so that pan-Indigenous interpretations are avoided.

In conclusion, Indigenous women in Australia, Canada, New Zealand, and the USA have an increased susceptibility to having pre-existing diabetes and

gestational diabetes during pregnancy. Diabetes during pregnancy results in poor birth and delivery outcomes, with serious long-term effects on the health of the mother and the child. System-wide and structural interventions to address the increased prevalence of pre-existing diabetes and gestational diabetes in Indigenous women in Australia, Canada, New Zealand and the USA should be considered.

#### Contributors

BV, DE, and MBO contributed to the design and conceptualisation of the study. BV, SR, OS, DE, and MBO contributed to the screening of studies for inclusion and data extraction. SC searched the databases. BV, MBO, DT, and SC contributed to the analysis and interpretation of the data. All authors contributed to the writing or editing and reviewing of the manuscript.

#### Declaration of interests

We declare no competing interests.

#### Acknowledgments

This study was supported by grants from the Lois Hole Hospital for Women through the Women's and Children's Health Research Institute (to MBO and BV) and the Canadian Institutes of Health Research (to MBO).

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