Care provided to women during and after a pregnancy complicated by hyperglycaemia: the impacts of a multi-component health systems intervention

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Summary

Background Aboriginal and Torres Strait Islander women experience a disproportionate burden of hyperglycaemia in pregnancy. A multi-component health systems intervention aiming to improve antenatal and postpartum care was implemented across Australia's Northern Territory (NT) and Far North Queensland (FNQ) between 2016 and 2019. Components included clinician education, improving recall systems, enhancing policies and guidelines, and embedding Diabetes in Pregnancy (DIP) Clinical Registers in systems of care. This program was evaluated to determine impacts on clinical practice and maternal health.

Methods Data for women with hyperglycaemia in pregnancy from primary care clinical records and the DIP Clinical Registers were analysed to assess changes in: antenatal and postpartum diabetes testing; HbA1c/glucose levels; medication use; weight checks performed, weight and body mass index; and postpartum contraception, smoking and breastfeeding.

Findings Clinical practice in the NT improved, including increased uptake of the recommended first trimester 75 g oral glucose tolerance test among women with hyperglycaemia risk factors (Aboriginal and Torres Strait Islander women 11.7% to 26.5%, $p < 0.001$; non-Indigenous women 6.2% to 19.3%, $p < 0.001$). In the NT, postpartum diabetes monitoring (56% to 68%, $p = 0.039$) and contraceptive use (41% to 60%, $p = 0.001$) increased among

Abbreviations: DIP, Diabetes in Pregnancy; FNQ, Far North Queensland; GDM, Gestational diabetes; GDM/DIP, Gestational diabetes or overt diabetes in pregnancy; NT, Northern Territory; T2D, type 2 diabetes

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Aboriginal and Torres Strait Islander women. In FNQ, postpartum glucose monitoring increased among women with T2D (26% to 68% Aboriginal and Torres Strait Islander, p = 0.002; 50% to 100% non-Indigenous, p = 0.008), although there were no improvements in antenatal care indicators.

Interpretation Aspects of care for women with hyperglycaemia in pregnancy improved in the NT and FNQ following a multi-component health systems intervention.

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Keywords: Diabetes in pregnancy; Gestational diabetes; Type 2 diabetes; Health systems; Quality improvement; Aboriginal and Torres Strait Islander; First Nations

Research in context

Evidence before this study

There are multiple barriers to providing optimal care during and after a pregnancy complicated by hyperglycaemia. Addressing such barriers to improve care has been identified by the International Federation of Gynecology and Obstetrics as a priority research area. We searched PubMed for health system interventions aiming to improve care during and/or after pregnancy for any form of hyperglycaemia in pregnancy. Search terms included ((diabetes, gestational[MeSH Terms]) OR (pregnancy in diabetics[MeSH Terms]) OR (diabetes in pregnancy[Text]) OR (hyperglycaemia in pregnancy[Text]) OR (pre-existing diabetes[Text]) OR (hyperglycemia in pregnancy [Text]) OR (pre-gestational diabetes[Text])) AND ((antenatal screening[MeSH Terms]) OR (care, postpartum[MeSH Terms]) OR (delivery of health care[MeSH Terms]) OR (health services [MeSH Terms]) OR (health systems[Text]) OR (health services [Text]) OR (quality improvement[Text])). There are multiple previous interventions, some of which have demonstrated improvements in birth outcomes or postpartum glucose screening rates. However, there are several gaps in the literature. Firstly, previous studies included only women with either gestational diabetes or pre-existing diabetes, without recognising the need to improve care across the entire spectrum of hyperglycaemia in pregnancy. Additionally, studies on postpartum care have focussed almost exclusively on improving glucose screening among women with gestational diabetes, without acknowledging the importance of a holistic approach to improving postpartum care. Finally, there is an absence of studies seeking to improve care specifically for First Nations women, who are disproportionately impacted by hyperglycaemia in pregnancy globally and face additional barriers to accessing care.

Added value of this study

Between 2016 and 2019 we implemented a multi-component health systems intervention in Australia's Northern Territory and Far North Queensland which aimed to improve systems of antenatal and postpartum care for women with hyperglycaemia in pregnancy. There was a specific focus on improving care for Aboriginal and Torres Strait Islander women (Australia's First Nations women), given they experience a disproportionate burden of hyperglycaemia in pregnancy and its complications. Post-intervention, there were improvements in care for Aboriginal and Torres Strait Islander women in the Northern Territory, including in early pregnancy screening, postpartum diabetes monitoring and contraceptive use. In Far North Queensland, postpartum glucose monitoring improved post-intervention.

Implications of all the available evidence

Hyperglycaemia in pregnancy is associated with short- and long-term complications for mothers and babies. There are multiple opportunities to improve the care provided to women with hyperglycaemia in pregnancy, which often does not meet the standards recommended in international guidelines. The available evidence, including our study, demonstrate that multicomponent health systems interventions, developed and implemented in collaboration with stakeholders, can lead to improvements in care provided. This is of particular importance for First Nations women, where reducing the risks associated with hyperglycaemia in pregnancy is a crucial strategy to address the escalating epidemic of diabetes affecting First Nations peoples globally.

Introduction

Hyperglycaemia in pregnancy, encompassing gestational diabetes (GDM), overt diabetes in pregnancy (DIP) and pre-existing diabetes, increases the risk of pregnancy complications, such as stillbirth and macrosomia.[1,2] There are additional long-term risks to both mother and child, including increased risk of diabetes for women who have had GDM,[3] and increased risk of

overweight and diabetes, particularly onset at a young age, for the infant.[4] In Australia, Aboriginal and Torres Strait Islander women experience a disproportionate burden of hyperglycaemia in pregnancy.[5,6] The intergenerational impact of this disproportionate burden is an important contributor to the high prevalence of type 2 diabetes (T2D) among Aboriginal and Torres Strait Islander peoples.[7,8]

Pregnancy and the postpartum period are critical times to reduce diabetes-related risks for Aboriginal and Torres Strait Islander women. Although multiple local and international bodies have developed guidelines for the antenatal and postpartum management of hyperglycaemia in pregnancy, care often falls below these recommended standards.[9,10] Clinician surveys in Australia's Northern Territory (NT) and Far North Queensland (FNQ) have revealed inconsistencies in practice in areas such as diabetes screening.[11,12] While guidelines recommend early screening at 6–12 weeks after a pregnancy complicated by GDM, only 54% of eligible Aboriginal or Torres Strait Islander women in the NT in 2013–14[13] and 24% in FNQ in 2004–2010[14] had any diabetes screening within 12 months postpartum. These figures are comparable to international reports.[10,15] Furthermore, evidence is lacking regarding postpartum screening and management of other cardiovascular risk factors, such as smoking.

The International Federation of Gynecology and Obstetrics has identified improving systems of care during and after a pregnancy complicated by hyperglycaemia as a research priority.[9] Optimising care provided during pregnancy improves birth outcomes among women with pre-existing diabetes.[16] Identifying GDM and initiating treatment early in women with diabetes risk factors has been associated with decreased adverse neonatal outcomes.[17] For women with GDM, improved systems of care have led to increased postpartum diabetes screening rates.[18,19] However, to our knowledge there are no programs in the literature which have specifically aimed to improve care for Aboriginal and Torres Strait Islander women. There are multiple challenges in providing care for hyperglycaemia in pregnancy in the regional and remote Australian setting, including siloed care, lack of role clarity between care providers, high turnover of clinical staff, limited capacity of Aboriginal and Torres Strait Islander workforce, and lack of effective communication across cultural and linguistic barriers.[11,12,20,21]

The Diabetes Across the Lifecourse: Northern Australia Partnership ("the Partnership") is a collaboration between clinicians, health services, researchers and policymakers with a vision of working in partnership with Aboriginal and Torres Strait Islander peoples to break the cycle of T2D and related conditions. The Partnership was established in the NT in 2011 and expanded to include FNQ in 2016. Between 2016 and 2019, the Partnership implemented a multi-component health systems intervention that aimed to improve antenatal and postpartum care for hyperglycaemia in pregnancy in Australia's NT and FNQ through addressing identified barriers. The aim of the current report was to determine whether clinical practice in providing care for women during and after a pregnancy complicated by hyperglycaemia had changed following the implementation of the health systems intervention. We also assessed whether indicators of antenatal and postpartum maternal health had changed.

Methods

Setting

The NT and FNQ's 500,000 residents occupy a large geographic area of 1.6 million km^2, including numerous islands and other remote communities inaccessible by road during the monsoonal wet season.[22–24] The proportion of residents identifying as Aboriginal and/or Torres Strait Islander is high compared to the national figure of 3.2%, being 27% and 19% in the NT and FNQ respectively.[22–25] Over 200 languages, including Aboriginal and Torres Strait Islander languages and those of migrant populations, are spoken across the regions.[22–24] Across the NT and FNQ there are approximately 7000 births per year, hyperglycaemia complicating 18.6% of pregnancies in the NT and 20% of pregnancies in FNQ.[26,27] Care for women with hyperglycaemia in pregnancy is provided by a complex network of hospital and primary care services. Primary care may be provided by an Aboriginal Community Controlled Health Service, a government clinic, or a private provider. Women with hyperglycaemia in pregnancy usually require multidisciplinary care provided by several services, potentially being required to travel great distances and relocate to larger centres prior to birth.

Health systems intervention design

Between 2016 and 2019, the Partnership implemented a multi-component health systems intervention to improve care during and after a pregnancy complicated by hyperglycaemia in the NT and FNQ (Fig. 1). Implementation methods for this intervention have been reported in detail previously,[28] and are included in Supplementary Material Section S1. Study activities were implemented across primary, secondary and tertiary health service levels in three study regions (Central Australia and Top End in the NT, and FNQ), and addressed five components: 1) increasing workforce capacity, skills and knowledge, and improving the health literacy of women; 2) improving access to healthcare through culturally and clinically appropriate pathways; 3) improving information management and communication; 4) enhancing policies and guidelines; and 5) embedding a clinical register for women with hyperglycaemia in pregnancy within models of care.

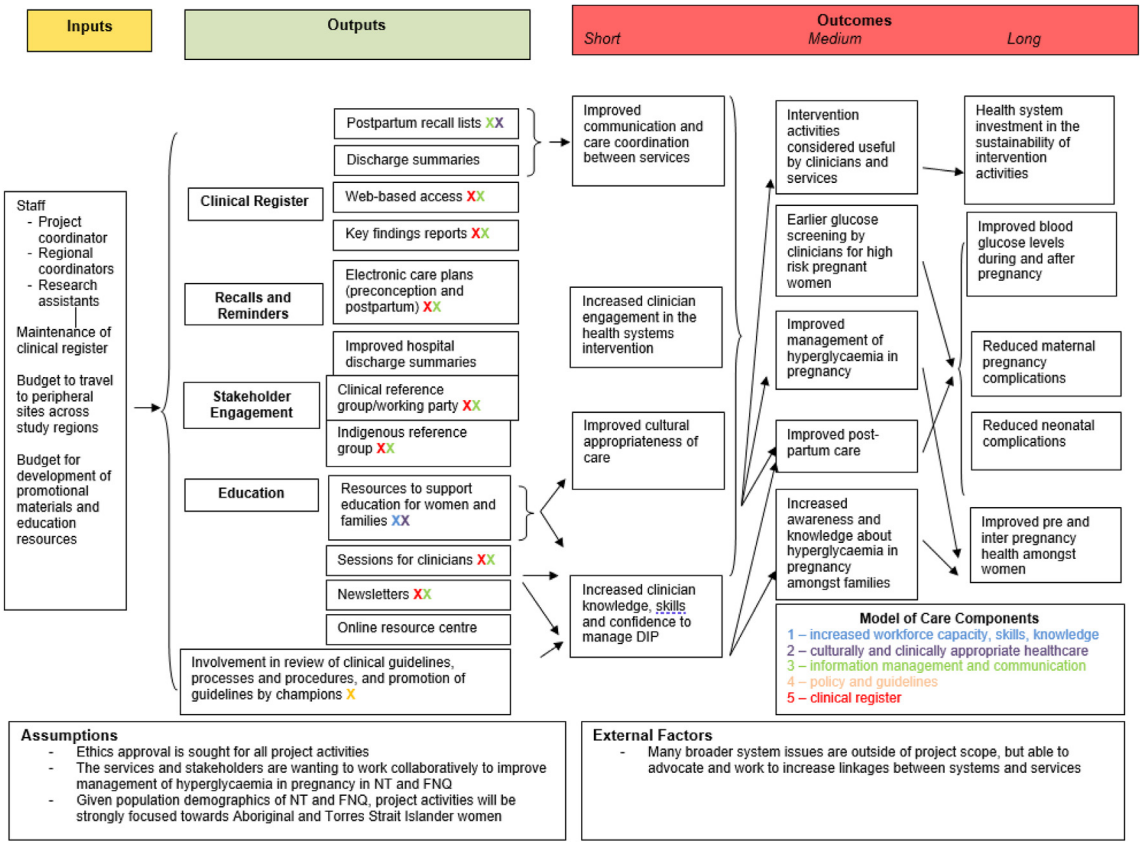

Fig. 1: Logic model for a health systems intervention to improve care during and after a pregnancy complicated by hyperglycaemia (licensed under CC BY 4.0 by MacKay D et al.[27]).

Evaluation methods

A mixed-methods evaluation of the health systems intervention was conducted. The evaluation aimed to determine the impact of the intervention on systems of care during and after pregnancy for women with hyperglycaemia in pregnancy, and the impact on birth outcomes. Design of the evaluation was underpinned by the RE-AIM framework (reach, effectiveness, adoption, implementation, maintenance).[29] Evaluation methods included analysis of pre- and post-intervention health record data and health professional surveys and qualitative interviews, and have been described in detail previously.[28] Evaluation indicators according to the RE-AIM domains are provided in Supplementary Table S2. In this paper we report quantitative evaluation findings relating to changes in care provided, as per recommended clinical standards (see Supplementary Table S3), for women with hyperglycaemia in pregnancy during and after their pregnancy. To assess care provided, we used data from the NT and FNQ Diabetes in Pregnancy Clinical Registers and from primary care electronic health records. Comparisons were made between pre- and post-intervention data. Findings from other aspects of the evaluation, including health professional perspectives and birth outcomes, will be reported elsewhere.

Data collection

In the NT, antenatal care outcomes were assessed using data from the NT DIP Clinical Register. Postpartum outcomes were assessed using data from primary care services (NT Department of Health and two large Aboriginal Community Controlled Health Services) as the Clinical Register did not contain postpartum data. Use of different data sources resulted in lower coverage of the postpartum dataset in comparison to the antenatal dataset. In the NT, due to data availability the baseline period included births between January 1, 2013 and December 31, 2014; the post-intervention comparison period included births between January 1, 2019 and December 31, 2019.

In FNQ, both antenatal and postpartum care were assessed using data from the FNQ DIP Clinical Register. The FNQ DIP Clinical Register contained data for postpartum glucose assessments, but not for other postpartum care indicators (see *Outcomes* section,

below). Data prior to the establishment of the FNQ Clinical Register were not available, thus the FNQ baseline period included births in the first full year of FNQ Clinical Register data, i.e., between January 1, 2017 and December 31, 2017. The post-intervention comparison period was the same as in the NT, including births between January 1, 2019 and December 31, 2019. Further detail regarding data sources is contained in the Supplementary material (Section S4).

Inclusion criteria

Women were included in the analysis if they had a diagnosis of GDM, DIP or pre-existing T2D during a pregnancy where the woman gave birth during either the baseline or post-intervention period. The type of diabetes for women in the NT and FNQ Diabetes in Pregnancy Clinical Registers was classified based on IADPSG/WHO criteria.[30,31] The type of diabetes for women in the primary care dataset was categorised based on the diabetes diagnosis contained in the electronic health record. Women were excluded if they had type 1 diabetes (FNQ n = 11; NT antenatal dataset n = 20, postpartum dataset n = 1); outcome of miscarriage or termination (FNQ n = 10; NT antenatal dataset n = 15, postpartum dataset n = 13); or no recorded birth outcome due to potential relocation from the NT/FNQ and receiving subsequent care elsewhere (FNQ n = 50; NT antenatal dataset n = 5, postpartum dataset n = 6).

Outcomes

Outcomes included indicators of antenatal and postpartum care, with reference to recommended standards of care (Supplementary Table S3). Among women with GDM/DIP with pre-existing risk factors for hyperglycaemia in pregnancy (defined in Supplementary methods, Section S3), completion of first trimester glucose testing as per local guidelines (see Supplementary Table S3) was assessed (any of glycated haemoglobin A1c (HbA1c), 75 g oral glucose tolerance test (75 g OGTT), fasting plasma glucose or random plasma glucose). Gestational age at first ultrasound was included as a surrogate marker of access to antenatal care. Antenatal care indicators also included use of glucose-lowering medications (metformin and/or insulin); documentation of weight; first trimester HbA1c (women with pre-existing T2D only) and third trimester HbA1c. Postpartum care indicators included: completion of diabetes screening/monitoring (any of HbA1c, 75 g OGTT, fasting plasma glucose or random plasma glucose) (within 6 or 12 months postpartum in FNQ; within 6 months postpartum in the NT (data not available to 12 months)); contraception discussed or prescribed; and documentation of weight, breastfeeding and smoking status.

Statistical analyses

Analyses were stratified by type of diabetes. Numbers of women with DIP were too small for analysis as a separate subgroup; this group was combined with the GDM group as the standard of care for both groups could be expected to be comparable (see Supplementary Table S3), thus the groups were GDM/DIP or pre-existing T2D. Analyses of NT and FNQ DIP Clinical Register data were additionally stratified by Aboriginal and Torres Strait Islander status. The primary care dataset used to analyse postpartum care in the NT had insufficient numbers of non-Indigenous women (n = 7) for stratification by Aboriginal and Torres Strait Islander status, so results for analyses using this dataset are only shown for Aboriginal and Torres Strait Islander women, stratified by type of diabetes, i.e., GDM/DIP or pre-existing T2D. Due to de-identification of the NT Clinical Register and primary care datasets, the NT antenatal and postpartum cohorts were unable to be linked and were thus handled as independent datasets. Pre- and post-intervention comparisons were made using Pearson chi-square tests for categorical variables, Student's t-tests for normally distributed continuous variables and Wilcoxon rank sum tests for non-normally distributed continuous variables, with continuous variables having been checked by visual inspection for normality. Multivariable logistic regression models were used to conduct sensitivity analyses; in model-building, independent variables with p value ≤ 0.2 on univariate analysis were included in the model building process, with only variables with p value ≤ 0.1 on stepwise multivariable analyses included in the final model for each outcome. Data were missing in each dataset for <1% of records, with exceptions noted in Table 1; missing data were handled using listwise deletion. Analyses were conducted with STATA 17.0 (StataCorp, College Station, Texas) with significance defined as $p < 0.05$.

Ethics, governance and community engagement

Ethical approval for this study was provide by FNQ Research Ethics Committee (HREC/16/QCH/15–1029), the Central Australian Human Research Ethics Committee (HREC-15-345), and the Human Research Ethics Committee of the NT Department of Health and Menzies School of Health Research (HREC 2015–2461 and 2018–3189). Aboriginal and Torres Strait Islander investigators (MW, AB) provided Indigenous leadership on this study and informed design, implementation and evaluation. The Partnership's Aboriginal and Torres Strait Islander Advisory Group was established during this study, and informed study implementation activities, as well as evaluation methods and interpretation of findings. Author DH represents the Advisory Group in this manuscript. Governance of this study was through the Partnership's Steering Committee, which includes representatives from Aboriginal Community Controlled Health Services in the study regions.

	Aboriginal and Torres Strait Islander				Non-Indigenous			
	Northern Territory (NT)							
	Baseline NT - Births 2013–2014		Post-intervention NT - Births 2019		Baseline NT- Births 2013–2014		Post-intervention NT - Births 2019	
	GDM/DIP n = 266	T2D n = 97	GDM/DIP n = 117	T2D n = 51	GDM/DIP n = 384	T2D n = 16	GDM/DIP n = 266	T2D n = 7
Age, mean (95% CI)	28.5 (27.7–29.2)	30.8 (29.6–31.9)	28.6 (27.6–29.6)	31.6 (30.0–33.2)	31.4 (30.9–31.9)	32.7 (29.7–35.6)	32.3 (31.7–33.0)[a]	32.5 (29.4–35.6)
Region, % (95% CI)								
Central Australia	32.7 (27.1–38.7)	52.6 (42.2–62.8)	56.4 (46.9–65.6)[c]	56.9 (42.2–70.7)	18.8 (15.0–23.0)	25.0 (8.3–52.4)	10.2 (6.8–14.4)[b]	0.0 (0.0–41.0)
Top End	67.3 (61.3–72.9)	47.4 (37.2–57.8)	43.6 (34.4–53.1)[c]	43.1 (29.3–57.8)	81.3 (77.0–85.0)	75.0 (47.6–92.7)	89.8 (85.6–93.2)[b]	100.0 (59.0–100.0)
Remote-dwelling, % (95% CI)	68.0 (62.1–73.6)	78.4 (68.8–86.1)	56.4 (46.9–65.6)[a]	72.0 (57.5–83.8)	4.9 (3.0–7.6)	0.0 (0.0–20.6)	3.0 (1.3–5.9)	28.6 (3.7–71.0)[a]
Smoking, % (95% CI)	113 (42.6)	38 (39.6)	38 (40.0)	20 (41.7)	6.0 (3.9–8.9)	0.0 (0.0–20.6)	7.7 (4.7–11.7)	16.7 (0.4–64.1)
Drinking alcohol, % (95% CI)	10.6 (7.1–14.9)	16.7 (9.8–25.7)	8.0 (3.7–14.7)	22.9 (12.0–37.3)	2.1 (0.9–4.1)	0.0 (0.0–20.6)	2.4 (0.1–5.2)	16.7 (0.4–64.1)
Parity, median (IQR)	2 (1–2)	2 (2–2)	1 (1–1)[b]	2 (2–3)	1 (0–1)	1.5 (0–2)	1 (0–1)	1 (0–2.37)
	Far North Queensland (FNQ)							
	Baseline FNQ - Births 2017		Post-intervention FNQ - Births 2019		Baseline FNQ - Births 2017		Post-intervention FNQ - Births 2019	
	GDM/DIP n = 74	T2D n = 31	GDM/DIP n = 96	T2D n = 25	GDM/DIP n = 214	T2D n = 8	GDM/DIP n = 231	T2D n = 11
Age, mean (95% CI)	30.7 (29.3–32.2)	31.3 (29.6–32.9)	29.7 (28.5–30.9)	31.4 (29.3–33.5)	31.5 (30.8–32.3)	33.6 (29.4–37.7)	31.9 (31.3–32.6)	31.8 (27.2–36.4)
Remote-dwelling, % (95% CI)	21.6 (12.9–32.7)	43.3 (25.5–62.6)	28.1 (19.4–38.2)	44.0 (24.4–65.1)	0.9 (0.1–3.3)	0.0 (0.0–36.9)	0.9 (0.1–3.1)	0.0 (0.0–28.5)
Smoking, % (95% CI)	21.6 (12.9–32.7)	46.7 (28.3–65.7)	33.3 (24.0–43.7)	48.0 (27.8–68.7)	7.0 (4.0–11.3)	25.0 (3.2–65.1)	8.3 (5.0–12.6)	9.1 (0.2–41.3)
Drinking alcohol, % (95% CI)	4.2 (0.9–11.9)	11.5 (2.4–30.2)	7.4 (3.0–14.6)	4.2 (0.1–21.1)	0.9 (0.1–3.4)	0.0 (0.0–36.9)	1.7 (0.5–4.4)	0.0 (0.0–28.5)
Parity, median (IQR)	2 (2–3)	2 (1–3)	2 (1–2)	2 (1–3.9)	1 (1–1)	0.5 (0–2.3)	1 (0–1)	1 (0–2.6)

GDM/DIP, gestational diabetes or overt diabetes in pregnancy; T2D, pre-existing type 2 diabetes. [a]$p < 0.05$ compared with baseline (2013–14 in Northern Territory, 2017 in Far North Queensland) for each ethnicity and type of diabetes (Pearson's Chi-squared test for categorical variables, Student's t test for age and Wilcoxon rank sum test for parity); denominators vary due to missing data. [b]$p < 0.01$ compared with baseline (2013–14 in Northern Territory, 2017 in Far North Queensland) for each ethnicity and type of diabetes (Pearson's Chi-squared test for categorical variables, Student's t test for age and Wilcoxon rank sum test for parity); denominators vary due to missing data. [c]$p < 0.001$ compared with baseline (2013–14 in Northern Territory, 2017 in Far North Queensland) for each ethnicity and type of diabetes (Pearson's Chi-squared test for categorical variables, Student's t test for age and Wilcoxon rank sum test for parity); denominators vary due to missing data.

Table 1: **Characteristics of women enrolled in the Northern Territory and Far North Queensland Diabetes in Pregnancy Clinical Registers.**

Role of the funding source

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Results

Characteristics of FNQ women and those in the NT antenatal care dataset are shown in Table 1. In the NT antenatal care dataset, 763 births were included from 2013–2014 (baseline) (57.6% Aboriginal or Torres Strait Islander) and 441 from 2019 (post-intervention) (38.1% Aboriginal or Torres Strait Islander) (Table 1). Significant differences in characteristics between baseline and post-intervention included higher mean age among non-Indigenous women with GDM/DIP post-intervention, and lower parity and decreased likelihood of being remote-dwelling among Aboriginal and Torres Strait Islander women with GDM/DIP.

For analysis of postpartum care in the NT, 239 births were included between 2013–14 and 103 from 2019 (Table 2); characteristics of women were similar in 2013–14 and 2019.

In FNQ, 327 births were included from 2017 (baseline) (32.1% Aboriginal or Torres Strait Islander) and 363 from 2019 (post-intervention) (33.3% Aboriginal or Torres Strait Islander) for analysis of both antenatal and postpartum care (Table 1), with no significant differences in characteristics between baseline and post-intervention.

Antenatal care

GDM/DIP

Results for antenatal care provided are shown in Table 3 (NT results in upper section, FNQ lower section). There was some variation in the changes observed in antenatal care by region and Aboriginal and Torres Strait Islander status.

In the NT, among Aboriginal and Torres Strait Islander women, who are recommended to undergo early pregnancy screening due to being at increased risk of hyperglycaemia in pregnancy, first trimester diabetes testing increased overall (47% versus 35%), with decreased use of random glucose and increased use of

	Births 2013–2014			Births 2019		
	GDM/DIP N = 175	T2D N = 64	Total 2013–14, n = 239	GDM/DIP N = 71	T2D N = 32	Total 2019 N = 103
Age, mean (95% CI)	27.8 (26.8–28.9)	32.0 (30.8–33.1)	29.0 (28.1–29.8)	29.3 (27.9–30.6)	31.9 (29.3–34.5)	30.1 (28.9–31.3)
Region, % (95% CI)						
Central Australia	43.0 (35.5–50.8)	66.7 (53.7–78.0)	49.4 (42.8–57.0)	43.7 (31.9–56.0)	62.5 (43.7–78.9)	49.5 (39.5–60.0)
Top End	57.0 (49.2–64.5)	33.3 (22.0–46.3)	51.7 (43.0–57.2)	56.3 (44.0–68.1)	37.5 (21.1–56.3)	50.5 (40.0–60.5)

Abbreviations: GDM/DIP, gestational diabetes or overt diabetes in pregnancy; T2D, pre-existing type 2 diabetes.

Table 2: **Characteristics of women with hyperglycaemia in the NT and postpartum primary healthcare records.**

75 g OGTT (27% versus 12%) and HbA1c (38% versus 20%). Among non-Indigenous women with risk factors for hyperglycaemia in pregnancy, overall first trimester diabetes testing did not change (26.6% versus 25.0%), although 75 g OGTT use increased (19% versus 6%) with decreased use of fasting and random plasma glucose. In FNQ, first trimester diabetes testing among Aboriginal and Torres Strait Islander women decreased (20% versus 35%). Among non-Indigenous women with GDM/DIP who had pre-existing risk factors for hyperglycaemia in pregnancy, there was no significant change in overall first trimester testing rates.

Post-intervention, among non-Indigenous women with GDM/DIP, first ultrasound (as a surrogate marker for access to antenatal care) occurred earlier in the NT (8.1 versus 9.3 weeks gestation); in FNQ, it occurred later (8.4 versus 7.9 weeks gestation), although this change was not significant on multivariable analysis (Supplementary Table S5). There was no change for Aboriginal and Torres Strait Islander women.

Fewer non-Indigenous women with GDM/DIP had weight documented in pregnancy post-intervention in the NT and FNQ (NT 97.7% versus 99.5%; FNQ 95.7% versus 99.5%), although in the NT this was no longer significant on multivariable analysis (Supplementary Table S5). In FNQ, documentation of weight also decreased for Aboriginal and Torres Strait Islander women (84.4% versus 98.7%). Among non-Indigenous women with GDM/DIP in FNQ, weight was first recorded later in pregnancy (18.6 versus 14.5 weeks gestation).

Among women with GDM/DIP, use of metformin increased for non-Indigenous women in the NT, with no change for Aboriginal or Torres Strait Islander women. The increase in metformin use among non-Indigenous women corresponded with decreased insulin use. In FNQ, metformin use appeared to increase among both Aboriginal and Torres Strait Islander and non-Indigenous women with GDM/DIP, although this change was not statistically significant. Among non-Indigenous women in FNQ with GDM/DIP, insulin use increased post-intervention.

T2D

First trimester mean HbA1c level was unchanged among women with T2D in the NT, although decreased post-intervention (7.0% versus 8.10%) among Aboriginal and Torres Strait Islander women with T2D in FNQ. In the NT, among Aboriginal and Torres Strait Islander women with T2D, insulin use increased (90.2% versus 74.2%). There were no other changes in indicators of antenatal care for women with T2D.

Postpartum care

GDM/DIP

In the NT, women with GDM/DIP were more likely to have had a postpartum HbA1c test performed (40.9% versus 18.3%), fasting or random glucose post-intervention (Fig. 2A). Use of the 75 g OGTT decreased, while having any postpartum diabetes screening increased, although these changes were non-significant.

Contraceptive use increased (63.4% versus 44.6%) post-intervention in the NT (Fig. 2C). Documentation of breastfeeding status and smoking status also increased, although breastfeeding and current smoking rates were unchanged (Table 4), with both high (breastfeeding >90%, smoking ≥40%) at baseline and post-intervention. There was no change in the proportion of women with a recorded weight (Fig. 3B) or in mean BMI (Table 4).

In FNQ, postpartum diabetes screening increased for women with GDM/DIP, although the increase was not statistically significant. There was no significant difference between baseline glucose levels or HbA1c (Table 4) in either the NT or FNQ.

T2D

Postpartum HbA1c testing and any diabetes monitoring appeared to increase in the NT among women with T2D, but were not statistically significant (Fig. 2B). Completion of other recommended postpartum checks also appeared to increase, but only reached significance for documentation of breastfeeding (84.5% versus 56.2%) (Fig. 2D).

In FNQ, diabetes monitoring at 12 months postpartum increased among both Aboriginal and Torres Strait Islander (68.0% versus 25.8%) and non-Indigenous (100 versus 50.0%) women with T2D (Fig. 3).

On multivariable analyses, in the NT there were increases in postpartum HbA1c (8.9% versus 7.0%) and

	Aboriginal and Torres Strait Islander				Non-Indigenous			
	Northern Territory							
	Births 2013–2014		Births 2019		Births 2013–2014		Births 2019	
	GDM/DIP N = 266	T2D N = 97	GDM/DIP N = 117	T2D N = 51	GDM/DIP N = 384	T2D N = 16	GDM/DIP N = 266	T2D N = 7
Gestational age at first USS, weeks, med (95% CI)[a]	12.7 (11.6–13.6)	11.7 (10.0–13.3)	11.5 (9.9–13.0)	10.9 (9.4–13.0)	9.3 (8.9–10.0)	11.4 (7.4–12.7)	8.1 (8.0–8.6)[e]	7.9 (6.4–23.1)
HbA1c checked in first trimester, % (95% CI)	19.9 (15.3–25.2)	70.1 (60.0–79.0)	37.6 (28.8–47.0)[e]	58.8 (44.2–72.4)	6.0 (3.8–8.9)	81.3 (54.4–96.0)	10.5 (7.1–14.9)[c]	71.4 (29.0–96.3)
First trimester HbA1c level, % (95% CI)	5.8 (5.6–5.9)	8.0 (6.9–8.8)	5.5 (5.2–5.5)[e]	8.2 (6.5–9.5)	5.5 (5.3–5.8)	6.9 (5.8–7.7)	5.5 (5.2–5.5)	7.5 (5.6–12.3)
Third trimester HbA1c level, % (95% CI)	5.9 (5.6–5.8)	7.3 (6.6–7.4)	5.7 (5.5–5.9)	7.8 (6.8–8.2)	5.4 (5.3–5.4)	6.3 (5.4–6.8)	5.6 (5.5–5.8)[d]	6.2 (6.1–6.3)
Medications used, % (95% CI)								
Metformin	49.6 (43.5–55.8)	92.8 (85.7–97.0)	53.0 (43.5–62.2)	88.2 (76.1–95.6)	24.7 (20.5–29.4)	87.5 (61.7–98.4)	49.6 (43.5–55.8)[e]	100.0 (59.0–100)
Insulin	33.1 (27.5–39.1)	74.2 (64.3–82.6)	24.8 (17.3–33.6)	90.2 (78.6–96.7)[c]	39.3 (34.4–44.4)	87.5 (62.6–98.4)	16.9 (12.6–22.0)[e]	100.0 (59.0–100)
Weight checked, % (95% CI)	97.7 (95.2–99.2)	97.9 (92.7–99.7)	94.9 (89.2–98.1)	92.2 (81.1–97.8)	99.5 (98.1–99.9)	100.0 (79.4–100)	97.7 (95.2–99.2)[c]	100.0 (59.0–100)
Gestational age at weight check, mean (95% CI)	15.6 (14.2–16.9)	13.7 (11.8–15.6)	15.9 (14.1–17.6)	13.7 (11.4–15.9)	14.8 (14.2–15.4)	13.1 (9.3–16.9)	15.4 (14.7–16.1)	10.5 (6.4–14.7)
Weight kg, mean (95% CI)	76.9 (74.3–79.5)	84.6 (81.3–88.0)	81.4 (77.2–85.5)	82.5 (78.0–87.0)	72.0 (70.3–73.8)	85.9 (71.7–100.2)	75.8 (73.4–78.1)[c]	92.3 (69.7–114.9)
BMI kg/m^2, mean (95% CI)	29.1 (28.2–30.0)	31.6 (30.4–32.8)	30.7 (29.2–32.1)	31.3 (29.6–32.9)	27.4 (26.8–28.0)	32.8 (28.2–37.3)	28.7 (27.9–29.5)[d]	35.3 (29.1–41.6)
	First trimester diabetes testing completed, high risk women[b]							
	n = 266	NA	n = 117	NA	n = 292	NA	n = 207	NA
75 g OGTT, % (95% CI)	11.7 (8.1–16.1)		26.5 (18.8–35.5)[e]		6.1 (3.7–9.6)		19.3 (14.2–25.4)[e]	
HbA1c, % (95% CI)	19.9 (15.3–25.2)		37.6 (28.8–47.0)[e]		7.5 (4.8–11.2)		11.6 (7.8–16.8)	
Fasting plasma glucose, % (95% CI)	2.3 (0.8–4.8)		0.9 (0.0–4.7)		9.6 (6.5–13.6)		1.5 (0.3–4.2)[e]	
Random plasma, % (95% CI)	14.7 (10.6–19.5)		0.9 (0.0–4.7)[e]		7.5 (4.8–11.2)		2.4 (0.8–5.5)[c]	
Any first trimester diabetes testing, % (95% CI)	34.6 (28.9–40.6)		47.0 (37.7–56.5)[c]		25.0 (20.1–30.4)		26.6 (20.7–33.1)	
	Far North Queensland							
	Births 2017		Births 2019		Births 2017		Births 2019	
	GDM/DIP n = 74	T2D n = 31	GDM/DIP n = 96	T2D n = 25	GDM/DIP n = 214	T2D n = 8	GDM/DIP n = 231	T2D n = 11
Gestational age at first ultrasound, weeks, median (95% CI)[a]	8.9 (8.3–11.5)	10.6 (7.5–13.5)	10.5 (8.7–11.7)	9.3 (8.0–13.5)	7.9 (7.8–8.0)	8.0 (6.7–12.3)	8.4 (8.0–8.6)[d]	10.0 (7.9–12.7)
HbA1c checked in first trimester, % (95% CI)	24.3 (15.1–35.7)	64.5 (45.4–80.8)	13.5 (7.4–22.0)	56.0 (34.9–76.6)	9.8 (6.2–14.6)	50.0 (15.7–84.3)	2.2 (0.7–5.0)[d]	63.6 (30.8–89.1)
First trimester HbA1c level, % (95% CI)	5.5 (5.3–5.9)	8.0 (7.0–8.8)	5.6 (5.1–5.8)	6.7 (6.2–7.6)[c]	5.2 (5.1–5.5)	7.4 (5.9–9.2)	5.4 (4.7–6.2)	5.9 (5.7–8.8)
Third trimester HbA1c level, % (95% CI)	5.5 (5.3–5.7)	7.1 (6.0–7.6)	5.5 (5.1–6.0)	6.5 (6.2–7.0)	5.3 (5.2–5.4)	5.4 (5.3–7.0)	5.2 (5.0–5.3)	5.7 (5.2–6.3)
Medications used, % (95% CI)								
Metformin	35.1 (24.4–47.1)	87.1 (70.2–96.4)	45.8 (35.6–56.3)	76.0 (54.8–90.6)	25.7 (20.0–32.1)	87.5 (47.3–100.0)	34.6 (28.5–41.2)	90.9 (58.7–100.0)
Insulin	31.1 (20.8–42.9)	87.1 (70.2–96.4)	40.6 (30.7–51.1)	88.0 (68.8–97.5)	24.3 (18.7–30.6)	100.0 (63.1–100.0)	45.0 (38.5–51.7)[e]	100.0 (71.5–100.0)
Weight checked, % (95% CI)	98.7 (92.7–100.0)	90.3 (74.2–98.0)	84.4 (75.5–91.0)[d]	84.0 (63.9–95.5)	99.5 (97.4–100.0)	100.0 (63.1–100.0)	95.7 (92.3–97.9)[d]	81.8 (48.2–97.7)
Gestational age at weight check, mean (95% CI)	14.7 (12.7–16.6)	18.4 (14.3–22.6)	15.8 (13.8–17.8)	17.1 (12.1–22.1)	14.5 (13.5–15.4)	23.4 (18.7–38.1)	18.6 (17.6–19.6)[e]	26.5 (23.4–29.7)
Weight kg, mean (95% CI)	87.4 (82.2–92.6)	81.8 (72.6–90.9)	91.2 (86.2–96.1)	91.9 (80.9–102.9)	80.4 (77.4–83.3)	88.3 (69.1–107.6)	81.4 (78.4–84.4)	91.6 (68.7–114.5)
BMI kg/m^2, mean (95% CI)	32.6 (30.7–34.5)	31.0 (27.9–34.2)	33.6 (31.9–35.3)	33.1 (29.7–36.5)	30.0 (29.0–31.1)	33.8 (27.6–39.9)	30.7 (29.6–31.7)	33.6 (28.2–39.0)

(Table 3 continues on next page)

	Far North Queensland							
	Births 2017		Births 2019		Births 2017		Births 2019	
	GDM/DIP n = 74	T2D n = 31	GDM/DIP n = 96	T2D n = 25	GDM/DIP n = 214	T2D n = 8	GDM/DIP n = 231	T2D n = 11
(Continued from previous page)								
	First trimester diabetes completed, high risk women[b]							
	n = 74		n = 96		n = 170		n = 192	
75 g OGTT, % (95% CI)	8.1 (3.0–16.8)		11.5 (5.9–19.6)		10.0 (5.9–15.5)		12.5 (8.2–18.0)	
HbA1c, % (95% CI)	24.3 (15.1–35.7)		13.5 (7.4–22.0)		10.0 (5.9–15.5)		2.1 (0.6–5.2)[d]	
Fasting plasma glucose, % (95% CI)	2.7 (0.3–9.4)		0.0 (0.0–3.8)		0.6 (0.0–3.2)		0.0 (0.0–1.9)	
Random plasma, % (95% CI)	6.8 (2.2–15.1)		0.0 (0.0–3.8)[c]		5.9 (2.9–10.6)		1.0 (0.1–3.7)[c]	
Any first trimester diabetes testing, % (95% CI)	35.1 (24.4–47.1)		19.8 (12.4–29.2)[c]		18.8 (13.2–25.5)		13.5 (9.0–19.2)	

95% CI 95 per cent confidence interval; BMI body mass index; GDM/DIP gestational diabetes or overt diabetes in pregnancy; HbA1c glycated haemoglobin A1c; T2D pre-existing type 2 diabetes; USS ultrasound scan. Data were missing for <1% of variables, with exceptions of date weight measured (15.3% NT, 10.6% FNQ), alcohol status (2.4% NT, 1.7% FNQ), smoking status (2.3% NT only) past diagnosis of GDM (2.7% NT, 1.8% FNQ), height (<1% NT, 1.7% FNQ) and ultrasound date (<1% NT, 1.7% FNQ). Denominators may vary due to missing data. [a]All women had at least one antenatal ultrasound. [b]First trimester = gestational age <14 weeks; high risk includes high risk ethnicity (Asian, Indian subcontinent, Aboriginal, Torres Strait Islander, Pacific Islander, Maori, Middle Eastern, non-white African), BMI >30, prior GDM, age >35 years (nb Northern Territory and Far North Queensland Diabetes in Pregnancy Clinical Registers do not contain data on other risk factors including: prior elevated glucose level (except in pregnancy); family history of diabetes; previous LGA; polycystic ovarian syndrome, corticosteroid or antipsychotic use). [c]$p < 0.05$ compared with baseline (2013–2014 in Northern Territory, 2017 in Far North Queensland) for each ethnicity and type of diabetes. [d]$p < 0.01$ compared with baseline (2013–2014 in Northern Territory, 2017 in Far North Queensland) for each ethnicity and type of diabetes. [e]$p < 0.001$ compared with baseline (2013–2014 in Northern Territory, 2017 in Far North Queensland) for each ethnicity and type of diabetes.

Table 3: **Indicators of antenatal care provided to women with hyperglycaemia in pregnancy in Far North Queensland and Northern Territory.**

BMI (32.1 kg/m^2 versus 28.8 kg/m^2; Table 4 and Supplementary Table S6). There were no changes to postpartum health indicators in FNQ.

Discussion

Our evaluation found large improvements in aspects of care provided to women with hyperglycaemia in pregnancy, although there were inconsistencies in improvements between groups. In the NT, care improved both during and after pregnancy, including improved diabetes testing for those at risk in early pregnancy, and improved postpartum monitoring. There was increased contraceptive use, and documentation of breastfeeding and smoking status in primary healthcare records, although HbA1c and BMI increased among women with T2D. In FNQ, postpartum diabetes testing improved, although there were no improvements to antenatal care, with contextual differences between study regions potentially contributing to the difference in results.

Following the implementation of the health systems intervention, first trimester testing for hyperglycaemia improved among women with risk factors for diabetes, including increased testing rates for Aboriginal and Torres Strait Islander women. Additionally, there was an increase in use of the 75 g OGTT or HbA1c, in line with local guidelines,[32,33] replacing random or fasting plasma glucose tests. These findings align with results of a health professional survey, conducted as part of this evaluation and reported in detail elsewhere.[34] NT clinicians had reported increased testing in early pregnancy and increased use of the 75 g OGTT, although in FNQ there was no change in early pregnancy testing reported by clinicians participating in the survey.

Despite improvements, most women in the NT and FNQ with risk factors for hyperglycaemia in pregnancy did not undergo first trimester glucose testing at baseline or post-intervention, indicating unaddressed barriers to diabetes testing in early pregnancy. Barriers reported previously include the unpleasantness of a 75 g OGTT, particularly in early pregnancy when morning sickness peaks; unavailability of childcare; and difficulty accessing testing if travel is required.[35] In the remote setting, it can be difficult for women to attend when fasting.[11] Contact between women and health services in early pregnancy may be limited: 36% of Aboriginal and Torres Strait Islander women in remote NT and 25% in FNQ and urban NT presented for antenatal care after the first trimester.[22,27] Strong relationships between women and service providers support engagement with maternal and child health services[36]; however, maintaining these relationships requires the support of a well-resourced Aboriginal and Torres Strait Islander health workforce.[37] Addressing barriers to diabetes testing in early pregnancy is essential to improve maternal and neonatal outcomes, enabling early

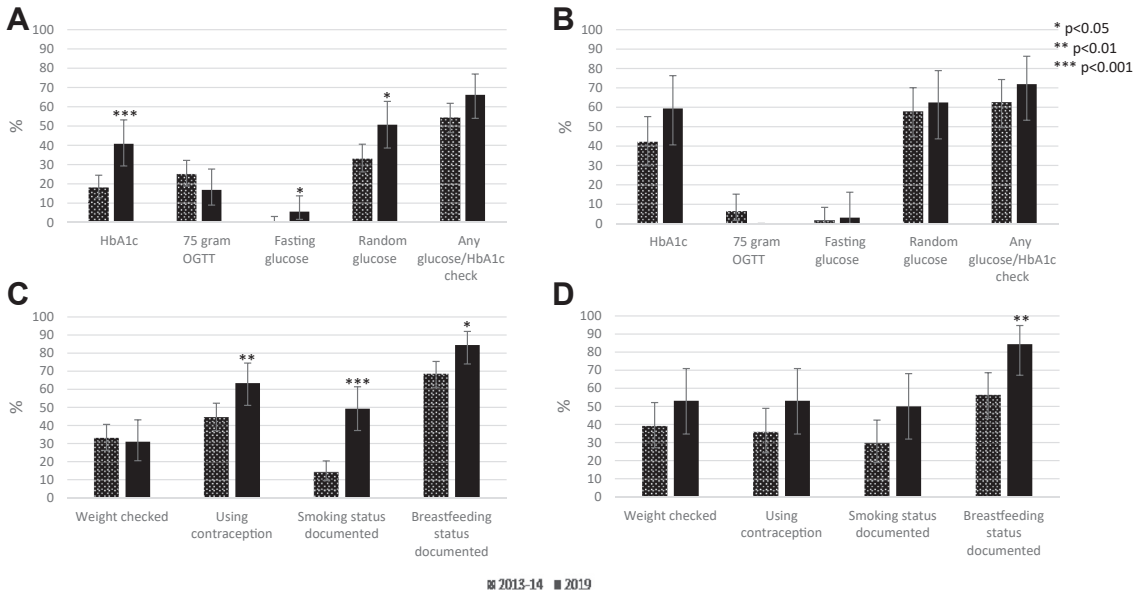

Fig. 2: Postpartum glucose testing (A—women with GDM/DIP, n = 246, B—women with T2D, n = 96) and other health checks (C—women with GDM/DIP, D—women with T2D) in the 6 months postpartum following a pregnancy complicated by diabetes, in line with five key postpartum health messages, Northern Territory; data shown for Aboriginal and Torres Strait Islander women only due to small number (n = 7) of non-Indigenous women; p values are for comparisons between 2017 and 2019.

identification of women with hyperglycaemia and providing an opportunity to intervene.[38,39] The updated edition of the local guideline used in the NT recommends the HbA1c rather than the OGTT as the initial screening test in early pregnancy in high risk women,[40] while validating alternative diagnostic strategies to the OGTT is an area of international research interest.[41]

Postpartum care improved, with increased diabetes monitoring in the NT and FNQ. Rates of postpartum diabetes screening among women with GDM/DIP were comparable to those reported internationally.[10,15] In the NT, contraceptive use and documentation of breastfeeding and smoking status also rose. Increased documentation may indicate more clinicians discussing these health factors with women. It is notable, however, that smoking rates remained high post-intervention. Encouragement from health professionals is an important predictor of smoking cessation among Aboriginal and Torres Strait Islander people,[42] and our results suggest more needs to be done to support these conversations between women and health professionals. Glucose checks, contraception, smoking cessation and breastfeeding were four of the five postpartum health messages (with the fifth being healthy weight) promoted during the intervention as a holistic approach to reducing diabetes-related risks. Our findings broadly indicate success with this approach, and correspond with qualitative evaluation data, in which clinicians reported increased attention to postpartum health due to the health systems intervention.[34] Clinicians also reported improved care coordination and use of recall systems, introduced as part of our intervention and likely contributing to the positive results reported here. Interview participants additionally reported an increased focus on effective cross-cultural communication; this may have resulted in improved understanding among women of the rationale behind postpartum measures including glucose checks and contraception, with subsequent increased uptake.[34] Improving cultural safety, such as through strengthening the Aboriginal workforce, has the potential to further increase engagement between women and service providers,[43] which in turn could lead to further improvements in care provided, such as diabetes screening, across preconception, pregnancy and postpartum.

The fifth message promoted was achieving and maintaining a healthy postpartum weight. Only a minority of NT women had weight documented postpartum, with no post-intervention improvement, suggesting additional barriers to addressing weight compared to the intervention's other postpartum health messages. While most NT and FNQ women had weight documented at least once during pregnancy, documentation in some groups concerningly decreased post-intervention. Attention to weight during and after pregnancy is needed due to the adverse impact of excessive gestational weight gain on pregnancy outcomes, as well as the impact of gestational weight gain on a woman's long-term health.[44] However, women commonly experience weight-related stigma during

	NT[a]					
	Births 2013–2014			Births 2019		
	GDM/DIP n = 175	T2D n = 64	Total 2013–14, n = 239	GDM/DIP n = 71	T2D n = 32	Total 2019 n = 103
Glucose levels, median (95% CI)						
HbA1c, %	5.7 (5.5–6.0)	6.6 (6.4–7.2)	6.1 (5.7–6.4)	5.6 (5.4–6.0)	8.4 (6.2–10.6)	6.0 (5.7–6.8)
75 g OGTT						
Fasting, mmol/L	4.4 (4.3–4.5)	6.1 (4.1–7.1)	4.4 (4.3–4.6)	4.7 (4.1–5.1)	N/A	4.7 (4.1–5.1)
1 h, mmol/L	8.1 (6.9–9.1)	11.4 (8.1–16.7)	8.4 (7.6–9.3)	7.4 (6.0–9.5)	N/A	7.4 (6.0–9.5)
2 h, mmol/L	5.9 (5.4–6.7)	9.1 (5.1–14.6)	5.9 (5.4–7.0)	5.9 (5.2–7.4)	N/A	5.9 (5.2–7.4)
Fasting glucose, mmol/L	6.0 (6.0–6.0)	4.8 (4.8–4.8)	5.4 (4.8–6.0)	4.7 (4.4–15.2)	3.7 (3.7–3.7)	4.6 (3.7–15.2)
Random glucose, mmol/L	6.2 (5.8–6.3)	7.2 (6.6–9.8)	6.5 (6.2–6.6)	5.5 (5.2–6.8)	10.7 (7.5–14.0)	6.9 (5.4–8.2)
Weight (kg), median (95% CI)	77.0 (67.5–82.0)	73.0 (68.5–82.8)	75.4 (69.0–81.0)	67.2 (65.4–88.5)	81.5 (72.2–96.5)	76.0 (66.9–88.3)
Body mass index (kg/m^2), median (95% CI)	29.0 (27.0–31.0)	28.9 (26.7–30.3)	29.0 (27.5–30.2)	25.8 (24.2–31.3)	29.9 (27.8–36.7)	28.6 (25.5–32.7)
Breastfeeding, %[b] (95% CI)	98.2 (93.6–100.0)	91.7 (77.5–98.2)	96.6 (92.2–98.9)	93.3 (83.8–98.2)	96.3 (81.0–99.9)	94.3 (87.1–98.1)
Current smoker, %[c] (95% CI)	40.0 (21.1–61.3)	42.1 (20.3–66.5)	40.9 (26.3–56.8)	40.0 (23.9–57.9)	37.5 (15.2–64.6)	39.2 (25.8–53.9)
Contraceptive method, %[d] (95% CI)						
Etonogestrel implant	72.3 (62.7–81.9)	56.0 (36.5–75.5)	68.5 (59.8–77.3)	71.7 (58.7–84.8)	58.8 (35.4–82.2)	68.3 (56.8–79.7)
Medroxyprogesterone injection	7.2 (1.7–12.8)	20.0 (4.3–35.7)	10.2 (3.8–14.7)	6.5 (0.0–13.7)	23.5 (3.4–43.7)	11.1 (3.4–18.9)
Oral	9.6 (3.3–16.0)	8.0 (0.0–18.6)	9.3 (3.8–14.7)	10.9 (1.9–19.9)	5.9 (35.4–82.2)	9.5 (2.3–16.8)
Levonogestrel IUD	1.2 (0.0–3.6)	4.0 (0.0–11.7)	1.9 (0.0–4.4)	8.7 (0.6–16.8)	0 (NA)	6.3 (0.3–12.4)
Tubal ligation	0 (NA)	0 (NA)	0 (NA)	0 (NA)	0.12 (0.0–27.1)	3.2 (0.0–7.5)
Barrier	3.6 (0.0–7.6)	4.0 (0.0–11.7)	3.7 (0.1–7.3)	0 (NA)	0 (NA)	0 (NA)
None	6.0 (0.9–11.1)	8.0 (0.0–18.6)	6.5 (1.8–11.1)	2.2 (0.0–6.4)	0 (NA)	1.9 (0.0–4.7)

	FNQ[e]							
	Births 2017				Births 2019			
	Aboriginal and Torres Strait Islander		Non-Indigenous		Aboriginal and Torres Strait Islander		Non-Indigenous	
	GDM/DIP n = 34	T2D n = 8	GDM/DIP n = 136	T2D n = 4	GDM/DIP n = 55	T2D n = 16	GDM/DIP n = 166	T2D n = 11
Glucose levels, median (95% CI)								
HbA1c, %	5.4 (5.2–5.8)	8.0 (6.0–12.6)	5.5 (5.4–5.7)	7.0 (6.2–8.6)	5.7 (5.4–5.9)	6.8 (1.1)	5.2 (5.1–5.3)	–6.5 (5.7–7.8)
75 g OGTT								
Fasting, mmol/L	5.1 (4.3–5.6)	NA	4.7 (4.1–5.1)	NA	4.8 (4.6–4.9)	NA	4.8 (4.7–5.0)	NA
1 h, mmol/L	7.3 (5.1–9.5)		5.4 (4.5–7.7)		7.5 (6.8–8.5)		8.2 (7.1–8.7)	
2 h, mmol/L	4.9 (3.9–6.9)		4.6 (4.1–6.1)		5.5 (5.2–6.2)		5.7 (5.2–6.3)	

75 g OGTT – 75 g oral glucose tolerance test; 95% CI – 95 per cent confidence interval; GDM/DIP – gestational diabetes or overt diabetes in pregnancy; IUD – intrauterine device; N/A – not applicable due to small numbers of results; T2D – pre-existing type 2 diabetes. [a]Checks within 6 months postpartum, includes only Aboriginal and Torres Strait Islander women due to small number (n = 7) of non-Indigenous women. [b]Percentage of women where status documented. [c]Percentage among women where smoking status documented. [d]Percentage among women where contraception use documented. [e]Checks within 12 months postpartum.

Table 4: **Postpartum health indicators after a pregnancy complicated by hyperglycaemia.**

pregnancy.[45] Implementation of a systematic approach to documenting antenatal and postpartum weight can be hindered by clinician concerns about contributing to stigma, despite most people living with obesity wanting their healthcare providers to discuss weight.[46,47] In the remote context, clinicians may feel ill-prepared to give advice regarding healthy weight, given issues with food insecurity.[48] More work is needed to identify best practice methods of engaging with women in conversations supporting a healthy weight during and after pregnancy. These practices need to account for culture, given cultural influences on perceptions of healthy weight and body size[49]; there is currently an evidence gap regarding understandings of Aboriginal and Torres Strait Islander concepts of healthy weight. An additional need is improving the availability of evidence-based and effective healthy weight programs during and after pregnancy, including in the setting of pervasive food insecurity.

Improvements in FNQ were more limited than those in the NT. Concerningly, first trimester diabetes testing in FNQ decreased post-intervention among Aboriginal and Torres Strait Islander women. Possible decreased early testing rates, coupled with a later gestational age at

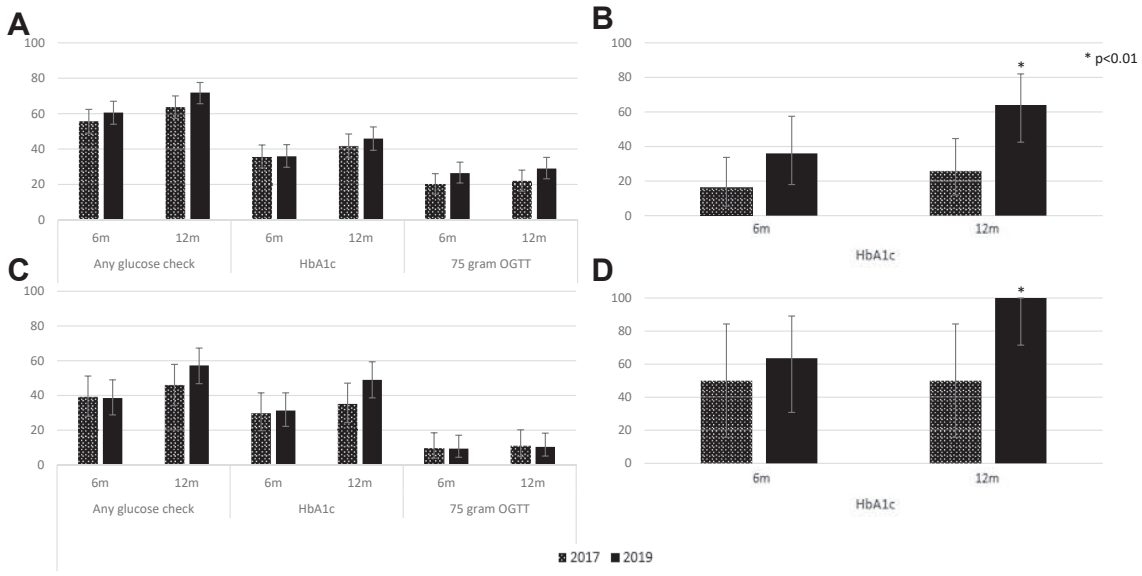

Fig. 3: Diabetes testing performed 6 and 12 months postpartum in Far North Queensland. A—Aboriginal and Torres Strait Islander women with gestational diabetes (GDM) or overt diabetes in pregnancy (DIP); B—Aboriginal and Torres Strait Islander women with pre-existing type 2 diabetes (T2D); C—Non-Indigenous women with GDM/DIP; D—Non-Indigenous women with pre-existing type 2 diabetes; p values are for comparisons between 2017 and 2019.

which non-Indigenous women with GDM/DIP in FNQ had their first ultrasound and weight documented in pregnancy, may indicate broader issues with access to care, warranting further investigation. Conversely, while rate of HbA1c testing remained stable among Aboriginal and Torres Strait Islander women with T2D in FNQ, the mean HbA1c level among participants decreased post-intervention, potentially indicating increased engagement with preconception care.

Several factors may account for the divergent results between FNQ and NT. Firstly, establishment of the Diabetes Across the Lifecourse: Northern Australia Partnership in the NT, with implementation of some improvements to antenatal care for hyperglycaemia in pregnancy, preceded this study by several years.[50,51] In contrast, Partnership activities in FNQ only commenced with this study. The substantial time and the complex processes involved in translating evidence-based recommendations into practice have been widely reported.[52] The earlier establishment of the Partnership in NT likely contributed to stronger stakeholder relationships and a higher awareness of hyperglycaemia in pregnancy at study commencement, enabling implementation of study activities. Limitations on data availability in FNQ meant we were unable to obtain baseline data for births prior to commencement of implementation; baseline data therefore comprised births which occurred during the early phase of the study. Although it is unlikely that significant changes in care were missed in this early phase when intervention activities were still being established, this also resulted in a short duration between baseline and post-intervention of only two years, potentially insufficient to show differences. Data have been collected for a detailed process evaluation to further explore the factors which account for the differences in results between study regions.

The changes in metformin and insulin use during pregnancy were unexpected findings. Among NT women with GDM/DIP, metformin use was much lower at baseline among non-Indigenous than among Aboriginal and Torres Strait Islander women, whereas by 2019 use among non-Indigenous women had increased to be similar to among Aboriginal and Torres Strait Islander women. This change was unlikely to be related to increasing severity of hyperglycaemia, as there was a corresponding decrease in insulin use, but may have been driven by the growing body of reassuring evidence regarding the safety of using metformin during pregnancy.[53–55] The high baseline use of metformin among Aboriginal and Torres Strait Islander women may relate to stigma associated with insulin use or pragmatic challenges, including inadequate access to refrigeration, risks of using insulin in the setting of pervasive food insecurity.[56] These issues illustrate the impact of the social determinants of health on a woman's ability to effectively manage hyperglycaemia in pregnancy. Interestingly, insulin use substantially increased during the study among Aboriginal and Torres Strait Islander women in the NT with T2D; possible explanatory factors include increasing education and patient acceptance of insulin and increased measures by clinicians to address issues such as

refrigeration to make insulin a more feasible option. In FNQ, insulin use increased among non-Indigenous women with GDM/DIP, potentially due to adoption of tighter glucose treatment targets in January 2019, although increased severity of hyperglycaemia is also possible.

Strengths of our study included wide engagement with stakeholders and communities, including primary healthcare services, Aboriginal Community Controlled Health Services and the Partnership's Aboriginal and Torres Strait Islander Advisory Group. This engagement occurred throughout all aspects of the study, informing study design, implementation activities and interpretation of evaluation findings. The multi-component nature of the intervention enabled a cohesive approach to addressing the barriers identified during formative work. Inclusion of a broad range of evaluation indicators beyond glucose testing rates recognises the holistic approach required to reduce the health risks associated with hyperglycaemia in pregnancy. While previous studies of health systems improvements have reported increased postpartum glucose screening after GDM,[18] ours is the first study to our knowledge to additionally demonstrate improvements in broader aspects of care such as contraception, while acknowledging contraceptive use is a woman's choice. Our study was also unique in aiming to improve both antenatal and postpartum care across the full spectrum of hyperglycaemia.

Implementation occurred across study regions and at multiple service levels, thus it was not possible to include a control arm for this study, and other factors in the study regions may have impacted on our findings. Additionally, a control group was not considered acceptable by our stakeholders, including members of the Aboriginal and Torres Strait Islander Advisory Group, as this would have required withholding or delaying implementation to the control site. It is therefore not possible to definitively attribute changes in practice to the health systems intervention. Other measures that occurred in the study regions during implementation and therefore may have influenced study findings included strengthening of a Midwifery Group Practice in Top End and introduction of a nurse navigator role in FNQ. However, the qualitative data, such as the abovementioned increased attention paid to postpartum health, supports a causative relationship between the intervention and changes in practice.

Our study had several other limitations. The data sources used for this evaluation serve as a proxy for the actual care provided to women, and we acknowledge there may have been under-reporting. During this study, the Clinical Registers relied on manual data entry from multiple sources which may have impacted on completeness of data; plans to transition to automated electronic data extraction aim to overcome this in future. The unavailability of data in FNQ prior to study implementation means only a short period of time elapsed between baseline and post-intervention samples, which may have been insufficient to demonstrate changes in practice. Our data sources in both the NT and FNQ only included women with hyperglycaemia in pregnancy, thus we are unable to assess changes in screening rates across all women. As mentioned above, the NT antenatal and postpartum cohorts were unable to be linked due to data de-identification. Small numbers of women with T2D in FNQ and in the postpartum data sample in the NT limits the ability to detect changes in our analyses. Small numbers of women or events also made it not possible to conduct multivariable analyses for some groups, including women with T2D (non-Indigenous in NT, both non-Indigenous and Indigenous in FNQ). This component of our evaluation assessed changes in clinical practice; it remains to be seen whether improvements in practice translate to changes in outcomes for women and infants, although this will be assessed in a subsequent component of this evaluation. The pragmatic approach required in obtaining study data led to only one year of data being available for analysis for the post-intervention period, leading to a discrepancy in sample size for NT where two years of data were available for baseline. NT postpartum data were largely only available for Aboriginal and Torres Strait Islander women, although this was accepted as this group was prioritised during study implementation activities due to the disproportionate burden of hyperglycaemia in pregnancy in this population. Given the increased long-term cardiovascular risk associated with hyperglycaemia in pregnancy,[57] it would be relevant to also consider screening rates and management of other cardiovascular risk factors such as blood pressure and lipids, although data for these outcomes were not collected in this study. Finally, we did not conduct corrections for multiple comparisons.

In summary, there were multiple improvements in important measures of antenatal and postpartum care for Aboriginal and Torres Strait Islander women with hyperglycaemia in pregnancy in the NT following the implementation of a multi-component health systems intervention. In FNQ, postpartum diabetes screening improved, and further observation of the antenatal care provided over a longer period is required to determine the impact of health system changes. The results of our study indicate a potential for multicomponent health systems interventions to lead to improvements in care for hyperglycaemia in pregnancy in other centres, both within Australia and globally, particularly for First Nations populations who are at increased risk of adverse outcomes. Our findings also demonstrate the importance of contextual factors and the challenges of rigorously evaluating the impacts of such interventions.

Contributors

DM developed the evaluation plan, obtained relevant approvals from ethics committees, data custodians and stakeholder organisations, collected and analysed data, interpreted findings, and was primary

author of the manuscript. NF contributed to development of the evaluation plan, interpretation of findings and manuscript revisions. JAB, SCa, AM, DH, CW, PVD, CC, EM, AS, YC-J, JO, HDM, JS and AB were responsible for study design and manuscript review for critical intellectual input. JAB and SCa additionally provided supervision to DM in development of the evaluation plan and interpretation of findings. RK was principal supervisor for DM, and supervised all aspects of the evaluation. LMB was principal investigator of the study, and led development of study concept and design, obtaining funding and ethics approval, supervision of study staff and intervention implementation. All authors have read and approved the manuscript.

Data sharing statement

Data from the NT and FNQ DIP Clinical Registers remain the property of the relevant partner organisation/health care provider. Use of DIP Clinical Register information to undertake clinical audits may be considered by the NT & FNQ DIP Steering Committee; enquiries can be made at diabetespartnership@menzies.edu.au. Data from primary care health services analysed for this study remain the property of the primary care service, and thus are not available for sharing by the researchers.

Declaration of interests

HDM has received payment or honoraria for presentations at the Pernambuco Brazil Diabetes Conference, Chinese National Conference on Diabetes in Pregnancy, Danish Diabetes Academy and Emirates Diabetes and Endocrinology Conference, and was supported as a Danish Diabetes Academy Visiting Professor 2017–2024. JS has received payment or honoraria for presentations by Astra Zeneca, Boehringer Ingelheim, Novo Nordisk, Roche, Zuellig Pharmaceutical, Eli Lilly and Abbott. LMB is the former Chair of the NT Diabetes Network. These relationships have not influenced the contents of this manuscript. The remaining authors declare that they have no conflicts of interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2025.101514.

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