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ORIGINAL RESEARCH

Anaemia in pregnancy among Aboriginal and Torres Strait Islander women of Far North Queensland: A retrospective cohort study

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Abstract

Aim: Anaemia during pregnancy is common worldwide. In Australia between 7.1% and 11% of mothers have been reported to have anaemia in pregnancy. Higher rates are reported for Aboriginal and Torres Strait Islander women (Townsville: 34.2%, remote Northern Territory: 50%). The present study describes anaemia in pregnancy among Aboriginal and Torres Strait Islander women of Far North Queensland.

Methods: Health service information was analysed for 2076 Aboriginal and Torres Strait Islander women who gave birth between 2006 and 2010. The prevalence of anaemia in pregnancy, characteristics of the mothers and pregnancy outcomes were described. Logistic regression for bivariate analyses and multivariable linear modelling with and without imputed data were used to compare those mothers who had anaemia in pregnancy with those who did not.

Results: More than half of Aboriginal and Torres Strait Islander women (54.5% (95% CI: 52.4%, 56.7%)) had anaemia in pregnancy. For mothers who gave birth in 2009 and 2010 (n = 1796) with more complete data, those who were iron deficient during pregnancy were more likely to be anaemic (RR: 1.40, $P = <0.001$). Mothers (29.0%) from localities of relative socioeconomic advantage had lower risk of anaemia in pregnancy (RR: 0.86, $P = 0.003$), as did mothers (31.9%) who were obese (RR: 0.87, $P = 0.013$).

Conclusions: The prevalence of anaemia in pregnancy among Aboriginal and Torres Strait Islander women of Far North Queensland is high. Prevention and treatment of anaemia will improve the health of these mothers, and possibly the health and early development of their children.

Key words: Aboriginal, anaemia, mother, pregnancy, Torres Strait Islander.

Introduction

The 'First Thousand Days' from conception to around age 2 years is a time of rapid growth and neurological development.[1,2] Anaemia in pregnancy—defined as blood haemoglobin levels below 110 g/L—is a concern because of poorer health and pregnancy outcomes of mothers, and also the potential detrimental effects on the health and development of their children.[1,3]

Infections, inflammation and genetic conditions (e.g. thalassaemia) can cause anaemia, as well as iron deficiency and other nutritional deficiencies.[3] Although an essential nutrient, iron can have negative metabolic effects.[4] To prevent damage, iron absorption is tightly regulated but increases when iron requirements are high, as in pregnancy.[4] The pregnant mother requires iron not only for her immediate demands—increased blood, tissue growth—but to provide iron stores to her baby.[5] The main source of iron for a baby in the first months of life is not breast milk or infant formula but these iron stores acquired before birth.[5] The high maternal iron requirements mean that anaemia in pregnancy is usually due to iron deficiency and is a strong predictor of early onset anaemia in the child.[3,6] High rates of early childhood anaemia are a continuing concern in remote Aboriginal and Torres Strait Islander communities of northern Australia.[7,8]

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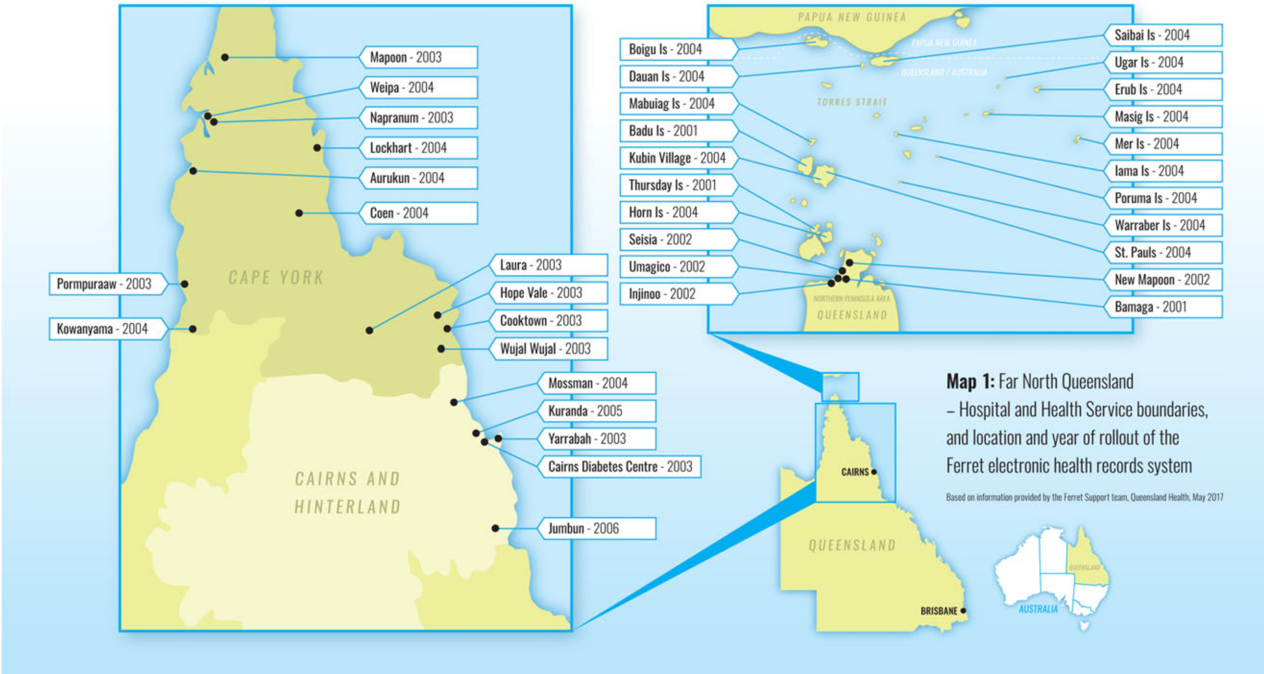

Figure 1 Far North Queensland: Hospital and Health Service boundaries, and location and year of rollout of the Ferret electronic health records system. Based on the information provided by the Ferret Support team, Queensland Health, May 2017. Reproduced with permission of the Australian New Zealand Journal of Public Health.[14]

Australian studies reporting anaemia in pregnancy include studies from South Australia (unsupplemented control group: 11% anaemic, births 1997–1999, including 3.3% Aboriginal mothers), Western Australia (6.2% anaemic >18 years, births 2005–2006, 7.3% Aboriginal and Torres Strait Islander mothers) and for all births in South Australia 1999–2005 (7.1% anaemic, 2.5% Aboriginal and Torres Strait Islander mothers).[9–11] Higher rates of anaemia in pregnancy have been reported for Aboriginal and Torres Strait Islander women accessing antenatal care in Townsville (34.2% anaemic, births 2001–2003) and in two remote Northern Territory communities (50.0% anaemic, births 2004–2006).[12,13]

Anecdotal reports by health service providers in Far North Queensland (Figure 1) indicate that anaemia among Aboriginal and Torres Strait Islander mothers and their children is also prevalent but published information is lacking. Consequently, research has been undertaken to investigate anaemia among Aboriginal and Torres Strait Islander mothers and their children in Far North Queensland from an intergenerational perspective. Here we describe anaemia in pregnancy, and investigate associations between anaemia and various maternal characteristics, health indicators, and pregnancy outcomes of these mothers for a pregnancy and birth between 2006 and 2010.

Methods

This is a retrospective cohort study using linked information extracted from three existing health service data collections for mothers resident in Far North Queensland, in respect of pregnancies and births of their babies born between 2006 and 2010.

Data sources: Electronic data systems used by health service providers store confidential client information with strict provisions for data security and confidentiality. However de-identified information may be released for research purposes, subject to stringent processes to ensure data security and confidentiality. The process of securing the necessary approvals and release of a linked, de-identified dataset has been described elsewhere.[14] Briefly, data collections accessed were the Queensland Perinatal Data Collection (PDC); the Queensland Health Pathology Services Data Collection (Auslab); and the community health services electronic record system, Ferret, used mainly in remote locations of Far North Queensland (Supporting information Table S1). Information extracted from Auslab had been recorded from 2000 up to 2010, from Ferret from date of rollout (see Figure 1), up to 2010 and from PDC from 2006 to 2010. Individual records were linked and de-identified by the Queensland Health Statistical Services Branch for release to the research group in May 2017.

Participants: Study data were extracted from these data collections for two cohorts—the Cape York cohort and the 2009–2010 cohort.

The Cape York cohort includes mothers of Aboriginal and Torres Strait Islander children born between 2006 and 2008, where the child had previously been included in an unpublished health service review of childhood growth in remote Cape York communities.

The 2009–2010 cohort includes all Aboriginal and/or Torres Strait Islander mothers with a PDC record for a birth in 2009 or 2010 in Far North Queensland.

As children were recruited to the Cape York child growth research after the neonatal period, information on perinatal mortality is not available for the Cape York cohort. Perinatal mortality information is available for babies of the 2009–2010 cohort.

Ethics approval was granted by Queensland Health Far North Queensland Human Research Ethics Committee (HREC/15/QCH/50-980) in June 2015. Subsequent to applications to the respective Data Custodians for data release, approval under the Queensland Public Health Act 2005 was granted by the Director General of Queensland Health in February 2016.

Variables and definitions: Anaemia in pregnancy was defined as haemoglobin less than 110 g/L as used by Queensland Health.[15,16] Measurements of haemoglobin used here are results of pathology laboratory measurements. Iron deficiency was defined as Ferritin levels below 15 ug/L.[15]

Information recorded on the PDC includes mothers' ethnicity, parity, pre-pregnancy weight, height, smoking in pregnancy; birth status of babies—live/still born, gestational age at birth. Other information was derived from PDC records (maternal age, teenage mothers, body mass index categories, prematurity and birthweight category) as defined by the Australian Institute of Health and Welfare and the National Health and Medical Research Council—see Table S2.[17–19] Pre-existing diabetes was defined as a fasting oral glucose tolerance test result ≥7.0 mmol/L and/or a glycated haemoglobin reading ≥6.5%. Gestational diabetes was defined as an oral glucose tolerance test result ≥5.1 (fasting) and/or 10.0 (1 hour) and/or 8.5 mmol/L (2 hours) among women without pre-existing diabetes.[16,20,21] For definitions of hypertension, iron deficiency, low red cell folate (RCF) and vitamin B12 levels, see Table S2. Information on food insecurity, diet or nutrient supplements are not recorded in these electronic data collections.

The Socio-Economic Index for Areas (SEIFA 2011) ranks Australian Bureau of Statistics Statistical Local Areas (SLAs) by deciles of relative socioeconomic advantage and disadvantage.[22] A ranking of '1' indicates a locality of greatest relative disadvantage while a ranking of '10' indicates a locality of greatest relative advantage.[22] The appropriate SEIFA decile ranking was allocated to each mother based on her usual place of residence. For the purpose of this analysis, SEIFA deciles (1–10) were reduced to two categories: SEIFA deciles 1 and 2 (the 20% most disadvantaged SLAs in Australia) or SEIFA decile 3 or higher. These categories were selected as most of the mothers in this study (71.1%) lived in SEIFA categories 1 and 2.

Statistical analysis: Categorical variables were described using absolute and relative frequencies. The distribution of numerical variables were assessed; symmetrically distributed numerical characteristics were described using mean values, SDs and ranges; numerical values with a skewed distribution (parity, Ferritin levels, baby's gestational age at birth) were described using median, interquartile ranges (IQRs) and ranges. The prevalence of anaemia was presented with 95% confidence intervals (95% CIs).

Bivariate analysis: Characteristics of the mothers and their pregnancy outcomes were compared between those mothers who had been anaemic in pregnancy and those who had not, using logistic regression.

Multivariable analysis: The following characteristics were considered during multivariable analyses (Cohort 1 '2009–2010 cohort' n = 1796; Cohort 2 'Cape York cohort' n = 280). Variables with complete dataset were ethnicity of mother, age of mother, SEIFA category for residence of mother, five or more antenatal care visits, pregnancy induced hypertension, birthweight of baby (Cohort 2: complete dataset). Variables with missing values were: BMI category of mother, parity, smoking during pregnancy, mother with pre-existing diabetes, gestational diabetes, low RCF value before or during pregnancy, low vitamin B12 value before or during pregnancy, iron deficiency during pregnancy, birthweight of baby (missing values Cohort 1). The number of missing values for variables used in multivariable analyses is shown in Tables 1–2 and Tables S1-S4.

'*Missing-ness*': Examination of patterns of missing data showed data missing for some key variables; year of birth of baby (that is, the cohort) was significantly associated with missing body mass index ($P < 0.001$), missing parity ($P = 0.042$), and missing iron status ($P < 0.001$), resulting in more missing data for the Cape York cohort mothers. Consequently it was decided to conduct analysis stratified by cohort. Tables S3 and S4 provide more information on missing values and patterns of 'missing-ness'.

Multivariable general linear models for the binomial family using the log link to estimate relative risks (RRs) were used to identify independent risk factors for anaemia during pregnancy for the complete case analysis. Backward and forward stepwise modelling procedures were initially conducted to establish basic multivariable models for both cohorts. Characteristics that were not part of the basic models were assessed for potential confounding effects. A confounder was assumed to be a variable that changed estimates of characteristics in the basic model by 10% or more.[23] Once a model was established, all possible two-way interactions involving variables in the model were assessed for statistical significance.

Multiple imputation: Multivariate multiple imputation was conducted using Stata's MI commands for sequential imputation using chained equations. Missing values were imputed for BMI of mother; parity; smoking during pregnancy; mother with pre-existing or gestational diabetes; iron deficiency during pregnancy; and birthweight of baby. Low RCF and vitamin B12 values before or during pregnancy were not imputed because these characteristics were missing in close to 80% of cases in both cohorts and they did not show statistically significant associations during bivariate or multivariable complete case analyses. Before imputation, patterns of missing values were investigated and assumed to be 'missing at random' in each cohort.[24] Linear regression was used to impute missing values of continuous characteristics; logistic regression was used to impute missing values of dichotomous characteristics. Imputation models were based on the

Table 1 Prevalence of anaemia during the cohort pregnancy by characteristics of mothers, 2009–2010 cohort

Characteristics of mothers (data available and data missing[1])	*Mothers (n)*	*Mothers with anaemia in cohort pregnancy (n)*	*Prevalence of anaemia in pregnancy, % (95% CI)*	P-*values (logistic regression)*
All	1796	976	54.3% (52.0%, 56.6%)	—
Ethnicity[1] (complete dataset)				
Aboriginal	910	493	54.2% (50.9%, 57.4%)	Base
Torres Strait Islander	653	363	55.6% (51.8%, 59.4%)	0.58
Both Aboriginal and Torres Strait Islander	233	120	51.5% (45.0%, 58.0%)	0.465
Usual residence (complete dataset)				
Cairns and Hinterland	1133	581	51.3% (48.4%, 54.2%)	Base
Cape York	220	120	54.5% (47.9%, 61.2%)	0.385
Torres and Northern Peninsula Area	443	275	62.1% (57.5%, 66.6%)	<0.001*
SEIFA category[1] (complete dataset)				
SEIFA 1 or 2	1276	719	56.3% (53.6%, 59.1%)	0.008*
SEIFA 3–10	520	257	49.4% (45.1%, 53.7%)	
Teenage mother	376	230	61.2% (56.2%, 66.1%)	0.003*
Antenatal Care 5 visits or more[1] (complete dataset), n = 1417 (78.9%)	1417	770	54.3% (51.7%, 56.9%)	0.996
Smoking this pregnancy[1] (1791 records—5 missing)	1022	567	55.5% (52.4%, 58.5%)	0.259
Body mass index categories[2] (all ages—1675 measures—121 missing)[1]				
Under weight (5.4%)	90	59	65.5% (55.5%, 75.6%)	0.152
Healthy weight (36.7%)	615	354	57.6% (53.6%, 61.5%)	Base
Over weight (26.0%)	436	233	53.4% (48.7%, 58.1%)	0.185
Obese (31.9%)	534	246	46.1% (41.8%, 50.3%)	<0.001*
Glucose tolerance				
Pre-existing diabetes[1] (1239 pathology measures—557 missing)	75	45	60.0% (48.7%, 71.3%)	0.390
Gestational diabetes[1] (793 pathology measures—1003 missing)	141	77	54.6% (46.3%, 62.9%)	0.595
Pregnancy-induced hypertension[1] (complete dataset)	92	58	63.0% (53.0%, 73.1%)	0.087
Nutrient status before/during cohort pregnancy				
Ever iron deficient during cohort pregnancy[1] (1133 pathology measures—663 missing)	672	452	67.3% (63.7%, 70.8%)	<0.001*
Ever iron deficient before cohort pregnancy (561 pathology measures)	324	224	69.1% (64.1%, 74.2%)	<0.001*
Low red cell folate before/during cohort pregnancy[1] (376 pathology measures—1420 missing), n = 66 (17.6%)	66	44	66.7% (55.0%, 78.3%)	0.785
Low B12 before/during cohort pregnancy[1] (328 pathology measures–1468 missing), n = 63 (19.2%)	63	48	76.2% (65.4%, 87.0%)	0.202

[1] Information on number of missing values provided for those variables used for multivariable analysis.
[2] Criteria for body mass index categories for adults applied for mothers aged 18 years and older, and age-based criteria for mothers younger than 18 years (where available, n = 1675).
* *P*-value less than 0.05.

following variables: anaemia during pregnancy, pregnancy induced hypertension, ethnicity, age, SEIFA index and antenatal care received. Twenty imputed datasets were created for each cohort. Multivariable general linear models for the binomial family using the log link to estimate RRs were used to identify independent risk factors for anaemia during pregnancy for imputed data.

Results of multivariable models for complete case and imputed data analyses are presented as RRs and 95% CIs. *P*-values of less than 0.05 were considered statistically significant. Analysis was conducted using Stata version 13 (StataCorp, Lakeway Drive, College Station, Texas).

Results

Data provided in May 2017 included information for 2332 mothers who gave birth to 2548 Aboriginal and Torres

Table 2 Prevalence of anaemia during the cohort pregnancy by characteristics of mothers, Cape York cohort

Characteristics of mothers (data available and data missing[1])	*Mothers (n)*	*Mothers with anaemia in cohort pregnancy (n)*	*Prevalence of anaemia in pregnancy, % (95% CI)*	*P-values (logistic regression)*
All	280	156	55.7% (49.9%, 61.6%)	n/a
Ethnicity[1] (complete dataset)				
Aboriginal	249	140	56.2% (50.0%, 62.4%)	Base
Torres Strait Islander, n = 16 (5.7%)[2]	16	—	—	0.335
Both Aboriginal and Torres Strait Islander, n = 15 (5.4%)[2]	15	—	—	0.775
Usual residence (complete dataset)				
Cairns and Hinterland	18	9	50.0% (24.4%, 75.6%)	Base
Cape York	261	146	55.9% (49.9%, 62.0%)	0.625
Torres and Northern Peninsula Area[2]	—	—	—	n/a
SEIFA category[1] (complete dataset)				
SEIFA 1 or 2	255	144	56.5% (50.3%, 62.6%)	0.81
SEIFA 3–10	25	12	48.0% (27.0%, 69.0%)	
Teenage mother	57	39	68.4% (56.0%, 80.9%)	0.032*
Antenatal Care 5 visits or more[1] (complete dataset)	251	137	54.6% (48.4%, 60.8%)	0.265
Smoking this pregnancy[1] (278 record—2 missing)	187	108	57.8% (50.6%, 64.9%)	0.257
Body mass index categories[3] (all ages 107 measures—173 missing)				
Under weight (23.4%)	25	14	56.0% (35.1%, 76.9%)	0.721
Healthy weight (35.5%)	38	23	60.5% (44.2%, 76.8%)	Base
Over weight (25.2%)[2]	27	—	↓	0.033*
Obese (15.9%)[2]	17	—	↓	—
Glucose tolerance[2]				
Pre-existing diabetes[1] (212 pathology measures—68 missing)	10	—	—	0.783
Gestational diabetes[1] (140 pathology measures—140 missing)	28	—	↓	0.006*
Pregnancy-induced hypertension[1] (complete dataset)[2]	2	—	—	0.097
Nutrient status (iron, folate, B12) before/during cohort pregnancy				
Ever iron deficient *during* cohort[1] pregnancy (136 pathology measures—144 missing)	54	34	63.0% (49.6%, 76.3%)	0.178
Ever iron deficient *before* cohort pregnancy (77 pathology measures—203 missing)	37	28	75.7% (61.2%, 90.2%)	0.022*
Low red cell folate *before/during* cohort pregnancy[1] (59 pathology measures—221 missing)[2]	—	—	—	0.443
Low B12 *before/during* cohort pregnancy[1] (51 pathology measures—229 missing)[2]	—	—	—	n/a

[1] Information on number of missing values provided for those variables used for multivariable analysis.
[2] Numbers too small to report are shown as —.
[3] Criteria for body mass index categories for adults applied for mothers aged 18 years and older, and age-based criteria for mothers younger than 18 years (where available, n = 107).
* *P*-value less than 0.05.

Strait Islander babies between 1 January 2006 and 31 December 2010 in Far North Queensland.

Exclusions: For the purpose of this report, non-Indigenous mothers (n = 15) and mothers normally resident outside of Far North Queensland (n = 29) were excluded. Births that were not the first birth in the cohort years were excluded (n = 289). Mothers with missing information for haemoglobin levels during pregnancy (n = 119) were also excluded. Following exclusions, the resultant dataset included information for 2076 Aboriginal and Torres Strait Islander mothers who gave birth to 2095 babies including 19 sets of twins, between 2006 and 2010 (Figure 2).

The 2009–2010 cohort: After exclusions there were 1796 mothers of whom half (50.7%) were Aboriginal, 36.4% Torres Strait Islander and 13.0% both Aboriginal and Torres Strait Islander (Table 1). More than half were normally resident in the Cairns and Hinterland Health Service District (63.1%), the remaining in Cape York (12.3%) or the Torres Strait and Northern Peninsula Area (24.7%) (Figure 1). Most mothers (71.1%) lived in localities with a SEIFA ranking in the lowest or second lowest decile.[22]

Table 3 Risk factors for anaemia during pregnancy—2009–2010 mothers (n = 1796): Multivariable analysis—complete case analysis and analysis with imputed data

	Complete case analysis (n = 1052)				*Imputed data analysis (n = 1796)*				
Characteristic	*Anaemia, n = 619 (58.8%)*	*No Anaemia, n = 433 (41.2%)*	*Relative risk (95% confidence interval)*	P-value	*Number of missing values (%)*	*Anaemia, n = 976 (54.3%)*	*No anaemia, n = 820 (45.7%)*	*Relative risk (95% confidence interval)*	P-value
Body mass index					121 (6.7%)				
Under weight	43 (7.0%)	20 (4.6%)	1.06 (0.88, 1.27)	0.533		66 (6.8%)	33 (4.0%)	1.10 (0.94, 1.29)	0.246
Healthy weight	255 (41.2%)	152 (35.1%)	1	–		391 (40.1%)	275 (33.5%)	1	–
Over weight	167 (27.0%)	114 (26.3%)	1.0 (0.89, 1.12)	0.971		253 (26.0%)	213 (26.0%)	0.97 (0.87, 1.08)	0.597
Obese	154 (24.9%)	147 (34.0%)	0.87 (0.76, 1.0)	0.049*		266 (27.2%)	299 (36.5%)	0.87 (0.77, 0.97)	0.013*
SEIFA category					nil				
SEIFA 1 and 2	468 (75.6%)	305 (70.4%)	1			719 (73.7%)	557 (67.9%)	1	
SEIFA 3–10	151 (24.4%)	128 (29.6%)	0.88 (0.78, 0.99)	0.033*		257 (26.3%)	263 (32.1%)	0.86 (0.78, 0.95)	0.003*
Mother was iron deficient during pregnancy					663 (36.9%)				
No	210 (33.9%)	222 (51.3%)	1			321 (32.9%)	423 (51.6%)	1	
Yes	409 (66.1%)	211 (48.7%)	1.34 (1.19, 1.50)	<0.001*		655 (67.1%)	397 (48.4%)	1.40 (1.23, 1.60)	<0.001*

Both models were adjusted for the confounding effect of age of mother (no missing values imputed). Imputed data are averages of 20 imputations.
* P-value less than 0.05.

Table 4 Risk factors for anaemia during pregnancy—Cape York mothers (n = 280): Multivariable analysis—complete case analysis and analysis with imputed data

	Complete cases analysis (n = 79)				*Imputed data analysis (n = 280)*				
Characteristic	*Anaemia, n = 33 (41.8%)*	*No Anaemia, n = 46 (58.2%)*	*Relative risk (95% confidence interval)*	P-value	*Number of missing values (%)*	*Anaemia, n = 156 (55.7%)*	*No Anaemia, n = 124 (44.3%)*	*Relative risk (95% confidence interval)*	P-value
Body mass index					173 (61.8%)				
Under weight	10 (30.3%)	6 (13.0%)	1.04 (0.63, 1.72)	0.869		55 (35.4%)	23 (18.8%)	1.07 (0.82, 1.39)	0.609
Healthy weight	14 (42.4%)	11 (23.9%)	1	—		64 (40.8%)	37 (29.6%)	1	—
Over weight	8 (24.2%)	16 (34.8%)	0.67 (0.35, 1.30)	0.238		27 (17.4%)	34 (27.7%)	0.74 (0.51, 1.07)	0.107
Obese	1 (3.0%)	13 (28.3%)	0.13 (0.02, 0.85)	0.034*		10 (6.4%)	30 (23.9%)	0.40 (0.19, 0.86)	0.019*

Both models were adjusted for the confounding effect of having had pre-existing diabetes or gestational diabetes (132 missing values imputed). Imputed data are averages of 20 imputations.
* P-value less than 0.05.

The mean age of mothers was 25.2 years (SD = 6.4) ranging from 13 up to 48 years. One in five mothers (21.0%) were teenagers. Median parity was two, ranging from 0 to 16. Most mothers (78.9%) had at least five antenatal health-care visits in pregnancy. More than half (57.1%) smoked in pregnancy. Mean body mass index of the mothers aged 18 years and over (measurements available n = 1535) was 27.7 (6.6) ranging from 16.0 to 56 kg/m^2.

Among mothers with glucose tolerance results, 6.1% (n = 1239) had pre-existing diabetes and 17.8% (n = 794) had gestational diabetes. PDC records showed that 5.1% had pregnancy-induced hypertension. Among mothers with prior records of blood pressure 17.6% (n = 812), had hypertension. More than half of the mothers with measures of Ferritin had iron deficiency during (59.3%, n = 1133) or before (57.8%, n = 561) the cohort pregnancy.

The Cape York cohort: The majority (88.9%) of these mothers (n = 280) were Aboriginal and the remaining were Torres Strait Islander (5.7%) or both Aboriginal and Torres Strait Islander (5.4%) (Table 2). Nearly all (93.2%) were usually resident in Cape York, 6.4% in Cairns and Hinterland Health Service District and one mother in the Torres Strait and Northern Peninsula Area (Figure 1). Most (91.1%) mothers lived in localities with a SEIFA ranking in the lowest or second lowest decile.[22]

The mean age of these mothers was 25.0 years (SD = 6.4) ranging from 15 to 40 years. One in five (20.4%) were teenagers. Median parity was two, ranging from nil to eight.

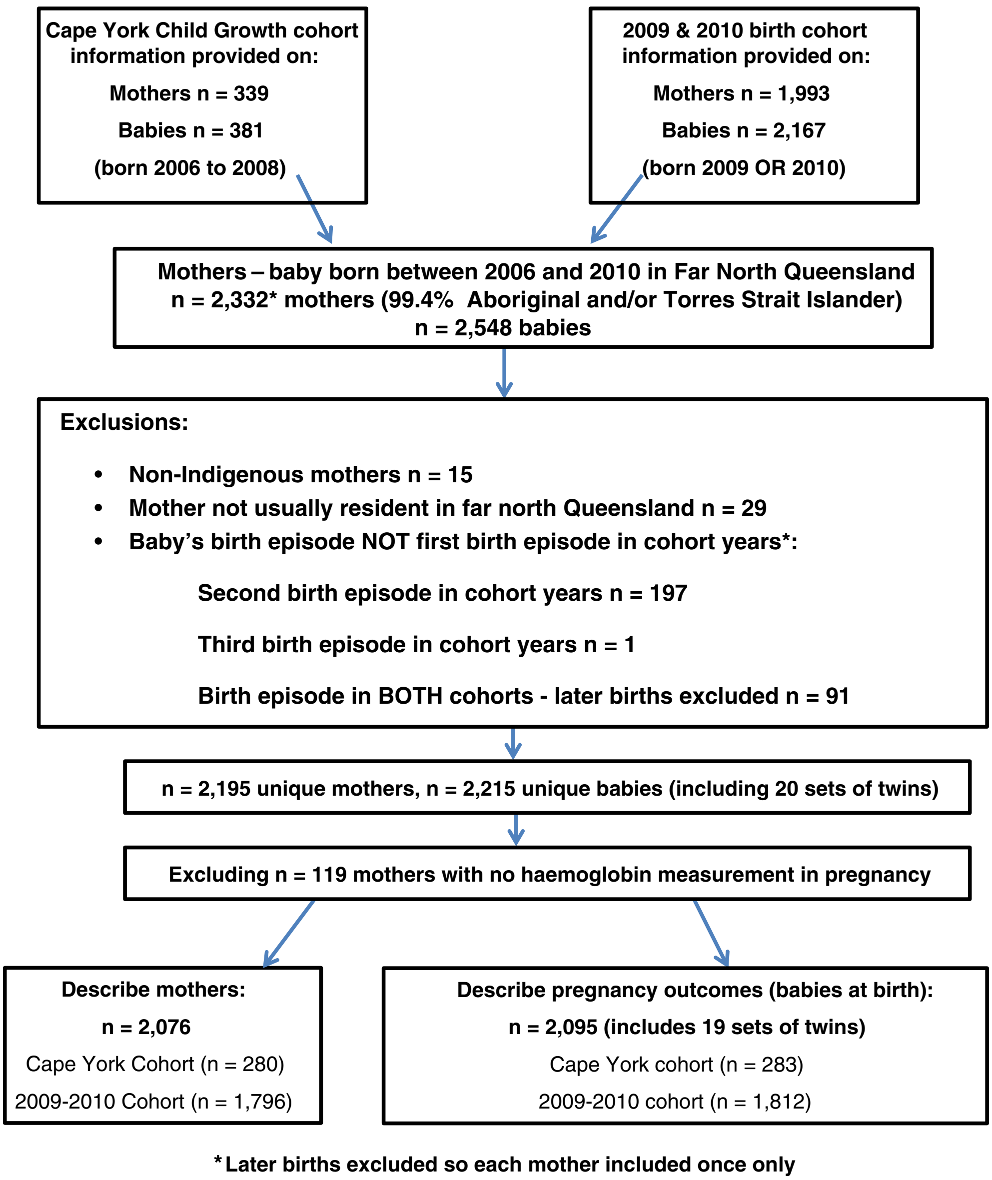

Figure 2 Flow chart: mothers and pregnancy outcomes showing study inclusions and exclusions.

Most mothers (89.6%) had at least five antenatal health-care visits in pregnancy. Many (67.3%) smoked in pregnancy. Mean body mass index of the mothers aged 18 years and over (measurements available n = 98) was 24.4 (5.8) ranging from 16.1 to 37.7 kg/m^2.

Where glucose tolerance results were available 4.7% (n = 212) had pre-existing diabetes and 20.0% (n = 140) had gestational diabetes. PDC records showed that 7.5% had pregnancy-induced hypertension. Among mothers with prior records of blood pressure, 20.6% (n = 272) had hypertension. Of those with measures of Ferritin, 39.7% (n = 54) had iron deficiency during the cohort pregnancy while 48.1% (n = 77) had iron deficiency before the cohort pregnancy.

2009–2010 cohort—Pregnancy outcomes: Among the 1812 babies born to these 1796 mothers, 53.9% were boys. Seventeen (0.9%) were still born and there were 10 (0.6%) neonatal deaths (Table S7). Among the liveborn babies (n = 1795), median gestational age at birth was 39 weeks, ranging from 22 to 42 weeks. Mean birthweight was 3240 g (SD = 649 g) ranging from 440 to 5430 g. About 1 in 10 babies were low birthweight (10.6%), premature (11.4%) or macrosomic (9.6%) (birthweight ≥ 4000 g).

Cape York cohort—Pregnancy outcomes: Among the 283 babies born to these 280 mothers, 51.9% were boys (Table S8). No information was available for perinatal mortality for this cohort. Median gestational age was 39 weeks, ranging from 27 to 42 weeks. Mean birthweight was 3097 g (SD = 591 g) ranging from 800 to 5320 g. About one in seven babies (13.8%) were low birthweight, 11.7% premature and some (4.6%) macrosomic (birthweight ≥ 4000 g).

Overall, more than half of the mothers (54.5% (95% CI: 52.4%, 56.7%)) had anaemia during pregnancy—2009 and 2010 birth cohort mothers: 54.3% (95% CI: 52.0%, 56.6%); Cape York Child Growth mothers: 55.7% (95% CI: 49.9%, 61.6%). There was no significant difference in prevalence of anaemia by cohort (P = 0.668). Compared to those not anaemic in pregnancy, mothers of the 2009-2010 cohort who had anaemia in pregnancy were younger (mean age 24.8 (24.4, 25.2) v 25.7 (25.3, 26.1) P =0.003, had lower mean BMI (27.0 (26.6, 27.4) v 28.4 (27.9, 28.9) P = <0.001), higher parity (median parity 2 (IQR 1, 4) v 2 (1, 3) P = 0.02) and lower Ferritin levels (anaemic mothers median Ferritin 14 (IQR 7,28) ug/L v non-anaemic mothers; 18.7 (10, 42) P = 0.039). Mothers with iron deficiency (P <0.001) and those living in socio-economically disadvantaged localities (p = 0.008) were more likely to have anaemia in pregnancy but mothers who were obese were less likely to have anaemia in pregnancy (P <0.001) (Table 1 and Table S5). Mothers with anaemia in pregnancy had babies with higher birth weights than babies of non-anaemic mothers (mean grams 3269 (95% CI 3230, 3308) v 3205 (3159, 3252) P = 0.038) and had fewer low birth weight babies (8.5% low birth weight babies (95% CI 6.9%, 10.4%) v 13.0% (10.9%, 15.5%) P = 0.002. No other differences were seen in pregnancy outcomes (Table S7). Compared to those not anaemic in pregnancy, Cape York mothers who had anaemia in pregnancy had lower mean BMI (22.3 (20.9, 23.7) v. 26.0 (24.3, 27.7) P = 0.002) and tended to be younger though the difference in age was not statistically significant (mean age 24.4 years (95% CI 23.4, 25.4) v. 25.9 (24.8, 27.0) P = 0.054). Mothers who were overweight (n = 9, P = 0.033) were less likely to be anaemic as were mothers with gestational diabetes (n = 7, P = 0.006) but the number of these mothers was small. No difference was seen in parity (anaemic mothers median parity 2 (IQR 1, 3) v 2 (1, 3) [P = 0.602). Similarly no difference was seen in Ferritin levels (anaemic mothers; median Ferritin 20.8 ug/L (IQR 10.3,47.8) v. 25.5 (15.3, 57.3) P = 0.589) but mothers with prior iron deficiency had more anaemia in pregnancy (P = 0.022) (Table 2 and Table S6). There were no differences in pregnancy outcomes for anaemic and non-anaemic Cape York mothers (Table S8). Results of bivariate comparisons of mothers with anaemia with those without, and their pregnancy outcomes, are shown in Tables S5–S8.

Multivariable analysis 2009–2010 cohort: After controlling for age, mothers who were iron deficient during pregnancy were more likely to be anaemic (RR: 1.40, P < 0.001) (Table 3; imputed data analysis). Mothers from relatively advantaged localities (SEIFA decile 3 and above) were less likely to be anaemic (RR: 0.86, P = 0.003), as were mothers who were obese (RR: 0.87, P = 0.013).

Cape York cohort: After controlling for existing or gestational diabetes, only body mass index remained statistically significant for these mothers (being obese: RR = 0.40, P = 0.019) (Table 4; imputed data analysis).

Discussion

Among the Aboriginal and Torres Strait Islander mothers of Far North Queensland described here, over half had anaemia in pregnancy (54.5%, n = 2076). This is much higher than among pregnant women elsewhere in Australia but similar to findings from two remote Northern Territory communities, where 50% of mothers had anaemia in pregnancy.[13] These results reflect the higher rates of anaemia reported among Australian Indigenous people in recent national health surveys.[25]

Although other conditions can cause anaemia, iron deficiency is the 'usual suspect' as the cause of anaemia in pregnancy.[15,26] Among the 2009 and 2010 birth mothers, for whom data were more complete, analysis confirmed that iron deficiency was strongly associated with anaemia in pregnancy.

Compared to the average Australian mother in 2016, the mothers described here were younger, more likely to smoke and they had less antenatal care.[27] The prevalence of obesity was higher among the 2009–2010 birth mothers, although not the Cape York mothers. About one in four of these Far North Queensland mothers had diabetes in pregnancy compared to about one in eight mothers Australia-wide in 2016.[27] Previous reports of the poor health and nutrition of young Indigenous women in North Queensland also flagged the potentially detrimental intergenerational effects.[28] The pregnancy outcomes reported here, with more premature and low birthweight babies, reflect the poor nutrition and health status of these mothers. The association of anaemia of mothers with increased birth weight of the babies may reflect their marginal nutrition status, with the requirements of bearing a healthy weight baby depleting the limited nutritional reserves of these mothers.

An unexpected finding was that obese mothers were less likely to be anaemic than other mothers, though their rates of anaemia (46.1%) were still high. It may be that the higher food intake resulting in obesity provides a higher nutrient intake. However, maternal obesity is never recommended because of the negative health effects on the mother and her baby.[28] Instead, mothers need diets sufficiently nutritious to meet their requirements without excessive energy intakes.

There are limitations in this study, which used health service information recorded during provision of routine care. Some information of interest is not recorded on electronic data collections such as indicators of food insecurity or nutrient supplement use. Missing data for some key variables particularly in the early years was a limitation. Some measurements used in this analysis may have been available only for selected mothers if clinical protocols prescribed specific pathology tests for 'high risk' mothers. Examples include measurements of glucose tolerance and Ferritin levels. Because 'missing at random' is an assumption for multiple imputation where 'missing not at random' was suspected, respective characteristics were carefully analysed in alternative models.

Despite these limitations, the findings reported here are consistent with the high rates of anaemia among young Aboriginal and Torres Strait Islander children and pregnant women reported elsewhere in remote Australia.[7,13] A recent review has shown that food insecurity is associated with increased risk of anaemia among women and young children in high and low income countries.[29] Food insecurity and poor diet of Aboriginal and Torres Strait Islander people have been documented in remote settings in Australia.[30,31]

There is increasing evidence of the importance of a nutrient-rich diet in pregnancy, not only for the mother but for the physical health and cognitive development of her child.[1,32] A nutrient-rich diet helps prevents anaemia and provides many nutrients needed for health. For mothers on low incomes, high cost is a barrier to healthy eating especially in remote settings.[33] Mothers with low iron status in pregnancy can benefit from supplements—in addition to a healthy diet—but reaching those with highest needs is challenging.[34] Fortification of flour with folate appears to have been especially effective at reaching vulnerable population groups.[35] But iron is a nutrient with potential for harm so iron supplementation must be targeted to those with specific needs.[4]

Complementary interventions to improve food security, promote good nutrition, and provide targeted iron supplementation and/or fortification are needed, designed and implemented in partnership with the Aboriginal and Torres Strait Islander communities.[36] Also essential are the policy commitment and funding to develop, implement and evaluate these interventions.[37] To 'Close the Gap'[38] in the health, education and economic status of Aboriginal and Torres Strait Islander people in Far North Queensland compared to their non-Indigenous peers, these high rates of anaemia in pregnancy among Aboriginal and Torres Strait Islander mothers must be reduced.

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Conflict of interest

The authors affirm that they have no conflict of interest to declare.

Authorship

DL conceived the research, obtained the necessary approvals to secure the data required, conducted preliminary statistical analysis and prepared the first draft of this manuscript. FT assisted with data management and preparation, and contributed to statistical analysis. PB contributed to study design and guided and contributed to statistical analysis. RM and MM contributed to study design, and manuscript development and preparation.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1 Data collections used as information sources to describe rates of anaemia in pregnancy and health indicators among Aboriginal and Torres Strait Islander mothers in Far North Queensland

Table S2 Definitions of variables used to describe Aboriginal and Torres Strait Islander mothers and their pregnancy outcomes in Far North Queensland, between 2006 and 2010

Table S3 Number and percentage (%) of missing values for variables used for multivariable analysis for risk factors for anaemia in pregnancy for each cohort

Table S4 Assessment of 'Missing-ness': *P*-values are results of statistical tests correlating missing (yes/no) with cohort, outcome anaemia, variables with no missing values and with other missing variables

Table S5 Mothers 2009 – 2010 cohort - comparison of mothers with anaemia during the cohort pregnancy with mothers who did not have anaemia during this pregnancy: Bivariate analysis – logistic regression

Table S6 Cape York mothers - comparing mothers with anaemia during the cohort pregnancy with mothers who did not have anaemia during this pregnancy: Bivariate analysis – logistic regression

Table S7 Pregnancy outcomes - 2009–2010 births: comparing those babies whose mother had anaemia in pregnancy with those babies whose mother did not have anaemia in pregnancy - results based on 1812 babies of whom 1795 were live born babies: Bivariate analysis – logistic regression

Table S8 Pregnancy outcomes - Cape York births: comparing those babies whose mother had anaemia in pregnancy with those babies whose mother did not have anaemia in pregnancy (n = 283 - all babies live-born): Bivariate analysis – logistic regression