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Risk and Protective Factors for Pregnancy Outcomes for Urban Aboriginal and Non-Aboriginal Mothers and Infants: The Gudaga Cohort

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Abstract This paper aims to describe delivery and birth outcomes of Aboriginal infants and their mothers in an urban setting on the east coast of Australia. The paper uses a causal pathway approach to consider the role of risk and protective factors for low birthweight. All mothers who delivered at Campbelltown Hospital between October 2005 and May 2007 were eligible. The study included 1,869 non-Aboriginal infants and 178 Aboriginal infants and their mothers. Information on delivery and birthweight was extracted from electronic medical records. Risk factors for poor outcomes were explored using regression and causal pathway analysis. Mothers of Aboriginal infants were younger than mothers of non-Aboriginal infants, and were more likely to be single, less educated, unemployed prior to pregnancy, and live in a disadvantaged neighbourhood. Health and service use was similar. They were significantly more likely to have a vaginal delivery than mothers of non-Aboriginal infants (77% cf 62.5%; $\chi^2_1 = 14.6$, $P < 0.001$) and less likely to receive intervention during delivery. Aboriginal infants (3,281.1 g) weighed 137.5 g (95%CI: 54–221 g; $P = 0.001$) less then non-Aboriginal infants (3,418.7 g). Gestational age, and single mother with incomplete education, prior unemployment, smoking, and living in a disadvantaged neighbourhood were associated with lower birthweight. Maternal vulnerability had a cumulative impact on birthweight. A causal pathway analysis demonstrated the associations between risk factors.

Keywords Indigenous · Birth outcomes · Risk factors · Protective factors

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Background

Poorer pregnancy outcomes for marginalised and disadvantaged women giving birth have been widely described in the literature [1, 2]. In Australia, women who identify as being of Aboriginal or Torres Strait Islander origin [3] comprise 3.6% of women giving birth [4]. These data also indicate that Aboriginal women giving birth are more likely than non-Aboriginal women to be aged less than 20 years, to live in disadvantaged or rural and remote areas, to smoke during pregnancy, and present late for antenatal care. Likewise, Aboriginal newborns are more likely than non-Aboriginal newborns to have higher rates of still birth, low birthweight, prematurity, and possibly macrosomia [5–9]. There is interest in whether poorer birth

outcomes are associated with Aboriginal status per se or other factors that are closely associated with Aboriginal status or membership of a minority group [8, 10].

A number of explanatory variables for poor birth outcomes have been identified in the research literature. Aboriginal Australians share common experiences of colonisation, loss of cultural and community identity, and marginalisation, prejudice and discrimination with other Indigenous populations in developed nations [3]. The impact of these influences on the health of Aboriginal people including birth outcomes is pervasive and difficult to measure. Alternate explanations include genetic differences in body size including birthweight; [1, 9–15] health and behavioural risk factors; [5, 8, 11–13, 15] excess alcohol consumption, active and passive smoking, and poor maternal nutrition; [6–8, 10, 16, 17] and maternal health before or during pregnancy [7, 18, 19]. Hypertension, vaginal bleeding, and infections are associated with LBW or preterm delivery [7, 19] while obesity, gestational diabetes and inadequate physical activity are associated with large birthweight [18]. Finally, socioeconomic status, independently and through association with increased exposure to other maternal risk factors, is associated with birth outcomes [7, 8, 15].

Many of the current explanations of risk for poor birth outcomes among Aboriginal infants are unhelpful and limited to conventional risk factors [7]. In previous research we concluded that low socioeconomic status and smoking largely explain reductions in birthweight among Aboriginal infants [8]. Other authors, in commenting on similar findings, suggest a need to develop [20] and implement interventions to address behavioural risk factors, particularly smoking, during antenatal care [21]. These explanations may overly simplify antenatal risk factors for poor birth outcomes for Aboriginal women. It is easy to underestimate the complex associations that exist between the context in which Aboriginal families live, antenatal risk factors and birth outcomes. An alternate approach is to consider the causal pathways involved. This approach may provide a more comprehensive and inclusive explanatory model for birth outcomes and better reflect the complex explanatory pathways involved [7, 22]. The use of causal pathways also enables protective factors to be identified and used in developing strategies to address risk factors for poor birth outcomes.

The Gudaga Study is a birth cohort study of Aboriginal infants in an urban area [23]. The establishment of the cohort provides a unique opportunity to study maternal and infant birth outcomes in an enumerated population of Aboriginal infants. The aim of this paper is to describe the pregnancy (including delivery intervention) and birth outcomes (including birthweight of infants) in an urban setting on the east coast of Australia and to compare and contrast these outcomes for Aboriginal with those of non-Aboriginal infants. Secondly, the paper aims to use a causal pathway approach to consider the role of risk and protective factors for pregnancy outcomes.

Methods

The study population was mothers of newborns who delivered at Campbelltown Hospital and were admitted to the maternity ward of this large urban hospital between October 2005 and May 2007 [23]. As a part of systematic enumeration and recruitment of Aboriginal infants to the Gudaga Study women were invited to complete a brief ward survey administered by the project's Aboriginal Project Officer [23]. The ward survey sought information from mothers on their education, marital status, and support on discharge. Using standard questions [24] mothers were also asked the Aboriginal or Torres Strait Islander status of themselves and their infant's biological father. Infants were identified as Aboriginal if either the mother or father identified as Aboriginal and/or Torres Strait Islander.

The ward survey included 1,953 mothers of non-Aboriginal infants and 155 mothers of Aboriginal infants. There were 20 mothers of Aboriginal infants who delivered at the hospital but who were not surveyed while on the maternity ward. An additional three mothers of Aboriginal infants birthed at the nearby tertiary hospital and were not surveyed. These 23 mothers were identified through other networks and their data were included in this study. The characteristics of these women did not differ from other mothers of Aboriginal infants in the cohort.

Obstetrics Data Collection

Data on obstetric care and birth outcomes were extracted from the administrative obstetrics data collection maintained by the health service. These data are collected by the midwives as part of their care provision to mothers both pre- and post-natally. Until November 2006, the Obstetrics Data Package (ODP), a stand alone data collection, was used. From 1st December 2006, this system was replaced by an electronic medical record system, Powerchart. While the data collections are essentially similar, the data collected and fields of interest were not always identical and some data could not be used for this study.

Data were extracted on the pregnancy and birth for all women who delivered at the hospital from the ODP for 1st October 2005 to 31st November 2006 and from Powerchart for 1st December 2006 to 31st May 2007. De-identified unit record data included medical record number (maternal and infant MRN), maternal demographic characteristics, health and health risk factors, some aspects of antenatal

care, obstetric outcomes including information on labour and delivery, and health status of the infant at delivery.

Data Manipulation and Linkage

Data from the ward survey and obstetrics data collection were linked using deterministic linkage based on the maternal and infant MRNs and infant's date of birth. This created a unit record data file for 2,131 women. There were three mothers of Aboriginal infants and 53 mothers of non-Aboriginal infants whose records could not be linked or were incomplete; we referred back to the medical records for the former and excluded the latter. In addition, 31 mothers of non-Aboriginal twins were excluded from this study (there were no multiple deliveries among mothers of Aboriginal infants). The final data collection comprised 2,047 records, of which 178 were mothers of Aboriginal infants and 1,869 were mothers of non-Aboriginal infants.

Outcome Variables

We were interested in maternal and infant pregnancy outcomes. The maternal outcomes of interest related to delivery and included three variables: induced labour, vaginal delivery, and caesarean section.

Infant birth outcomes of interest related to gestational age at delivery, birthweight, and admission to the special care nursery. Birthweight was our primary outcome measure and can be presented in different ways [1, 7, 9, 15, 19, 25]. In addition to birthweight (grams) as a continuous variable, we report data on low birthweight (LBW; defined as birthweight <2,500 g, [9, 19] macrosomia (birthweight greater than 4,000 g), [1, 7, 9, 19] and size for gestational age (SGA). SGA was calculated according to the methods of Roberts [26] and defined as birthweight less than 10th percentile for gestational age [9, 19, 25]. The Ponderal Index (PI), a measure of birthweight (bw) in grams for length in centimetres (length), was calculated according to the method of Sayers: $PI = (bw/length^3)$ [9]. Gestational age at delivery is presented as a continuous variable in weeks and as the proportion of infants that were delivered at less then 37 weeks (premature). Admission to the special care nursery was presented as a dichotomous variable as we had limited information on the length of admission.

Study Factors

We used an ecological framework to organise infant, maternal, family, and environmental study factors [27]. Infant factors included gender and gestational age. Maternal factors were grouped as demographic characteristics, socioeconomic status, behavioural risk factors, maternal health, maternal vulnerability, and antenatal care. These were collected by self-report during the ward survey or extracted from the Obstetrics Data Collection.

The maternal demographic characteristics examined were: age measured as a continuous variable and grouped to mothers aged less than 20 years or not, and marital status dichotomised to married or de facto relationship or other. Maternal socioeconomic status was measured according to educational attainment based on whether the mother completed year 10 or did not, and employment status prior to this pregnancy grouped as paid employment or not. The only behavioural risk factor that was examined was maternal smoking during pregnancy; other factors such as overweight or drug and alcohol use were unreliably and inconsistently reported partly due to changes in data collections and could not be included in the analysis. There were similar issued with maternal health status during pregnancy; data on health services use (high risk, diabetes, or Foetal Monitoring Unit) were used as a proxy for pregnancy related health problems and were collected by self report during the maternity ward survey. Eight questions, asked during antenatal care provision were designed to identify vulnerable mothers. These data may be under-reported. Maternal vulnerability was treated as a cumulative variable and a summative score ranging from 0 (no risk factors noted) to 8 (all eight vulnerabilities reported) was created. Information on maternal support following discharge was extracted from the ward survey. Antenatal care was classified as less than or equal to or greater than 20 weeks of gestation.

Family and environment factors include Aboriginality of infant and suburb of residence. The Australian Bureau of Statistics Socioeconomic Index for Area (SEIFA) is an area based measure of socioeconomic status. The SEIFA Index of Relative Socioeconomic Disadvantage was extracted for NSW suburbs and merged onto our database using suburb of residence; these were grouped according to quintiles for NSW [28].

Data Analysis

All data analyses were undertaken using SPSS v17 for Windows (Rel. 17.0.0 2008, Chicago: SPSS Inc).

Descriptive statistical methods were used. For continuous variables such as birthweight, data were summarised as the mean ± the standard deviation and differences between groups such as mothers of Aboriginal and non-Aboriginal infants were tested using the Student *t*-test.

Categorical data such as low birthweight or admission to special care nursery were summarised as the proportion of infants with the characteristic of interest and the difference between groups tested for statistical significance using the chi-square statistic.

Further analysis using multivariate methods based on linear regression analysis was undertaken to further explore infant and maternal factors that were associated with birthweight.

Using an ecological approach [27] we developed a causal pathway model to enable us to explore the relationships among risk factor variables further [7, 22, 29]. We grouped the risk factors for low birthweight identified above to three levels: proximal, medial, and distal (Fig. 1). Firstly there were those that arise during the pregnancy and delivery (proximal) such as pregnancy related disease and prematurity; those that are associated with the mother (medial) such as maternal smoking, educational attainment, and maternal age; and a final group of distal factors that are about the mother's environment. Finally we used logistic regression to calculate the unadjusted of association between risk factor variables and between these and birth outcome (low birthweight).

Ethics

The project was approved by the Ethics committees of the NSW Aboriginal Health and Medical Research Council, Sydney South West Area Health Service and the University of NSW. The research has the full support of the Board of Tharawal Aboriginal Corporation and of the Area Health Service. Mothers were aware of the research; all gave verbal consent to the ward survey and mothers of Aboriginal infants provided written consent to participate in the Gudaga Study. The research team is committed to using the processes for undertaking health research with Aboriginal communities recommended by the National Health and Medical Research Council (NHMRC) [30, 31]. These strategies have been described elsewhere [32].

Results

Data on 2,047 infants and their mothers were included in this study: 178 infants (8.7%) were Aboriginal; and 1869 were non-Aboriginal.

The characteristics of mothers are summarised in Table 1. Briefly mothers of Aboriginal infants were younger (25.4 years) than mothers of non-Aboriginal infants (28.4 years) and were less likely to be in a relationship (59.6 and 83.7% respectively were married or in a de facto relationship). Mothers of Aboriginal infants were more likely to have not completed year 10, to live in a disadvantaged suburb according to SEIFA, and to smoke during pregnancy. Health services use was similar for mothers of Aboriginal and non-Aboriginal infants although mothers of Aboriginal infants were more likely to have been visited at home and 29.4% were seen by the Aboriginal home visiting team. Mothers of Aboriginal infants were more likely to report psychosocial risk factors; the mean number reported as 1.6 for mothers of Aboriginal infants and 0.9 for mothers of non-Aboriginal infants ($t(193) = -5.4$; $P < 0.001$). Mothers of Aboriginal infants were significantly more likely to report a history of mental health problems, childhood abuse, and history of domestic violence than mothers of non-Aboriginal infants and were more likely to be unsupported.

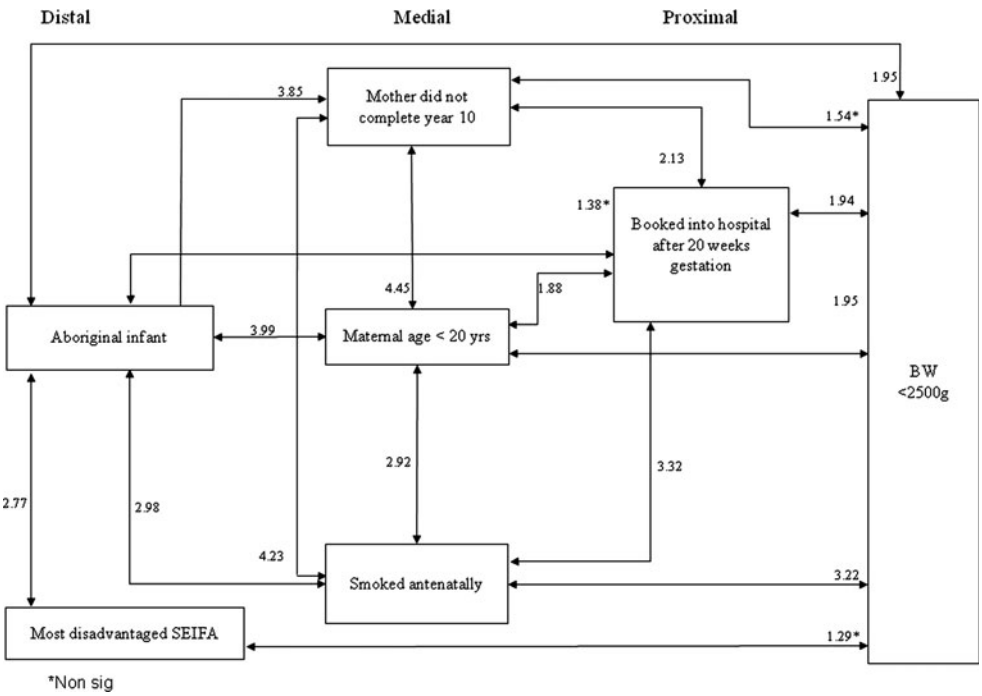

Fig. 1 Example of causal pathway analysis of infant, maternal, and community factors associated with low birth weight

Table 1 Characteristics of mothers of infants by Aboriginal status of infants

	Total ($n = 2047$)		Aboriginal infants ($n = 178$)		Non- Aboriginal infants ($n = 1869$)		
Demographic characteristic	Mean (sd)		Mean (sd)		Mean (sd)		t(df)
Mean maternal age (years)	28.1 (5.7)		25.4 (6.2)		28.4 (5.6)		6.6 (2045)***
	n	%	n	%	n	%	χ_1^2
Mother under 20 years	143	7.0	35	19.7	108	5.8	48.2***
Married/de facto	1671	81.6	106	59.6	1565	83.7	63.4***
First baby	740	36.2	50	28.1	690	36.9	5.5*
SES characteristic (mother)							
Year 10 not completed	217	10.6	49	27.5	168	9.0	58.9***
Paid employment at booking in	889	43.4	36	20.2	853	45.6	42.7***
SEIFA quintile							
First (most disadvantaged)	733	35.8	104	58.4	629	33.7	44.5***
Second	493	24.1	37	20.8	456	24.4	
Third	323	15.8	20	11.2	303	16.2	
Fourth	308	15.0	14	7.9	294	15.7	
Fifth (most advantaged)	190	9.3	3	1.7	187	10.0	
Behavioural risk factor							
Mother smoked during pregnancy	419	20.5	72	40.4	347	18.6	47.8***
Health service use							
High risk clinic	494	24.1	46	25.8	448	24.0	0.3
Diabetes clinic	205	10.0	11	6.2	194	10.4	3.2
Foetal maternal assessment unit	126	6.2	8	4.5	118	6.3	0.9
Any service visited home	61	3.0	41	23.0	20	1.1	271.2***
Mother seen by aboriginal home visiting team	–	–	51	29.3	–	–	–
Psychosocial risks							
Reported childhood abuse	226	11.0	39	21.9	187	10.0	23.5***
Self-esteem/anxiety problem	18	0.9	4	2.2	14	0.7	–[a]
Edinburgh Depression Scale >=10	311	15.2	29	16.3	282	15.1	0.2
Recent stressor	495	24.2	57	32.0	438	23.4	6.5
History of domestic violence	75	3.7	20	11.2	55	2.9	31.7***
Mother unsupported	16	0.8	6	3.4	10	0.5	–*[a]
Late antenatal care	345	16.9	38	21.3	307	16.4	2.8
	Mean (SD)		Mean (SD)		Mean (SD)		t(df)
Number of psychosocial risks[b,c]	0.97		1.6 (1.6)		0.9 (1.2)		−5.4(193)***[d]

* $P \leq 0.05$

** $P \leq 0.01$

*** $P \leq 0.001$

[a] 25% of cells have expected count less than 5, Fisher's exact test used

[b] Includes mother under the age of 20 years

[c] Mothers had all psychosocial vulnerabilities missing and were excluded from the analysis

[d] Levene's Test for Equality of Variances not met ($F = 51.4$, $P < 0.001$)

Pregnancy and Birth Outcomes

The pregnancy outcomes for mothers of Aboriginal and non-Aboriginal infants are summarised in Table 2. A vaginal delivery was recorded for 1,306 (63.8%) mothers; mothers of Aboriginal infants were significantly more likely to have a vaginal delivery than mothers of non-Aboriginal infants (77, 62.5%, $P < 0.001$); they were less

Table 2 Birth outcomes by Aboriginal status of infant

Outcome	Total ($n = 2047$)		Aboriginal ($n = 178$)		Non-Aboriginal ($n = 1869$)		
	n	%	*n*	%	*n*	%	χ^2_1
Maternal							
Induced labour	538	26.3	35	19.7	503	26.9	4.4*
Normal vaginal delivery	1306	63.8	137	77.0	1169	62.5	14.6***
Caesarean section	622	30.4	35	19.7	587	31.4	10.6***
Admitted to special care nursery	286	14.0	26	14.6	260	13.9	0.1
Infant							
Birthweight <2500 g	106	5.2	16	9.0	90	4.8	5.8*
Gestational age <37 weeks	129	6.3	21	11.8	108	5.8	9.7*
Small for gestational age[a]	215	10.5	23	12.9	192	10.3	1.2
Female infant	991	48.4	94	52.8	897	48.0	1.5
	Mean (sd)		Mean (sd)		Mean (sd)		t(df)
Birthweight (gms)	3406.8 (546.3)		3281.1 (620.6)		3418.7 (537.4)		3.2 (2045)***
Gestational age (weeks)	39.4 (1.6)		39.1 (2.2)		39.4 (1.5)		1.8 (193)[c]
Ponderal index[b] (mean)	2.6 (0.4)		2.61 (0.4)		2.65 (0.3)		−1.1 (1964)

* $P \leq 0.05$

** $P \leq 0.01$

*** $P \leq 0.001$

[a] 3 babies with gestational ages recorded greater than 45 weeks not included

[b] Missing lengths meant 81 indexes could not be calculated

[c] Levene's Test for Equality of Variances not met ($F = 18.3$, $P < 0.001$)

likely to have their pregnancy induced (19.7, 26.9%, $P = 0.04$), or to receive a caesarean section (19.7, 31.4%, $P = 0.001$) (Table 2).

The mean birthweight of infants was 3,406.8 g; for Aboriginal infants the mean birthweight was 3,281.1 g compared to 3,418.7 g for non-Aboriginal infants, a mean difference of 137.5 g (95%CI: 54–221 g; $P = 0.001$) (Table 2). Aboriginal infants were significantly more likely to have birthweight less than 2,500 g (9.0%) and gestational age less than 37 weeks (11.8%) than non-Aboriginal infants (4.8 and 5.8% respectively; $P = 0.02$ for both). However, Aboriginal infants were no more likely to be admitted to the special care nursery or to be small for gestational age.

In bivariate analysis (Table 3, column 2) a number of the factors studied were associated with infant birthweight. Female infants were lighter than male infants (difference: −115.8 g, 95%CI: −163 to −69 g) as were infants who were born at less than 37 weeks gestation (difference: −177 g, 95%CI: −164 to −190 g). The risk and protective factors for birthweight are also summarised in this Table. Infants of mothers who were not in a married or de facto relationship, had not completed year 10 at school, were not in paid employment prior to the pregnancy, or who smoked during pregnancy were more likely to weigh significantly less than infants whose mothers were not exposed to these risk factors. Maternal vulnerability factors had a cumulative impact on birthweight; for each additional vulnerability reported birthweight decreased by 37 g (95%CI: −56.8 to −16.5 g).

We used multivariate analyses to explore further the relationships between Aboriginality of the infant and birthweight. A series of partial models were constructed (Table 3, column 2). Every partial model controlled for marital status, maternal age, primiparity, gender and Aboriginality of infant. A single risk or protective factor was entered into each partial model. For each factor, we observed a statistically significant effect on birthweight. In addition to the impact of the factor on birth weight, Aboriginal infants remained significantly lighter than non-Aboriginal infants. When all of the risk and protective factors were included in a multivariate model (Table 3, column 3), the association between being an Aboriginal infant and birthweight was no longer statistically significant. Gestational age, not completing year 10 of school, and maternal smoking during pregnancy were associated with lower birthweight.

Although birthweight is lower for Aboriginal infants overall, our analyses presented above suggest that factors other than being Aboriginal are associated with this lower

Table 3 Risk factors associated with birthweight (grams)

Risk Factor	Bivariate		Multivariate			
	Mean difference	95% CIs	Partial model[a]		Full model[b]	
			Mean difference	95% CIs	Mean difference	95% CIs
Aboriginal infant	−137.5	−221.4, −53.7***	−127.2	−212.9, −41.4**	−29.7	−102.6, 43.3
Married/de facto	66.0	4.9, 127.1*	50.1	−12.5, 112.7	−12.5	−67.3, 42.4
Maternal age	2.5	−1.7, 6.6	−0.8	−5.4, 3.7	0.1	−3.8, 4.0
Primiparious	−47.0	−96.3, 2.3	−55.9	−109.0, −2.1*	−140.3	−187.6, −93.0***
Female infant	−115. 8	−163.0, −68.7***	−115.6	−162.6, −68.6***	−126.8	−166.2, −87.4***
Gestational age (weeks)	176.9	164.2, 189.7***	182.5	169.8, 195.1***	179.0	166.4, 191.7***
Aboriginal infant			−67.7	−140.5, 5.0		
Year 10 not completed	−131.1	−207.8, −54.6***	−116.9	−195.7, −38.1**	−78.7	−146.6, −10.8*
Aboriginal infant			−111.5	−197.7, −25.2**		
Paid employment at booking in	57.5	9.7, 105.2*	62.4	10.6, 114.2*	3.6	−41.4, 48.6
Aboriginal infant			−120.0	−205.8, −34.1**		
Mother smoked antenatally	−232.6	−290.5, −174.8***	−228.6	−289.1, −168.1***	−168.1	−221.4, −114.9***
Aboriginal infant			−98.0	−183.0, −13.0*		
Attended high risk clinic	−118.4	−173.5, −63.3***	−125.7	−180.7, −70.7***	−20.5	−67.4, 26.4
Aboriginal infant			−123.9	−209.3, −38.5***		
Cumulative vulnerabilities (0–8)	−36.6	−56.8, −16.5***	−32.4	−52.9, −11.9*	−2.9	−20.6, 14.9
Aboriginal infant			−114.9	−200.8, −29.0**		
Most disadvantaged SEIFA	−80.4	−129.7, −31.2***	−69.4	−119.6, −19.3**	−28.3	−71.8, 15.3
Aboriginal infant			−114.6	−200.7, −28.5**		

* $P \leq 0.05$

** $P \leq 0.01$

*** $P \leq 0.001$

[a] Partial model controlled for marital status, maternal age, primiparity, gender of infant, and Aboriginality status of infant

[b] Full model included all variables

birthweight. Many of these risk and protective factors are inequitably associated with mothers of Aboriginal infants. The causal pathway model (Fig. 1) attempts to demonstrate these relationships. For example Aboriginal infants were nearly twice as likely to weigh less than 2,500 g at birth. Mothers of Aboriginal infants were nearly three times as likely to live in the most disadvantaged suburbs. They were also more likely not to complete year 10, to be a teenage mother, and to smoke during pregnancy; these factors also associated with increased odds of LBW. For example, mothers of Aboriginal infants are nearly four times as likely to be a teenage mother at delivery. Teenage mothers were more than twice as likely not to have completed year 10 and to smoke during pregnancy; and they are nearly twice as likely to book late into antenatal care, and to go on to have a LBW infant.

Discussion

This study described maternal and infant birth outcomes for Aboriginal and non-Aboriginal infants in an urban environment in south west Sydney. Two primary outcomes of this study were described. Firstly mothers of Aboriginal infants were significantly less likely to receive intervention during labour and delivery. Data collected by the midwives on antenatal care and maternal risk and health did not suggest that mothers of Aboriginal infants have less need for intervention. Secondly, Aboriginal infants were smaller than non-Aboriginal infants and a greater proportion of Aboriginal infants were delivered before 37 weeks. However, no significant differences in size for gestational age were observed between Aboriginal and non-Aboriginal infants. These findings were associated with a range of

maternal, socioeconomic, environmental, behavioural, psychosocial factors.

The results of this study highlight the relative socioeconomic disadvantage among all mothers delivering at this urban hospital. For both mothers of Aboriginal and non-Aboriginal infants, 11% had not completed year 10 and more than one-third of all mothers lived in suburbs that are among the most disadvantaged in NSW. Mothers of Aboriginal infants were more severely disadvantaged.

The observation of lower rates of intervention during delivery for mothers of Aboriginal infants compared to mothers of non-Aboriginal infants was of interest and it is important to consider the antecedents of this. We found mothers of Aboriginal and non-Aboriginal infants reported similar antenatal health service use of the diabetes and high risk clinic. This would suggest that the need for delivery intervention might be similar for both these groups of women. Further research is needed to explore this and to better identify the antecedents to intervention to ensure that this is based equitably on need rather than other factors such as ability to demand additional services.

Our analyses identified a range of socioeconomic, behavioural, health and environmental factors that influence birthweight. When these are adjusted for in a partial regression model that controlled for some additional demographic factors (maternal age, parity, infant gender) Aboriginal infants had a lower birthweight than non-Aboriginal infants. However, when all risk and protective factors were included in the full multivariate model, there was not statistically significant difference in birth weight between Aboriginal and non-Aboriginal infants. Only gestational age (not unexpected), maternal education (left school without completing year 10), and maternal smoking before and during pregnancy remained significant predictors of lower birthweight. These findings suggest that many risk factors are mutable and that strategies to reduce socioeconomic disadvantage among mothers of Aboriginal infants will reduce the gap in birth outcomes. Neither the explanations nor the interventions are simple.

We found the causal pathway model provided some further insight into the complex inter-relationships between the risk and protective factors explored in this study. This approach has been previously proposed as a way of understanding complex relationships such as presented above, [22] and has been used previously for this type of analysis [7]. Our approach illustrates the complexity of the interrelationships between risk and protective factors.

These data have implications for services that deal with Aboriginal families. They strongly demonstrate the importance of moving beyond birth outcomes and antenatal care if initiatives to reduce the gaps in outcomes for mothers and their newborn infants are to succeed. Approaches need to consider the whole of childhood and adolescence to ensure that many of the medial factors that currently contribute to poor outcomes are addressed. Proposals to develop Child and Family Centres under the leadership of the Secretariat of National Aboriginal and Islander Child Care offer opportunities for developing innovative solutions that are wholistic and intersectorial [33].

Strengths and Limitations of this Study

The near complete enumeration of Aboriginal infants born to mothers residing in a defined urban region is an important strength of this study. The establishment of the Gudaga Study provided a unique opportunity undertake this study and to explore factors that are associated with birth outcomes for Aboriginal infants and their mothers. The study subjects were identified through a brief survey of all mothers admitted to the maternity ward that systematically asked new mothers about their Aboriginal status and that of their infant's biological father. Further, our strong links to the community and health service and location of the Aboriginal project officer within that hospital's maternity ward enabled us to identify a further 23 infants who delivered at the hospital but were not initially included in the survey. As a part of recruitment of the Gudaga cohort we also identified and extracted data on mothers of non-Aboriginal infants to provide an enumerated comparison group. Such identification is rarely achieved in studies that rely on identification through administrative data collections alone where identification of Aboriginal infants remains problematic [8, 34]. The survey also completed some personal information.

The limitations to our study relate to our use of administrative data collections and our definitions of maternal and infant birth outcomes. Missing and incomplete data were an issue due partly to data entry issues and substantially to the change in data collection from ODP to Powerchart during recruitment. These created difficulties as health related data were inconsistently collected and recorded, or were collected at different stages of antenatal care and were incomplete when pregnancy occurred across the two data systems or totally in the new system. Consequently, we were not able to use data on maternal health from the administrative data collections but relied on maternal report of health services used as a proxy for health status. We were not able to explore in depth maternal and infant birth outcomes and used proxy indicators of these. Labour and delivery was our indicator of maternal outcome although we recognise that labour and delivery may not totally represent maternal outcomes at delivery. As we did not have independent confirmation of gestational age, for example, the results of a dating ultrasound, we were not able to reliable explore intrauterine growth restriction and our calculations

of size for gestational age may have underestimated growth restriction. Birthweight and estimated gestational age were useful proxy indicators of infant outcomes.

Conclusions

The health and development of Aboriginal infants remains cause for concern in Australia. There have been few studies of outcomes among Aboriginal infants in urban settings on the Eastern seaboard of Australia.

The use of a causal pathway model to explain relationships between a number of study factors and maternal and infant birth outcomes supplements the findings of traditional univariate and multivariate analysis. The analyses demonstrate fewer interventions among mothers at delivery despite little evidence to support lower need for intervention and poorer outcomes for Aboriginal infants (when birthweight is the proxy measure of outcome). The study also demonstrated that the study factors were important for both mothers and their infants. The causal pathway approach provides a way forward for services to Aboriginal families to improve these outcomes and supports the importance on co-operative approaches across different services including those outside health to address these gaps in outcomes.

The Gudaga Study is having a strong impact on antenatal services in the region. There is recognition of the need to identify and anticipate Aboriginal infants through services and to ensure that mothers of Aboriginal infants are systematically targeted within antenatal services to maximise their outcomes. These data are informing new services both within health and in the community controlled sector.

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Conflict of interest None.

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