BMJ Open

Effect of socioeconomic disadvantage, remoteness and Indigenous status on hospital usage for Western Australian preterm infants under 12 months of age: a population-based data linkage study

Natalie A Strobel,[1] Sue Peter,[2] Kimberley E McAuley,[1] Daniel R McAullay,[1,3] Rhonda Marriott,[4] Karen M Edmond[1]

To cite: Strobel NA, Peter S, McAuley KE, *et al*. Effect of socioeconomic disadvantage, remoteness and Indigenous status on hospital usage for Western Australian preterm infants under 12 months of age: a population-based data linkage study. *BMJ Open* 2017;**7**:e013492. doi:10.1136/bmjopen-2016-013492

▸ Prepublication history and additional material is available. To view please visit the journal (http://dx.doi.org/10.1136/bmjopen-2016-013492).

Received 19 July 2016
Revised 20 December 2016
Accepted 21 December 2016

CrossMark

For numbered affiliations see end of article.

Correspondence to
Dr Natalie A Strobel; natalie.strobel@uwa.edu.au

ABSTRACT

Objectives: Our primary objective was to determine the incidence of hospital admission and emergency department presentation in Indigenous and non-Indigenous preterm infants aged postdischarge from birth admission to 11 months in Western Australia. Secondary objectives were to assess incidence in the poorest infants from remote areas and to determine the primary causes of hospital usage in preterm infants.

Design: Prospective population-based linked data set.

Setting and participants: All preterm babies born in Western Australia during 2010 and 2011.

Main outcome measures: All-cause hospitalisations and emergency department presentations.

Results: There were 6.9% (4211/61 254) preterm infants, 13.1% (433/3311) Indigenous preterm infants and 6.5% (3778/57 943) non-Indigenous preterm infants born in Western Australia. Indigenous preterm infants had a higher incidence of hospital admission (adjusted incident rate ratio (aIRR) 1.24, 95% CI 1.08 to 1.42) and emergency department presentation (aIRR 1.71, 95% CI 1.44 to 2.02) compared with non-Indigenous preterm infants. The most disadvantaged preterm infants (7.8/1000 person days) had a greater incidence of emergency presentation compared with the most advantaged infants (3.1/1000 person days) (aIRR 1.61, 95% CI 1.30 to 2.00). The most remote preterm infants (7.8/1000 person days) had a greater incidence of emergency presentation compared with the least remote preterm infants (3.0/1000 person days; aIRR 1.82, 95% CI 1.49 to 2.22).

Conclusions: In Western Australia, preterm infants have high hospital usage in their first year of life. Infants living in disadvantaged areas, remote area infants and Indigenous infants are at increased risk. Our data highlight the need for improved postdischarge care for preterm infants.

Strengths and limitations of this study

- To the best of our knowledge, this is the first study to investigate the effect of risk factors on hospital usage and the burden of hospital admissions in Indigenous preterm infants under 12 months of age.
- This study uses population-based data for all Western Australian preterm infants born in 2010–2011 and high-quality administrative data sets to determine hospital use for these infants.
- The sample size was sufficient to determine the differences in hospital use between Indigenous preterm infants, socioeconomic status and remoteness for preterm infants.
- Environmental factors and maternal education were unable to be assessed.

INTRODUCTION

In 2010, it was estimated globally that 15 million babies, 11.1% of all live births worldwide, were born preterm (<37 weeks gestation).[1] Preterm infants are at a greater risk of experiencing serious health complications than full-term infants. Complications include respiratory infections, anaemia, vision and hearing loss, and developmental delay.[1] Infants with complications from prematurity need many more health and social services than full-term infants and infants without these complications.[2,3] This places a high economic, health and social burden on families and health systems.[4]

In 2013, 8.6% of all babies born in Australia were preterm, most with a gestational age of between 32 and 36 completed weeks.[5] These data are similar to other developed countries. However, during 2013, 14% of babies born to Australian Aboriginal and Torres Strait Islander (hereafter referred to as Indigenous) mothers were preterm.[5] This high preterm risk has changed little over the past decade.[6] These data are comparable to many of the poorest countries in the world where the most recent data indicate that ~12% of babies are born preterm.[7]

Despite the high risks, there has been little focus on understanding hospital usage patterns and what follow-up care is needed for high-risk preterm Aboriginal infants, especially the poorest infants who live in remote areas. This is particularly important because mothers who carry a higher burden of ill health and social dysfunction have a higher risk of delivering a preterm or low birthweight infant.[8 9] These mothers often have more difficulties accessing the health system and adhering to medication regimens.[8]

Western Australia (WA) has a large de-identified prospective longitudinal population-based data system involving the probabilistic systematic record linkage of total population administrative health data sets.[10] Data are available for birth cohorts and include information on maternal and infant characteristics, hospital admission and emergency department presentations including length of stay, cause of hospital admission, Indigenous status and socioeconomic status.

Our study was designed to assess differentials in incidence of all-cause hospital admission and emergency department presentation for Indigenous and non-Indigenous preterm infants (born <37 weeks) during their first 12 months of life. Our primary objective was to determine the incidence of hospital admission and emergency department presentation in Indigenous and non-Indigenous infants from time of discharge from birth admission to 11 months (0–11 months). Secondary objectives were to assess incidence in the poorest infants from remote areas and to determine the primary causes of hospital usage in preterm infants.

METHODS

Study setting and database access

All live births occurring at <37 weeks gestational age in WA from 1 January 2010 to 31 December 2011 were included in this study. Prospective population-based linked data from the WA Midwives' Notification System, Hospital Morbidity Data System, Emergency Department Data Collection, Death Registrations, the Index of Relative Socio-Economic Disadvantage (IRSD)[11] and the Accessibility/Remoteness Index of Australia (ARIA)[12] were obtained from the Department of Health of Western Australia (DOHWA).

The Midwives' Notification System includes clinical (infant weight, gestational age, Apgar score, multiple birth, gravidity) and sociodemographic (baby's gender, mother's age, Indigenous status, socioeconomic status, remoteness index) data on all WA live births and stillbirths of more than 20 weeks' gestation or birth weight >400 g which are reported by trained midwives within 48 hours of delivery. The Hospital Morbidity Data System and Emergency Department Data Collection include data on all completed hospital admissions and emergency department presentations to all public hospitals in WA. These data are entered by trained medical records staff following the occasion of service. Death Registrations are linked monthly and include date and cause of death. The Australian Bureau of Statistics (ABS) IRSD divides statistical local areas based on the 2006 Australian national census data into quintiles from most deprived (1) to least deprived (5).[11] The ARIA was developed by the Department of Health and Aged Care and is maintained by the Australian Institute of Health and Welfare (AIHW).[12] This index classifies geographic location on the basis of isolation and distance from service centres and healthcare facilities. ARIA data are split into five categories from least remote (1; major cities) to most remote (5; remote area communities).

The databases were systematically linked by DOHWA data linkage staff using probabilistic matching and de-identified. The final database included date of hospital admission, date of emergency department presentation, hospital length of stay, maternal ethnicity, maternal age, gravidity, infant age, infant birth weight, gestational age, infant sex, multiple birth and infant health status at birth (Apgar score). ISRD quintile, ARIA level and health region from the Midwives' Notification System were also included.

Inclusion and exclusion criteria

Infants were classified as Indigenous if the mother was recorded in the Midwives' Notification System as an Aboriginal and/or Torres Strait Islander.[13] All other infants were classified as non-Indigenous. To avoid clustering within multiple births, the population was limited to singleton babies.

Definitions

Specific cut points were used to define preterm; 'extremely preterm' (<28 weeks gestation); 'very preterm' (births between 28 and <32 weeks gestation); and 'moderate preterm' (births between 32 and <37 weeks gestation).[1] The small for gestational age index was calculated as small for gestational age 'SGA' (<10th centile for weight); appropriate for gestational age 'AGA' (10–90th centile for weight); large for gestational age 'LGA' (>90th centile).[14]

We defined the 'person time at risk' as the number of days between discharge from the birth admission to 11 months of chronological age. This excluded the stay in hospital after birth for both well and unwell babies. Hospital admissions were defined as the number of admissions of infants to a WA hospital ward for care during the period between discharge from the birth admission to 11 months. Between hospital transfers were included as one admission. Emergency department presentations were defined as the number of presentations of infants to a WA hospital emergency department (regardless of whether the child was admitted) during the period between discharge from the birth admission to 11 months. The frequency of emergency department presentations was defined as the count of presentations to any emergency department regardless of whether the child was admitted to hospital. 'Low socioeconomic status' was defined as the two lowest IRSD quintiles (IRSD 1–2). 'Remote residence' was defined as the two most remote ARIA categories (ARIA 4–5).

Primary cause of hospitalisation and emergency department presentations were classified using the International Classification of Disease V.10 (ICD-10) classification system by medical record staff. Each admission only received one diagnostic code.[15] All hospital admissions were classified with a primary cause of hospitalisation but secondary diagnoses or comorbidity data were not available. No data on cause of emergency department presentation were available. Causes of hospitalisation were defined according to the AIHW,[16] and adapted for use with infants.[17] Diseases were categorised as the respiratory system, digestive system, skin and subcutaneous tissue, ear and mastoid process, infectious and parasitic diseases, nutritional diseases, injury and poisoning, perinatal conditions (eg, prematurity, hypoxic-ischaemic encephalopathy), congenital malformations, chromosomal abnormalities and all other conditions.

Sample size and data analysis

Our primary outcome measure was the incidence of hospital admissions between discharge from the birth admission to 11 months of chronological age in Indigenous and non-Indigenous preterm infants from 2010 to 2011.

Incidence of hospital usage was calculated as the number of events (hospital admissions or emergency presentations) between discharge from birth admission to 11 months of chronological age divided by the total days at risk between discharge from the birth admission to 11 months. All incidence rates were expressed as 1000 person days. We also calculated median and IQR (25th–75th centile) estimates.

Analyses were completed using multilevel generalised estimating equation modelling clustering for geographical location. Crude incident rate ratios (IRRs), adjusted IRRs (aIRRs) and 95% CI were calculated using negative binomial regression analysis with an exchangeable correlation structure to assess the association between hospital admissions and emergency presentations for preterm infants and Indigenous status, socioeconomic status and remoteness.[18 19] Potential confounders were included in the models a priori to adjust for the effect of important explanatory variables. We identified factors that are known to be associated with both the exposure and the outcome and were not a causal step in the pathway. We only included variables from the Midwives' Notification System: maternal characteristics (maternal age, gravidity), infant factors (gender of child, birth weight), Indigenous status and socioeconomic status (ISRD). Data analyses were conducted using STATA V.13.1 (StataCorp, USA).

We calculated that our study population of 4211 infants would provide 90% power to detect at least a 10% difference in hospital admission incidence between Indigenous and non-Indigenous infants. We assumed a 5% significance level, a hospital admission incidence of 5.0/1000 person days and that the ratio between Indigenous to non-Indigenous infants would be ~1:9.

RESULTS

During 2010–2011 in WA there were 62 965 live births; 98.3% (61 254) were singletons and 6.9% (4211) of these infants were preterm. Of these, 2.0% (84/4211) preterm infants died in the first year of life (web appendix A). In total, 13.1% (433/3311) of the preterm infants were classified as Indigenous and 6.5% (3778/57 943) were classified as non-Indigenous (table 1). In total, 37.2% (161) of preterm Indigenous infants were classified in the most disadvantaged quintile compared with 3.5% (132) non-Indigenous infants. In total, 38.6% (167) of preterm Indigenous infants lived in the most remote area (ARIA 5) compared with 3.6% (134) of non-Indigenous infants (table 1).

The median (IQR) length of stay during the birth admission was 75 days (IQR 4–107) for infants with gestational age <28 weeks; 33 days (IQR 21–48) for infants with gestational age 28 to <32 weeks and 5 days (IQR 3–8) for infants with gestational age 32 to <37 weeks. Web appendix A provides further detail of the length of hospital stay in birth hospital.

Overall, there were a total 5284 hospital admissions in 3102 preterm infants and 5657 emergency presentations in 2220 preterm infants during the period between discharge from birth admission to 11 months of chronological age. Of the hospital admissions, 2233 (42.3%) were elective admissions, 3007 (56.9%) were emergency-related admissions and the remaining 44 (0.8%) were unknown. In total, 73.7% (3102) of preterm infants had at least one hospital admission and 52.7% (2220) of infants had at least one emergency department presentation between discharge from birth admission to 11 months (web appendix B).

Indigenous preterm infants had a higher incidence of emergency department presentation (aIRR 1.71, 95% CI 1.44 to 2.02) and hospital admission (aIRR 1.24, 95% CI 1.08 to 1.42) compared with non-Indigenous preterm infants even after adjusting for confounding factors (table 2). Preterm infants with gestational age under 32 weeks had a greater incidence of hospital admission (5.9/1000 person days) compared with infants with a gestational age 32–37 weeks (3.3/1000 person days; aIRR 1.79, 95% CI 1.67 to 1.93; table 2). There was also an increased incidence of emergency department presentations for infants with a gestational age under 32 weeks (aIRR 1.40, 95% CI 1.27 to 1.54). Length of stay for birth admissions over 28 days was significantly associated with subsequent hospital admissions (aIRR 1.98, 95% CI 1.81 to 2.17) and emergency

Table 1 Sociodemographic characteristics in the study population, 2010–2011

Characteristics	Total number of infants n=4211	Number of Indigenous infants n=433	Number of non-Indigenous infants n=3778	OR 95% CI	p Value
Infant					
Prematurity (week)					
<28	186 (4.4%)	28 (6.5%)	158 (4.2%)	1.58 (1.05 to 2.40)	0.030
28<32	311 (7.4%)	45 (10.4%)	266 (7.0%)	1.53 (1.10 to 2.14)	0.012
32<37	3714 (88.2%)	360 (83.1%)	3354 (88.8%)	0.62 (0.48 to 0.82)	0.001
Child sex					
Male	2316 (55.0%)	226 (52.2%)	2090 (55.3%)	0.88 (0.72 to 1.08)	0.216
Female	1895 (45.0%)	207 (47.8%)	1688 (44.7%)	1.13 (0.93 to 1.38)	0.216
Birth weight					
Low birth weight (<2500 g)	1983 (47.1%)	258 (59.6%)	1725 (45.7%)	0.57 (0.47 to 0.70)	<0.001
Normal birth weight (≥2500 g)	2228 (52.9%)	175 (40.4%)	2053 (54.3%)	1.75 (1.43 to 2.15)	<0.001
Small for gestational age index					
SGA (<10th centile)	335 (8.0%)	48 (11.1%)	287 (7.6%)	1.52 (1.10 to 2.10)	0.011
AGA (10th–90th centile)	3386 (80.4%)	341 (78.8%)	3045 (80.6%)	0.91 (0.71 to 1.16)	0.431
LGA (>90th centile)	483 (11.5%)	42 (9.7%)	441 (11.7%)	0.82 (0.58 to 1.14)	0.231
Data missing	NP	NP	NP		
APGAR 5 score					
<7 (abnormal)	259 (6.2%)	31 (5.1%)	228 (6.0%)	1.20 (0.81 to 1.76)	0.369
≥7 (healthy)	3951 (93.8%)	402 (94.9%)	3549 (93.9%)	0.83 (0.56 to 1.23)	0.357
Data missing	NP	NP	NP		
Maternal					
Maternal age (years)					
<20	243 (5.8%)	87 (18.4%)	156 (4.1%)	5.84 (4.39 to 7.76)	<0.001
20–24s	671 (15.9%)	135 (31.6%)	536 (14.2%)	2.74 (2.19 to 3.42)	<0.001
25–29	1115 (26.5%)	109 (27.3%)	1006 (26.6%)	0.93 (0.74 to 1.17)	0.516
30–34	1207 (28.7%)	57 (12.9%)	1150 (30.4%)	0.35 (0.26 to 0.46)	<0.001
35+	975 (23.2%)	45 (9.8%)	930 (24.6%)	0.36 (0.26 to 0.49)	<0.001
Gravidity					
0	1358 (32.2%)	95 (21.9%)	1263 (33.4%)	0.56 (0.44 to 0.71)	<0.001
1	1121 (26.6%)	90 (20.8%)	1031 (27.3%)	0.70 (0.55 to 0.89)	<0.001
2	736 (17.5%)	65 (15.0%)	671 (17.8%)	0.82 (0.62 to 1.08)	0.154
≥3	996 (23.7%)	183 (42.3%)	813 (21.5%)	2.67 (2.17 to 3.28)	<0.001
Area					
Socioeconomic status					
Most disadvantaged 1	293 (7.0%)	161 (37.2%)	132 (3.5%)	17.09 (13.13 to 22.22)	<0.001
2	646 (15.3%)	58 (13.4%)	588 (15.6%)	0.86 (0.64 to 1.15)	0.299
3	537 (12.8%)	56 (12.9%)	481 (12.7%)	1.04 (0.77 to 1.40)	0.793
4	1143 (27.1%)	75 (17.3%)	1068 (28.3%)	0.54 (0.42 to 0.70)	<0.001
Least disadvantaged 5	1486 (35.3%)	65 (15.0%)	1421 (37.6%)	0.30 (0.23 to 0.39)	<0.001
Data missing	106 (2.5%)	18 (4.2%)	88 (2.3%)		
Geographic location					
Major city	1802 (42.8%)	84 (19.4%)	1718 (45.5%)	0.29 (0.23 to 0.37)	<0.001
Inner regional	1559 (37.0%)	82 (18.9%)	1477 (39.1%)	0.37 (0.29 to 0.47)	<0.001
Outer regional	327 (7.8%)	58 (13.4%)	269 (7.1%)	2.07 (1.52 to 2.80)	<0.001
Remote	116 (2.8%)	24 (5.5%)	92 (2.4%)	2.40 (1.51 to 3.81)	<0.001
Very remote	301 (7.1%)	167 (38.6%)	134 (3.6%)	17.87 (13.76 to 23.20)	<0.001
Data missing	106 (2.5%)	18 (4.2%)	88 (2.3%)		

AGA, appropriate for gestational age; LGA, large for gestational age; NP, not publishable due to small numbers and confidentiality restrictions; SGA, small for gestational age.

department presentations (aIRR 1.66, 95% CI 1.48 to 1.86) compared with stays <14 days (web appendix C). There were no marked effects of other sociodemographic characteristics on hospital usage in preterm infants (table 2).

Preterm infants living in the most disadvantaged areas had an increased incidence of presenting to the emergency department (7.8/1000 person days) compared with the most advantaged (ISRD 5) preterm infants (3.1/1000 person days; aIRR 1.61, 95% CI 1.30

Table 2 Rate of hospital usage in preterm infants postdischarge from birth admission to 11 months by sociodemographic characteristics, 2010–2011

Characteristics	Events	Time at risk	(Events/ risk)×1000	Unadjusted IRR (95% CI)	p Value	aIRR (95% CI)*	p Value
All-cause hospitalisations postdischarge from birth admission to 11 months							
Infant							
Indigenous status							
Indigenous	745	152 285	4.89	1.44 (1.28 to 1.62)	<0.001	1.24 (1.08 to 1.42)	0.002
Non-Indigenous	4539	1 335 534	3.40	1.00		1.00	
Prematurity† (week)							
<28	340	54 951	6.19	1.95 (1.74 to 2.19)	<0.001	1.91 (1.70 to 2.13)	<0.001
28<32	598	103 070	5.80	1.76 (1.61 to 1.93)	<0.001	1.73 (1.59 to 1.88)	<0.001
32<37	4346	1 329 798	3.27	1.00		1.00	
Child sex							
Male	3036	818 577	3.71	1.10 (1.04 to 1.17)	0.002	1.16 (1.09 to 1.24)	<0.001
Female	2248	669 242	3.36	1.00		1.00	
Birth weight							
Low birth weight (<2500 g)	3212	685 424	4.69	1.84 (1.72 to 1.96)	<0.001	1.83 (1.72 to 1.96)	<0.001
Normal birth weight (≥2500 g)	2072	802 395	2.58	1.00		1.00	
SGA index							
SGA (<10th centile)	576	116 067	4.96	1.42 (1.26 to 1.59)	<0.001	1.41 (1.26 to 1.58)	<0.001
AGA (10th–90th centile)	4226	1 196 920	3.53	1.00		1.00	
LGA (>90th centile)	482	172 420	2.80	0.79 (0.72 to 0.86)	<0.001	0.78 (1.26 to 1.58)	<0.001
APGAR 5 score							
<7 (abnormal)	396	87 068	4.55	1.33 (1.18 to 1.50)	<0.001	0.94 (0.83 to 1.06)	0.322
≥7 (healthy)	4885	1 400 390	3.49	1.00		1.00	
Maternal							
Maternal age (years)							
<20	372	86 080	4.32	1.22 (1.06 to 1.42)	0.007	1.15 (0.99 to 1.34)	0.060
20–24	853	237 825	3.59	1.02 (0.93 to 1.13)	0.664	0.98 (0.88 to 1.08)	0.633
25–29	1378	393 858	3.50	1.00		1.00	
30–34	1459	427 127	3.42	0.98 (0.90 to 1.07)	0.704	1.00 (0.92 to 1.09)	0.987
35+	1222	342 931	3.56	1.03 (0.95 to 1.12)	0.444	0.99 (0.91 to 1.08)	0.865
Gravidity							
0	1658	479 189	3.46	0.98 (0.90 to 1.06)	0.572	0.89 (0.82 to 0.97)	0.009
1	1323	396 837	3.33	0.94 (0.86 to 1.03)	0.186	0.91 (0.83 to 0.99)	0.039
2	924	261 034	3.54	1.00		1.00	
≥3	1379	350 759	3.93	1.12 (1.01 to 1.24)	0.033	1.02 (0.92 to 1.12)	0.770
Area							
Socioeconomic status							
Most disadvantaged 1	467	103 279	4.52	1.34 (1.12 to 1.59)	0.001	1.11 (0.95 to 1.30)	0.183
2	793	227 854	3.48	1.04 (0.92 to 1.16)	0.553	0.98 (0.86 to 1.11)	0.742
3	665	190 211	3.50	1.03 (0.91 to 1.17)	0.597	0.98 (0.89 to 1.08)	0.679
4	1444	404 092	3.57	1.06 (0.95 to 1.17)	0.287	1.02 (0.93 to 1.13)	0.619
Least disadvantaged 5	1776	525 038	3.38	1.00		1.00	
Geographic location							
Major city	2089	635 695	3.29	1.00		1.00	
Inner regional	1982	552 517	3.59	1.09 (1.02 to 1.17)	0.012	1.07 (1.01 to 1.14)	0.017
Outer regional	507	115 243	4.40	1.34 (1.18 to 1.52)	<0.001	1.24 (1.09 to 1.41)	0.001
Remote	128	40 877	3.13	0.95 (0.80 to 1.13)	0.569	0.95 (0.81 to 1.13)	0.574
Very remote	439	106 142	4.14	1.27 (1.05 to 1.54)	0.014	1.09 (0.92 to 1.29)	0.330
All-cause emergency department presentations postdischarge from birth admission to 11 months							
Infant							
Indigenous status							
Indigenous	1257	152 285	8.25	2.20 (1.94 to 2.49)	<0.001	1.71 (1.44 to 2.02)	<0.001
Non-Indigenous	4400	1 335 534	3.29	1.00		1.00	

Continued

Table 2 Continued

Characteristics	Events	Time at risk	(Events/risk)×1000	Unadjusted IRR (95% CI)	p Value	aIRR (95% CI)*	p Value
Prematurity† (week)							
<28	295	54 951	5.37	1.47 (1.23 to 1.76)	<0.001	1.48 (1.25 to 1.76)	<0.001
28<32	526	103 070	5.10	1.36 (1.21 to 1.52)	<0.001	1.36 (0.21 to 1.53)	<0.001
32<37	4836	1 329 798	3.64	1.00		1.00	
Child sex							
Male	3327	818 577	4.06	1.16 (1.09 to 1.25)	<0.001	1.20 (1.11 to 1.29)	<0.001
Female	2330	669 242	3.48	1.00		1.00	
Birth weight							
Low birth weight (<2500 g)	2821	685 423	4.12	1.18 (1.09 to 1.27)	<0.001	1.16 (1.06 to 1.26)	0.001
Normal birth weight (≥2500 g)	2836	802 395	3.53	1.00		1.00	
SGA index							
SGA (<10th centile)	523	116 067	4.51	1.19 (1.03 to 1.39)	0.020	1.19 (1.02 to 1.38)	0.024
AGA (10th–90th centile)	4491	1 196 920	3.75	1.00		1.00	
LGA (>90th centile)	643	172 419	3.73	0.95 (0.82 to 1.09)	0.426	0.97 (0.84 to 1.12)	0.698
APGAR 5 score							
<7 (abnormal)	343	87 067	3.94	1.05 (0.90 to 1.23)	0.541	0.92 (0.78 to 1.08)	0.295
≥7 (healthy)	5312	1 400 390	3.79	1.00		1.00	
Maternal							
Maternal age (years)							
<20	538	86 080	6.25	1.53 (1.29 to 1.81)	<0.001	1.51 (1.22 to 1.87)	<0.001
20–24	1309	237 825	5.50	1.39 (1.23 to 1.56)	<0.001	1.37 (1.20 to 1.56)	<0.001
25–29	1462	393 858	3.71	1.00		1.00	
30–34	1360	427 127	3.18	0.90 (0.81 to 1.00)	0.060	0.92 (0.81 to 1.05)	0.231
35+	988	342 931	2.88	0.82 (0.73 to 0.92)	0.001	0.80 (0.70 to 0.91)	0.001
Gravidity							
0	1620	479 189	3.38	0.91 (0.79 to 1.04)	0.153	0.82 (0.70 to 0.95)	0.010
1	1437	396 836	3.62	0.97 (0.84 to 1.11)	0.642	0.92 (0.78 to 1.07)	0.278
2	990	261 034	3.79	1.00		1.00	
≥3	1610	350 759	4.59	1.16 (1.00 to 1.35)	0.047	1.14 (0.98 to 1.33)	0.089
Area							
Socioeconomic status							
Most disadvantaged 1	809	103 279	7.83	2.46 (1.93 to 3.14)	<0.001	1.61 (1.30 to 2.00)	<0.001
2	796	227 854	3.49	1.17 (0.92 to 1.49)	0.199	1.04 (0.86 to 1.25)	0.679
3	838	190 211	4.41	1.39 (1.06 to 1.80)	0.016	1.25 (1.03 to 1.51)	0.023
4	1464	404 092	3.62	1.14 (0.89 to 1.47)	0.302	1.09 (−0.89 to 1.34)	0.402
Least disadvantaged 5	1603	525 038	3.05	1.00		1.00	
Geographic location							
Major city	1881	635 695	2.96	1.00		1.00	
Inner regional	1976	552 517	3.58	1.26 (1.06 to 1.49)	0.008	1.11 (0.97 to 1.27)	0.137
Outer regional	624	115 243	5.41	1.82 (1.48 to 2.24)	<0.001	1.48 (1.26 to 1.75)	<0.001
Remote	202	40 877	4.94	1.70 (1.27 to 2.26)	<0.001	1.39 (1.06 to 1.84)	0.018
Very remote	827	106 142	7.79	2.72 (2.20 to 3.37)	<0.001	1.82 (1.49 to 2.22)	<0.001

*Adjusted for Indigenous status, socioeconomic status, maternal age, gravidity, gender of child, birth weight.
†Prematurity was not adjusted for birth weight due to collinearity.
AGA, appropriate for gestational age; IRR, incident rate ratio; aIRR, adjusted incident rate ratio; LGA, large for gestational age; SGA, small for gestational age.

to 2.00; table 2). There also appeared to be some evidence of a dose–response with increased incidence of emergency department presentation with increased levels of disadvantage for Indigenous infants (p value for trend=0.004; table 3) but not for infants overall (p value for trend=0.615) and for non-Indigenous preterm infants (p value for trend=0.178; tables 2 and 3). Preterm infants living in the most disadvantaged areas had a higher but not significant incidence of hospital admissions (4.5/1000 person days) compared with the most advantaged infants (3.4/1000 person days; aIRR 1.11, 95% CI 0.95 to 1.30). There was no obvious trend (p value for trend=0.800; tables 2 and 3).

Table 3 Effect of socioeconomic quintile and geographic location on hospital usage in Indigenous and non-Indigenous preterm infants postdischarge from birth admission to 11 months, 2010–2011

	Indigenous				Non-Indigenous			
	Events	Time at risk	(Events/ risk)×1000	aIRR×(95% CI)*	Events	Time at risk	(Events/ risk)×1000	aIRR×(95% CI)*
Hospital admissions								
Socioeconomic status								
Most disadvantaged 1	300	56 795	5.28	1.29 (0.93 to 1.80)	167	46 484	3.59	1.04 (0.85 to 1.28)
2	98	20 178	4.86	1.08 (0.74 to 1.58)	695	207 676	3.35	0.97 (0.84 to 1.12)
3	88	19 685	4.47	0.92 (0.61 to 1.38)	577	170 526	3.38	0.99 (0.91 to 1.09)
4	130	26 672	4.87	1.12 (0.68 to 1.84)	1314	377 420	3.48	1.01 (0.94 to 1.09)
Least disadvantaged 5	97	22 800	4.25	1.00	1679	502 239	3.34	1.00
				p Value trend 0.654				p Value trend 0.835
Geographic location								
Most remote	331	66 865	4.95	1.51 (1.10 to 2.06)	236	80 154	2.94	0.95 (0.82 to 0.10)
Outer regional	117	20 521	5.70	1.56 (1.02 to 2.39)	390	94 722	4.12	1.23 (1.10 to 1.37)
Inner regional	159	28 882	5.51	1.58 (1.14 to 2.21)	1823	523 635	3.48	1.05 (0.98 to 1.12)
Major city	106	29 861	3.55	1.00	1983	605 834	3.27	1.00
				p Value trend 0.043				p Value trend 0.252
Emergency presentations								
Socioeconomic status								
Most disadvantaged 1	544	56 795	9.58	1.03 (0.74 to 1.41)	265	46 484	5.70	1.79 (1.51 to 2.12)
2	108	20 178	5.35	0.57 (0.40 to 0.81)	688	207 676	3.31	1.12 (0.94 to 1.33)
3	159	19 685	8.08	0.87 (0.62 to 1.22)	679	170 526	3.98	1.30 (1.10 to 1.55)
4	167	26 672	6.26	0.63 (0.43 to 0.94)	1297	377 420	3.44	1.14 (0.95 to 1.38)
Least disadvantaged 5	207	22 800	9.08	1.00	1396	502 239	2.78	1.00
				p Value trend 0.004				p Value trend 0.178
Geographic location								
Most remote	641	66 865	9.59	1.92 (1.53 to 2.40)	388	80 154	4.84	1.61 (1.31 to 1.99)
Outer regional	178	20 521	8.67	1.65 (1.31 to 2.09)	446	94 722	4.71	1.48 (1.23 to 1.78)
Inner regional	206	28 882	7.13	1.38 (1.02 to 1.86)	1770	523 635	3.38	1.08 (0.94 to 1.23)
Major city	160	29 861	5.36	1.00	1721	605 834	2.84	1.00
				p Value trend <0.001				p Value trend <0.001

*Adjusted for maternal age, gravidity, sex of child, birth weight.
aIRR, adjusted incidence rate ratio.

There was an increased incidence of emergency department presentation for the most remote preterm infants (7.8/1000 person days) compared with non-remote preterm infants (3.0/1000 person days; aIRR 1.82, 95% CI 1.49 to 2.22; table 2). There was also some evidence of a dose–response for increased incidence of emergency department presentation with increased levels of remoteness overall (p value for trend<0.001; table 2) and for Indigenous (p value for trend<0.001) and non-Indigenous (p value for trend<0.001) preterm infants (table 3). Remote area preterm infants had a higher but not significant incidence of hospitalisation (4.1/1000 person days) compared with the least remote preterm infants (3.3/1000 person days; aIRR 1.09, 95% CI 0.92 to 1.29; table 2). There was also some evidence of a dose–response with increased risk of hospital admission with increased levels of remoteness for Indigenous preterm infants (p value for trend=0.043); however, there was no trend for non-Indigenous preterm infants (p value for trend=0.252) and overall (p value for trend=0.058) preterm infants (tables 2 and 3).

Overall, the distribution of causes was similar in Indigenous and non-Indigenous infants (table 4). Indigenous infants appeared more likely to be hospitalised for respiratory disease (1.6/1000 person days) than non-Indigenous infants (0.5/1000 person days; table 4). Indigenous infants appeared more likely to be hospitalised for infectious and parasitic diseases (0.4/1000

Table 4 ICD-10 classification of primary cause of hospital admissions in preterm infants postdischarge from birth admission to 11 months by Indigenous status, 2010–2011

Primary cause of hospital admission	Total			Indigenous			Non-Indigenous		
	Events	Time at risk	(Events/risk)×1000 (95% CI)	Events	Time at risk	(Events/risk)×1000 (95% CI)	Events	Time at risk	(Events/risk)×1000 (95% CI)
Respiratory system	620	1 091 028	0.57 (0.53 to 0.65)	178	113 466	1.57 (1.27 to 2.00)	442	977 562	0.45 (0.42 to 0.52)
Infectious and parasitic diseases	188	1 091 028	0.17 (0.14 to 0.20)	45	113 466	0.40 (0.26 to 0.56)	143	977 562	0.15 (0.12 to 0.17)
Digestive system	212	1 091 028	0.19 (0.17 to 0.24)	23	113 466	0.20 (0.13 to 0.33)	189	977 562	0.19 (0.17 to 0.24)
Skin and subcutaneous tissue	36	1 091 028	0.03 (0.02 to 0.05)	NP	NP	NP	NP	NP	NP
Ear and mastoid process	39	1 091 028	0.04 (0.03 to 0.05)	12	113 466	0.11 (0.05 to 0.18)	27	977 562	0.03 (0.02 to 0.04)
Nutritional diseases	15	1 091 028	0.01 (0.01 to 0.02)	NP	NP	NP	NP	NP	NP
Injury and poisoning	57	1 091 028	0.05 (0.04 to 0.07)	12	113 466	0.11 (0.04 to 0.16)	45	977 562	0.05 (0.03 to 0.06)
Perinatal conditions	3354	1 091 028	3.07 (3.02 to 3.14)	358	113 466	3.16 (2.95 to 3.40)	2996	977 562	3.06 (3.01 to 3.14)
Congenital malformations, deformations and chromosomal abnormalities	169	1 091 028	0.15 (0.13 to 0.18)	11	113 466	0.10 (0.03 to 0.16)	158	977 562	0.16 (0.13 to 0.19)
Other	594	1 091 028	0.54 (0.49 to 0.62)	101	113 466	0.89 (0.53 to 1.26)	493	977 562	0.50 (0.46 to 0.58)
Total admissions	5284	1 091 028	4.84 (4.78 to 5.04)	745	113 466	6.57 (6.05 to 7.36)	4539	977 562	4.64 (4.58 to 4.82)

NP, not publishable due to small numbers and confidentiality restrictions.
ICD-10, International Classification of Disease V.10.

person days) than non-Indigenous infants (0.2/1000 person days; table 4). However, the numbers were too small to perform statistical tests.

COMMENTS

In our WA population-based study, 53% of preterm infants presented to a hospital emergency department and 74% were admitted in the time between discharge from birth admission to 11 months of chronological age. Incidence of hospital admission and emergency department presentation was 1.2-fold to 1.7-fold greater in Indigenous compared with non-Indigenous infants. Preterm infants located in the poorest and most remote areas of WA had significantly greater hospital usage compared with preterm infants living in less poor and urban areas.

In the past 10 years, there have been a number of studies showing that preterm infants are at greater risk of hospital admissions and emergency presentations than term infants.[2 20] Despite this, few have investigated whether preterm infants from vulnerable families have an increased risk of hospital usage compared with the general population. Hispanic and African-American preterm infants have been reported to have a greater risk of hospital admission and emergency presentation compared with white preterm infants.[20] Bar-Zeev *et al*[21] reported that 60% of Indigenous preterm infants were readmitted to hospital in the Top End of the Northern Territory of Australia in the first year of life compared with only 44% of Indigenous term infants. However, there have been no published reports of the differences in hospital usage between Australian Indigenous and non-Indigenous preterm infants in the past 10 years.

Population-based studies in infants of all gestational ages have shown increased risk of hospital admissions,[22 23] length of stay[23] and emergency presentations[24] in socially disadvantaged infants compared with the least disadvantaged infants. We reported that the most disadvantaged preterm infants had a 60% greater incidence of emergency department presentations compared with infants from the most advantaged areas. Although preterm infants are more likely to be born to families who are socially disadvantaged,[8] we located no other studies that examined how socioeconomic status may influence subsequent hospital use in preterm infants. Preterm infants living in remote areas in our study had a 1.1-fold to 1.8-fold greater risk of presenting to the emergency department and hospital admission compared with the least remote infants. Population-based studies have reported that infants located in remote areas have an increased risk of readmission[22] and emergency department presentation[24] in the first 6 weeks after birth. However, we were unable to locate other studies that examined the effect of geographic location on hospital use in preterm infants.

We also showed that length of stay for the birth admission was significantly associated with subsequent hospital admissions and emergency department presentations. Length of hospital stay can be seen as a proxy for the health status and 'unwellness' of the child during the hospital admission. It has been shown in many studies to have a clear influence on subsequent hospital usage.[25 26]

Over the past 10 years, there has been significant Australian Federal Government funding to improve access to urban, rural and remote paediatric services including building hospitals, clinics and Aboriginal Community Controlled Health Services (ACCHS).[27 28] There has also been an increase in staffing levels of all healthcare providers in rural and remote areas and major investments in specialist outreach services and care coordination. In WA, there is free antenatal care and culturally appropriate midwifery and postdischarge care for disadvantaged mothers and infants, home visits within 72 hours of discharge,[29] regular medical and developmental follow-up of all preterm infants,[30] and universal and targeted surveillance and screening programmes.[29 31] It is highly likely that these initiatives have improved health status and subsequent morbidity and mortality risks. However, our study shows that important inequities remain in service use in remote areas, in poor families and in Indigenous families.

The most common causes of hospitalisation were respiratory, and infectious and parasitic diseases in Indigenous and non-Indigenous preterm infants. Respiratory disease has previously been cited as the most common cause for hospital admissions for Indigenous infants up to 12 months in the Northern Territory[21] and WA.[24] For all preterm infants under 12 months of age, respiratory and infectious conditions have repeatedly been shown to be the main cause of admission.[26 32] Many of these conditions are preventable by improving coverage of routine childhood vaccines such as pneumococcal and rotavirus vaccines and also through improving housing and education levels in families. Cause of emergency presentations was not assessed in this study due to no data being available; however, existing evidence suggests that many emergency presentations may also be the result of potentially avoidable conditions.[17 33] Our data indicate that more can be done to improve health services and reduce hospital use in preterm infants in WA. We are also aware that the underlying socioeconomic determinants of health such as education and employment are also important determinants of health service use and many improvements are needed in these areas.

Our study had some limitations. Our study was observational and could only report associations and did not provide proof of causality. Indigenous status can be missing or misclassified, which may result in an underestimation of risk.[34 35] Despite this, our results show a highly significant effect of Indigenous status on hospital usage and it is unlikely that any misclassification would have biased the results. Where available, we adjusted for all potential confounding factors. However, we were unable to adjust for measures of maternal illness or education or any underlying social conditions (eg, housing and infrastructure) that may have played a role in hospital usage, particularly preventable causes of hospital use.[36] Within Australia, socioeconomic data are primarily based on AIHW IRSD quintiles which can cause misclassification when applied at an individual level.[11] However, we did show strong associations between hospital usage and socioeconomic status and any differential misclassification would have biased towards the null. Small sample size for Indigenous preterm infants in some of the subanalyses could have resulted in a type II error as a result of reduced power to detect true differences. We did not have the mode of separation variable in our data; therefore, we are unable to determine whether a baby was discharged home or transferred to another hospital following the length of stay at the birth hospital. However, our length of stay data are similar to previously reported data from New South Wales (Australia) which were published earlier in 2016 (median length of stay for infants <28 weeks gestation 87 (IQR 31) and median length of stay for infants 28–23 weeks gestation 47 (IQR 23)).[26]

There are strengths related to the data collections we used. The cause-specific hospitalisation data were limited to primary cause of hospitalisation. These data are considered to be highly accurate,[10 37] because the Hospital Morbidity Data System uses the WHO ICD-10 coding system[15] and highly trained coders. The Midwives' Notification System uses clear definitions that are based on Australian standard definitions[5] and is reported to have a very high level of completion and clinical certainty.[38 39] Our emergency department presentations were also recorded in a clearly defined patient administration system Emergency Department Information System (EDIS).[40 41] This system is considered by emergency department staff to be highly reliable though formal documentation of its accuracy is not available. In contrast, the accuracy of cause-specific emergency department data has been questioned,[33] which is why we did not include cause-specific emergency department data in this study. Finally, we controlled for confounding effects of multiple births by restricting the analysis to singleton births.

Our study has implications for policy and programme development. Despite investments in maternal and child health services, we reported that preterm infants had high hospital usage rates and that important risk groups were infants living in disadvantaged areas, remote area infants and Indigenous infants. Our data highlight the need for improved postdischarge care of preterm infants, particularly in remote regions and for poor, Indigenous infants. This includes preventive programmes focused on improving skills of families and service providers in caring for small infants and care coordination programmes. The WA government has provided recent funding to improve postdischarge care and care coordination for Indigenous children across WA. These interventions have the potential to improve hospital usage and long-term health outcomes of these vulnerable infants and reduce long-term burden on families. We will continue to monitor impacts and report trends in subsequent papers.

Author affiliations
[1]School of Paediatrics and Child Health, The University of Western Australia, Perth, Western Australia, Australia
[2]Princess Margaret Hospital for Children, Perth, Western Australia, Australia
[3]Kurongkurl Katitjin, Centre for Indigenous Australian Education and Research, Edith Cowan University, Perth, Western Australia, Australia
[4]School of Psychology and Exercise Science, Murdoch University, Perth, Western Australia, Australia

Acknowledgements Estelle Dawes and WA Data Linkage Branch.

Contributors SP, KME, DRM and RM conceived and designed the experiments. NAS and KEM performed the experiments. NAS, KEM and KME analysed the data. NAS contributed reagents/materials/analysis tools. NAS, SP, KEM, DRM, RM and KME wrote the paper.

Funding This research was funded by a grant from the Telethon-Perth Children's Hospital Research Fund (F-AA-18845/02), a joint initiative of the Channel 7 Telethon Trust and the Department of Health WA.

Competing interests None declared.

Ethics approval WA Department of Health Human Research Ethics Committee, the University of Western Australia Human Research Ethics Committee, and the Western Australian Aboriginal Health Ethics Committee (WAAHEC).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Data are available from the Western Australia Department of Health Data Linkage Branch with ethical approval through the Western Australia Department of Health Human Research Ethics Committee (Ref 2013/33). To maintain confidentiality and security, interested individuals may apply for access to linked data by contacting the Western Australian Data Linkage Branch. Contact details are DataServices@health.wa.gov.au; +61-8-9222 2370. The computing code is available on request from the corresponding author.

Open Access This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

REFERENCES

1. Blencowe H, Cousens S, Oestergaard MZ, *et al*. National, regional, and worldwide estimates of preterm birth rates in the year 2010 with time trends since 1990 for selected countries: a systematic analysis and implications. *Lancet* 2012;379:2162–72.
2. Slimings C, Einarsdottir K, Srinivasjois R, *et al*. Hospital admissions and gestational age at birth: 18 years of follow up in Western Australia. *Paediatr Perinat Epidemiol* 2014;28:536–44.
3. Luu TM, Lefebvre F, Riley P, *et al*. Continuing utilisation of specialised health services in extremely preterm infants. *Arch Dis Child Fetal Neonatal Ed* 2010;95:F320–5.
4. Blencowe H, Lee AC, Cousens S, *et al*. Preterm birth-associated neurodevelopmental impairment estimates at regional and global levels for 2010. *Pediatr Res* 2013;74(Suppl 1):17–34.
5. AIHW. *Australia's mothers and babies 2013—in brief. Perinatal statistics series no. 31*. Cat no. PER 72. Canberra: AIHW, 2015.
6. Diouf I, Gubhaju L, Chamberlain C, *et al*. Trends in maternal and newborn health characteristics and obstetric interventions among Aboriginal and Torres Strait Islander mothers in Western Australia from 1986 to 2009. *Aust N Z J Obstet Gynaecol* 2016;56:245–51.
7. March of Dimes, PMNCH, Save the Children, WHO. Born Too Soon: The Global Action Report on Preterm Birth. Eds CP Howson, MV Kinney, JE Lawn. World Health Organization. Geneva, 2012.
8. Snelgrove JW, Murphy KE. Preterm birth and social inequality: assessing the effects of material and psychosocial disadvantage in a UK birth cohort. *Acta Obstet Gynecol Scand* 2015;94:766–75.
9. Panaretto K, Lee H, Mitchell M, *et al*. Risk factors for preterm, low birth weight and small for gestational age birth in urban Aboriginal and Torres Strait Islander women in Townsville. *Aust N Z J Public Health* 2006;30:163–70.
10. Holman CD, Bass AJ, Rosman DL, *et al*. A decade of data linkage in Western Australia: strategic design, applications and benefits of the WA data linkage system. *Aust Health Rev* 2008;32:766–77.
11. Pink B. Socio-Economic Indexes for Areas (SEIFA)—Technical Paper 2006. Canberra: Australian Bureau of Statistics, 2008.
12. Department of Health and Aged Care. *Measuring remoteness: Accessibility/remoteness index of Australia (ARIA)*. Revised edition. Occasional Papers: New Series Number 14 2001. Canberra: Commonwealth of Australia, 2001.
13. Joyce A, Hutchinson M. *Western Australia's mothers and babies 2010: twenty-eighth annual report of the Western Australian Midwives' Notification System*. Western Australia: Department of Health, 2012.
14. Fenton TR, Kim JH. A systematic review and meta-analysis to revise the Fenton growth chart for preterm infants. *BMC Pediatr* 2013;13:59.
15. WHO. *International statistical classification of diseases and related health problems 10th revision (ICD-10)*. Geneva, 2015.
16. National Health Performance Authority. Healthy Communities: Potentially preventable hospitalisations in 2013–14. 2015.
17. Duncan C, Williams K, Nathanson D, *et al*. Emergency department presentations by Aboriginal children: issues for consideration for appropriate health services. *J Paediatr Child Health* 2013;49: E448–50.
18. Byers AL, Allore H, Gill TM, *et al*. Application of negative binomial modeling for discrete outcomes: a case study in aging research. *J Clin Epidemiol* 2003;56:559–64.
19. Martina R, Kay R, Maanen RV, *et al*. The analysis of incontinence episodes and other count data in patients with overactive bladder by Poisson and negative binomial regression. *Pharm Stat* 2016;15:379.
20. Kuzniewicz MW, Parker SJ, Schnake-Mahl A, *et al*. Hospital readmissions and emergency department visits in moderate preterm, late preterm, and early term infants. *Clin Perinatol* 2013;40:753–75.
21. Bar-Zeev SJ, Kruske SG, Barclay LM, *et al*. Use of health services by remote dwelling Aboriginal infants in tropical northern Australia: a retrospective cohort study. *BMC Pediatr* 2012;12:19.
22. Martens PJ, Derksen S, Gupta S. Predictors of hospital readmission of Manitoba newborns within six weeks postbirth discharge: a population-based study. *Pediatrics* 2004;114:708–13.
23. Petrou S, Kupek E. Socioeconomic differences in childhood hospital inpatient service utilisation and costs: prospective cohort study. *J Epidemiol Community Health* 2005;59:591–7.
24. McAuley K, McAullay DR, Strobel NA, *et al*. Hospital utilisation in Indigenous and non-Indigenous infants under 12months of age in Western Australia, prospective population based data linkage study. *PLoS ONE* 2016;11:e0154171.
25. Lain SJ, Nassar N, Bowen JR, *et al*. Risk factors and costs of hospital admissions in first year of life: a population-based study. *J Pediatr* 2013;163:1014–19.
26. Stephens AS, Lain SJ, Roberts CL, *et al*. Survival, hospitalization, and acute-care costs of very and moderate preterm infants in the first 6 years of life: a population-based study. *J Pediatr* 2016;169:61–8 e3.
27. Griew R. The link between primary health care and health outcomes for Aboriginal and Torres Strait Islander Australians. Canberra: Report for the Office of Aboriginal and Torres Strait Islander Health, Department of Health and Ageing, 2008.
28. Gruen RL, Bailie RS, Wang Z, *et al*. Specialist outreach to isolated and disadvantaged communities: a population-based study. *Lancet* 2006;368:130–8.
29. Women and Newborn Health Service. *Neonatal clinical guidelines: section 19 transfer and discharge: Home Visiting Nurse Service (HVN)*. Perth, Western Australia: King Edward Memorial Hospital and Princess Margaret Hospital, 2014.
30. Women and Newborn Health Service. *Neonatal Clinical Guidelines: section 19 transfer and discharge: neonatal follow-up program*. Perth, Western Australia: King Edward Memorial Hospital and Princess Margaret Hospital, 2014.
31. Child and Adolescent Health Service. 3.3 Guidelines for universal meeting schedule. *Child and Adolescent Community Health: Birth to School Entry*. Department of Health Western Australia, 2012.
32. Srinivasjois R, Slimings C, Einarsdottir K, *et al*. Association of gestational age at birth with reasons for subsequent hospitalisation:

18 years of follow-up in a Western Australian population study. *PLoS ONE* 2015;10:e0130535.
33. Moore HC, de Klerk N, Jacoby P, *et al*. Can linked emergency department data help assess the out-of-hospital burden of acute lower respiratory infections? A population-based cohort study. *BMC Public Health* 2012;12:703.
34. Thompson SC, Woods JA, Katzenellenbogen JM. The quality of indigenous identification in administrative health data in Australia: insights from studies using data linkage. *BMC Med Inform Decis Mak* 2012;12:133.
35. Lawrence D, Christensen D, Mitrou F, *et al*. Adjusting for under-identification of Aboriginal and/or Torres Strait Islander births in time series produced from birth records: using record linkage of survey data and administrative data sources. *BMC Med Res Methodol* 2012;12:90.
36. AIHW. *The health and welfare of Australia's Aboriginal and Torres Strait Islander peoples: 2015*. Cat. no. IHW 147. Canberra: AIHW, 2015.
37. Mnatzaganian G, Ryan P, Norman PE, *et al*. Accuracy of hospital morbidity data and the performance of comorbidity scores as predictors of mortality. *J Clin Epidemiol* 2012;65:107–15.
38. DoH. *Data quality in the midwives notification system*. Perth, Western Australia: Maternal and Child Health Unit, Data Integrity Directorate Performance Activity and Quality Division, 2013.
39. Downey F. *A validation study of the Western Australian Midwives' Notification System. 2005 data*. Perth, Western Australia: Department of Health, 2007.
40. DoH. *Emergency Department Data Collection Data Dictionary Version 1.0*. Western Australia: Information Management and Reporting, 2007.
41. OAG. Emergency Department Information System—Department of Health. https://audit.wa.gov.au/reports-and-publications/reports/information-systems-application-controls-audits/emergency-department-information-system-department-of-health/