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THE INFLUENCE OF ANTENATAL AND MATERNAL FACTORS ON STILLBIRTHS AND NEONATAL DEATHS IN NEW SOUTH WALES, AUSTRALIA

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Summary. This study identified the influences of maternal socio-demographic and antenatal factors on stillbirths and neonatal deaths in New South Wales, Australia. Bivariate and multivariate analyses were used to explore the association of selected antenatal and maternal characteristics with stillbirths and neonatal deaths. The findings of this study showed that stillbirths and neonatal deaths significantly varied by infant sex, maternal age, Aboriginality, maternal country of birth, socioeconomic status, parity, maternal smoking behaviour during pregnancy, maternal diabetes mellitus, maternal hypertension, antenatal care, plurality of birth, low birth weight, place of birth, delivery type, maternal deaths and small gestational age. First-born infants, twins and infants born to teenage mothers, Aboriginal mothers, those who smoked during the pregnancy and those of lower socioeconomic status were at increased risk of stillbirths and neonatal deaths. The most common causes of stillbirths were conditions originating in the perinatal period: intrauterine hypoxia and asphyxia. Congenital malformations, including deformities and chromosomal abnormalities, and disorders related to slow fetal growth, short gestation and low birth weight were the most common causes of neonatal deaths. The findings indicate that very low birth weight (less than 2000 g) contributed 75·6% of the population-attributable risks to stillbirths and 59·4% to neonatal deaths. Low gestational age (less than 32 weeks) accounted for 77·7% of stillbirths and 87·9% of neonatal deaths. The findings of this study suggest that in order to reduce stillbirths and neonatal deaths, it is essential to include strategies to predict and prevent prematurity and low birth weight, and that there is a need to focus on anti-smoking campaigns during pregnancy, optimizing antenatal care and other healthcare programmes targeted at the socially disadvantaged populations identified in this study.

Introduction

During the 20th century, due to improved medical technology and education campaigns about immunization, Sudden Infant Death Syndrome (SIDS) and infant sleeping position, the rate of neonatal deaths (those occurring within the first 28 days of life), post-neonatal deaths (those occurring on or after the 28th day but in the first year of life) and overall infant deaths (those who died within the first year of life) dramatically declined in both Australia and overseas (Hein & Lathrop, 1986; Singh & Yu, 1995; Wong & Bauman, 1997; Reid, 2001; Stephansson *et al*., 2001; Australian Institute of Health & Welfare, 2002; Liu *et al.,* 2002; Sing *et al*., 2003). Studies have identified epidemiological risk factors for infant deaths, especially neonatal and post-neonatal deaths. In most previous studies, stillbirths (late fetal deaths) and early neonatal deaths often have been combined into the single category of 'perinatal deaths'. In the past such a combination was justified by the fact that asphyxia was a common cause of death during labour and shortly after birth. In more recent years, fewer early neonatal deaths have been due to asphyxia (Kramer *et al*., 2002).

Preterm birth and low birth weight (less than 2500 g) are risk factors associated with perinatal and infant mortality and childhood morbidity (Kramer, 1987; Berkowitz & Papiernik, 1993; Hagan *et al.,* 1996; McIntire *et al.,* 1999; Wen *et al.*, 2000; Mohsin *et al*., 2003). During recent decades, many studies have identified the risk factors for low birth weight, preterm births and infant mortality (Bell & Lumley, 1992; de Costa & Child, 1996; Wong & Bauman, 1997; Rousham & Gracey, 1998; Lekea-Karanika *et al*., 1999; Mackerras, 2000; Chan *et al*., 2001; Humphrey & Holzheimer, 2001; Mohsin *et al.,* 2003). Although stillbirths account for a significant proportion of perinatal mortality, the risk factors for stillbirths and neonatal deaths have been less well researched. Furthermore, the causes of stillbirths are rarely reported.

Plurality is a biological determinant of low birth weight. Twins, triplets and higher order births have a greater risk of low birth weight, and neonatal morbidity and mortality (Institute of Preventive Medicine, 1985; Mohsin *et al.,* 2003). Although in New South Wales (NSW) multiple births accounted for about 3·2% of the total births, the impact of multiple births on the incidence of preterm births and low birth weight is substantial (Mohsin *et al*., 2003). The present study examines any differences in this analysis for singleton and multiple births, adjusting for other risk factors influencing stillbirths and neonatal deaths.

In Australia, the risk factors for and causes of stillbirths and neonatal deaths have not been extensively researched (de Costa, 1988; Jonas & Lumley, 1997; Coory, 1998; Roberts *et al.*, 2002; van der Klis *et al.*, 2002; Dodd *et al*., 2003; Coory, 2003; Chan *et al*., 2004). Strategies to improve child and maternal health require identification of the risk factors for stillbirths and neonatal deaths. This study assesses associations between biological and socio-cultural factors (e.g. maternal age, marital status, smoking and other maternal and neonatal characteristics) and the incidence of stillbirths and neonatal deaths. The ultimate goal is to provide information that can guide the development of preventive strategies for identified high-risk populations to reduce the incidence of stillbirths and neonatal deaths.

Methods

The data for this study were from the NSW Midwives Data Collection (MDC) for the five-year period 1998–2002. The MDC is a population-based surveillance system covering all births in public and private hospitals in NSW, as well as home births. The MDC is administered by the Epidemiology and Health Services Evaluation Branch, NSW Health Department. The MDC database contains information on all live births and stillbirths of at least 20 weeks gestation or with a birth weight of 400 g or more, regardless of gestational age. This database contains some maternal- and pregnancy-related characteristics. Gestational age is defined as the duration of pregnancy (in completed weeks) from the day of a mother's last normal menstrual period, and is reported on all births (including stillbirths). A stillbirth (late fetal death) is usually defined as a death prior to the complete expulsion or extraction from its mother of a product of conception of 20 or more completed weeks of gestation or of 400 g or more birth weight. The death is indicated by the fact that after such separation the fetus did not breathe or show any other evidence of life, such as the beating of the heart, pulsation of the umbilical cord, or definite movement of voluntary muscles. A neonatal death is defined as the death of a live birth occurring during the first 28 days of life. The neonatal deaths are only those deaths reported to the MDC. As the MDC form is completed at discharge or transfer of the newborn, deaths occurring after this time may not be reported to the MDC. Socioeconomic status (SES) was constructed using the Socio-Economic Indexes for Areas (SEIFA) and postcode of residence.

As the causes of stillbirths and neonatal deaths are not clearly documented in the MDC, the NSW perinatal mortality data were used to identify the principal causes of stillbirths and neonatal deaths. Until 1998, the NSW perinatal mortality data used ICD9 codes and from 1999 ICD10 codes were used to record causes of stillbirths or neonatal deaths. This study used 1999–2000 perinatal mortality data (the most recent data available) to identify the principal causes of stillbirth and neonatal deaths.

Bivariate (cross-tabulations) analyses were used to explore the association between selected neonatal and maternal characteristics, e.g. infant sex, maternal age, country of birth, smoking behaviour during pregnancy, parity, maternal hypertension, gestational age, birth weight. Although birth weight and gestational age variables were continuous, in this study they were re-coded as categorical variables: e.g. very low birth weight (birth weight less than 2000 g); low birth weight (birth weight 2000 g to 2499 g); birth weight of 2500 g or more; and gestational age (1=gestational age of less than 32 weeks, 2=gestational age of 32 weeks to less than 37 weeks and 3=gestational age of 37 weeks or more). As stillbirths and neonatal deaths (occurred Yes=1, No=0) were coded as dichotomous dependent variables, multiple logistic regression analyses were employed to examine the relative contributions of each of the above variables to the risk of stillbirths and neonatal deaths (Hosmer & Lemeshow, 1989). To identify the relative contribution of gestational age on stillbirths and neonatal deaths two separate logistic regression models were constructed. For the analysis of stillbirths, all births were included; and for neonatal deaths, only live births were included in the analyses.

Population-attributable risks (PAR%) for predictors of stillbirths and neonatal deaths were calculated from the adjusted odds ratios (AOR) and appropriate

prevalence (p) using the standard mathematical formula: PAR%=[(AOR − 1)/{AOR+(100 − p)/p}]100 (Bruzzi *et al.,* 1985).

Results

During the period 1998 to 2002, a total of 433,379 births (430,603 live births) were registered in NSW and of these 3·2% were plural. On average, 4·5% of all mothers were teenagers (<20 years of age) and 18% were aged 35 years and older. About 2·4% of the NSW mothers had an Aboriginal background and 18% smoked during their pregnancy period. Of all births, 51·4% were boys, 41·3% were first born and 14% of the mothers had made their first antenatal care visit by 20 weeks of gestation. Two-thirds of the total births (66·2%) were through vaginal delivery, followed by Caesarean section (22·2%), vacuum extraction (6·2%), forceps (4·4%) and vaginal breech (0·9%). The proportion of low birth weight (less than 2500 g) for all births (including stillbirths) was 6·3%. Almost half of all newborns had birth weights ranging from 2500 to 3499 g and 43·4% of newborns had birth weights of 3500 g or more. About 7·1% of all babies were born preterm. Twenty-six mothers died in childbirth. In 1998–2002, there were 2776 stillbirths (6·4 per 1000 births) and 1188 of the total live births (2·8 per 1000 live births) died within 28 days of their birth. Risk factors for stillbirths and neonatal deaths are shown in Tables 1 and 2, and are discussed below.

Factors influencing stillbirths

The risk of stillbirth varied by maternal age, country of birth, Aboriginality, SES, smoking during pregnancy, maternal diabetes mellitus, maternal hypertension, antenatal care, amniocentesis, parity, infant sex, plurality of birth, place of birth, type of delivery, birth weight and gestational age (Table 1). Overall male fetuses were at greater risk of stillbirth than female fetuses. The incidence of stillbirths was 2·5 to 3·4 times higher for twin or multiple births compared with singleton births. Teenage mothers and those aged 35 years or older had higher rates of stillbirths than those aged 20–34 years. The rates of stillbirths were higher for primiparous mothers (6·9 per 1000 births) than for parity one to two (5·5 per 1000 births), but lower than for mothers of parity greater than two (8·8 per 1000 births). Mothers who had amniocentesis during pregnancy were twice as likely to have a stillbirth than women who did not have an amniocentesis. The rate of stillbirths was 40 per 1000 for those who did not book in an antenatal care visit and babies from this category were 1·78 to 2·34 times more likely to be born as stillbirths compared with those who received antenatal care. Low birth weight and gestational age showed relatively strong associations with stillbirths. After controlling for gestational age and adjusting for all other factors, babies with birth weights of <2000 g or between 2000 and 2499 g were 157·8 and 10·2 times more likely to be stillbirths respectively compared with those born with a weight of 2500 g or more. Of babies whose mothers died during the childbirth, 22% were stillborn (220 per 1000 births; six stillbirths out of 27 births). Compared with Australian-born mothers, the risk of stillbirths among Middle Eastern background mothers was 25% higher (OR=1·25; 95%CI, 1·01–1·55).

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Table 1. Rate of stillbirths per 1000 births by selected risk factors and adjusted odds ratios (with 95%CI) from multiple logistic regression analysis considering stillbirths as the dependent variable in NSW 1998–2002

		Stillbirths		Results from multiple logistic regression analysis: adjusted odds ratio (95%CI)	
	Total births	*n*	Rate per 1000 births	Model 1	Model 2[a]
All births	433,379	2776	6·4		
Maternal age (years)†					
<20	19,648	182	9·3	1·02 (0·85–1·20)	1·03 (0·86–1·25)
20–34 (ref.)[b]	33,6826	1989	5·9	1·00	1·00
35+	76,654	604	7·9	1·20 (1·06–1·35)**	1·18 (1·05–1·33)**
Maternal country of birth†					
Australia (ref.)	316,069	2054	6·5	1·00	1·00
NZ and Oceania	17,757	145	8·2	1·19 (0·97–1·46)	1·14 (0·93–1·39)
Europe	24,869	130	5·2	0·75 (0·61–0·93)**	0·77 (0·62–0·95)*
Middle East	17,000	122	7·2	1·25 (1·0–1·55)*	1·18 (0·96–1·46)
Asia	46,546	256	5·5	0·84 (0·72–0·98)*	0·77 (0·66–0·9)**
America/Africa	7182	47	6·5	1·13 (0·8–1·58)	1·1 (0·79–1·54)
Others	3626	19	5·2	1·00 (0·59–1·68)	0·94 (0·56–1·58)
Aboriginal status†					
Non-Aboriginal (ref.)	422,790	2663	6·3	1·00	1·00
Aboriginal	10,589	113	10·7	1·05 (0·83–1·33)	1·12 (0·89–1·42)
Smoked during pregnancy†					
No (ref.)	355,826	2081	5·8	1·00	1·00
Yes	77,401	682	8·8	1·05 (0·94–1·17)	1·17 (1·05–1·31)**
Socioeconomic status†					
Low	211,887	1486	7·0	1·18 (1·04–1·35)**	1·11 (0·99–1·25)
Medium	107,957	694	6·4	1·15 (1·02–1·30)*	1·17 (1·03–1·34)*
High (ref.)	106,946	542	5·1	1·00	1·00
Maternal diabetes mellitus†					
No (ref.)	431,403	2743	6·4	1·00	1·00
Yes	1976	33	16·7	1·82 (1·16–2·84)**	2·00 (1·29–3·11)**
Maternal hypertension†					
No (ref.)	429,080	2727	6·4	1·00	1·00
Yes	4299	49	11·4	1·20 (0·86–1·66)	1·21 (0·87–1·66)
No. previous pregnancies†					
None	178,870	1243	6·9	1·07 (0·97–1·19)	1·07 (0·97–1·18)
1–2 (ref.)	213,958	1175	5·5	1·00	1·00
3+	40,311	356	8·8	1·06 (0·92–1·23)	1·08 (0·93–1·24)
1st antenatal care visit (weeks)†					
<20 (ref.)	373,162	2220	5·9	1·00	1·00
20+	60,217	556	9·2	1·14 (1·02–1·28)*	1·12 (1·01–1·26)*

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Table 1. *Continued*

	Total births	Stillbirths		Results from multiple logistic regression analysis: adjusted odds ratio (95% CI)	
		n	Rate per 1000 births	Model 1	Model 2[a]
Amniocentesis (<20 weeks)?†					
No (ref.)	420,119	2550	6·1	1·00	1·00
Yes	13,260	226	17·0	1·88 (1·56–2·25)**	2·01 (1·68–2·41)**
Booked for antenatal care?†					
Booked (ref.)	423,212	2369	5·6	1·00	1·00
Not booked?	10,167	407	40·0	2·04 (1·78–2·34)**	1·6 (1·4–1·83)**
Mother's discharge status†					
Discharged/ transferred (ref.)	433,266	2769	6·4	1·00	1·00
Died	27	6	222·2	2·75 (0·63–11·96)	3·88 (0·91–16·45)
Baby's sex†					
Female (ref.)	210,455	1281	6·1	1·00	1·00
Male	222,660	1462	6·6	1·05 (0·96–1·15)	1·14 (1·05–1·25)**
Plurality of birth†					
Singleton (ref.)	419,688	2511	6·0	1·00	1·00
Twins or multiple	13,691	265	19·4	2·91 (2·49–3·4)**	3·35 (2·87–3·91)**
Baby's place of birth†					
Hospital & birth centre (BC) (ref.)	425,861	2719	6·4	1·00	1·00
Planned birth in hospital, BC, home	5740	25	4·4	1·03 (0·66–1·59)	0·98 (0·64–1·5)
Born before arrival	1775	32	18·0	1·32 (0·7–2·48)	1·17 (0·63–2·16)
Delivery type†					
Normal vaginal (ref.)	287,109	1680	5·9	1·00	1·00
Forceps	19,278	54	2·8	0·7 (0·52–0·93)*	0·64 (0·48–0·86)**
Vacuum extraction	26,693	30	1·1	0·35 (0·23–0·51)**	0·29 (0·19–0·42)**
Vaginal breech	4101	677	165·1	2·98 (2·61–3·41)**	3·8 (3·34–4·32)**
Caesarean section	96,126	335	3·5	0·25 (0·22–0·28)**	0·23 (0·2–0·26)**
Birth weight (g)†					
<2000	10,943	1792	163·8	19·9 (15·92–24·87)**	157·84 (141·52–176·04)**
2000–2499	16,510	224	13·6	4·6 (3·74–5·65)**	10·2 (8·71–11·95)**
2500+ (ref.)	405,696	675	1·7	1·00	1·00
Gestational age (weeks)†					
<32	6194	1605	259·1	14·41 (11·44–18·14)**	
32–36	24,653	488	19·8	3·65 (3·01–4·44)**	
37+ (ref.)	402,468	682	1·7	1·00	

†Variable found significant in bivariate analyses ($p<0·05$).
*Significant at $p<0·05$; **significant at $p<0·01$.
[a]Model 2: gestational age excluded from the model.
[b]Used as 'Reference category' in logistic regression analysis.

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Factors influencing neonatal deaths

Neonatal death rates differed markedly by neonatal and maternal characteristics (Table 2). Models are presented with and without adjusting for gestational age. After adjusting for all potential confounders, infant boys were significantly more likely to die in the neonatal period compared with girls. Babies born to mothers aged 12–19 years or 35 years and older were more likely to die as neonates than those born to mothers aged 20–34 years. The neonatal death rates were higher for the babies born to mothers who smoked during pregnancy and who had hypertension. The incidence of neonatal deaths among the babies born on the way to hospital or before arrival of hospital was higher (10·9 per 1000 live births) than those who were born in hospital or in a birth centre. Vaginal breech delivery, low birth weight and gestational age had relatively strong associations with neonatal deaths. After controlling for gestational age and adjusting for all other factors, babies born with weight less than 2000 g and between 2000 and 2499 g compared with those who were born with weight 2500 g or more were 244·2 and 9·2 times more likely to die in the neonatal period respectively. The risk of neonatal deaths among babies born through vaginal breech delivery (OR = 3·68; 95%CI, 3·02–4·49) and Caesarean section delivery (OR = 1·36; 95%CI, 1·25–1·47) was higher compared with normal vaginal delivery babies. Babies born to Middle Eastern background mothers were 1·53 times more likely to die as neonates compared with Australian-born mothers (OR = 1·53; 95%CI, 1·11–2·11).

Principal causes of stillbirths and neonatal deaths

In 1999–2000, there were 819 stillbirths and 621 neonatal deaths registered in NSW. Of the stillbirths, 45·7% (374 out of 819) were due to conditions originating in the perinatal period, followed by intrauterine hypoxia and birth asphyxia (22·5%), congenital malformations including deformities and chromosomal abnormalities (15%) and disorders related to slow fetal growth, short gestation and low birth weight (9·2%). The most common causes of neonatal deaths were congenital malformations including deformities and chromosomal abnormalities (27·5%), disorders related to slow fetal growth, short gestation and low birth weight (22·7%), respiratory distress of the newborn and other respiratory conditions (17·9%), haemorrhagic, haematological, transitory endocrine and digestive disorders of the fetus and newborn (9·7%), conditions originating in the perinatal period (6·4%), infections specific to the perinatal period (5%) and intrauterine hypoxia and birth asphyxia (4%).

Population-attributable risks for stillbirths and neonatal deaths

Low birth weight, small gestational age and vaginal breech delivery were the strongest predictors for both stillbirths and neonatal deaths. To estimate the community impact, the PAR% for stillbirths and neonatal deaths were calculated for low birth weight and small gestational age (Table 3). Very low birth weight (birth weight less than 2000 g) accounted for 75·6% of stillbirths and 59·4% of neonatal mortality. Preterm (less than 32 weeks) accounted for 77·7% of stillbirths and 87·9% of neonatal deaths. Low birth weight and gestational age contributed 78·7% and 79·3% to neonatal mortality respectively.

Table 2. Rate of neonatal deaths per 1000 live births by selected risk factors and adjusted odds ratios (with 95%CI) from multiple logistic regression analysis considering neonatal deaths as the dependent variable in NSW 1998–2002

		Neonatal deaths[c]		Results from multiple logistic regression analysis: adjusted odds ratio (95%CI)	
	Total number of live births	*n*	Rate per 1000 live births	Model 1	Model 2[a]
All live births	430,603	1188	2·8		
Maternal age (years)†					
<20	19,466	79	4·1	1·15 (0·87–1·52)	1·25 (0·96–1·63)
20–34 (ref.)	334,837	846	2·5	1·00	1·00
35+	76,050	263	3·5	1·02 (0·85–1·18)	1·03 (0·86–1·20)
Maternal country of birth†					
Australian (ref.)	314,015	850	2·7	1·00	1·00
NZ and Oceania	17,612	62	3·5	1·46 (1·09–1·97)*	1·39 (1·04–1·85)*
Europe	24,739	74	3·0	1·07 (0·81–1·41)	1·14 (0·87–1·48)
Middle East	16,878	57	3·4	1·53 (1·11–2·11)**	1·45 (1·07–1·97)*
Asia	46,290	108	2·3	0·97 (0·76–1·24)	0·88 (0·70–1·10)
America/Africa	7135	25	3·5	1·40 (0·88–2·23)	1·39 (0·89–2·17)
Others	3607	9	2·5	0·96 (0·47– 1·92)	0·94 (0·46–1·94)
Aboriginal status†					
Non-Aboriginal (ref.)	420,127	1140	2·7	1·00	1·00
Aboriginal	10,476	48	4·6	1·01 (0·72–1·42)	1·09 (0·78–1·52)
Smoked during pregnancy†					
No (ref.)	353,745	909	2·6	1·00	1·00
Yes	76,719	276	3·6	1·17 (0·98–1·38)	1·31 (1·11–1·54)**
Socioeconomic status†					
Low	210,401	608	2·9	1·11 (0·92–1·35)	1·06 (0·88–1·28)
Medium	107,263	288	2·7	1·06 (0·9–1·26)	1·01 (0·86–1·119)
High (ref.)	106,404	261	2·5	1·00	1·00
Maternal diabetes mellitus†					
No (ref.)	428,660	1178	2·7	1·00	1·00
Yes	1943	10	5·1	1·04 (0·5–2·13)	1·03 (0·51–2·11)
Maternal hypertension†					
No (ref.)	426,353	1168	2·7	1·00	1·00
Yes	4250	20	4·7	1·11 (0·68–1·8)	1·13 (0·7–1·81)
No. previous pregnancies†					
None	177,627	561	3·2	1·01 (0·89–1·18)	1·01 (0·88–1·16)
1–2 (ref.)	212,783	472	2·2	1·00	1·00
3+	39,955	152	3·8	1·02 (0·82–1·27)	1·04 (0·84–1·29)

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Table 2. *Continued*

	Total number of live births	Neonatal deaths[c] *n*	Neonatal deaths[c] Rate per 1000 live births	Results from multiple logistic regression analysis: adjusted odds ratio (95%CI) Model 1	Model 2[a]
1st antenatal care visit (weeks)†					
<20 (ref.)	370942	948	2·6	1·00	1·00
20+	59661	240	4·0	1·05 (0·88–1·25)	1·04 (0·88–1·23)
Amniocentesis (<20 weeks)? †					
No (ref.)	417,569	1071	2·6	1·00	1·00
Yes	13,034	117	9·0	3·19 (2·48–4·11)**	3·2 (2·52–4·05)**
Booked for antenatal care?†					
Booked (ref.)	420,843	840	2·0	1·00	1·00
Not booked?	9760	348	35·7	1·03 (0·88–1·21)	1·54 (1·32–1·78)**
Mother's discharge status[c]					
Mother died	21	1	47·6		
Discharged alive	430,497	1186	2·8		
Baby's sex†					
Female (ref.)	209,174	522	2·5	1·00	1·00
Male	221,198	662	3·0	1·14 (1·01–1·30)*	1·29 (1·14–1·47)**
Plurality of birth†					
Singleton (ref.)	417,177	919	2·2	1·00	1·00
Twin or multiple	13,426	269	20·0	1·14 (0·97–1·35)	1·44 (1·23–1·7)**
Baby's place of birth†					
Hospital & birth centre (BC) (ref.)	423,142	1160	2·7	1·00	1·00
Planned birth in hospital, BC, home	5715	9	1·6	1·66 (0·76–3·62)	1·25 (0·59–2·68)
Born before arrival	1743	19	10·9	1·77 (1·01 –3·16)*	1·74 (1·01–2·99)*
Delivery type†					
Normal vaginal (ref.)	285,429	518	1·8	1·00	1·00
Forceps	19,224	33	1·7	1·30 (0·88–1·91)	1·14 (0·79–1·67)
Vacuum extraction	26,663	13	0·5	0·67 (0·38–1·17)	0·46 (0·27–0·82)**
Vaginal breech	3424	254	74·2	3·68 (3·02–4·49)**	4·67 (3·87–5·64)**
Caesarean section	95,791	370	3·9	1·36 (1·25–1·47)**	1·38 (1·28–1·51)**
Birth weight (g) †					
<2000	9151	943	103·0	15·23 (9·92–23·39)**	244·2 (202·31–294·76)**
2000–2499	16,286	67	4·1	4·43 (2·97–6·59)**	9·24 (6·86–12·45)**
2500+ (ref.)	405,021	175	0·4	1·00	1·00

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Table 2. *Continued*

	Total number of live births	Neonatal deaths[c]		Results from multiple logistic regression analysis: adjusted odds ratio (95%CI)	
		n	Rate per 1000 live births	Model 1	Model 2[a]
Gestational age (weeks) †					
<32	4589	888	193·5	38·41 (25·01–58·97)**	
32–36	24,165	120	5·0	2·73 (1·86–4·02)**	
37+ (ref.)	401,786	179	0·4	1·00	

†Variable found significant in bivariate analyses ($p<0·05$).
*Significant at $p<0·05$; **significant at $p<0·01$.
[a]Model 2: gestational age excluded from the model.
[b]Used as 'Reference category' in logistic regression analysis.
[c]Neonatal deaths include deaths reported to the MDC only. As the MDC form is completed at discharge or transfer of the baby, deaths occurring after this time may not be reported to the MDC.

Table 3. Population-attributable risk for stillbirths and neonatal deaths by birth weight and gestational age in NSW 1998–2002

	Stillbirths			Neonatal deaths		
	Rate of stillbirths per 100 births	AOR (adjusted odds ratio)	PAR%	Rate of neonatal deaths per 100 live births	AOR (adjusted odds Ratio)	PAR%
Birth weight (g)		**69·8**			**78·7**	
<2000	16·38	19·9	75·6	10·3	15·23	59·4
2000–2499	1·36	4·6	4·7	0·41	4·43	1·4
2500+ (ref.)	0·17	1·00		0·04		
Gestational age (weeks)		**66·6**			**79·3**	
<32	25·91	14·41	77·7	19·35	38·41	87·9
32–36	1·98	3·65	5·0	0·5	2·73	0·9
37+ (ref.)	0.17	1·00		0·04		

Discussion

The findings of this study confirm that stillbirths and neonatal deaths are significantly related to biological and socio-demographic factors. These are: mother's age, country

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of birth, Aboriginality, SES, smoking behaviour during pregnancy, maternal diabetes mellitus, maternal hypertension, parity, antenatal care, amniocentesis, infant sex, plurality of birth, place of birth, type of delivery, birth weight and gestational age. Babies born to mothers who smoked during pregnancy were at increased risk of stillbirths and neonatal deaths. This study also found that the principal causes of stillbirths differ from the causes of neonatal deaths. Although plurality is a biological determinant for low birth weight and preterm birth, this study showed that after adjusting for low birth weight and gestational age, the incidences of stillbirth and neonatal deaths were higher for plural births compared with singleton births (Institute of Preventive Medicine, 1985). The higher incidence of stillbirths and neonatal deaths among babies born to teenage or older mothers may be because teenage mothers are at higher risk of smoking, in a lower social class, lack of antenatal care, have higher rates of low birth weight babies and premature births, and older mothers might have, in general, more pregnancy complications, e.g. diabetes and hypertension (Mohsin *et al*., 2003). The findings from both bivariate and multivariate analyses confirmed that small gestational age and low birth weight were the two most important determinants of stillbirths and neonatal deaths. The results from multivariate analyses controlling for birth weight and gestational age suggests that the increased stillbirth and neonatal death risks for preterm infants were in part explained by their low birth weight.

Consistent with previous studies, this study found that stillbirths and neonatal deaths among Middle-Eastern-born mothers were significantly higher than among Australian-born mothers (de Costa, 1988). A higher rate of consanguineous marriage among the Middle Eastern background mothers may be one of the possible reason for this higher rate of stillbirths and neonatal deaths (de Costa, 1986, 1988).

As demonstrated in other studies, teenage mothers who smoke are more likely to be unmarried (Institute of Preventive Medicine, 1985; Mohsin & Bauman, 1997; Kramer *et al*., 2002), their pregnancies are often unwanted or unplanned and they are often late in seeking antenatal care (Bai *et al*., 2000; Kramer *et al*., 2002) and more likely to have low birth weight and preterm babies (Mohsin *et al*., 2003). These factors were partially responsible for the higher rate of stillbirths and neonatal deaths.

Studies have found that Aboriginal mothers are four to eight times more likely to smoke than non-Aboriginal mothers (Mohsin & Bauman, 1997), possibly drink more during pregnancy (Kliewer & Stanley, 1989), and have higher rates of low birth weight and preterm babies (Mohsin *et al*., 2003). A review of NSW Aboriginal women found that Aboriginal mothers have less antenatal care, are younger and are more likely to be single (NSW Health Department, 1994). These are known risk factors for stillbirths and neonatal deaths. To reduce the risk of stillbirths and neonatal deaths among Aborigines, strategies are needed to provide antenatal care that is acceptable to Aboriginal women, preferably through increasing co-operation with Aboriginal-controlled antenatal services.

Maternal hypertension is the disease most often associated with fetal growth retardation (Institute of Preventive Medicine, 1985) and previous studies have found that preterm birth and low birth weight are significantly higher in mothers with essential and pregnancy-induced hypertension (Mohsin *et al.*, 2003), which influence stillbirths and neonatal deaths. Medical intervention is needed to reduce the severity

of maternal hypertension, preventing complications such as preterm birth and low birth weight (Institute of Preventive Medicine, 1985), which will ultimately lower the risk of stillbirths and neonatal deaths.

Although many of the obstetric and medical risk factors for stillbirths and neonatal deaths, such as diabetes and hypertension, may not be preventable, a focus on the non-medical and socioeconomic factors identified in this study may reduce the risk of stillbirths and neonatal deaths. For example, as maternal smoking is one of the few known preventable risk factors, further anti-smoking campaigns during pregnancy are warranted. A recent study indicated that continine-validated, maternal cessation of smoking during pregnancy resulted in an increase in mean birth weight of 241 g, whereas a reduction in maternal smoking during pregnancy resulted in an increase of 92 g (Li *et al*., 1993). Smoking has major impacts on preterm birth and low birth weight (Mohsin *et al.*, 2003). The PAR% for neonatal deaths indicates that very low birth weight (less than 2000 g) (PAR: 59·4%) and very prematurely born infants (less than 32 weeks) constitute most of the neonatal deaths (PAR: 87·9%). A similar pattern was also observed for stillbirths. The findings of this study showed that after adjusting for low birth weight, plurality of birth and other factors, smoking has significant associations with stillbirths and neonatal deaths. It is also well established that infants of mothers who smoke are less likely to survive (Kramer *et al*., 2002; Institute of Preventive Medicine, 1985; Becerra & Smith, 1982; McIntosh, 1984; Kleinman *et al*., 1988). Thus, effective interventions to help women stop smoking during pregnancy should reduce the risk of stillbirths and neonatal deaths. Fundamentally, healthy pregnancies begin before conception (Institute of Preventive Medicine, 1985). Thus, to reduce the incidence of stillbirths and neonatal deaths it is important to identify the populations at risk and to provide relevant services to improve maternal and child health outcomes. Strategies to improve perinatal health should include prevention and treatment of pregnancy complications such as hypertension, adequate nutrition during pregnancy (for better birth weight), improved care at delivery and better care for neonates.

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