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Early influences on developmental outcomes among children, at age 5, in Australia's Northern Territory

Steven Guthridge[a,b,*], Lin Li[a], Sven Silburn[b], Shu Qin Li[a], John McKenzie[b], John Lynch[c]

[a] Department of Health, Northern Territory, Australia
[b] Centre for Child Development and Education, Menzies School of Health Research, Australia
[c] School of Public Health, University of Adelaide, Australia

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ABSTRACT

Redressing developmental and school learning inequalities among children requires an understanding of the factors that influence development across population groups. This study utilized the 2009 Australian Early Development Census (AEDC) to explore the association of perinatal health and socio-demographic factors with early development of children in the Northern Territory of Australia. The study cohort included 1110 Aboriginal and 812 non-Aboriginal children, most aged 5 years, whose developmental status was assessed during their first year of full-time school enrollment. Individual-level information was probabilistically linked across three administrative datasets. Logistic regression models were used to estimate the association (odds ratio (OR)) between early life characteristics of children and teacher-rated vulnerability on one or more of five domains of development. The crude OR for developmental vulnerability was much greater for Aboriginal than non-Aboriginal children (OR: 6.93, 95% CI: 5.62–8.56). After adjustment for other variables, the increased risk of developmental vulnerability for Aboriginal children was substantially moderated (OR: 1.68, 95% CI: 1.21–2.32). Influential factors in the adjusted model included: English as a second language (OR: 3.11, 95% CI: 2.27–4.26), gestational age at birth of 34–36 weeks (OR: 2.08, 95% CI: 1.27–3.39) and living in a very remote area (OR: 1.68, 95% CI: 1.19–2.37). There was a gradient in the strength of the association with the level of primary caregiver's education. An additional risk, for Aboriginal children only, was not having attended a day care or pre-school program (OR: 1.43, 95% CI: 1.01–2.04). The study demonstrates the emerging capacity for linkage of data across administrative datasets to inform our understanding of the extent to which multiple factors in early-life operate in their association with children's early development. Our findings are of particular relevance to initiatives to improve outcomes for Aboriginal children by demonstrating that potentially modifiable health and socio-economic factors account for almost all of the difference in developmental vulnerabilities observed between Aboriginal and non-Aboriginal children.

1. Introduction

A child's engagement with formal learning is recognized as fundamental to their health and wellbeing across the life-span (AIHW, 2012) and there is increasing evidence of longer-term adverse health and social consequences of impaired early child development (D'Angiulli, Warburton, Dahinten, & Hertzman, 2009; Hillemeier, Morgan, Farkas, & Maczuga, 2011; Quigley et al., 2012; Silburn et al., 2009). Measures of developmental vulnerability in early childhood highlight wide variations between children (AIHW, 2012; Janus & Duku, 2007) and there is increasing interest in identifying the early influences of children's health, development and well-being in order to inform services needed to better support vulnerable children and their families (Lynch, Law, Brinkman, Chittleborough, & Sawyer, 2010).

1.1. Reducing life-course disadvantage

Australian government policy over the past decade has seen increased investment in early childhood development as a key strategy for reducing disadvantage and building the human capital of the nation (Council of Australian Governments, 2008a). A life-course human development perspective has also been a key feature of national policies seeking to reduce health, education and other life outcome disparities for Aboriginal Australians (Council of

* Corresponding author at: Health Gains Planning, Department of Health, PO Box 40596, Casuarina, NT 0811, Australia.
E-mail address: steve.guthridge@nt.gov.au (S. Guthridge).

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Australian Governments, 2008b). (Authors' note; the term "Aboriginal" is used in this paper to respectfully include all of Australia's First Peoples including Torres Strait Islanders.) These policy initiatives have been accompanied by parallel investments to build Australia's capacity for national, state/territory monitoring and progress reporting against indicators agreed by all Australian governments (state, territory and federal). These indicators include the annual assessment and public reporting of aggregated literacy and numeracy attainments of primary and secondary school students (ACARA, 2014), and a nation-wide census of the early development of all Australian children enrolled in their first year of full-time schooling at around age 5 years. This census was first implemented in 2009 utilizing the Australian Early Development Index (AEDI), an on-line, teacher-rated measure adapted from the Canadian Early Development Instrument (EDI) in collaboration with its Canadian developers (Janus et al., 2007; Janus, Brinkman, & Duku, 2011). It provides a community-level measure of the status of children's development in five domains of function considered relevant to their making a successful transition into school learning (Janus et al., 2007, 2011; Centre for Community Child Health and Telethon Institute for Child Health Research, 2009). Now named the Australian Early Development Census (AEDC) the instrument contains over 100 items across the domains of physical health and wellbeing, social competence, emotional maturity, language and cognitive skills, and communication skills and general knowledge. (Authors' note; the AEDI was officially renamed the AEDC in July 2014. To maintain consistency with this new nomenclature, this paper hereafter refers to the measure used in the analysis as the AEDC). The AEDC was repeated in 2012 and is now being implemented every three years as one of the progress measures for human capital within Australia's National Reform Agenda (Council of Australian Governments, 2008a).

1.2. Australian Aboriginal children and the AEDC

Importantly, the adaptation process for the development of the AEDC included cross-cultural validation studies to maximize its cultural inclusiveness and measurement equivalence for use with Aboriginal children and English as a Second Language (ESL) children (Brinkman, Sayers, Goldfeld, & Kline, 2009; Brinkman et al., 2007; Silburn et al., 2009). The design of the Aboriginal adaptation process was informed by the guidelines of the International Test Commission for the adaptation of psychometric measures for use with other language and cultural groups (Coyne and Bartram, 2006, Herdman, Fox-Rushby, & Badia, 1998). These identify conceptual, pragmatic, and ethical issues which should be addressed to maximize the cultural inclusiveness and measurement equivalence of the adapted measure and the meaningful interpretation and communication of findings. The AEDC adaption process was overseen by a National Indigenous Reference Group comprising Aboriginal educators, policy makers, and national and state peak-body education organizations. The first stage of adaptation for Aboriginal children involved conducting 85 community and focus group consultations to obtain the views of over 500 Aboriginal teachers, parents, community elders and other Aboriginal education stakeholder in metropolitan, rural and remote communities. These elicited suggestions for how the administration process could be adapted to maximize Aboriginal community support and understanding of the AEDC assessments. They also reviewed the cultural relevance of each item, domain scale and the accompanying explanatory information for teachers. Next, quantitative analysis of the psychometric characteristics of the AEDC was carried out using data from 1474 Aboriginal children and 30,087 non-Aboriginal children already available from the pilot stages of the national rollout of the AEDC (2006–2007). This included Rasch scaling analysis to identify any items having differential response characteristics (i.e., bias) which might require their elimination or adaptation to achieve a satisfactory level of measurement equivalence and multilevel modeling examining the extent of teacher and community level variation. The main modifications to emerge from the adaptation project included:

- The recommended use of Aboriginal school personnel (including Aboriginal Teaching Assistants and Aboriginal & Torres Strait Islander Education Officers) to work with teachers in completing the AEDC checklists for Aboriginal children.
- Modifications to the on-line teacher guide to provide additional information so that specific cultural considerations could be taken into account on certain checklist items.
- Addition of a number of extra checklist items recommended as being of relevance to understanding the particular circumstances of Aboriginal children (e.g., school absence for cultural reasons; proficiency in use of home language; history of otitis media or hearing difficulties) as well as those of all children living in conditions of extreme poverty.

These modifications were then piloted in 49 schools throughout urban, regional, and remote regions of Western Australia. The final version of AEDC used in the 2009 national census included these item and scale adaptations plus a few additional questions applying only to Aboriginal students (e.g., traditional language group).

1.3. Northern Territory children

The Northern Territory (NT) of Australia is situated in the north and central part of Australia and while covering about one sixth of the area of Australia (ABS, 2010) contains the smallest population (243,826 in 2015) (ABS, 2015) and the highest proportion of the population living in remote and very remote areas (ABS, 2013a) among the six states and two territories of Australia. The NT also has a distinctive population structure with the Aboriginal population making up almost 30% of the total NT population compared with 3% of the total Australian population. The Aboriginal population is the most socially disadvantaged population in Australia as a result of the negative impacts of colonization and the compounding effects of low income, poor education, poor health, unemployment, poor housing and a lack of essential services. (ABS, 2013b; Carson, Dunbar, Chenhall, & Bailie, 2007; Zhao, You, Wright, Guthridge, & Lee, 2013). In this context, the NT has two distinct populations of children. Non-Aboriginal children make up about 55% of 5–9 year olds and have health and education outcomes similar to the rest of Australia, while Aboriginal children (including approximately 4% Torres Strait Islander children (ABS, 2007)) make up the balance of 45% in this age group and have much poorer outcomes (AEDI, 2013; Li, Guthridge, d'Espaignet, & Paterson, 2007; McTurk, Nutton, Lea, Robinson, & Carapetis, 2008; Silburn, McKenzie, & Moss, 2010; Silburn, Robinson, Arney, Johnstone, & McGuinness, 2011). In terms of health measures, NT Aboriginal children have a lower average birth weight and higher rates of many childhood diseases, including malnutrition and hearing loss, than non-Aboriginal children. Hospital admission rates among 1–4 year olds are approximately 2.5 times greater among Aboriginal than non-Aboriginal children and infant mortality rates are 2–3 times greater (Li, Guthridge et al., 2007). The extent of these disparities may also be gauged from the results of the 2009 AEDC in which almost two thirds (65.1%) of all NT Aboriginal children assessed were developmentally vulnerable on one or more domains in contrast to 22.6% of their non-Aboriginal counterparts (Centre for Community Child Health and Telethon Institute for Child Health Research, 2009). In 2012, when this same cohort of NT children, most aged 8 years, was assessed in the Australian National Literacy and Numeracy Assessment Program (NAPLAN) 60.4% of Aboriginal students had reading scores below

the national minimum standard compared to 9% of non-Aboriginal students (ACARA, 2012).

1.4. Research aim

Redressing developmental and school learning inequalities for Aboriginal children requires an understanding of the modifiable factors that influence child health and development across population groups (Brinkman et al., 2012; Hart, Brinkman, & Blackmore, 2003). The aim of this study was to identify factors that negatively affect early child development for both NT Aboriginal and non-Aboriginal children by quantifying the associations between perinatal health and socio-demographic factors and developmental vulnerability as measured with the AEDC (AEDI, 2013). This is the first Australian population-based study, with a substantial sample of Aboriginal children, to use data linkage to enable investigation of the links between early life health and social factors and early child development.

2. Method

2.1. Participants

This is an historical cohort study of NT children, most aged 5 years, who were assessed soon after commencing school. The study cohort was established by the availability of linked unit level information, for each child, in three datasets—NT Perinatal Data Register, government school enrollment and AEDC. There were 3230 children (39.4% Aboriginal) who completed the AEDC, in 2009, which was 93.5% of the estimated NT population of 5 year olds. In addition 475 children were assessed, in 2010, in a supplementary collection with a focus on remote communities (Silburn et al., 2010). After exclusion of duplicates and those records with incomplete linkage information (missing names etc.), AEDC records were available for 3606 children (97.3% of total).

Of the 3606 children, perinatal information was available for 2229 children (61.8%). After further linkage with school enrollment data there was a total of 2021 children (56.0%) for whom information was available from all three datasets. After exclusion of 98 children not eligible for formal AEDC assessment because of medically diagnosed special needs and one child aged 3 years who was outside the age range for AEDC assessment (4–6 years) information was available for 1922 children (1110 Aboriginal (57.8%) and 812 non-Aboriginal children (42.2%)). There were several reasons for the substantial proportion of children whose information was unavailable for linkage. The first is that the NT has a high level of inter-state migration of non-Aboriginal families with many children born in the NT leaving before commencing school (though replaced by a similar number of non-Aboriginal children migrating to the NT). A second reason for non-linkage was that enrollment information was only available for government schools and not for approximately 16% of children who were enrolled in non-government schools (ABS, 2013c). A third reason for non-linkage would have been the small proportion of children with inconsistent identifying information such as a change in name. Interstate migration and non-availability of non-government school data disproportionately affect the availability of linked information for non-Aboriginal children which is evident in the difference in distribution of children, by Indigenous status, between AEDC participants in 2009 and 2010 combined (46.5% Aboriginal) and the study cohort (57.8% Aboriginal).

A comparison of the distribution of available variables was made between the study cohort and all children who completed the AEDC, for Aboriginal and non-Aboriginal children separately. For Aboriginal children, there were 57.3% of all participating children vulnerable on one or more domains compared with 59.1% among children in the study cohort ($p < 0.01$). There was no evidence for a difference in distribution of results, for Aboriginal children, between the two groups for age categories, gender ($p = 0.89$), English as a second language ($p = 0.51$) and attendance at day care or pre-school ($p = 0.56$). Among non-Aboriginal children there were differences between all participants and the study cohort for developmental vulnerability (21.3% and 23.0% respectively, $p < 0.01$), English as a second language (12.0% and 8.6% respectively, $p < 0.01$) and attendance at day care or preschool (85.9% and 89.8% respectively, $p < 0.01$) but no evidence for a difference in age distribution ($p = 0.38$) or sex ($p = 0.58$).

2.2. Data sources

The NT Perinatal Data Register is an administrative dataset which contains comprehensive antenatal and birthing information for all NT births from 1986 onwards. Perinatal details are recorded by the birth attendant immediately following a birth and then collated and validated in a single centralised dataset. Most children born in the NT and who commenced at an NT school in 2009 were part of the cohort of 3536 children born in the NT between 1 July 2003 and 30 June 2004. Predictor variables from the NT Perinatal Data Register were selected on the basis of previous research on perinatal inequalities (Brinkman et al., 2012; Curtin, Madden, Staines, & Perry, 2013; Dickson, Gregg, & Robinson, 2013; Harrison and McLeod, 2010; Lawlor et al., 2005; McTurk et al., 2008; Resnick et al., 1999; Ribeiro et al., 2011; Centre for Community Child Health and Telethon Institute for Child Health Research, 2009), with the factors also overlapping with those adopted as indicators of progress in early child development within the Australian Government's "Closing the Gap" initiatives (SCRGSP, 2011). The selected variables were maternal age at the time of birth, gestational age, Apgar score at 5 min after birth, birthweight, child's gender, remote residence based on the Australian Standard Geographical Classification 2006 (Trewin, 2006), parity (number of previous births for the mother), plurality (number of births from this pregnancy) and the mother's self-reported status for smoking and alcohol consumption during pregnancy.

School enrollment information was provided, by the child's primary caregiver, at the time the child commenced school and includes demographic information about the child and parents at that time. Enrollment data for all NT Government schools are maintained in a central data warehouse. A predictor variable selected from student enrollment records was the school education level of the child's "primary caregiver". The enrollment information includes school education level of both "Parent 1" and "Parent 2", in which "Parent 1" is typically the child's biological mother but may be another carer including the father, guardian or grandparent.

The AEDC data used in this study were collected on children enrolled in their first year of full-time school in all NT government schools. AEDC results were used as the outcome measures for this study. The AEDC reflects developmental outcomes and milestones that children should be able to achieve under optimal circumstances in physical and socio-emotional health as well as in their cognitive development (Brinkman et al., 2012; Janus et al., 2007). AEDC results provide information in five domains of early childhood development considered relevant to success in school learning.

Consistent with national AEDC reports (Centre for Community Child Health and Telethon Institute for Child Health Research, 2009; Australian Government, 2013), children with scores in the lowest 10% of the national AEDC population were classified as 'developmentally vulnerable' on that particular domain. An additional binary outcome measure of overall developmental vulnerability was defined based on a child having scored in the vulnerable range

in one or more domains. The validity studies for the development of the AEDC found that children who were vulnerable on one or more AEDC domains typically needed some form of additional learning or language support in their transition into school learning (Brinkman et al., 2007). Additional predictor variables available from AEDC records were: child's Indigenous status, English as a Second Language (ESL) and whether the child had attended day care or a pre-school program. A recent article provides evidence for the accuracy of teachers' reports of day care and pre-school attendance by children participating in the AEDC (Goldfeld et al., 2016).

2.3. Linkage of datasets

Unit record level, identifying information from the three datasets—NT Perinatal Data Register, government school enrolment and AEDC, was provided by the respective data custodian to a data linkage unit (SA NT DataLink, 2014) where it was probabilistically linked to create an anonymous linkage key unique to individuals within the datasets. Probabilistic linkage methods involve the calculation of linkage probability weights for potential matches among individuals in different datasets and are estimated given all the observed agreements and disagreements of the data values of the matching identifying variables (Méray, Reitsma, Ravelli, & Bonsel, 2007). The probabilistic linkage was undertaken using the following fields—first name, last name, gender, date of birth, suburb and postal area code. Supplementary clerical review was undertaken for uncertain or incomplete matches and included the use of additional fields—year of AEDC test, school name, place of birth and Indigenous status.

The identifiable datasets, with the addition of the unique linkage keys, were returned to the respective data custodians. The data custodians then combined the identifiable dataset and the unique linkage key with their complete dataset. Each data custodian then extracted a de-identified research dataset that contained the selected variables and the unique linkage keys and released the research dataset to the research team. The research team were then able to link unit record level information across the three research datasets using the unique linkage key.

2.4. Statistical analysis

Chi-square tests were used for comparison of the distributions of variables for the study cohort with all NT children participating in the AEDC. Crude and multivariable logistic regression were used to calculate odds ratios (ORs) and 95% confidence intervals (95% CI) for the association of each of the selected predictor variables with developmental vulnerability. The OR is the ratio of the odds of an event occurring in one population compared to the odds of that event occurring in a second population. A result which includes an OR of 1.00, within a specified confidence interval, indicates that the event is equally likely in both populations. Conversely an OR that does not include 1.00, within the confidence interval, indicates that the odds of the event are either less likely (OR < 1.00) or more likely (OR > 1.00) to occur in the first than the second population. Analyses were conducted using the statistical program Stata version 13 (StataCorp, 2013).

The number of children available for analysis varied with missing variable-level data. Most predictor variables, within the linked dataset, had less than 1% missing values and the exceptions were maternal smoking status (9.4%), maternal alcohol consumption status (13.4%) and primary caregiver school education level (35.0%). There was also a proportion of children who were eligible for AEDC assessments but had missing results in one or more domains (7.2%). We used multiple imputation by chained equations (MICE) in Stata to account for missing data (Royston and White, 2011). This approach, under the assumption of missing at random and conditional on all other variables, uses multiple multivariable imputations to estimate missing values from the information available in other explanatory variables. A set of twenty imputation datasets was generated and used for all explanatory variable based models with results combined. Multinomial logistic regression was used for ordinal and categorical variables.

2.5. Ethics approval

The study protocol was approved by the Human Research Ethics Committee of the NT Department of Health and Menzies School of Health Research, and Central Australian Human Research Ethics Committee.

3. Results

Crude and adjusted odds ratios (OR) for the association of each of the selected perinatal and socio-demographic factors were estimated for the outcome of a child being assessed as developmentally vulnerable on one or more domains. The results were similar for complete-case and imputed analyses, so results using imputation are presented in all tables as they involve less restrictive assumptions than complete-case analysis. There were 1922 children available in the imputed analysis for Table 1 compared with 1783 (93%) children available for complete-case analysis. For other analyses, the availability of complete-cases ranged from 88% through to 99% of all cases used for imputed analyses. For comparison the OR estimates using complete-case analysis for the key results of Indigenous status are presented as notes to accompany Tables 1 and 3.

3.1. All children combined

The results for all children combined are presented in Table 1. The proportion of children who were assessed as being developmentally vulnerable on one or more domains was 49.2% for all children and 68.3% and 23.2% for Aboriginal and non-Aboriginal children respectively. Before adjustment for other variables, an Aboriginal child had a 6.93 times greater odds (95% CI: 5.62–8.56) of being assessed as developmentally vulnerable than a non-Aboriginal child. After adjustment for all other variables in the model, the crude result for Aboriginal children was substantially reduced (OR: 1.68, 95% CI: 1.21–2.32). Independent factors associated with developmental vulnerability in the combined model were; ESL children (OR: 3.11, 95% CI: 2.27–4.26); gestational age at birth of 34–36 weeks (OR: 2.08, 95% CI: 1.27–3.39); being a boy (OR: 2.25, 95% CI: 1.78–2.84) and living in a very remote area (OR: 1.68, 95% CI: 1.19–2.37). Birth order was also important, with evidence that second-born children (parity = 1) were at increased risk of vulnerability (OR: 1.43, 95% CI: 1.05–1.94) compared with first-born children. Some variables had a gradient effect; a child was increasingly likely to be developmentally vulnerable on one or more domains with increasing remoteness of residence and lower level of school education completion of the primary caregiver. There was no evidence for an association of the outcome with the variables of: attending a day school or pre-school program, Apgar score, birthweight above or below 2500 g, age of mother at birth, plurality, mother's consumption of alcohol nor mother's smoking status.

3.2. Separate analysis for Aboriginal and non-Aboriginal children

The analysis was next stratified by Indigenous status to test the association of the predictor variables with the outcome measure for developmental vulnerability in each population (Table 2). After adjustment for other variables, Aboriginal children who

Table 1
Crude and adjusted odds ratios for children assessed as developmentally vulnerable on one or more AEDC domains ($n = 1922$).

	Vulnerable/not vulnerable	Crude OR	Adjusted OR[a]
Indigenous status			
Non-Aboriginal child	188/624	Ref	Ref
Aboriginal child	758/352	^6.93 (5.62–8.56)***	^^1.68 (1.21–2.32)**
English as a second language			
No	242/733	Ref	Ref
Yes	704/243	8.37 (6.77–10.34)***	3.11 (2.27–4.26)***
Attended day care or pre-school program			
Yes	627/834	Ref	Ref
No	319/142	2.94 (2.31–3.75)***	1.35 (1.00–1.82)
Estimated gestational age of the baby in completed weeks			
<34	33/22	1.77 (1.01–3.08)*	1.79 (0.79–4.05)
34–36	106/52	2.32 (1.63–3.31)***	2.08 (1.27–3.39)**
>=37	807/902	Ref	Ref
Apgar 5 (numerical score to evaluate the baby's condition 5 min after birth)			
>=7	930/963	Ref	Ref
<7	16/13	1.27 (0.61–2.67)	1.18 (0.46–3.01)
Birthweight (grams)			
>=2500	833/897	Ref	Ref
<2500	113/79	1.58 (1.16–2.15)**	0.72 (0.44–1.19)
Sex			
Girl	406/555	Ref	Ref
Boy	540/421	1.74 (1.44–2.10)***	2.25 (1.78–2.84)***
Age of mother at the time of the birth (years)			
<18	120/39	3.67 (2.41–5.61)***	1.57 (0.90–2.72)
18–19	115/54	2.68 (1.83–3.92)***	1.45 (0.89–2.36)
20–24	276/210	1.69 (1.30–2.20)***	1.13 (0.80–1.58)
25–29	205/274	Ref	Ref
30–34	145/244	0.77 (0.59–1.02)	1.00 (0.72–1.40)
>=35	85/155	0.72 (0.52–0.99)*	0.98 (0.66–1.44)
Remoteness			
Outer regional area	223/550	Ref	Ref
Remote area	168/246	1.66 (1.28–2.15)***	1.10 (0.81–1.48)
Very remote area	555/180	6.98 (5.45–8.95)***	1.68 (1.19–2.37)**
Primary caregiver's school education level			
Year 9 or less	442/141	8.97 (6.51–12.36)***	2.16 (1.40–3.33)**
Year 10 or equivalent	252/218	3.36 (2.43–4.66)***	1.84 (1.22–2.79)**
Year 11 or equivalent	112/159	2.20 (1.56–3.09)***	1.37 (0.92–2.05)
Year 12 or over	140/458	Ref	Ref
Parity (number of previous births for the mother)			
0	296/363	Ref	Ref
1	234/287	1.05 (0.83–1.33)	1.43 (1.05–1.94)*
>1	416/326	1.62 (1.30–2.02)***	1.26 (0.92–1.74)
Plurality count (number of births from this pregnancy)			
1	931/965	Ref	Ref
2	15/11	1.42 (0.65–3.11)	1.96 (0.75–5.16)
Mother's alcohol consumption during pregnancy			
No	849/870	Ref	Ref
Yes	97/106	1.01 (0.74–1.37)	0.94 (0.64–1.38)
Mother's smoking status during pregnancy			
No	530/680	Ref	Ref
Yes	416/296	1.88 (1.53–2.31)***	1.17 (0.88–1.54)

Notes. Ref-reference group.
Complete-case analysis: ^OR: 6.61, 95% CI: 5.35–8.16 ^^OR:1.64, 95% CI:1.19–2.26.
[a] Adjusted for all other variables shown in the table.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

had not attended day care or pre-school were more likely to be developmentally vulnerable (OR: 1.43, 95% CI: 1.01–2.04), while the caregiver's level of education was no longer associated with child vulnerability. Among non-Aboriginal children, younger age of mother (OR 3.09, 95% CI 1.20–7.97, for mothers aged 18–19 years) and maternal smoking during pregnancy (OR: 1.95, 95% CI: 1.25–3.06) were associated with increased risk of vulnerability while living in remote areas was not.

3.3. All children combined for AEDC domains

The association between perinatal and socio-demographic characteristics and developmental vulnerability on each of the five

Table 2
Crude and adjusted odds ratios for children assessed as developmentally vulnerable on one or more AEDC domains, by Indigenous status.

	Aboriginal ($n = 1110$)			Non-Aboriginal ($n = 812$)		
	Vulnerable/not vulnerable	Crude OR	Adjusted OR[a]	Vulnerable/not vulnerable	Crude OR	Adjusted OR[a]
English as a second language						
No	88/145	Ref	Ref	154/588	Ref	Ref
Yes	670/207	4.98 (3.64–6.82)***	2.75 (1.82–4.14)***	34/36	3.65 (2.21–6.05)***	4.29 (2.45–7.53)***
Attended day care or pre-school program						
Yes	461/271	Ref	Ref	166/563	Ref	Ref
No	297/81	2.07 (1.50–2.86)***	1.43 (1.01–2.04)*	22/61	1.31 (0.77–2.25)	1.18 (0.66–2.13)
Estimated gestational age of the baby in completed weeks						
<34	26/10	1.41 (0.65–3.06)	1.77 (0.63–4.97)	7/12	2.03 (0.79–5.24)	1.08 (0.24–4.82)
34–36	92/30	1.56 (0.99–2.45)	1.98 (1.10–3.56)*	14/22	2.21 (1.11–4.42)*	2.56 (1.01–6.48)*
> = 37	640/312	Ref	Ref	167/590	Ref	Ref
Apgar 5 (numerical score to evaluate the baby's condition at 5 min after birth)						
> = 7	742/348	Ref	Ref	188/615		
<7	16/4	1.89 (0.62–5.70)	2.21 (0.63–7.78)	0/9		
Birthweight (grams)						
> = 2500	662/306	Ref	Ref	171/591	Ref	Ref
<2500	96/46	1.02 (0.69–1.50)	0.70 (0.40–1.23)	17/33	1.75 (0.95–3.23)	1.12 (0.37–3.38)
Sex						
Girl	341/217	Ref	Ref	65/338	Ref	Ref
Boy	417/135	1.93 (1.47–2.54)***	2.08 (1.52–2.84)***	123/286	2.21 (1.57–3.11)***	2.78 (1.91–4.06)***
Age of mother at the time of the birth (years)						
<18	116/33	1.69 (1.02–2.79)*	1.59 (0.81–3.10)	4/6	2.22 (0.61–8.15)	1.40 (0.34–5.77)
18–19	102/41	1.26 (0.79–2.03)	1.25 (0.69–2.26)	13/13	3.34 (1.46–7.60)**	3.09 (1.20–7.97)*
20–24	246/115	1.09 (0.75–1.58)	1.22 (0.77–1.92)	30/95	1.14 (0.68–1.89)	0.98 (0.55–1.73)
25–29	148/83	Ref	Ref	57/191	Ref	Ref
30–34	95/56	0.90 (0.58–1.39)	1.14 (0.69–1.87)	50/188	0.89 (0.58–1.37)	0.93 (0.59–1.49)
>=35	51/24	1.14 (0.65–2.01)	1.28 (0.67–2.43)	34/131	0.87 (0.54–1.40)	0.87 (0.52–1.48)
Remoteness						
Outer regional area	98/124	Ref	Ref	125/426	Ref	Ref
Remote area	119/89	1.70 (1.12–2.57)*	1.24 (0.77–2.00)	49/157	1.03 (0.70–1.51)	1.01 (0.66–1.55)
Very remote area	541/139	4.49 (3.12–6.45)***	2.00 (1.24–3.22)**	14/41	1.09 (0.57–2.10)	1.26 (0.62–2.59)
Primary caregiver's school education level						
Year 9 or less	425/108	3.71 (2.33–5.92)***	1.72 (0.95–3.11)	17/33	2.57 (1.27–5.23)**	1.52 (0.65–3.54)
Year 10 or equivalent	200/102	1.94 (1.13–3.35)*	1.43 (0.73–2.82)	52/116	2.30 (1.47–3.59)***	2.00 (1.19–3.36)**
Year 11 or equivalent	66/69	1.13 (0.65–1.95)	0.81 (0.44–1.52)	46/90	2.20 (1.38–3.51)**	1.97 (1.17–3.34)*
Year 12 or over	67/73	Ref	Ref	73/385	Ref	Ref
Parity (number of previous births for the mother)						
0	230/118	Ref	Ref	66/245	Ref	Ref
1	165/73	1.29 (0.89–1.87)	1.44 (0.91–2.27)	69/214	1.19 (0.81–1.74)	1.40 (0.91–2.16)
>1	363/161	1.25 (0.92–1.70)	1.28 (0.82–1.99)	53/165	1.19 (0.78–1.80)	1.19 (0.73–1.93)
Plurality count (number of births from this pregnancy)						
1	748/350	Ref	Ref	183/615	Ref	Ref
2	10/2	2.38 (0.52–10.92)	2.00 (0.37–10.93)	5/9	1.84 (0.61–5.56)	1.19 (0.28–5.01)
Mother's alcohol consumption during pregnancy						
No	680/305	Ref	Ref	169/565	Ref	Ref
Yes	78/47	0.80 (0.53–1.20)	0.93 (0.57–1.51)	19/59	1.17 (0.67–2.02)	1.04 (0.56–1.93)
Mother's smoking status during pregnancy						
No	402/165	Ref	Ref	128/515	Ref	Ref
Yes	356/187	0.85 (0.64–1.14)	0.91 (0.64–1.30)	60/109	2.18 (1.50–3.19)***	1.95 (1.25–3.06)**

Notes. Ref-reference group.
[a] Adjusted for all other variables shown in the table.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

AEDC domains is presented in Table 3. After adjustment for all other predictor variables in each of the five models, Aboriginal children were estimated as having increased risk of vulnerability, compared to non-Aboriginal children, across all domains. For Aboriginal children the greatest area of inequality, compared with non-Aboriginal children, was for the Language and Cognitive Development domain (OR: 2.32, 95% CI: 1.57–3.41). ESL children, compared with non-ESL children, showed higher risk of vulnerability in four of the five domains, with the exception of Social Competence. For children with ESL status, the highest OR was for the Language and Cognitive Development domain (OR: 3.01, 95% CI: 2.13–4.27). Boys, compared with girls, were assessed to have higher vulnerability in four domains with the exception being the Physical Health and Wellbeing domain. There was also evidence for the importance of birth order with third and subsequent children more vulnerable than first-born children in the Physical Health and Wellbeing domain (OR: 1.93, 95% CI: 1.36–2.74) and Language and Cognitive Skills domain (OR: 1.43, 95% CI: 1.01–2.03). Children were also at increased vulnerability in these same two domains if they had not attended day care or pre-school. Those children, whose

Table 3
Adjusted odds ratios[a] for children assessed as developmentally vulnerable on each of five AEDC domains ($n = 1922$).

	Physical health and well-being Adjusted OR	Social competence Adjusted OR	Emotional maturity Adjusted OR	Language and cognitive skills Adjusted OR	Communication and general skills Adjusted OR
Indigenous status					
Non-Aboriginal child	Ref	Ref	Ref	Ref	Ref
Aboriginal child	^1 1.71 (1.17–2.51)**	^2 1.97 (1.22–3.19)**	^3 1.67 (1.07-2.62)*	^4 2.32 (1.57–3.41)***	^5 2.09 (1.20-3.62)**
English as a second language					
No	Ref	Ref	Ref	Ref	Ref
Yes	2.68 (1.87–3.83)***	1.26 (0.79–2.00)	2.07 (1.36–3.17)**	3.01 (2.13–4.27)***	2.14 (1.30–3.52)**
Attended day care or pre-school program					
Yes	Ref	Ref	Ref	Ref	Ref
No	1.78 (1.31–2.43)***	0.94 (0.64–1.37)	1.37 (1.00–1.89)	1.56 (1.16–2.10)**	0.67 (0.48–0.94)*
Estimated gestational age of the baby in completed weeks					
<34	1.23 (0.57–2.67)	2.05 (0.87–4.86)	1.25 (0.53–2.93)	1.51 (0.69–3.31)	2.82 (1.24–6.42)*
34–36	1.20 (0.77–1.89)	0.76 (0.42–1.40)	1.05 (0.63–1.75)	1.16(0.72–1.88)	1.17 (0.69–1.98)
> = 37	Ref	Ref	Ref	Ref	Ref
Apgar 5 (numerical score to evaluate the baby's condition at 5 min after birth)					
> = 7	Ref	Ref	Ref	Ref	Ref
<7	1.18 (0.47–2.97)	0.32 (0.07–1.44)	0.75 (0.26–2.13)	1.32 (0.52–3.35)	0.77 (0.24–2.46)
Birthweight (grams)					
> = 2500	Ref	Ref	Ref	Ref	Ref
<2500	1.28 (0.80–2.03)	1.43 (0.79–2.59)	1.27 (0.74–2.19)	1.16 (0.72–1.88)	1.38 (0.79–2.41)
Sex					
Girl	Ref	Ref	Ref	Ref	Ref
Boy	1.25 (0.97–1.60)	1.93 (1.41–2.64)***	2.45 (1.86–3.24)***	2.00 (1.57–2.53)***	2.30 (1.71–3.10)***
Age of mother at the time of the birth (years)					
<18	1.55 (0.93–2.58)	1.78 (0.93–3.41)	1.09 (0.61–1.97)	1.29 (0.76–2.20)	0.98 (0.52–1.83)
18–19	1.13 (0.70–1.82)	1.38 (0.77–2.48)	1.21 (0.68–2.14)	1.90 (1.17–3.07)**	1.18 (0.66–2.08)
20–24	0.89 (0.63–1.26)	1.17 (0.72–1.89)	1.29 (0.86–1.92)	1.06 (0.75–1.51)	1.06 (0.69–1.64)
25–29	Ref	Ref	Ref	Ref	Ref
30–34	0.82 (0.57–1.19)	1.37 (0.86–2.19)	1.09 (0.70–1.70)	0.86 (0.59–1.26)	1.02 (0.62–1.68)
>=35	0.56 (0.35–0.89)*	1.02 (0.57–1.82)	1.15 (0.69–1.93)	1.11 (0.71–1.74)	1.21 (0.68–2.14)
Remoteness					
Outer regional area	Ref	Ref	Ref	Ref	Ref
Remote area	1.17 (0.82–1.66)	0.82 (0.52–1.30)	0.78 (0.51–1.19)	1.21 (0.84–1.72)	0.82 (0.50–1.37)
Very remote area	0.82 (0.56–1.22)	1.08 (0.68–1.70)	1.53 (0.98–2.39)	1.37 (0.93–2.04)	0.99 (0.61–1.63)
Primary caregiver's school education level					
Year 9 or less	2.93 (1.85–4.66)***	1.20 (0.64–2.25)	1.14 (0.61–2.17)	1.92 (1.07–3.46)*	3.25 (1.68–6.29)**
Year 10 or equivalent	1.95 (1.25–3.03)**	1.42 (0.77–2.61)	1.53 (0.87–2.69)	2.31 (1.43–3.75)**	2.75 (1.42–5.32)**
Year 11 or equivalent	1.49 (0.88–2.50)	0.75 (0.36–1.54)	1.11 (0.56–2.19)	1.43 (0.83–2.46)	0.98 (0.42–2.30)
Year 12 or over	Ref	Ref	Ref	Ref	Ref
Parity (number of previous births for the mother)					
0	Ref	Ref	Ref	Ref	Ref
1	1.38 (0.98–1.95)	1.06 (0.69–1.63)	0.83 (0.57–1.21)	1.39 (0.99–1.95)	1.20 (0.79–1.83)
>1	1.93 (1.36–2.74)***	1.22 (0.79–1.88)	1.08 (0.72–1.61)	1.43 (1.01–2.03)*	1.07 (0.69–1.67)
Plurality count (number of births from this pregnancy)					
1	Ref	Ref	Ref	Ref	Ref
2	0.35 (0.10–1.21)	0.20 (0.03–1.58)	0.97 (0.30–3.16)	1.65 (0.59–4.58)	1.13 (0.35–3.63)
Mother's alcohol consumption during pregnancy					
No	Ref	Ref	Ref	Ref	Ref
Yes	0.96 (0.63–1.45)	0.67 (0.38–1.20)	1.07 (0.66–1.73)	1.05 (0.68–1.64)	1.24 (0.76–2.03)
Mother's smoking status during pregnancy					
No	Ref	Ref	Ref	Ref	Ref
Yes	1.41 (1.07–1.85)*	1.25 (0.88–1.80)	0.69 (0.50–0.94)*	0.87 (0.66–1.16)	1.05 (0.74–1.49)

Note. Ref-reference group.
Complete-case analysis: ^1OR: 1.71, 95% CI:1.17–2.49 ^2OR:1.97, 95% CI:1.21–3.20 ^3OR:1.63, 95% CI:1.03–2.56 ^4OR:2.25, 95% CI:1.54–3.29 ^5OR:2.05, 95% CI:1.19–3.53.
[a] Adjusted for all other variables shown in the table.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

primary caregiver's highest education level was Year 10 or less (compared with Year 12 and over), showed higher vulnerability in three domains with the exceptions being Social Competence and Emotional Maturity.

4. Discussion

This study explored the association between perinatal and socio-demographic risk factors and early childhood development as measured by the Australian Early Development Census (AEDC) and is important as the first Australian paper to report the association of these factors for both Aboriginal and non-Aboriginal

Australian children. The findings estimated that half of the NT children (49.2%) in this study had levels of developmental vulnerability such that, without additional learning and language support, they were likely to experience major difficulties in their transition to formal school learning. This result highlights the substantial gap for Aboriginal children who, before adjustment for other factors, were almost seven times more likely to be assessed as developmentally vulnerable than non-Aboriginal children on this teacher-rated measure.

4.1. Factors associated with developmental vulnerability

Across the study cohort, the results identified early life factors associated with increased vulnerability in early childhood development. The association of children's ESL status was particularly notable, independently of other perinatal and socio-demographic factors. Interestingly, this vulnerability was apparent across four of the five AEDC domains—Physical Health and Wellbeing, Emotional Maturity, Language and Cognitive Skills (school-based), Communication Skills and General Knowledge, and is a finding that is consistent with a similar study conducted in Ireland (Curtin et al., 2013). The implication of this finding is the need for better recognition that ESL children need additional and early support in order to engage fully in their school education transition. Among the demographic characteristics examined, boys were assessed as 2.3 times more likely to be developmentally vulnerable than girls, which has also been shown in many other studies assessing gender differences in the school achievement, social and behavioral outcomes of young children (Curtin et al., 2013; Janus & Duku, 2007; Lawlor et al., 2005; Resnick et al., 1999; Ribeiro et al., 2011). Consistent with previous studies on birth order and educational outcomes (Fergusson, Horwood, & Boden, 2006; Malacova et al., 2009) the results in several analyses in this study suggest that second or later born children may be more vulnerable at school entry than first born children.

The analyses also underscored the clear gradient in the association between primary caregiver education level and children's developmental vulnerability, a result which is consistent with a recent study in the same population that reported the association between primary caregiver education level and school academic performance in year 3 at age eight (Guthridge et al., 2015). Other studies have also reported that parents who were at school longer tend to have children who perform better at school (Dickson et al., 2013; Harrison & McLeod, 2010; Hillemeier et al., 2011). A recent review of the evidence on the definition of school readiness in an Australian Aboriginal context found that low levels of parental education are widely recognized as a risk factor in early child development and emphasized the benefit of a mothers' completion of high school (McTurk et al., 2008). Parents with higher education attainment may have greater interest and engagement in their child's education and higher expectations for their children (Davis-Kean, 2005).

Factors related to perinatal health were also associated with increased risk, with results consistent with the "biological vulnerability" described in a Canadian study (Santos, Brownell, Ekuma, Mayer, & Soodeen, 2012). Children who were born preterm were more likely to be vulnerable in early childhood development at age five than children born full term. The adverse consequences of preterm birth for child development are well documented. Children born prematurely have been found in a large number of studies to have lower average scores on IQ and other measures of cognitive functioning than those born at term and our results are consistent with these findings (Chyi, Lee, Hintz, Gould, & Sutcliffe, 2008; Harrison and McLeod, 2010; Hillemeier et al., 2011; Quigley et al., 2012; Talge et al., 2010; Weindrich, Laucht, & Schmidt, 2003). A meta-analysis indicated that children who were born preterm were at significant risk for reduced cognitive performance at school age and that gestational age was directly related to their mean cognitive test scores (Bhutta, Cleves, Casey, Cradock, & Anand, 2002). Also consistent with previous studies (Janus and Duku, 2007; Juárez & Merlo, 2013; McTurk et al., 2008; Reichman, 2005), maternal smoking during pregnancy contributed to the level of vulnerability in early childhood development, particularly in non-Aboriginal NT children.

Of relevance to the NT child rearing circumstance was the finding that Aboriginal children who had not attended day care or pre-school program were more likely to be vulnerable in early childhood development. This finding is consistent with reports indicating that children at risk of poor developmental and educational outcomes benefit from attending high-quality education and care programs in the years before school (Barnett, 2011; Campbell et al., 2012; Duncan and Te One, 2012). It also supports the potential benefit of recent Australian governments' investments providing Aboriginal children in remote communities aged 3–4 years having access to preschool for up to 15 h per week (Council of Australian Governments, 2009).

Of particular importance in this study is the recognition that together these factors mediate the strength of the developmental vulnerability associated with Indigenous status which, after adjustment for all other factors, was reduced from a seven-fold to less than two-fold greater risk. International studies have reported similar findings, for example in the United Stated the differences in math and reading assessments for black and white children in kindergarten, the "black-white test score gap", disappeared after adjustment for a range of health and socio-demographic domains (Fryer and Levitt, 2004). Similarly in Canada, the population level variation in EDI results was substantially moderated by adjustment for a range of socioeconomic, demographic and family factors (Janus and Duku, 2007). The results highlight that the poor outcomes for developmental vulnerability reported for Aboriginal children in the NT are substantially explained by potentially modifiable risk factors that are shared with disadvantaged children in the wider population. The inclusion of other factors not available for this study such as community-level influences or more direct measurement of some of the available factors may have further reduced this remaining difference.

4.2. Informing interventions

Estimates of population-level risk are important for targeting the most cost-effective methods for reducing vulnerability in early childhood development (Hart et al., 2003). The risk estimates can be used to inform the development of services for the early identification and intervention for vulnerable children. These risk factors include both those that are amenable to intervention in the short term (e.g., ensuring that schools provide the language and education supports appropriate to their students' developmental and learning needs) and the broader challenge presented by the extreme levels of inequity in the socio-economic environment and the health status of children in the Northern Territory. Targeting services based on the risk factors associated with the largest population-level risks will, if effective, have the greatest impact on reducing the rate of vulnerability in early childhood development and represent the most efficient use of resources (Robinson, Silburn, & Arney, 2011a, [Robinson et al., 2011b]2011b). Importantly, the availability of linked individual information along the pathway of a child's development reinforces the importance of developing a cohesive package of responses that cross the sector boundaries between health, early childhood and education services.

4.3. Strengths and limitations

Major strengths of this study are the substantial number of Aboriginal children in the study cohort and the whole-population availability of AEDC results. The availability of population-level assessments of early development is in contrast to direct measures of the cognitive capacities of individual children which are used to identify children who may benefit from targeted support. Other strengths include the population-based cohort design and availability of both perinatal and socio-demographic factors. Data linkage has many benefits. The administrative data are population-based, thereby minimizing possible selection bias and can provide detailed information on past events, such as births, avoiding the risk of recall bias associated with parent responses. Data linkage also provides substantial saving in both time and money compared with prospective longitudinal studies as a new means of evaluating the longer-term outcomes and impacts of evidence-informed investments.

There is a range of limitations in our study. The first limitation was that linkage was only possible for children who were born and later attended government schools in the NT. There was a substantial proportion of the NT birth cohort who were unavailable for linkage as the result of interstate migration of families before a child commenced school and the unavailability of non-government schools data. This resulted in the study cohort having a larger proportion of Aboriginal children and children for whom English was a second language than all children undertaking the AEDC. These factors were included in the adjusted models. A second limitation was that the information for the study was based on reports collated in administrative datasets and not by rigorously collected or measured data and may therefore be subject to reporter bias. As an example information on smoking during pregnancy was self-reported by the mothers which, given the social acceptability and well-recognized health risks, may have resulted in underreporting of the true smoking behaviors and underestimation of the effects of fetal nicotine exposure. A further limitation is that in our study we did not have a direct measure of income, but were limited to the proxy measure of the education level of primary caregiver. It is plausible that the inclusion of income, as a more direct measure of social disadvantage, may have further reduced the association of Indigenous status with AEDC result.

A final limitation is whether the AEDC accommodates differences in language and learning styles for cross cultural settings (Li, D'Angiulli, & Kendall, 2007; McCormack & Verdon, 2015). This concern extends to the capacity for class-room teachers, who are most commonly mono-lingual English speakers, to assess non-English speaking children. These questions have particular relevance to Aboriginal communities in the Northern Territory in which the first language of many children is a traditional Aboriginal language and many of whom will have had limited exposure to English before starting school (Simpson and Wigglesworth, 2008). Learning styles are also important. As an example, for Aboriginal communities the traditional learning style is informal and non-verbal and many young children may not be exposed to the westernized teaching routine of questions and answers until starting school (Simpson and Wigglesworth, 2008). To ensure cross cultural appropriateness, there has been substantial investment to adapt and validate the AEDC (Janus, Hertzman, Guhn, Brinkman, & Goldfeld, 2009). These adaptations have been detailed earlier in this paper and include modifications of questions and the inclusion of an Aboriginal "cultural consultant" to assist the class room teacher in their assessment of children. While AEDC assesses "school readiness", which is largely a westernized construct, the AEDC is nevertheless of relevance for all children in a high income country like Australia because of its meaning for future education success, and subsequent access to employment, income and health enhancing resources.

5. Conclusion

Within the population of NT children, the study findings demonstrate that early childhood development, as measured by the AEDC, varies substantially in relation to socio-demographic and perinatal factors. The differing occurrence and varying combinations of these factors within the Aboriginal and non-Aboriginal child populations accounts for much of the disparity in the developmental vulnerability of Aboriginal children. Our findings showing the extent to which early life health and socio-demographic factors are associated with children's developmental outcomes at age 5 years are of particular relevance to policy and service initiatives to improve the school education outcomes of Aboriginal children. Importantly, the preventive strategies needed to address these risks cross service sector boundaries and indicate the necessity for collaboration across health, early childhood and education services to implement strategies which optimize the developmental opportunities of children in their most formative years.

Conflict of interest

The authors declare no conflict of interest.

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