Neighbourhood socioeconomic status and maternal factors at birth as moderators of the association between birth characteristics and school attainment: A population study of children attending government schools in Western Australia

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Neighbourhood socioeconomic status and maternal factors at birth as moderators of the association between birth characteristics and school attainment: A population study of children attending government schools in Western Australia

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Abbreviations

POBW, Percentage of optimal birth weight; POBL, Percentage of optimal birth length; POHC, Percentage of optimal head circumference; SEIFA, Socioeconomic Indexes for Areas; SD, Standard deviation.

Abstract

Background: This article investigates whether reading and writing skills among children of equivalent perinatal characteristics differ by neighbourhood socioeconomic status and maternal factors.
Methods: Notifications of births for all non-Aboriginal singletons born in 1990-1997 in Western Australia subsequently attending government primary schools were linked to the State literacy tests in grade three and with information on socioeconomic status of the school and the residential area. Using multilevel modelling, the associations between birth characteristics (gestational age, intrauterine growth, birth order and Apgar score at 5 minutes) and literacy attainment in grade three were examined in models that included socioeconomic and demographic factors of the child, mother and community.
Results: Higher percentages of optimal head circumference and birth length and term birth were positively and independently associated with literacy scores. A higher percentage of optimal birth weight was associated with higher reading scores especially for children born to mothers residing in educationally advantaged areas. First birth was positively associated with reading and writing attainment: this association was stronger for children born to single mothers and additional advantage in writing was also associated with first birth in children living in disadvantaged areas.
Conclusions: These findings suggest that having sub-optimal growth *in utero* or an older sibling at birth increases vulnerability to poor literacy attainment especially among children born to single mothers or those in disadvantaged neighbourhoods. These data provide evidence for advocating lifestyles compatible with optimum fetal growth and socioeconomic conditions conducive to healthy lifestyles, particularly during pregnancy.

Keywords: appropriateness of intrauterine growth; birth outcomes; socioeconomic factors; literacy; Western Australia;

Introduction

Research including a systematic review over the whole range of birth weight has consistently shown that perinatal characteristics are associated with neurodevelopmental, cognitive and educational outcomes, particularly in infants who were extremely premature and low birth weight.[1-15] Yet, previous studies of low birth weight infants seldom differentiate between infants with low birth weight due to early delivery and those with restricted intrauterine growth.[12-14] Studies also rarely estimate the extent to which non-biological risk factors, such as maternal socio-demographic factors and the social environment at birth, modify the relationship between perinatal characteristics and neurocognitive development.[4,9,15]

Educational outcomes, mental health and intellectual disability represent different aspects of neurocognitive development. Recently, three measures of intrauterine growth adjusted for gestational duration, infant sex, maternal height and parity have been developed,[16] and have been shown to be associated with mental health outcomes and intellectual disability.[1] We have recently used these measures for the first time to examine the association of perinatal characteristics with numeracy outcomes and how this association varied across different socioeconomic and demographic groups of children.[9] We found that neighbourhood socioeconomic status at birth modified the connection between perinatal characteristics (intrauterine growth in terms of birth weight, birth length, first birth and Apgar scores) and numeracy attainment in children. It is now accepted that boys perform better in numeracy and girls do so in literacy. It is possible that social environmental factors and birth outcomes as well as their interactions may also have a differential impact on literacy and numeracy.

In the present study we have analysed total population-based linked data of non-Aboriginal singleton children at age eight attending government schools in Western Australia to determine the associations of perinatal characteristics with literacy outcomes (reading and writing skills) and whether literacy achievement among children of equivalent perinatal characteristics differed by children's neighbourhood socioeconomic status and maternal factors. As this was a total population-based study and children were not selected by birth weight or gestational age, bias due to missing data is minimal and the results are generaliseable to all non-Aboriginal single born children later attending government schools in Western Australia.

Methods

Sources of data

Data from three existing statutory state-wide databases were linked by the Western Australian Data Linkage System.[17] The Midwives' Notification System contains records of all non-Aboriginal singleton live births in Western Australia attended by a midwife between 1990 and 1997 (Midwives data contain 99.5 % of

all births which were of 20 weeks gestation or >400g).[18] The Western Australian Literacy Assessment program is a curriculum-based test administered annually to all children in grade three in Western Australia. It is used by the Australian government for national monitoring and reporting on children's progress in literacy skills across Australia. This literacy dataset, which has been obtained from the Western Australian Department of Education and Training,[19,20] contains individual Rasch-transformed test scores for reading and writing for the period of 2000-2005, which are comparable over time within the same school subject (reading or writing).

In the final analyses, however, records for year 2001 were removed because the 2001 test results unexpectedly differed from other years for reasons which were unknown and not able to ascertain. In addition, writing scores were unavailable for that year at the time of this analysis. The Australian census data included neighbourhood socioeconomic characteristics expressed as Socioeconomic Indices for Areas (SEIFA).[21,22]

Subjects

Of 96,653 non-Aboriginal children in Western Australia who had been born between 1990 and 1997 and subsequently attended Western Australian government schools during 2000-2005, 77,950 had a school record for grade three (Figure 1). We excluded multiples and the 7,948 children with missing predictor variables, of which the majority was missing due to neighbourhood socioeconomic status, and 12,704 children who had a grade three record in year 2001, a year for which it was not possible to obtain writing scores at the time of data extraction and in which mean reading scores displayed considerable differences compared to other years. After excluding those with missing outcome data (n=1,766 for reading and n=2,058 for writing attainment), the final dataset contained 55,533 students in 596 schools who had reading and 55,240 students in 594 schools who had writing scores.

Measures

Outcome measures

The reading and writing tasks assessed children's ability to effectively read and write in everyday life and were measured in two literacy test scores. The reading test consisted of multiple-choice, short- and open-response questions, whereas the writing test required writing a short story, fable or an anecdote.

Predictors at the student and school levels

Preterm birth was defined as a gestational age of less than 37 completed weeks. Appropriateness of intrauterine growth was assessed by calculating the percentage of optimal birth weight (POBW), percentage of optimal birth length (POBL) and percentage of optimal head circumference (POHC) achieved by each neonate. The optimum value for each measure for a given gestational duration, gender, maternal height, parity and age is estimated from models derived from Western Australian neonatal survivors unaffected by the most

frequently occurring pathological determinants of intrauterine growth in the Western Australian population.[16]

Apgar scores of less than 8 at five minutes were defined as low. Birth order was categorised as having none, one, two or three, or four or more surviving older siblings. Maternal age was grouped as <20 years, 20-24 years, 25-29 years, 30-34 years, and >34 years. Mother's marital status was classified as single (never married, widowed, divorced and separated) and married (including *de facto* relationships).

Socioeconomic and educational disadvantage of the child's residential area at birth was measured using the Indices of Relative Socioeconomic Disadvantage and of Education and Occupation (SEIFA) from the Australian Bureau of Statistics.[21,22] The indices attributed to each birth at the census collection district level were derived from the census data for 1991 or 1996 whichever is the closest to a child's birth year. In this study, SEIFA values were divided into six quantiles, with the first quantile (lowest 10%) being the most disadvantaged.

Additional variables

We adjusted for the year in which the reading and writing tests were taken and for child language background, which was self reported at the time of testing, indicating English or non-English language background at home. We also adjusted for child gender, age and mother's ethnicity (Caucasian or non-Caucasian, with non-Caucasian mothers being predominantly of Asian origin). School socioeconomic scores were obtained from the 2001 Australian Census data at the collection district level, where families whose children attended the school lived. These scores were created by combining five socioeconomic indicators using principal component analysis and included dimensions of parental education, occupation, Aboriginality, single parent family, and family income, with the first three dimensions being double weighted (based on an unofficial document by the Western Australia Department of Education and Training).

Statistical analysis

The associations between literacy scores and maternal, sociodemographic and infant factors at birth and their interactions were analysed using a two-level model, with a lower level ascribed to students and a higher one to schools.[23] Only variables that significantly ($p<=0.05$) predicted literacy score were retained for testing interactions, and these included: POBW, POBL, POHC, Apgar score, first birth and term birth with marital status ("single"), teenage pregnancy, SEIFA Educational disadvantage (<10%) and, in the case of writing attainment, with SEIFA Disadvantage (<10%).

Results

The average age of students at testing was 8.2 years and the reading scores

ranged from -90 to 632, with a mean of 280 (SD=83), while the writing scores varied from -97 to 665, with a mean of 267 (SD=97). Negative values were due to adjustments of test scores to ensure comparability over time. The means of POBW, POBL, POHC and school socioeconomic status were 98.3% (SD=12.2), 100.5% (SD=4.3), 100.6% (SD=3.9) and 101.4% (SD=7.9), respectively. In order to improve the model fit, we included a squared term for POBW and squared and cubic terms for child age in models predicting both reading and writing scores.

In univariate analysis, higher mean scores in both reading and writing were obtained by female students and children born at term, those with Apgar score 8-10, being first birth, or born to mothers who were aged over 20 years old, married and from non-Caucasian backgrounds. Non-English speaking children had higher mean writing but lower mean reading scores (Table 1). The mean of reading and writing scores was also significantly associated with both SEIFA Indices.

Table 1. Mean reading and writing scores, standard deviations and p-values for difference for all categorical variables in non-Aboriginal singletons born in Western Australia who undertook the Western Australian Literacy test in 2000, 2002-2005

Variable	Reading				Writing			
	N	Mean	SD*	p value†	N	Mean	SD	p value
Gender								
Girl	26,898	304	77		26,696	281	94	
Boy	28,635	289	79	<0.001	28,544	242	99	<0.001
Gestational age (weeks)								
Preterm (<37)	2,660	289	79		2,645	246	103	
Term birth (37+)	52,873	297	78	<0.001	52,595	262	99	<0.001
Apgar score at 5 minutes								
<8 (lower)	1,675	288	79		1,665	243	104	
8-10 (higher)	53,858	297	78	<0.001	53,575	261	99	<0.001
Birth order								
First born	22,546	305	79		22,439	267	99	
Second born	19,241	296	77		19,160	264	97	
Third or fourth born	12,389	285	77		12,296	248	99	
Fifth born or more	1,357	262	77	<0.001†	1,345	224	104	<0.001
Mother's age (years)								
<20	2,425	268	75		2,418	218	100	
20-24	10,574	279	76		10,560	240	98	
25-29	18,119	294	77		18,026	260	98	
30-34	16,617	308	78		16,503	273	97	
35+	7,798	312	79	<0.001	7,733	278	96	<0.001
Mother's marital status								
Married/de facto	49,661	299	78		49,362	264	98	
Single/other	5,872	277	78	<0.001	5,878	232	100	<0.001
Mother's ethnicity								
Caucasian	51,715	296	79		51,435	259	99	
Non-Caucasian	3,818	303	76	<0.001	3,805	281	100	<0.001
Language background								
Non-English	5,061	293	74		5,030	265	97	
English	50,472	297	79	<0.001	50,210	260	99	<0.001

SEIFA* – Index of Relative socio-economic disadvantage (quantiles)

<10%	(lowest)	5,409	271	78		5,372	229	101	
10-25%	(low)	9,167	283	78		9,135	245	100	
25-50%	(low middle)	15,511	291	77		15,438	255	98	
50-75%	(high middle)	13,881	301	76		13,819	268	96	
75-90%	(high)	7,473	314	77		7,406	282	95	
>90%	(highest)	4,092	332	74	<0.001	4,070	298	91	<0.001
SEIFA* – Index of Education and occupation (quantiles)									
<10%	(lowest)	6,350	269	77		6,297	228	102	
10-25%	(low)	10,102	281	77		10,081	245	99	
25-50%	(low middle)	14,336	291	76		14,251	255	98	
50-75%	(high middle)	14,524	303	76		14,462	270	95	
75-90%	(high)	6,855	320	76		6,801	287	93	
>90%	(highest)	3,366	342	75	<0.001	3,348	303	91	<0.001
Total		55,533				55,240			

* SEIFA, Socioeconomic Indexes for Areas; SD, Standard deviation.
† Analysis of Variance (ANOVA) for linear trend across categories or t-test for difference (when only 2 categories).

In multilevel multivariate analysis, children born with a gestational age of 37 weeks or more had higher scores in both reading and writing compared to children born preterm (Table 2), irrespective of their neighbourhood socioeconomic background. Similarly, POHC and POBL were positively associated with literacy attainment, independently of socioeconomic and demographic factors. In contrast, the association between POBW and reading and writing attainments varied by the educational status of the residential area. While POBW was positively associated with reading attainment among children born to mothers residing in both educationally privileged (>10% SEIFA) and deprived (<10% SEIFA) areas, the association was much weaker for children born into educationally deprived areas (Figure 2). In the latter, increases in POBW were associated with only limited improvement in reading scores. The negative squared term suggested that POBW had a curvilinear association with literacy attainment and that increases beyond two SDs above (and below) the optimal birth weight were associated with a sharp decrease in literacy scores (Table 2). However, such increases beyond two SDs applied to very few children (3%), which perhaps explain why the squared term did not reach statistical significance in the interaction model.

Table 2. Mutually adjusted parameter estimates (and 95% Confidence Intervals) from the fixed and random parts of multilevel multivariable analysis of reading and writing achievement among non-Aboriginal singletons born in Western Australia who undertook the Western Australian Literacy test in 2000, 2002-2005*

Variable	Reading		Writing	
	β*	95% CI*	β	95% CI
Fixed effects				
Intercept	292	286, 297	227	220, 234
Gestational age (weeks) (vs Preterm)				
Term birth (37+)	4.20	1.39, 7.03	9.07	5.54, 12.6
Percentage of optimal birth weight (POBW)				
POBW (centred)†	0.24	0.16, 0.31	0.24	0.15, 0.32
POBW(centred)^{squared}	-0.008	-0.010, -0.005	-0.009	-0.012, -0.006

Percentage of optimal birth length (POBL)				
POBL (centred)	0.35	0.17, 0.52	0.51	0.30, 0.73
Percentage of optimal head circumference (POHC)				
POHC (centred)	0.46	0.27, 0.64	0.37	0.14, 0.60
Apgar score (vs lower)				
Higher Apgar score (8-10)	4.74	1.24, 8.24	9.87	5.50, 14.2
Birth Order (vs second born)				
First	15.1	13.6, 16.5	10.6	8.74, 12.5
Third or fourth	-11.9	-13.5, -10.2	-15.9	-17.9, -13.8
Fifth or more	-30.0	-34.1, -26.0	-34.7	-39.7, -29.6
Mother's marital status (vs married)				
Single/other	-13.0	-16.3, -9.68	-19.7	-23.9, -15.6
Mother's age (years) (vs 25-29)				
<20	-22.5	-25.8, -19.3	-32.1	-36.2, -28.0
20-24	-11.3	-13.1, -9.54	-13.7	-15.9, -11.4
30-34	10.3	8.79, 11.9	9.20,	7.26, 11.1
35+	15.2	13.2, 17.2	14.8	12.2, 17.3
SEIFA* – Index of Relative socioeconomic disadvantage (quantiles) (vs SEIFA>10%)				
<10% (lowest)	-	-	-6.54	-10.6, -2.52
SEIFA – Index of Education and occupation (quantiles) (vs highest)				
<10% (lowest)	-23.8	-27.5, -20.2	-22.7	-27.7, -17.6
10-25% (low)	-17.9	-21.3, -14.4	-16.7	-21.0, -12.4
25-50% (low middle)	-13.9	-17.2, -10.6	-13.3	-17.4, -9.16
50-75% (high middle)	-11.0	-14.2, -7.82	-8.42	-12.4, -4.42
75-90% (high)	-6.80	-10.1, -3.54	-4.61	-8.69, -5.29
School socioeconomic status				
School socioeconomic status (centred)	1.93	1.17, 2.15	2.17	1.86, 2.49
Academic Year (vs 2000)				
2002	-	-	15.4	13.1, 17.6
2003	-	-	9.72	7.48, 12.0
2004	-	-	10.6	8.29, 12.8
2005	-	-	6.93	4.15, 9.71
Gender (vs boy)				
Girl	14.6	13.4, 15.8	38.0	36.5, 39.4
Child age (months)				
Age (centred)	1.97	1.75, 2.19	2.54	2.26, 2.82
Age (centred)^{squared}	-0.15	-0.19, -0.11	-0.20	-0.25, -0.15
Age (centred)^{cubic}	-0.021	-0.025, -0.017	-0.029	-0.034, -0.023
Language background (vs English)				
Non-English	-9.28	-11.7, -6.90	-6.60	-9.59, -3.60
Mother's ethnicity (vs Caucasian)				
Non-Caucasian	7.90	5.20, 10.6	21.3	17.9, 24.7
Interactions				
POBW x SEIFA Education (<10%)	-0.20	-0.35, 0.50	-	-
First born x Single mothers	5.64	1.49, 9.79	9.21	4.02, 14.4
First born x SEIFA Disadvantage (<10%)	-	-	5.59	0.40, 10.8
Random effects				
Remaining variance between schools	325	277, 374	742	637, 847
Remaining variance between students	5056	4996, 5116	7832	7739, 7925

* β, parameter estimate; CI, confidence interval; SEIFA, Socioeconomic Indexes for Areas; All results were significant at the 5% confidence level.
† These variables were centred around their mean value.

There was a positive association between Apgar scores and literacy attainment, independent of maternal and area sociodemographic characteristics (Table 2). Birth order was strongly and negatively associated with literacy attainment, but its effect varied with mothers' marital status. Being first born was more positively associated with literacy attainment in children born to single mothers (Figure 3), narrowing the deficit in attainment of these children. The same positive association between being first born and writing attainment was also observed for children born to mothers residing in disadvantaged areas.

Discussion

We found a significant positive association between the literacy skills of children in grade three and both gestational age and head growth, independent of neighbourhood socioeconomic status. This was consistent with our previous study that examined numeracy outcomes using the same record-linked population data for Western Australian children.[9] This is also in agreement with two meta-analyses of studies that examined the association between preterm birth and later cognitive outcomes, [4,8] and with reports of the association between head circumference at birth and subsequent IQ and reasoning skills.[24,25] Our results also show that skeletal growth is associated with improved literacy skills, irrespective of maternal socio-demographic characteristics and neighbourhood socioeconomic status. Thus a greater length of gestation and appropriate growth *in utero* appear to be beneficial for all children regardless of their place of residence and maternal socio-demographic characteristics. However, some children do not reach optimum birth outcomes due to pathological and physiological factors. Smoking tobacco during pregnancy is the most easily preventable risk factor of adverse birth outcomes,[26] which influences, for example, infants' length of gestation via immunological and fetal infection pathways.[27] Data from a recent national survey indicate that smoking and drinking among 14-49 year-old women continues to be widespread across Australia, with about 1 in 6 women smoking daily.[28] Unfortunately, the population-based administrative data used for our analyses have no information on maternal smoking in pregnancy (before 1999). Hence we were unable to investigate the extent to which this known risk factor for poor birth outcomes and low school achievement played a role in the associations that we found. It will be possible to investigate the role of smoking in future cohorts using these linked data, when those born after 1999 enter school.

Literacy attainment was not linearly associated with increase in birth weight, with values beyond two SDs (above or below the optimal growth) being increasingly negatively associated with both reading and writing skills. This is similar to our previous findings for numeracy outcomes [9] and another study reporting an association between high birth weight and more adverse neurocognitive outcomes in the long term.[1] Not all pathological determinants of intrauterine growth decrease fetal body mass. Maternal impaired glucose tolerance can expose the fetus to high levels of insulin, increasing the tendency to fat

deposition without a similar increase in skeletal growth. The prevalence of maternal obesity and its attendant tendencies to glucose intolerance and type II diabetes [29] has increased markedly since the 1960s, particularly in socioeconomically disadvantaged communities.[30] The curvilinear association with POBW (but not POBL or POHC) and the reduced association between POBW and literacy skills in disadvantaged areas suggests that the causes of increased birth weight may vary with neighbourhood socioeconomic status. In births to mothers living in socioeconomically advantaged areas, increased birth weight may be more likely to be associated with increased skeletal growth, while in socioeconomically disadvantaged areas it is more likely to be associated with excess adipose deposition. It is well-established that parental socioeconomic status, such as education, occupation and income, is strongly associated with offspring's educational attainment. What is much less well understood is how the socioeconomic status of a neighbourhood or a residential area influences children's educational achievement. Due to the lack of information about socioeconomic status at the individual or familial level (maternal and paternal), we were unable to investigate if our results would still hold once parental educational level was controlled for in the analysis. Previous studies have revealed that both the socioeconomic status of family and of neighbourhood have a distinct influence on cognitive outcomes. However, the relative contribution of each factor remains unresolved. While some studies have shown that the estimated neighbourhood effects tend to be generally smaller in comparison to maternal or paternal influences,[31] others have reported that the neighbourhood effect is the most influential with respect to changes in intelligence quotient.[32] Our results are not directly comparable to studies reporting association of birth weight alone and educational outcomes,[7,33] as birth weight is dependent on both appropriate growth *in utero* and gestation length and aetiologies and outcomes differ between those born too small and those born too soon.[16]

Higher Apgar scores at five minutes after birth were associated with better reading and writing skills in grade three, as would be expected from the extensive literature showing better cognitive outcomes in this group.[26] This underscores the importance of monitoring Apgar scores, as low values may indicate suboptimal oxygenation immediately after birth, and also reflect more long standing neurological deficits.

The positive association of first birth with literacy skills is consistent with earlier evidence that first births have an educational advantage.[33,34] However, we found no support for a curvilinear relationship between birth order and literacy skills (as suggested by testing for a quadratic relationship) as documented in previous studies that made comparisons within families (as opposed to between families).[35] Consistent with results for numeracy skills, the relative advantage of being first born was greater in children born to single mothers. This may be due to relatively fewer resources available to subsequent children rather than reflecting a positive advantage for the first born child. This is consistent with the "resource-dilution hypothesis" which is supported by ample research on sibship

and educational attainment in Western societies.[36,37] Single mothers would have less access to most resources that can assist parenting. For writing skills, we found that the relative advantage associated with being first born was more pronounced for children born to mothers residing in disadvantaged areas. As in the case of higher birth order children born to single mothers, children of higher birth order born to mothers residing in educationally deprived areas are likely to suffer similar disadvantages, which may have influenced the outcomes. This suggests that providing additional support such as targeted enriched programs for single parent families with more than one child may improve literacy results among disadvantaged groups of children.

This study, which underscores the importance of socioeconomic contextual factors in understanding the association between child birth characteristics and literacy skills, overcomes many of the limitations of previous studies. It is a large study using 5 years of administrative data from two State government departments. Thus, it ensures the inclusion of the total eligible population of non-Aboriginal grade three singletons attending government schools in Western Australia, thereby minimising participation bias. We found no indication of bias in terms of birth characteristics for those with missing essential information (of which 90% were due to missing SEIFA values). The use of a multilevel model accounted for the underlying correlation between children's performance attending the same school by explicitly modelling variance between and within schools,[38] and multivariate and interaction analyses allowed for the possibility of differential effects between socioeconomic strata. Finally, the study population was sufficiently large to allow separate analyses to be run for each year, confirming that the observed trends were consistent across years.

Of all 96,653 non-Aboriginal singletons born in Western Australia between 1990 and 1997 who also attended government schools (2000 and 2005), there were 39,355 children which were excluded on the basis of either being too old when the WALNA program started and hence they had no grade three scores, or because they had missing information on essential variables or having a grade three record in year 2001 (see Figure 1). Since we have no reason to believe that these children systematically differ from their peers and younger cohorts, it seems unlikely that their exclusion would have introduced a systematic bias in our study. However, children who had missing either reading (3.1%) or writing (3.6%) scores were those either absent during the testing week or exempted due to intellectual impairment, lack of competency in English or in special circumstances. Although these children were likely to have come from more disadvantaged backgrounds, their small proportion would have unlikely introduced any significant bias in our results.

In conclusion, our study of a large cohort of primary-school children suggests that term birth, high Apgar scores and optimal intrauterine head and skeletal growth are all independently associated with better literacy outcomes, while the association with greater intrauterine growth in terms of birth weight (for reading

skills) and being first born vary with maternal (for both reading and writing skills) and neighbourhood characteristics (for writing skills). Further research is needed to explore the causal mechanisms underlying these associations. Our findings, along with our previous study on numeracy skills, highlight both the need to optimise intrauterine growth and birth outcomes and the importance of addressing neighbourhood socioeconomic disadvantage, which has a strong modifying influence on later educational achievement. Efforts to optimise health in pregnancy by provision of adequate pre-conception and antenatal care should be now both a health and an educational priority, as these are likely to improve outcomes especially among the most vulnerable children from disadvantaged neighbourhoods.

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Disclaimer
Any views expressed in this article are solely those of the authors and do not necessarily represent those of the Government Departments.

Ethical approval
The study was approved by the University of Western Australia Human Research Ethics Committee and Confidentiality of Health Information Committee of Western Australia.

What is already known on this topic
Children with poor perinatal characteristics tend to have low neurodevelopmental, cognitive and educational outcomes. However, little is known about the moderating effects of socioeconomic and demographic factors.

What this study adds

The relative benefit of a higher percentage of optimal birth weight on standardised reading test are lower for children born to mothers living disadvantaged residential areas.

First birth is associated with improved reading and writing achievement on standardised tests, especially among children born to single mothers and born in educationally deprived areas. Socioeconomic factors are therefore potentially modifiable characteristics that may influence health as well as educational outcomes.

Competing Interest: None declared.

Figure 1: The flow diagram of data selection for the analysis of reading and writing achievement among non-Aboriginal singletons born in Western Australia between 1990 and 1997 who undertook the Western Australian reading and writing tests in Year 3 in 2000, 2002-2005

Figure 2: The adjusted effect of POBW (centred) on reading achievement for different SEIFA Education groups among non-Aboriginal singletons born in Western Australia who undertook the Western Australian reading test in 2000, 2002-2005

Figure 3: The adjusted effect of mother's marital status on reading achievement for first born or subsequently born among non-Aboriginal singletons born in Western Australia who undertook the Western Australian reading test in 2000, 2002-2005

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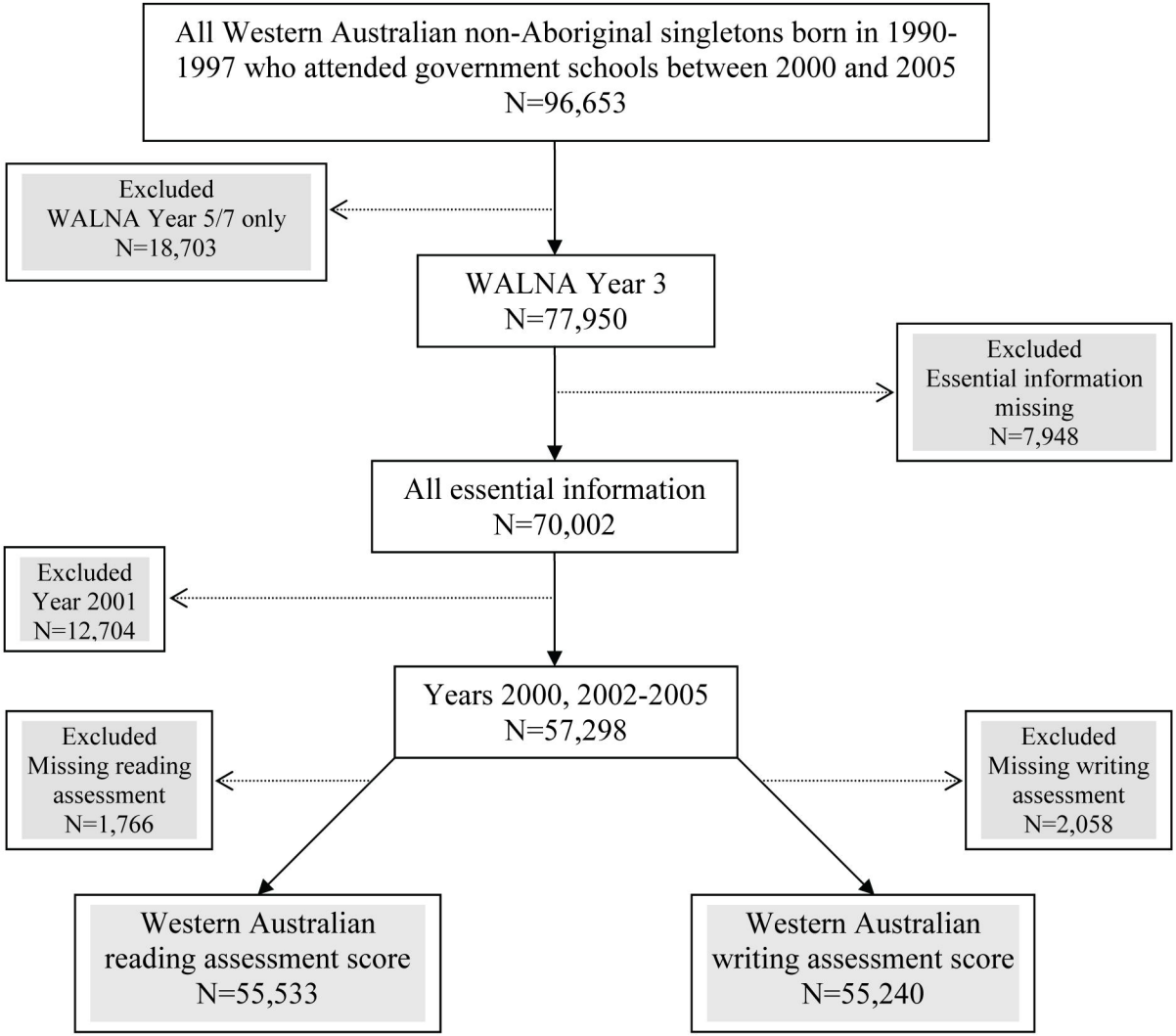
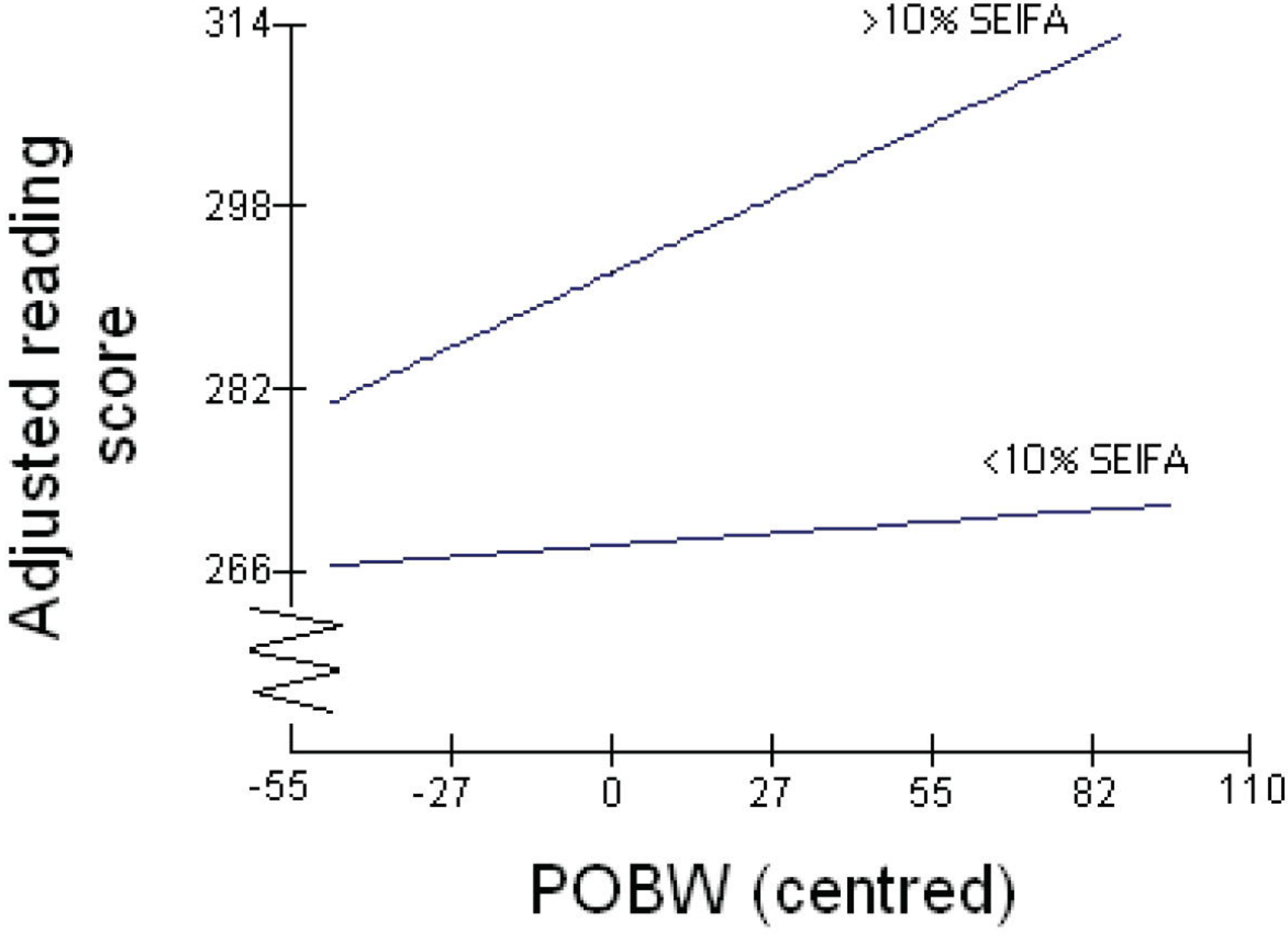
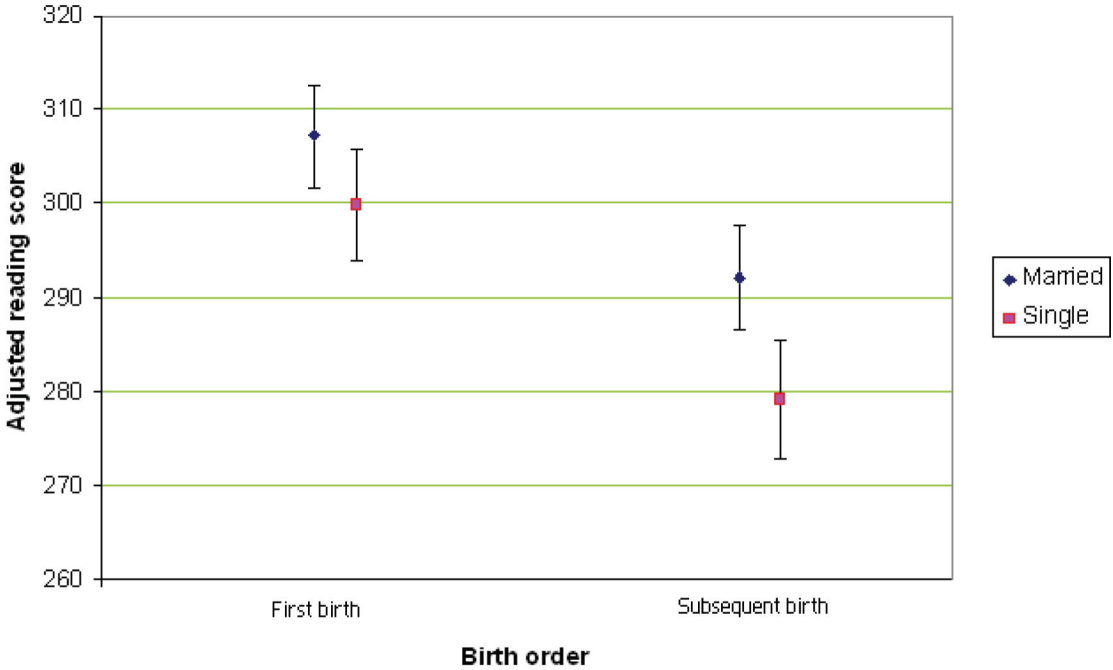

All Western Australian non-Aboriginal singletons born in 1990-1997 who attended government schools between 2000 and 2005
N=96,653
Excluded
WALNA Year 5/7 only
N=18,703
WALNA Year 3
N=77,950
Excluded
Essential information missing
N=7,948
All essential information
N=70,002
Excluded
Year 2001
N=12,704
Years 2000, 2002-2005
N=57,298
Excluded
Missing reading assessment
N=1,766
Excluded
Missing writing assessment
N=2,058
Western Australian reading assessment score
N=55,533
Western Australian writing assessment score
N=55,240


Adjusted reading score
314
298
282
266
>10% SEIFA
<10% SEIFA
-55
-27
0
27
55
82
110
POBW (centred)


320
310
300
290
280
270
260
Adjusted reading score
First birth
Subsequent birth
Birth order
Married
Single