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Early birth is a key factor in educational disadvantage of twins: a data linkage study

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Short Title: Early birth linked to educational disadvantage in twins

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Abbreviations:

NAPLAN: National Assessment Program in Literacy and Numeracy

NMS: National Minimum Standard

aRRs: adjusted relative risks

IQ: intelligence quotient

SGA: small for gestational age

NSW: New South Wales

PDC: Perinatal Data Collection

APDC: Admitted Patient Data Collection

RR: relative risks

CI: Confidence Interval

ART: Assisted Reproductive Technology

SEIFA: Socio-Economic Indexes for Areas

Abstract

Aim: To assess educational outcomes of twins and quantify the degree this is mediated by gestational age and other perinatal factors.

Methods: We conducted a population-based record-linkage cohort study of all livebirths ≥ 24 weeks gestation in New South Wales, Australia with a corresponding standardised school test result for grade 3 in 2008-2014. The primary outcome was whether a child met the National Minimum Standard (NMS) cut-off in literacy and numeracy domains. Robust multivariable Poisson models were used to obtain adjusted relative risks (aRRs) and mediation analysis conducted to assess contributing factors on the causal pathway.

Results: Of 351,791 liveborn infants, 10,365 (2.9%) were twins. After adjusting for maternal covariates and compared with singletons, twins had an increased risk of not meeting the NMS for all five literacy and numeracy domains (aRR 1.27-1.45, $p < 0.001$). Gestational age alone mediated up to 73% of aRRs and small-for-gestational-age further attenuated these effects with only minimal risk remaining after adjusting for all mediators (aRR 0.94-1.07).

Conclusion: Almost all of the educational disadvantage experienced by twins, compared with singletons, is attributable to the risk associated with shorter gestational age, and partly by poor fetal growth. These findings support efforts to prolong gestation of twin pregnancies.

Key Words: twins, cognitive outcome, perinatal, gestational age, data linkage

Key Notes:

Twins, compared with singletons, may have poorer educational outcomes, but the degree to which this is mediated by gestational age and other perinatal factors is unknown.

Twins, on average, have poorer educational outcomes compared with singletons and almost all the educational disadvantage is attributable to the risk associated with shorter gestational age, with small-for-gestational age conferring a small risk.

Further efforts to prolong the gestation of twin pregnancies are required.

Introduction

It is well established that twins have, on average, poorer health outcomes than singletons in the perinatal period and during the first few years of life. At birth, twins have higher perinatal mortality(1) and an increased risk of congenital abnormalities(2). This disadvantage has also been shown to extend into childhood with an increased risk of cerebral palsy(3), more hospital admissions, higher inpatient costs and utilization of healthcare resource(4).

Twin cognitive development has also been implicated, with a meta-analysis finding a significant disparity in intelligence quotient (IQ) of twins compared with singletons(5). As a complicating factor, twins are associated with maternal and socio-demographic characteristics such as later maternal age, higher parity, ethnicity and use of assisted reproductive technology(2, 6, 7). While

some of these characteristics may affect neurological development(7), evidence is not strong for others(8, 9). Twin pregnancies are also known to be associated with some perinatal factors that are themselves independently associated with poorer child health and educational outcomes(10). Compared with singletons, twins are more likely to be born preterm and small for gestational age (SGA), with 62% born at <37 weeks gestation and a third (33%) being SGA(11, 12). Even among term pregnancies, twins are more likely to be born at early term with some guidelines recommending delivery of monochorionic twins from 36 weeks(13) and dichorionic twins from 37 weeks(14).

The relative degree to which gestational age and other perinatal factors mediate the developmental disparity between twins and singletons is understudied, though would be critical in a comprehensive assessment of clinical guidelines for twin pregnancies. A 2012 review of the neurodevelopment of twins found that retrospective studies had tended to be underpowered or failed to fully account for gestational age or birthweight(15). More recent studies have been inconsistent in their design, duration of follow-up and covariate adjustment, precluding them from being assessed by a meta-analysis(16). Randomized trials on the timing of twin birth have been small and underpowered for even short term, let alone long term, outcomes(17).

The objectives of this study were two-fold. First, we aimed to assess educational outcomes and quantify the level of educational disadvantage experienced by twins in early years of schooling. By adjusting for pre-existing maternal characteristics, relevant measures of risk at the point of twin pregnancy were calculated. Second, we investigated the relative role of gestational age and other mediators as drivers of the disadvantage. In doing so we were able to fill a considerable gap in the current literature and cross-examine clinical guidelines recommending delivery of uncomplicated twins at early term.

Methods

The study cohort comprised all 351,791 singleton and twin live births from 24 weeks gestation in New South Wales (NSW), Australia from 1996 to 2006 with an available 3rd grade school test result from 2008 to 2014.

The study utilized routinely collected administrative birth, hospital and education data. Birth records were obtained from the NSW Perinatal Data Collection (PDC), a population-based statutory surveillance system that captures information on maternal characteristics, pregnancy, labor, delivery factors and infant outcomes for all births ≥ 20 weeks gestation or 400 grams birthweight. Higher order multiple births were excluded, as were records with missing birthweight, records with duplicate birth entries and records with duplicate school testing results. The birth records were probabilistically linked to other databases using linkage keys provided by the Centre for Health Record Linkage following approval from the NSW Population and Health Services Research Ethics Committee (reference number 2012-12-430). Information on hospitalisations was ascertained from the NSW Admitted Patient Data Collection (APDC). The APDC records include demographic, facility, diagnosis, and procedure information for every inpatient admitted to any public or private hospital in NSW. Educational outcomes were determined using school test results sourced from the NSW Department of Education National Assessment Program for Literacy and Numeracy (NAPLAN). NAPLAN requires an annual assessment of all 3rd grade students across five domains; reading, writing, spelling, grammar and punctuation, and numeracy. Scores within each domain are categorized into one of six bands and students with scores in the lowest band are considered to be performing below the National Minimum Standard (NMS) in the respective domain. It is recommended that these students receive intervention and support to achieve the skills they require to progress satisfactorily through their schooling(18). Students exempted from taking part in the test due to significant intellectual disability and/or significant co-existing conditions are also included in the lower band.

The main study risk factor was plurality and there were five outcomes of interest based on the proportion of children scoring below the NMS in each of the NAPLAN domains. Covariates of interest were categorised into potential confounders, including preconception factors (maternal age, parity, socioeconomic status, use of assisted reproductive technology, language spoken at home other than English, highest educational attainment of parents, occupation category of parents) and mediators (gestational age, SGA, labor onset and sex). SGA was defined as infants born in the lowest 10th birthweight percentile for gestational age and sex. Given that immediate perinatal outcomes differ by plurality-specific birth weight standards, SGA for singletons was

calculated using singleton centile charts(19) whereas SGA for twins was calculated two ways; based on singleton and twin birthweight centile charts(20).

Regarding statistical analysis, characteristics of twin and singleton births were described using descriptive statistics stratified by preterm (<37 weeks' gestation) and term (37+ weeks' gestation) birth. We also compared the proportion of infants classified as SGA by plurality and gestational age, using both singleton and twin birthweight centile charts for twins.

Crude (univariable) relative risks (RR) of poor educational outcomes for twins compared with singletons were estimated using robust Poisson models fitted using generalized estimating equations with a log-link and exchangeable correlation to account for clustering between siblings (Model 1). Following the crude estimates, three subsequent models were developed to evaluate the effect on risk estimates of the incremental addition of pre-conception factors (Model 2), and mediating factors based on two definitions of SGA using plurality-specific (Model 3) and singleton-only (Model 4) birthweight centile charts. In addition, the proportion of relative risk accounted for by individual mediators was estimated by sequentially adding mediators into the pre-conception model in order of decreasing univariable statistical significance.

Gestational age was modelled using a linear spline, with a single knot ("cut-point") at 37 weeks, thus allowing us to estimate the effect of gestational age separately for preterm and term births, and to formally test if this differed. The spline was created by using two composite variables: one which counts the weeks up until 37 (value stays at 37 beyond 37 weeks gestation), and the other counting the weeks beyond 37 (maximum value 4). Goodness of fit test were conducted on the whole models (Hosmer-Lemeshow) and across gestational age specifically to assess the appropriateness of chosen functional form. Potential covariates were assessed using progressive backwards selection and variables retained if they were significant at $p\text{-value} < 0.05$. Interaction effects involving plurality, gestational age and SGA were also considered, but as none were significant, these were not retained in models. To address confounding by indication for at risk births, we repeated Model 4 for a subset of 135,816 births for low-risk pregnancies, defined as women aged 20 to 34 years without diabetes or hypertension with liveborn infants born at ≥ 37 weeks' gestation and with a birth weight for gestational age, sex and plurality between the 10th and 90th percentiles. All analyses were performed in SAS 9.4 (SAS Institute, Inc., Cary, NC).

Results

The 351,791 livebirths comprised 10,365 (2.9%) twins. This sample size resulted after removal of 544 higher order multiple births, 172 births with missing birthweight, 247 with a duplicate birth record and 300 with a duplicate 3rd grade NAPLAN test. Almost half of twins were born preterm (47.2%) compared with 5.4% of singletons. For both preterm and term births, compared with singletons, twins were more likely to be born to mothers who were older, non-smoking, born in Australia, resident in urban areas and with higher levels of social advantage (**Table 1**). Twins were also more likely than singletons to be conceived by assisted reproductive technology and to be delivered by induced labor or planned cesarean section. At birth, twins were more likely to be SGA and to be female (**Table 1**).

Using twin birthweight charts adjusted for sex and gestational age, 11.7% of twins were classified as SGA, though 27.6% would be considered SGA if categorised using the equivalent singleton charts. The discrepancy increased with greater gestational age so that nearly half (49.4%) of twins were defined as SGA at 39 weeks gestation using singleton charts. For singletons, the percentage of SGA was 11.2%, and this was stable across gestational age (**Supplementary table S1**).

When evaluating the crude association between plurality and educational outcomes, twins had a greater risk of performing below the NMS than singletons in all five domains (all $p < 0.001$) (**Model 1, Table 2**). The relative risk for twins was highest for the reading and numeracy domains, with twins incurring an increased risk of 1.27 (95% Confidence Interval (CI) 1.16-1.39) and 1.36 (95%CI 1.24-1.49) in performing below the NMS, respectively. Once pre-conception covariates were adjusted for, the risk of poor school test scores for twins increased further for all five domains, with twins having a relative risk of 1.35 (95%CI 1.23-1.47) of performing below the NMS in reading and 1.45 (95%CI 1.32-1.59) in numeracy (**Model 2, Table 2**).

Of the mediators, gestational age was the primary contributor to this increased risk accounting for 73.0% and 71.4% (**Table 3**) of the increased relative risk experienced by twins for reading and numeracy, respectively. For every week of additional gestation at birth, the probability of poor educational outcomes decreased by 9.1% and 5.0% for preterm and term births, respectively (**Table 4**). The combination of gestational age and SGA (using singleton charts) accounted for an

even larger proportion of the relative risk with 89.5% and 86.4% of the disadvantage faced by twins in reading and numeracy being explained, respectively (**Table 3**). Sex and labor onset had a smaller mediating effect. Once all mediators were adjusted for, none of the relative risks across all domains were significant (**Model 4, Table 2**).

On repeating Model 4 for low-risk pregnancies, the relative risks were very similar to those estimated from the full cohort. No model failed a goodness of fit test.

Discussion

To our knowledge, this is one of the largest population-based investigation into educational outcomes for twins versus singletons, and the first to adjust for prenatal confounders and mediators separately. Our findings suggest that twins have a substantially higher risk of poorer educational outcomes at Grade 3, which is mostly attributable to the risks associated with shorter gestational age, and partly due to additional risks by being SGA.

Regarding prenatal confounders, we found that twin births were more common in older mothers with higher socioeconomic status and in mothers using Assisted Reproductive Technology (ART), as have previous studies(2, 4, 6). The mechanism for this is likely a combination of a higher potential for twins with increasing maternal age and a higher use of ART. The implication of such a socioeconomic association is that the unadjusted relative risks (as well as any anecdotal evidence) would tend to under-estimate the true disadvantage faced by twins.

Considering mediators, the overwhelming liability of lower gestational age on educational disadvantage is an important impetus to reduce risk factors for preterm birth among women with a twin pregnancy. The marginal effect of gestational age on preterm babies being twice the effect for term babies reinforces this point. The pathophysiology of preterm birth is likely to be different for singleton pregnancies than it is for twin pregnancies, with the latter being far less commonly examined in the academic literature. A reduction in alcohol consumption, stress, cessation of smoking and provision of adequate social support, might reduce the risk of preterm birth for pregnancies in general(21), but more research is needed on the differential effects of these factors for twin pregnancies, particularly as a substantial proportion (more than one fifth in

our study) of babies born preterm are twins(11). Vaginal progesterone treatment may provide some benefit in improving some neonatal outcomes associated with prematurity of twins, particularly if there is a short cervix, however in non-selected women cerclage, progesterone and pessary have not been shown to be of benefit in preventing preterm birth(22). Other strategies to reduce the risk of spontaneous preterm birth in twin pregnancies are required.

The developmental benefit of increasing gestational age beyond 37 weeks is relevant considering some current recommendations on the timing of birth for uncomplicated twin births(14). A systematic review of observational and cohort studies has shown an increased risk of stillbirth for mothers with monochorionic twins $\geq 36+0-6$ weeks gestation and dichorionic twins $\geq 37+0-6$ weeks gestation(23), leading to recommendations for birth from 36 weeks for uncomplicated monochorionic twins(13) and from 37 weeks for dichorionic twins(14). However a study from Ireland found that, with close standardized ultrasound surveillance, the risk of perinatal death after 33 weeks gestation for uncomplicated dichorionic twins was nil and that perinatal morbidity decreased with gestational age. This suggests that, for appropriately growth concordant dichorionic twins, birth could be deferred to >38 weeks(24). Given stillbirths were not included in our study, evidence presented here of the developmental benefit of delaying planned twin births suggests a need for further research into the risk of stillbirth for these pregnancies. For liveborn infants, premature birth has consistently been shown to be associated with poor educational outcomes (Bentley, Scotland study) which have potential long-term health, social and economic implications including poorer health and wellbeing, lower rate of graduation from high school, reduced attainment of post-school education, reduced employment and lifetime earnings(25). This has led to greater public health interest in adverse short term and long term outcomes of the risk of late preterm and early term births in singletons has led to changes in clinician-initiated late preterm and early term birth rates in some countries(26).

Having adjusted for all confounders and mediators, the residual “twinning” effect on educational outcomes appears minimal at best, concurring with the results presented in the systematic review of Neurodevelopmental Outcomes of Twins published in 2012(15). Available research on educational outcomes for twins show a disadvantage in IQ when testing at early years of schooling(27, 28) though evidence is mixed for older years(29). Almost all studies noted a likely

effect of shorter gestation and reduced birthweight(5), though our study appears to be the first to actually model prenatal factors and mediators separately, and assess their contributions individually and combined.

The strengths of our study include population coverage, with state-wide birth records over 13 years linked to national school testing, allowing for comprehensive estimates of effects. School testing outcomes were collected prospectively and independently of perinatal factors. Missing data were minimal across both datasets linked. As for limitations, given the use of administrative data, we were unable to collect information on every potentially relevant confounder. In particular, we did not have any information on zygosity or chorionicity of twin pairs, which would have enabled us to assess the role of genetic and environmental factors in explaining variation in outcomes(30). As a proxy for not knowing zygosity, we conducted a post-hoc analysis by repeating all models using opposite-sex twin pairs and same-sex twin pairs, separately. We found no evidence in a difference in the educational disadvantage for divergent/opposite-sex twins compared with same-sex twins (**Supplementary tables S2-S5**).

In conclusion, twins are on average disadvantaged compared with singletons in educational outcomes. We found this disadvantage is experienced across all the studied areas of schooling, including reading, numeracy and grammar. Almost all of the relative disadvantage faced was attributed to the reduced gestational age experienced by twins and being SGA. Effective strategies for increasing gestation for twin births could assist in closing the educational gap.

Conflict of interest

The authors have no conflicts of interest to declare. The sponsor had no role in study design; the collection, analysis, and interpretation of data; the writing of the manuscript; and the decision to submit the paper for publication.

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References

1. Vasak B, Verhagen JJ, Koenen SV, Koster MP, de Reu PA, Franx A, et al. Lower perinatal mortality in preterm born twins than in singletons: a nationwide study from The Netherlands. *Am J Obstet Gynecol* 2017; 216 2:161 e1- e9.
2. Dawson AL, Tinker SC, Jamieson DJ, Hobbs CA, Rasmussen SA, Reefhuis J, et al. Epidemiology of twinning in the National Birth Defects Prevention Study, 1997 to 2007. *Birth Defects Res A Clin Mol Teratol* 2015; 103 2:85-99.
3. Topp M, Huusom LD, Langhoff-Roos J, Delhumeau C, Hutton JL, Dolk H, et al. Multiple birth and cerebral palsy in Europe: a multicenter study. *Acta Obstet Gynecol Scand* 2004; 83 6:548-53.
4. Chambers GM, Hoang VP, Lee E, Hansen M, Sullivan EA, Bower C, et al. Hospital costs of multiple-birth and singleton-birth children during the first 5 years of life and the role of assisted reproductive technology. *JAMA Pediatr* 2014; 168 11:1045-53.
5. Voracek M, Haubner T. Twin-singleton differences in intelligence: a meta-analysis. *Psychol Rep* 2008; 102 3:951-62.
6. Abel EL, Kruger ML. Maternal and paternal age and twinning in the United States, 2004-2008. *J Perinat Med* 2012; 40 3:237-9.
7. Hviid MM, Skovlund CW, Mørch LS, Lidegaard O. Maternal age and child morbidity: A Danish national cohort study. *PLoS One* 2017; 12 4:e0174770.
8. Hediger ML, Bell EM, Druschel CM, Buck Louis GM. Assisted reproductive technologies and children's neurodevelopmental outcomes. *Fertil Steril* 2013; 99 2:311-7.
9. McLennan AS, Gyamfi-Bannerman C, Ananth CV, Wright JD, Siddiq Z, D'Alton ME, et al. The role of maternal age in twin pregnancy outcomes. *Am J Obstet Gynecol* 2017; 217 1:80 e1- e8.

10. MacKay DF, Smith GC, Dobbie R, Pell JP. Gestational age at delivery and special educational need: retrospective cohort study of 407,503 schoolchildren. *PLoS Med* 2010; 7 6:e1000289.
11. Australian Institute of Health and Welfare. Australia's mothers and babies 2017. Perinatal statistics Sn, Cat no PER 72 Canberra: AIHW, 2018
12. Mendez-Figueroa H, Truong VTT, Pedroza C, Chauhan SP. Growth among Twins: Use of Singleton versus Twin-Specific Growth Nomograms. *Am J Perinatol* 2018; 35 2:184-91.
13. RCOG. Management of Monochorionic Twin Pregnancy: Green-top Guideline No. 51. *BJOG* 2017; 124 1:e1-e45.
14. National Collaborating Centre for Women's and Children's Health (UK). Multiple Pregnancy: The Management of Twin and Triplet Pregnancies in the Antenatal Period. London, 2011
15. Lorenz JM. Neurodevelopmental outcomes of twins. *Semin Perinatol* 2012; 36 3:201-12.
16. Babatunde OA, Adebamowo SN, Ajayi IO, Adebamowo CA. Neurodevelopmental Outcomes of Twins Compared With Singleton Children: A Systematic Review. *Twin Res Hum Genet* 2018; 21 2:136-45.
17. Dodd JM, Deussen AR, Grivell RM, Crowther CA. Elective birth at 37 weeks' gestation for women with an uncomplicated twin pregnancy. *Cochrane Database Syst Rev* 2014; 2:CD003582.
18. Australian Curriculum Assessment and Reporting Authority. Measurement Framework for Schooling in Australia Sydney, Australia 2015
19. Dobbins TA, Sullivan EA, Roberts CL, Simpson JM. Australian national birthweight percentiles by sex and gestational age, 1998-2007. *Med J Aust* 2012; 197 5:291-4.
20. Li Z, Umstad MP, Hilder L, Xu F, Sullivan EA. Australian national birthweight percentiles by sex and gestational age for twins, 2001-2010. *BMC Pediatr* 2015; 15:148.
21. The L. The unfinished agenda of preterm births. *Lancet* 2016; 388 10058:2323.
22. Jarde A, Lutsiv O, Park CK, Barrett J, Beyene J, Saito S, et al. Preterm birth prevention in twin pregnancies with progesterone, pessary, or cerclage: a systematic review and meta-analysis. *BJOG* 2017; 124 8:1163-73.

23. Cheong-See F, Schuit E, Arroyo-Manzano D, Khalil A, Barrett J, Joseph KS, et al. Prospective risk of stillbirth and neonatal complications in twin pregnancies: systematic review and meta-analysis. *BMJ* 2016; 354:i4353.
24. Breathnach FM, McAuliffe FM, Geary M, Daly S, Higgins JR, Dornan J, et al. Optimum timing for planned delivery of uncomplicated monochorionic and dichorionic twin pregnancies. *Obstet Gynecol* 2012; 119 1:50-9.
25. Burgess S. Human Capital and Education: The State of the Art in the Economics of Education. . Institute for the Study of Labor (IZA) DP No 9885. Bonn, Germany, 2016
26. Richards JL, Kramer MS, Deb-Rinker P, Rouleau J, Mortensen L, Gissler M, et al. Temporal Trends in Late Preterm and Early Term Birth Rates in 6 High-Income Countries in North America and Europe and Association With Clinician-Initiated Obstetric Interventions. *JAMA* 2016; 316 4:410-9.
27. Eriksen W, Sundet JM, Tambs K. Twin-singleton differences in intelligence: a register-based birth cohort study of Norwegian males. *Twin Res Hum Genet* 2012; 15 5:649-55.
28. Tsou MT, Tsou MW, Wu MP, Liu JT, Taiwanese Cohort S. Academic achievement of twins and singletons in early adulthood: Taiwanese cohort study. *BMJ* 2008; 337:a438.
29. Christensen K, Petersen I, Skytthe A, Herskind AM, McGue M, Bingley P. Comparison of academic performance of twins and singletons in adolescence: follow-up study. *BMJ* 2006; 333 7578:1095.
30. Grasby KL, Coventry WL, Byrne B, Olson RK, Medland SE. Genetic and Environmental Influences on Literacy and Numeracy Performance in Australian School Children in Grades 3, 5, 7, and 9. *Behav Genet* 2016; 46 5:627-48.

Table 1: Maternal, infant and school test characteristics of singleton and twin births, stratified by preterm and term births in NSW, 1996-2006.

Maternal, Infant and School Test Characteristics	Preterm (24-36 weeks)		Term (37+ weeks)		Total	
	Singletons	Twins	Singletons	Twins	Singletons	Twins
	(n=18,460)	(n=4,893)	(n=322,966)	(n=5,472)	(n=341,426)	(n=10,365)
	%	%	%	%	%	%
Maternal Age (years)						
<20	6.8	2.4	5.1	1.7	5.2	2.0
20-24	17.7	11.5	16.5	10.2	16.5	10.8
25-29	26.7	26.5	29.1	25.3	29.0	25.9
30-34	28.9	35.8	31.1	36.2	31.0	36.0
35-39	15.7	19.3	15.1	22.5	15.1	21.0
40+	4.2	4.5	3.1	4.1	3.2	4.3
Nulliparous	44.1	47.6	40.7	37.3	40.9	42.1
Mother born in Australia	76.0	79.1	73.9	75.2	74.0	77.0
Mother smoked during pregnancy	28.6	17.2	18.8	15.2	19.3	16.1
Socioeconomic Quintile						
1st (MOST disadvantaged)	20.5	16.2	18.8	16.3	18.9	16.2
2nd	17.4	16.1	16.8	16.1	16.8	16.1
3rd	26.1	23.9	23.7	22.6	23.8	23.2
4th	18.3	17.9	18.9	18.9	18.8	18.4
5th (LEAST disadvantaged)	17.8	25.9	21.8	26.1	21.6	26.0
Residence in major city	75.6	78.8	76.3	77.7	76.3	78.2
Private hospital delivery	12.7	18.3	18.6	23.3	18.3	20.9

Use of Assisted Reproductive Technology	1.5	12.4	0.9	10.7	1.0	11.5
Labor Onset						
Spontaneous	65.0	58.8	62.8	25.4	63.0	41.2
Induced	11.9	9.2	24.7	35.1	24.0	22.9
No labor	23.1	32.0	12.4	39.5	13.0	36.0
Small for Gestational Age- Singleton Charts	10.4	17.1	11.2	37.0	11.2	27.6
Small for Gestational Age- Twins charts	N/A	11.4	N/A	12.0	N/A	11.7
Sex of Baby						
Male	55.4	50.0	51.6	49.5	51.8	49.8
Female	44.6	50.0	48.4	50.5	48.2	50.2
Age at NAPLAN exam						
7	5.0	4.3	5.9	4.6	5.8	4.4
8	78.5	77.7	81.7	81.8	81.5	79.9
9	16.4	17.9	12.4	13.6	12.6	15.6
10+	0.1	0.1	0.0	0.1	0.0	0.1
Highest level of Parental Educational Achievement						
Incomplete high school	21.8	15.7	15.6	15.0	15.9	15.3
Completed high school	9.2	8.4	9.1	7.9	9.1	8.2
Diploma or Certificate I-IV	45.8	44.5	45.3	45.9	45.3	45.2
Bachelors degree or higher	23.2	31.4	30.0	31.2	29.6	31.3
Highest level of Parental Occupation						

Senior management- large business	19.6	25.6	23.6	26.2	23.4	25.9
Other business managers, arts/media/sports	21.1	25.0	24.6	24.7	24.4	24.8
Tradesmen/women, clerks and skilled officers	23.9	22.0	23.5	22.7	23.5	22.3
Machine operators, hospitality staff	19.5	15.6	17.5	15.9	17.6	15.7
Not in paid work in last 12 months	15.8	11.8	10.8	10.6	11.1	11.2
Non-English speaking background	22.9	22.0	25.9	23.6	25.7	22.8

Table 2: Risk ratios comparing twin births to singletons not meeting national minimum standards in given literacy and numeracy domains

School Test Domains	Models			
	1. Crude	2. Adjusted for pre-conception covariates	3. Adjusted for all covariates (using plurality-specific SGA charts)	4. Adjusted for all covariates (using singleton SGA charts only)
Reading	1.27 (1.16 1.39)*	1.35 (1.23 1.47)*	1.11 (1.01 1.22)*	1.06 (0.96 1.16)
Writing	1.22 (1.09 1.36)*	1.28 (1.15 1.44)*	1.00 (0.89 1.12)	0.94 (0.84 1.06)
Spelling	1.22 (1.10 1.34)*	1.27 (1.15 1.40)*	1.01 (0.91 1.11)	0.95 (0.86 1.05)
Grammar	1.25 (1.14 1.36)*	1.34 (1.23 1.45)*	1.13 (1.03 1.23)*	1.07 (0.98 1.17)
Numeracy	1.36 (1.24 1.49)*	1.45 (1.32 1.59)*	1.13 (1.03 1.24)*	1.07 (0.97 1.18)

SGA: Small for gestational age; *Statistically significant at $p=0.05$

MODEL EXPLANATIONS:

Model 1: Crude model created as Poisson model for domain failure with log link, clustered on mother ID, with no additional covariates.

Model 2: Pre-conception covariates model adds the following covariates to the crude model: mother's age, socio-economic status, assisted reproductive technology, parity, language spoken other than English, parental occupation, parental education

Model 3: This model additionally incorporates sex, gestational age, labor onset and birthweight. Birthweight is defined as an indicator which flags where the baby is in the bottom 10% for gestational age and plurality. Gestational age is input as a numerical variable but with a cut-point at 37 weeks. "Gestage" thus comprises two composite variables - one which counts the weeks up until 37 (value stays at 37 beyond 37 weeks gestation), and the other counting the weeks beyond 37 (max value = 4)

Model 4: This model is the same as model 3 above but SGA is redefined as where the baby is in the bottom 10% for gestational age for singletons.

Table 3: Percentage reduction in relative risk for twin birth not meeting the national minimum standards in given school test domain after adjusting for mediating variables

School Test Domains	Relative risk before mediator adjustments	Percentage reduction in relative risk				Relative risk after mediator adjustments
		Mediator (added cumulatively)				
		Gestational age	+ sga (singleton charts)	+ sex	+ labor onset	
Reading	1.35	73.0%	89.5%	81.1%	83.2%	1.06
Writing	1.28	100.0% *	100.0% *	100.0% *	100.0% *	0.94
Spelling	1.27	100.0% *	100.0% *	100.0% *	100.0% *	0.95
Grammar	1.34	69.9%	87.5%	78.2%	79.0%	1.07
Numeracy	1.45	71.4%	86.4%	82.4%	84.7%	1.07
Average		71.4%	87.8%	80.6%	82.3%	

SGA: Small for gestational age;

*Relative risk reduced to 1

Table 4: Marginal effect of one additional week's gestation[†] on probability of not meeting minimum standards in a given domain, for preterm and term births

School test domains	Preterm birth (<37 weeks)	Term birth (37+ weeks)
	β-coefficients (95%CI)	β-coefficients (95%CI)
Reading	-8.3% (-7.1% -9.4%)	-4.1% (-2.7% -5.4%)
Writing	-10.4% (-9.2% -11.6%)	-5.6% (-4.1% -7.1%)
Spelling	-8.6% (-7.4% -9.7%)	-6.6% (-5.2% -7.9%)
Grammar	-8.4% (-7.3% -9.4%)	-3.5% (-2.3% -4.7%)
Numeracy	-10.1% (-9.0% -11.1%)	-5.1% (-3.7% -6.5%)

[†]Exponentiated beta-coefficients from model 4

CI: Confidence Intervals

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