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Early Life Exposures

Preterm delivery and risk for early language delays: a sibling-control cohort study

Imac M Zambrana,[1]* Margarete E Vollrath,[2,3] Verena Sengpiel,[4] Bo Jacobsson[5,6] and Eivind Ystrom[2,3]

[1]Norwegian Center for Child Behavioral Development, Oslo, Norway, [2]Norwegian Institute of Public Health, Division of Mental Health, Oslo, Norway, [3]Department of Psychology, Faculty of Social Sciences, University of Oslo, Oslo, Norway, [4]Department of Obstetrics and Gynaecology, Sahlgrenska University Hospital, Gothenburg, Sweden, [5]Department of Obstetrics and Gynaecology, Institute of Clinical Sciences, Gothenburg University, Gothenburg, Sweden and [6]Norwegian Institute of Public Health, Division of Epidemiology, Oslo, Norway

*Corresponding author. Norwegian Center for Child Behavioral Development, Postbox 7053 Majorstuen, 0306 Oslo, Norway. E-mail: i.m.zambrana@atferdssenteret.no

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Abstract

Background: Studies suggest that preterm delivery is a risk factor for early language delays, but knowledge is scarce about the persistence of the delays and whether the association is of a linear kind. To resolve this, effects of confounding risk factors that are both shared within a family and pregnancy specific need to be distinguished from effects of preterm delivery. Our study examines the association between early gestational age and language outcomes, using a sibling-control design.

Methods: The sample comprises 22 499 siblings from the Norwegian Mother and Child Birth Cohort Study, recruited between 1999 and 2008. Mothers rated child language comprehension and production at 18 and 36 months. Analyses compared siblings discordant on gestational age group (early preterm, delivery at week 22–33; late preterm, 34–36; early term, 37–38; full term, >38) and type of onset of delivery (spontaneous; provider-initiated), and compared these findings with conventional cohort analyses.

Results: The findings revealed inverse linear relations between the gestational age groups, and persistent but diminishing language delays. Effects of preterm delivery were substantial on both language production and comprehension at 18 months. By 36 months, the effects of preterm delivery were weaker, but still extensive, in particular for language production in provider-initiated births. When comparing sibling-control with cohort analyses, preterm group was less important among spontaneous births, but remained important in provider-initiated births. Familial and pregnancy risk factors partly explained this.

Conclusions: Distinctive factors seem to underlie effects of preterm delivery across spontaneous and provider-initiated births.

Key words: Preterm delivery, gestational age, spontaneous labour, induced labour, provider-initiated, language delay, sibling design, MoBa cohort study

Key Messages

- Preterm birth is associated with delayed language at 18 and 36 months of age, with the delays tapering off at 36 months.
- Lower gestational age combined with provider-initiated delivery was associated with the most severe and persistent language delays.
- Familial risk factors could not account for the effect of preterm birth on the language outcomes in children from provider-initiated delivery.
- The results suggest that different factors might underlie language delays associated with provider-initiated delivery, and future studies could identify what these factors might be.

Introduction

Preterm delivery (i.e. birth occurring before gestational week 37) is a major global health problem, and early preterm delivery (gestational weeks 22–33) is particularly associated with neonatal mortality and short- and long-term morbidity.[1,2] The number of preterm deliveries has increased.[3] This is mostly driven by greater numbers of late preterm deliveries (gestational weeks 34–36), related to increases in obstetric interventions.[4,5] In addition, an increasing number of deliveries now occur early term (gestational weeks 37–38).[6,7]

Because preterm delivery poses a risk for early developmental delays, the increasing numbers of births before term are bound to have a huge impact on public health.[8] Although most children with language delays are born full term,[9] this adverse developmental outcome is strongly associated with preterm deliveries.[10–13] Moreover, both children born at term with language delays and preterm born children show risks for later problems with socio-emotional functioning, reading and writing,[13–16] making it vital to understand and identify language delay trajectories related to different gestational ages.

Because children born early term display a risk for language delays too, although to a lesser extent than for preterm deliveries,[7,8,16–19] an inverse linear relation between gestational age and the severity of the language delays might be assumed. Younger gestational age could also be related to delays in both language comprehension and production which, in children with specific language impairments, involves more impairing and severe delays.[20–23]

However, examining associations between gestational length and language delay poses methodological challenges. Rather than gestational age at birth per se, unmeasured risk factors that differ between families (e.g. genetic risks or absence of stimulating environments) may explain the association.[24–25] A design that compares siblings who are discordant with respect to gestational age can take such factors into account.[26–28] In combination with adjustment for observed risk factors that may vary between siblings within families (e.g. hypertension or maternal smoking),[29] this would improve the effect estimates (see Figure 1).

Most preterm deliveries occur spontaneously by onset of preterm labour or rupture of the membranes, and less than one-third of preterm deliveries are provider-initiated by obstetricians to ward off greater harm to the health of the mother or child (e.g. due to intrauterine growth restriction).[3,30,31] Because provider-initiated preterm deliveries might represent more imperilled pregnancies,[32] this might relate to more serious and persistent language delays and different risk factors, compared with spontaneous preterm deliveries. However, this remains to be examined.

A prospective sibling-control design was used to revisit and expand the examination of three issues: (i) potential inverse linear associations between gestational age at delivery and risk for language delays across spontaneous and provider-initiated deliveries; (ii) the strength and persistence of these associations across ages 18 and 36 months; And (iii) the degree to which these associations are brought about by risk factors stable within families, risk factors variable within families or actual gestational age effects of preterm delivery.

Methods

Participants

Data from birth until 3 years of age was derived from the population-based Norwegian Mother and Child Birth Cohort Study (MoBa) conducted at the Norwegian Institute of Public Health.[33] The cohort includes 114 500

Accounting for:	**Cohort**	**Adjusted Cohort**	**Sibling-control**	**Adjusted sibling-control**
Factors shared between siblings: e.g. socioeconomic status, maternal chronic disease, genetic effects	No	No	Yes	Yes
Measured factors specific to pregnancy: e.g. gestational diabetes, stress, malformations, smoking	No	Yes	No	Yes
Unmeasured factors specific to pregnancy: e.g. undiagnosed disease	No	No	No	No

Figure 1. Representation of putative confounders adjusted for in cohort, adjusted cohort, sibling-control and adjusted sibling-control designs.

children and 95 200 mothers, recruited from across Norway in the period 1999–2008, with a maternal informed consent rate of 40.6% and concession from the Norwegian Data Protection Authority.

This study utilised data from the Medical Birth Registry of Norway (MBRN) and maternal-reported MoBa questionnaires at the 17th and 30th week of gestation, and child ages of 18 and 36 months (with response rates of 95%, 92%, 77% and 62%, respectively). We used data version 7, quality-assured and released in 2013 [http://www.fhi.no/moba-en]. We included all sibling pregnancies for which gestational age data from MBRN, as well as data at child age 18 months ($n = 21\ 453$) or 36 months ($n = 17\ 899$) were available. This comprised 22 499 siblings, from 10 299 sibling pairs, 607 sibling trios and 20 sibling quartets. As twins are concordant for the exposure, we included the first-borns ($n = 220$) from multiple births with other older or younger participating siblings. Table 1 shows descriptive sample information.

Table 1. Descriptive characteristics of sibling sample from the Norwegian Mother and Child Birth Cohort Study ($N = 22\ 499$)

Variables	N (M ± SD)	N missing
Child		
Gestational age at birth, weeks	(39.9 ± 11.8)	0
Boys	11 577	0
Twins	220	0
Malformations at birth	535	0
SGA	335	16
Pregnancy		
Unplanned pregnancy	3599	439
Preeclampsia	712	0
IVF	370	0
Gestational diabetes	294	0
Recurrent urinary tract infections	665	0
Bleeding between weeks 13–28	347	0
Hypertensive state	1 115	0
Depressive symptoms (SCL cutoff)	1036	370
Smoking during pregnancy	1264	26
Alcohol during pregnancy	6432	692
Maternal weight status (BMI)	–	627
BMI < 18.5	601	–
BMI > 18.5 - < 30.0	19 385	–
BMI > 30.0	1886	–
Demographics		
Mother's completed education	–	1 114
University > 4 years	5955	–
University ≤ 4 years	9929	–
High school or lower	5501	–
Marital status during pregnancy	–	317
Married/partner	21 832	–
Divorced/Single	227	–
Other	123	–
Age mother, years	(30.2 ± 4.1)	0

N, sample size; M, median; S, standard deviation; SGA, small for gestational age; IVF, *in vitro* fertilization; SCL, Hopkins Symptom Checklist-5; BMI, body mass index.

Measures

Delivery

Gestational age at birth was based on ultrasound examinations (or for $n = 64$ on the date of last menstruation registered in MBRN), and was divided into four gestational age groups: early preterm (gestation weeks 22/0 to 33/6); late preterm (weeks 34/0 to 36/6); early term (weeks 37/0 to 38/6); and full term (> weeks 39/0). We also divided delivery into two onset types: spontaneous and provider-initiated (i.e. induced or primary caesarean delivery on maternal or fetal indications).[3,34] Frequencies and sibling discordance of gestational age group and type of delivery onset are shown in Table 2. In the sibling-control analyses, the difference between the gestational age average of the

Table 2. Number (%) of children in each delivery group (left side) and members of discordant sibling groups (right side)

	Number of children in each group		Members of discordant sibling group	
Gestation	Spontaneous	Provider-initiated	Spontaneous	Provider-initiated
duration (weeks)	$n = 18\,484$ (%)	$n = 4015$ (%)	of $n = 18\,484$ (%)	of $n = 4015$ (%)
< 34	127 (0.7)	101 (2.5)	110 (0.6)	92 (2.3)
34–36	469 (2.5)	266 (6.6)	381 (2.1)	232 (5.8)
37–38	2439 (13.2)	1068 (26.6)	1783 (9.7)	770 (19.5)
> 38	15 449 (83.6)	2580 (64.3)	2503 (13.5)	404 (10.1)

The columns to the left show the total number of children delivered spontaneously and provider-initiated from the different delivery groups. The columns to the right display how many of these children were members of a discordant sibling group (not born in the same group) and subsequently included in the sibling analyses.

sibling group and the individual score (e.g. for a trio we divide it by 3), provided 'deviations from the family means' in any family.

Outcomes

Language skills at 18 and 36 months were assessed by maternal-reported items derived from several established scales: the Norwegian version of the Ages and Stages Questionnaires,[35] the Modified Checklist for Autism in Toddlers,[36] the Non-Verbal Communication Checklist,[37] the Early Screening of Autistic Traits Questionnaire,[38] the Social Communication Questionnaire[39] and a question about the complexity and comprehensibility of child utterances with six response categories.[40] Our language comprehension[41] and language production[42] outcomes are latent variables based on previous Confirmatory Factor Analyses (CFA) work showing very good model fits with high non-overlapping factor loadings (see references[41,42] for description of construction, validation and specific items included). The language comprehension constructs at 18 months (five items) and 36 months (seven items) captured understanding of or appropriate responses to the language utterances of others, and were measurement invariant across time.[41] The language production construct at 18 months was based on one item enquiring whether the child could utter eight or more words, in addition to 'mama' and 'dada', and at 36 months this construct captured the complexity of child utterances and conversations (seven items). These were thus not the same across time.[42]

Confounders

In the adjusted analyses, we only controlled for pregnancy-specific child, mother or pregnancy factors that can vary between pregnancies and that preceded the exposure. Confounders from MBRN included: parity, smoking, alcohol intake, pregnancy-specific hypertensive state, bleeding (weeks 13–28), recurrent urinary tract infections, unplanned pregnancy, gestational diabetes, *in vitro* fertilization, low (< 18.5) and high (> 30) body mass index (BMI), gender, multiple birth status, serious malformations at birth and small for gestational age [SGA; i.e. 2 standard deviations (SD) difference from the uterine growth curve[43]]. Mothers also reported on anxiety and depressive symptoms during pregnancy, set above the clinical cut-off on the Hopkins Symptom Checklist-5.[44] Due to high correlations between hypertensive state and preeclampsia ($r = 0.74$), and maternal age and parity ($r = 0.91$), preeclampsia and maternal age were not included.

Statistical analyses

Four models were examined for both outcomes at 18 and 36 months, using Mplus version 7.2.[45] In all analyses the outcome was modelled as a latent variable using an item response theory approach (i.e. multi-level CFA for categorical (ordinal) data using a logit link function).[46] First, main effect cohort analyses including all siblings were conducted to address possible inverse linear trends in associations between gestational age and the outcomes, and adjusted cohort analyses were examined for comparison purposes. Next, the same associations were examined by first calculating unadjusted (only adjusting for unobserved stable family factors) and then adjusted sibling-control (also adjusting for pregnancy-specific observed factors) models (see Supplementary text and Supplementary Figure S1, available as Supplementary data at *IJE* online, for details about the sibling models).

We standardized the beta coefficients for the means by dividing them by the square root of the total (within + between) variance, so the spontaneous term group was the group of reference with a mean of 0 and a variance of 1. The same sibling sample was used for all analyses but, as separate analyses were performed for the outcomes, sample sizes vary. Because we estimated missing data in a multilevel sample using a full-information maximum likelihood approach that does not allow missing data estimation of independent variables, codes for missing data in the variables unplanned pregnancy (2.0%), smoking (0.1%)

Table 3. Means (95% confidence interval) of language skills at age 18 months (not adjusted for gestational age)

	Language comprehension ($N = 21\ 353$)							
	Cohort unadjusted[a]		Cohort adjusted[b]		Sibling-control unadjusted[c]		Sibling-control adjusted[d]	
Gestation duration (weeks)	Spontaneous	Provider-initiated	Spontaneous	Provider-initiated	Spontaneous	Provider-initiated	Spontaneous	Provider-initiated
< 34	−1.06***	−1.10***	−0.95***	−0.97***	−0.55**	−1.71*** [e]	−0.42*	−1.54*** [e]
	(−1.31, −0.80)	(−1.36, −0.84)	(−1.20, −0.70)	(−1.23, −0.70)	(−0.88, −0.23)	(−2.15, −1.28)	(−0.75, −0.10)	(−1.98, −1.10)
34–36	−0.34***	−0.39***	−0.29***	−0.27**	−0.30***	−0.72*** [e]	−0.23**	−0.54***
	(−0.46, −0.22)	(−0.57, −0.22)	(−0.41, −0.17)	(−0.45, −0.08)	(−0.46, −0.13)	(−0.99, −0.45)	(−0.40, −0.07)	(−0.81, −0.27)
37–38	−0.14***	−0.23***	−0.15***	−0.16**	−0.12*	−0.30*** [e]	−0.14***	−0.19*
	(−0.21, −0.08)	(−0.32, −0.15)	(−021, −0.09)	(−0.26, −0.07)	(−0.20, −0.04)	(−0.45, −0.15)	(−0.22, −0.06)	(−0.34, −0.05)
> 38	0.00	−0.08*	0.00	−0.03	0.00	−0.09***	0.00	−0.06*
	Reference	(−0.14, −0.02)	Reference	(−0.08, 0.02)	Reference	(−0.14, −0.04)	Reference	(−0.11, −0.01)
	Language production ($N = 21\ 231$)							
	Cohort unadjusted[a]		**Cohort adjusted[b]**		**Sibling-control unadjusted[c]**		**Sibling-control adjusted[d]**	
Gestation duration (weeks)	**Spontaneous**	**Provider-initiated**	**Spontaneous**	**Provider-initiated**	**Spontaneous**	**Provider-initiated**	**Spontaneous**	**Provider-initiated**
< 34	−0.47***	−0.59***	−0.40***	−0.57***	−0.30*	−1.15***[e]	−0.26	−1.17***[e]
	(−0.66, −0.28)	(−0.83, −0.36)	(−0.59, −0.21)	(−0.80, −0.34)	(−0.57, −0.02)	(−1.60, −0.69)	(−0.53, 0.01)	(−1.62, −0.71)
34–36	−0.18**	−0.22**	−0.15**	−0.13	−0.18*	−0.53***[e]	−0.18*	−0.44***
	(−0.29, −0.07)	(−0.36, −0.07)	(−0.26, −0.04)	(−0.28, 0.02)	(−0.33, −0.02)	(−0.77, −028)	(−0.33, −0.02)	(−0.68, −0.20)
37–38	−0.08**	−0.19***[e]	−0.09**	−0.14**	−0.06	−0.33***[e]	−0.09*	−0.20**
	(−0.13, −0.03)	(−0.26, −0.12)	(−0.14, −0.04)	(−0.22, −0.06)	(−0.14, 0.01)	(−0.47, −0.19)	(−0.16, −0.02)	(−0.34, −0.06)
> 38	0.00	0.01	0.00	0.02	0.00	−0.03	0.00	−0.01
	Reference	(−0.05, 0.06)	Reference	(−0.02, 0.07)	Reference	(−0.07, 0.02)	Reference	(−0.05, 0.04)

[a]Analyses with the same sibling sample used in a conventional cohort design.

[b]Analyses with the same sibling sample used in a conventional cohort design, controlling for pregnancy-specific confounders (parity, smoking or alcohol intake, hypertensive state, bleeding in weeks 13–28, recurrent urinary tract infections, unplanned pregnancy, gestational diabetes, *in vitro* fertilization, low (< 18.5) and high (> 30) BMI (middle group is reference), maternal anxiety and depressive symptoms, child gender, multiple births status, serious malformations at birth and small for gestational age).

[c]Analyses using the sibling-control design, controlling for unobserved familial risks, but not for measured confounders.

[d]Analyses using the sibling-control design, controlling for unobserved familial risks, and for pregnancy-specific confounders (parity, smoking or alcohol intake, hypertensive state, bleedingin weeks 13–28, recurrent urinary tract infections, unplanned pregnancy, gestational diabetes, in vitro fertilization, low (<18.5) and high (> 30) BMI (middle group is reference), maternal anxiety and depressive symptoms, child gender, multiple births status, serious malformations at birth and small for gestational age).

[e]Significant mean level difference between equivalent spontaneous and provider-initiated delivery groups at the ≤ 0.05 level.

$*P = < 0.05$, $**P = < 0.01$, $***P = < 0.001$.

and alcohol intake during pregnancy (3.1%), depressive symptoms (1.6%), BMI (2.8%) and SGA (0.1%) were included as dummy variables.

Neither participation nor attrition in MoBa is random.[47,48] When examining attrition as a function of preterm birth using conditional logistic regression on the total sample of siblings in MoBa, children delivered early preterm were underrepresented as shown by odds ratios for non-response at 18 and 36 months (2.14, $P = .000$; 1.90, $P = .000$), whereas late preterm (0.53, $P = .000$; 0.57, $P = .000$) and early term children (0.86, $P = .012$; 0.91, $P = .088$) were overrepresented, compared with the term group.

Results

At 18 months (see Table 3), the cohort analyses revealed a clear inverse trend showing poorer language comprehension with shorter gestational length, with similar effects for spontaneous and provider-initiated births. Compared with the full term groups, the early preterm groups showed mean levels of language comprehension that were around 1 SD lower, which is a sizeable effect equal to 15 points on an IQ test. The effects were smaller in the late preterm (0.34–0.39 SD) and early term groups (0.14–0.23 SD). The adjusted cohort model reduced the effects only marginally. In the unadjusted sibling-control model, the linear trends for the spontaneous deliveries were sustained overall, but for the early preterm delivery group the effect was substantially smaller than in the cohort analyses. Among provider-initiated births, the inverse linear trend was even more pronounced, with effects for the early preterm, late preterm and early term groups being stronger than among corresponding spontaneous groups. The adjusted sibling-control model shows that the pregnancy-specific covariates accounted for a lesser portion of the effects for all groups, as the inverse linear trends of gestational age were preserved and only slightly diminished. The effects for the provider-initiated births were still larger than in the cohort analyses, and the effect for the provider-initiated early preterm group was still stronger than for the corresponding spontaneous group.

We also found an inverse linear trend between shorter gestational length and poorer language production with the cohort model at 18 months, for both spontaneous and provider-initiated delivery, with a stronger association in the provider-initiated early term than in the equivalent spontaneous group. In the adjusted cohort model, all effects were marginally smaller, and less substantial for the provider-initiated late preterm group. In the unadjusted sibling-control analysis, the language production delays across the spontaneous groups decreased compared with the cohort results. In contrast, the effects in the provider-initiated groups doubled in size, and became different from the means of all equivalent spontaneous groups. In the adjusted sibling-control model, only the mean level difference across the two early preterm groups was sustained.

The cohort results in Table 4 shows that the language delays are less pronounced at 36 months. There were no effects of preterm group on language comprehension for spontaneous deliveries. For provider-initiated deliveries, there was an inverse linear tendency: the early preterm group and late preterm group both showed poorer language comprehension than the full term group, the former being different from the equivalent spontaneous group. These effects were not sustained in the sibling-control analyses, and the minor effect of spontaneous early term delivery in the unadjusted sibling-control model disappeared in the adjusted model.

For language production, lower gestational age was still related to poorer levels in the unadjusted cohort results, with strongest effects in children from provider-initiated delivery, and with the early preterm group effect being different from the same spontaneous group. The confounder adjustments slightly reduced these effects. When comparing siblings across unadjusted and adjusted models, the language production delays in the spontaneous groups only remained for the early term group. In contrast, the language production delays in children from provider-initiated delivery were the same in the cohort and sibling models, except for the early term group where there was no longer strong evidence of an effect. Tests of linear trends are described in Supplementary text, available as Supplementary data at *IJE* online.

Discussion

As expected,[8,10,11] preterm delivery was a major risk factor for early language delays. The cohort results indicate the level of delays the children struggle with every day: at 18 months, both language comprehension and production delays are profoundly affected by gestation duration, with shorter gestations predicting poorer language skills. By 36 months, the delays are less pronounced. Given that comprehension delays reflect more severe impairments,[20–23] overall language delays seem to be less extensive at 36 months. Nevertheless, the delays are still substantial for some children,[12] particularly regarding language production, and for those who experience provider-initiated deliveries.

The sibling-control models enabled us to ascertain the effects adjusted for unmeasured familial risk factors possibly related to both preterm delivery and language delay. First, we found that among the spontaneous births, some of the apparent inverse linear effects of gestational age on language comprehension and production delays at 18 months, as well as almost all effects at 36 months, were accounted for by unobserved familial risk factors.[26–28] Pregnancy-specific risk factors did not account for a substantial share of the effects,[28] and the remaining effects at 18 months indicated that gestational age was a major explanatory factor for these delays, whereas the 36 months delays were mainly explained by familial risk factors.

In contrast, we found that for the provider-initiated deliveries, familial and pregnancy-specific risk factors did not account for the effects of gestational age on language comprehension and production at either 18 or 36 months. In fact, the sibling-control analyses rather strengthened the notion that preterm delivery is a profound risk factor at 18 months, suggesting that pregnancies ending in provider-initiated preterm deliveries involve additional risks compared with spontaneous preterm births. Moreover, the earlier the provider-initiated delivery, the more implications this has for the children. The reasons for the differential effects are not evident. As we adjusted for typical conditions that obstetricians base their decisions to deliver on, such as hypertension or SGA,[30,31] other unmeasured pregnancy-specific risk factors could be important. Alternatively, gestational age could have added implications for children from provider-initiated delivery.

Several limitations should be mentioned. Even if the outcomes' construct validity and reliability were

Table 4. Means (95% confidence interval) of language skills at age 36 months (not adjusted for gestational age)

	Language comprehension ($N = 17\ 871$)							
	Cohort unadjusted[a]		Cohort adjusted[b]		Sibling-ontrol unadjusted[c]		Sibling-Control Adjusted[d]	
Gestation duration (weeks)	Spontaneous	Provider-initiated	Spontaneous	Provider-initiated	Spontaneous	Provider-initiated	Spontaneous	Provider-initiated
< 34	0.14 (−0.36, 0.64)	−0.53**[e] (−0.90, −0.16)	0.17 (−0.33, 0.67)	−0.45*[e] (−0.83, −0.06)	0.45 (−0.25, 1.15)	−0.59[e] (−1.24, 0.05)	0.52 (−0.16, 1.21)	−0.51[e] (−1.20, 0.18)
34–36	−0.21 (−0.44, 0.02)	−0.36** (−0.61, −0.10)	−0.17 (−0.40, 0.05)	−0.27 (−0.54, 0.00)	0.03 (−0.28, 0.34)	−0.27 (−0.78, 0.24)	0.08 (−0.24, 0.40)	−0.18 (−0.70, 0.34)
37–38	−0.06 (−0.17, 0.04)	−0.12 (−0.28, 0.03)	−0.06 (−0.16, 0.05)	−0.10 (−0.28, 0.07)	−0.17* (−0.33, 0.00)	−0.06 (−0.36, 0.25)	−0.16 (−0.32, 0.00)	−0.01 (−0.32, 0.30)
> 38	0.00 Reference	0.01 (−0.09, 0.12)	0.00 Reference	0.02 (−0.07, 0.11)	0.00 Reference	−0.06 (−0.15, 0.03)	0.00 Reference	−0.06 (−0.14, 0.03)
	Language production ($N = 17\ 896$)							
	Cohort unadjusted[a]		Cohort adjusted[b]		Sibling-control unadjusted[c]		Sibling-control adjusted[d]	
Gestational length (weeks)	Spontaneous	Provider-initiated	Spontaneous	Provider-initiated	Spontaneous	Provider-initiated	Spontaneous	Provider-initiated
<34	−0.36** (−0.59, −0.13)	−0.74***[e] (−1.00, −0.47)	−0.30* (−0.53, −0.06)	−0.63***[e] (−0.89, −0.36)	0.00 (−0.33, 0.33)	−0.84**[e] (−1.35, −0.34)	0.03 (−0.29, 0.36)	−0.76**[e] (−1.29, −0.24)
34–36	−0.23** (−0.38, −0.09)	−0.36*** (−0.52, −0.20)	−0.21** (−0.34, −0.07)	−0.23** (−0.39, −0.07)	−0.15 (−0.35, 0.05)	−0.45** (−0.74, -0.16)	−0.09 (−0.28, 0.11)	−0.30* (−0.59, −0.01)
37–38	−0.08* (−0.15, −0.02)	−0.13* (−0.22, −0.03)	−0.09** (−0.15, −0.03)	−0.06 (−0.17, 0.05)	−0.09* (−0.18, 0.00)	−0.15 (−0.33, 0.02)	−0.11* (−0.19, −0.02)	−0.09 (−0.26, 0.08)
> 38	0.00 Reference	−0.08* (−0.14, −0.01)	0.00 Reference	−0.02 (−0.07, 0.03)	0.00 Reference	−0.08** (−0.13, -0.03)	0.00 Reference	−0.06* (−0.11, −0.01)

[a]Analyses with the same sibling sample used in a conventional cohort design.

[b]Analyses with the same sibling sample used in a conventional cohort design, controlling for pregnancy-specific confounders (parity, smoking or alcohol intake, hypertensive state, bleeding in weeks 13–28, recurrent urinary tract infections, unplanned pregnancy, gestational diabetes, *in vitro* fertilization, low (< 18.5) and high (> 30) BMI (middle group is reference), maternal anxiety and depressive symptoms, child gender, multiple births status, serious malformations at birth and small for gestational age).

[c]Analyses using the sibling-control design, controlling for unobserved familial risks, but not for measured confounders.

[d]Analyses using the sibling-control design, controlling for unobserved familial risks, and for pregnancy-specific confounders (parity, smoking or alcohol intake, hypertensive state, bleeding in weeks 13–28, recurrent urinary tract infections, unplanned pregnancy, gestational diabetes, in vitro fertilization, low (< 18.5) and high (> 30) BMI (middle group is reference), maternal anxiety and depressive symptoms, child gender, multiple births status, serious malformations at birth and small for gestational age).

[e]Significant mean level difference between equivalent spontaneous and provider-initiated delivery groups at the ≤ 0.05 level.

*$P =< 0.05$, ** $P =< 0.01$, *** $P =< 0.001$.

established,[41,42] clinical data would have been useful in addition to maternal reports. Moreover, although we did not have access to gestational age-adjusted outcomes, the different impacts across the spontaneous and provider-initiated groups and the large overall effects would not likely be explained by 2 months of language development. Relatedly, the lack of time-invariant language production measures did not permit longitudinal analyses or statistical comparison of effect sizes over time. Importantly, for comparison reasons, the adjusted cohort analyses only included pregnancy-specific confounders, and we need to be careful about generalizing to women with only one child. Furthermore, MoBa mothers show socio-demographic advantages compared with the average Norwegian woman giving birth in the same period,[47,48] possibly explaining the low SGA prevalence. The inclusion of missing data as dummy variables could also potentially introduce bias. Finally, our sample is affected by attrition. If mothers lost to follow-up have a higher rate of both preterm deliveries and children with language delays, this would lead to additional bias. We included covariates not shared by siblings and modelled random measurement error in our outcome. However, we acknowledge that estimates from sibling designs can be biased if covariates more familial than the exposure are included and random measurement error is not accounted for.[49]

In sum, this study emphasizes the importance of sibling-control designs when studying effects of preterm deliveries. First, we could ascertain robust inverse linear associations between gestational age at delivery and early language delays. Second, we found that these associations were particularly strong for provider-initiated deliveries. Third, even if language delays diminish between 18 and 36 months, the delays persist for the early preterm children, particularly those from provider-initiated delivery. Finally, we find that different factors probably underlie the language delays of preterm children delivered provider-initiated compared with spontaneous delivery. Indeed, this underlines the need for examining spontaneous and provider-initiated preterm births separately, to address issues of aetiology,[32] and future studies could aim to identify such factors, for example by comparing similarity in full and half siblings.

Supplementary Data

Supplementary data are available at IJE online.

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