Gestational age on trajectories of social competence difficulties into adolescence

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Abstract

Objective To examine if gestational age groups predict the development of social competence difficulties from childhood into mid-adolescence and to assess the mediation by maternal psychological distress during infancy on these trajectories.

Design Nationally representative population-based birth cohort (UK Millennium Cohort Study).

Participants 15,821 children born in 2000-2002

Outcome measures Social competence difficulties (derived from peer and prosocial subscales of Strengths and Difficulties Questionnaire) were assessed by parent report when the participants were aged 3, 5, 7, 11 and 14 years. Maternal psychological distress was self-rated using Rutter Malaise Inventory when the children were 9 months of age. Data were modelled using latent growth curve analysis.

Results Developmental trajectories of social competence difficulties were u-shaped in all groups. Very preterm children (VP, <32 weeks, n=173) showed pronounced difficulties throughout with the coefficient difference from the full-term at age 14 being 0.94 (95%CI 0.23–1.66, equivalent to 0.32 SD of the population average social competence difficulties). Moderate-to-late preterm children (32-36 weeks, n=1,130) and early-term children (37-38 weeks, n=3,232) showed greater difficulties compared with the full-term peers around age 7, which resolved by age 14 (b=0.20, -0.05–0.44; 0.03, -0.12–0.17, respectively). Maternal psychological distress during infancy mediated 20% of the above association at age 14 for the VP.

Conclusion There was a dose-response association between gestational age and the trajectories of social competence difficulties. Monitoring and providing support on social development throughout childhood and adolescence and treating early maternal psychological distress may help children who were born earlier than ideal, particularly those born VP.

Key words Gestational age, preterm, early-term, social competence, maternal psychological distress

INTRODUCTION

Social competence is the ability to attain successful relationships with others in social situations.[1] Difficulty in social competence is associated with peer problems,[2] educational underachievements,[3] internalising and externalising problems,[4] and poorer functioning in adulthood, including increased risk of psychiatric problems.[5] Preterm birth (< 37 weeks completed gestation) is a known risk factor for children's development, including cognitive, motor and behavioural problems,[6] but less is known about prematurity and social competence.

Growing evidence shows that children born very preterm (VP, <32 weeks) are at increased risk for social competence difficulties (SCD) compared with their full-term peers.[7-10] Although the evidence to support the association between SCD and children born moderate-to-late preterm (MLP, 32–36 weeks) is limited to early-childhood,[11-14] and scarce for children born at early-term (37-38 weeks), it is possible that there is a link between gestational age and SCD. Further, given that cognitive development during childhood differs by gestational age,[15-17] the development of SCD across childhood and adolescence could differ by gestational age.

Postnatal environmental factors that influence early parent-child interaction may play a role in the underlying mechanism underlying increased SCD among children born preterm.[9 18] In particular, preterm birth could lead to increased parental psychological distress during their child's infancy, particularly among mothers,[19 20] which in turn could affect early parent-child interaction and subsequent social development.[21] Therefore, maternal psychological distress during infancy might be a modifiable mediator on the pathway between preterm birth and later SCD. However, this potential mediation has yet to be examined.

Using a nationally representative population-based cohort in the United Kingdom (UK), this study examines developmental trajectories of SCD from early childhood to mid-adolescence by gestational age groups (i.e. VP, MLP, early-term and full-term). We also assess the role of maternal psychological distress during infancy in the association between gestational age and SCD.

METHODS

Study sample

The Millennium Cohort Study (MCS) is a population-representative cohort study which follows the health and development of children born in the UK between September 2000 and January 2002.[22] Data were collected when the cohort members were 9 months and 3, 5, 7, 11, 14 years old. Details of the study design are described elsewhere.[22] Of the 18,818 children who participated at the first wave of the study (i.e. age 9 months), we excluded those whose main respondent was not the natural mother or those with missing or implausible gestational age or birth weight. Those born post-term ($\geq$ 42 weeks) were also excluded due to known poor agreement between maternal recall and hospital records for this group in the MCS.[23] In this study, children with valid information on their SCD on at least one of all five waves (i.e. age 3, 5, 7, 11 and 14 interviews) were included, resulting in 15,821 children in the analytic sample (Figure S1).

Gestational age groups

Gestational age in weeks was calculated based on the mother's report of the expected due date, which corresponded well with gestational age recorded in the linked hospital data.[23] Children were divided into four groups based on their reported-gestational age:

- VP (23–31 weeks completed gestation)

- MLP (32–36 weeks)

- Early-term (37–38 weeks)

- Full-term (39–41 weeks).

Social competence difficulties (SCD) score

SCD during childhood and adolescence were assessed using peer and prosocial subscales of the parent-rated Strengths and Difficulties Questionnaire (SDQ)[24] measured at ages 3, 5, 7, 11 and 14. Peer and prosocial subscales of the SDQ represented the two key concepts of social competence (i.e. prosocial behaviour representing the appropriateness of the behaviours in social situations, and social initiation/ peer competence representing active participation in social interactions).[25] The total of peer and reverse-coded prosocial scale scores were summed to give a SCD score (range 0-20, higher scores indicate more severe difficulties). Cronbach's alpha for SCD ranged from 0.65 to 0.74 across the five waves.

Maternal psychological distress

Maternal psychological distress was assessed using a modified version of the Rutter Malaise Inventory measured when the child was approximately 9 months old.[26] This is a 9-item self-completed questionnaire which has respectable reliability and correlates well with the original 24-item version that has good validity.[26] The scores range from 0 to 9 with higher scores indicating more severe psychological distress.

Covariates

The following covariates, all measured at 9 months, were included in the study model as potential confounders based on previous literature[8 11 13]: child's sex, multiple birth indicator,

highest maternal educational attainment (attaining GCSE Advanced level or equivalent which is the qualification level required to enter university, or not), relative poverty of the household indicated by household equivalised income of less than 60% of the UK national median household income,[22] and mother's age at the cohort child's birth.

Data Analyses

We first conducted descriptive and sample bias analysis for our study variables. To predict the children's SCD over time by gestational age groups, we modelled the group-average trajectory of SCD using latent growth curve models. We included linear and quadratic slopes to account for the curved shape of children's average trajectories. Chronological age was used as the time scores and age was centred at age 14 (i.e. the last available interview conducted) to explore group differences at that age. All models were adjusted for sex and multiple birth status. In Model 0, intercept, linear and quadratic slope factors were included. In Model 1, gestational age was included to demonstrate the association between gestational age and the child's SCD at age 14 and how it changed with age. Model 2 controlled for time-invariant family confounders. We examined possible mediation of the association by maternal psychological distress when the child was 9 months old in two ways: 1) adjusting for this factor in the model (Model 3) and 2) examining direct and indirect effects in a mediation model. Further, to aid our understanding of group differences at each age point, we repeated the analyses by centring at the beginning of the study period (i.e. age 3) and around the midpoint (i.e. age 7). As a sensitivity analysis, we repeated the analyses by restricting the sample to those with a valid social competence score at all five time-points (n = 10,460). We imputed missing covariates using multiple imputation by chained equations to create 20 imputed data sets.[27] Imputed results were broadly similar to those obtained using observed samples (Table S1); hence we report the imputed results. Growth curve models and mediation

analysis were conducted using Mplus 8.3. (Muthén & Muthén, Los Angeles, CA) and descriptive analyses and figure plotting were conducted using Stata version 15.1 (Stata Corp, College Station, TX). All analyses took into account the clustering and stratified sampling of the MCS and were weighted using survey weights. The data collection of MCS is approved by the UK National Health Service Research Ethics Committee.[28]

RESULTS

Descriptive characteristics of our study sample by gestational age groups are presented in Table 1. Of the 15,821 children included, 11,286 (71.2%) were born full-term, 3,232 (20.4%) as early-term, 1,130 (7.3%) as MLP and 173 (1.1%) as VP. Compared with the full-term, more multiple births were present among the preterm groups. Mean maternal psychological distress when the child was 9 months was significantly higher in the VP (2.4, 95%CI 2.1–2.7) compared to the other groups (1.6, 1.5–1.6 for full-term; 1.7, 1.6–1.7 for MLP; 1.7, 1.6–1.8 for early-term). In all groups, the mean SCD scores were highest at age 3 and decreased with age, then increased again around age 11 to 14. Scores were higher for shorter gestational age groups at all ages (Table 2). The result of our sample bias analysis showed that those from more disadvantaged families and with younger mothers were more likely to be excluded from the analysis (Table S2).

The estimated results for the growth curve models examining the association between gestational age and SCD from age 3 to 14 are shown in Table 3 (with full set of covariates are shown in Table S3). The coefficients for each gestational age group represent the difference from the full-term (reference group) at age 14. In Model 1, this coefficient increased across gestational age groups (b=0.048, 95%CI -0.104–0.199 for early-term; 0.235, -0.012–0.483 for MLP; 1.031, 0.275–1.786 for VP), with the VP showing significantly higher SCD at age 14

compared to the rest. The coefficient for the interaction between gestational age group and linear and quadratic slopes were nonsignificant, providing no evidence to suggest that the overall change in the patterns of trajectory was different across groups. Adjusting for family confounders in Model 2 did not change the results. Here, the coefficient for VP was 0.943 which was approximately 0.32 SD of the population average at age 14. Restricting our analysis to children with SCD score for all five-time points showed similar results (Table S4).

The mean trajectory of SCD was u-shaped for all gestational age groups (Figure 1); SCD levels declined from age 3 to around age 7, followed by a stable low period and then increased again from around age 11. The VP showed a consistently elevated SCD trajectory from age 3 to age 14 compared to all other groups, suggesting higher levels of SCD throughout childhood and into mid-adolescence. Despite no significant interaction between gestational age group and linear and quadratic slopes, a small difference for the MLP from that of the full-term emerged around age 5, persisting throughout mid-childhood before gradually narrowing during adolescence. The trajectory for the early-term overlapped with that of the MLP but with a smaller gap from the full-term during mid-childhood, ending with a gap which was no longer evident around age 14. These unique group differences at each age were further supported by our supplementary analyses centred at different ages; while only the VP showed a significant difference from the full-term at age 3, all groups (i.e. early-term, MLP and VP) showed a significant difference from the full-term at age 7 (Table S5). Adding maternal psychological distress in Model 3 mainly attenuated the association with VP birth (Table 3). Mediation analyses (Table 4, with full estimates presented in Table S6) confirmed that maternal psychological distress accounted for 20% of the association between VP birth and the SCD intercept at age 14.

DISCUSSION

Trajectories of SCD were u-shaped across gestational age groups; they declined during early childhood to around age 7, followed by a stable low period and then an escalation as the children entered adolescence. While the VP group showed pronounced difficulties throughout, the MLP and early-term groups showed slightly greater difficulties around age 7 compared with the full-term group which resolved by age 14. Maternal psychological distress when the child was 9 months old partially mediated the association between VP birth and SCD.

Our findings that VP children showed persistently greater SCD from early-childhood into mid-adolescence concur with previous studies.[7-10] Trajectory analyses demonstrated that these difficulties for the VP children did not decrease with age compared with the full-term children, showing a 0.32 SD difference at age 14. Previous research found a 1SD decrease in social competence scores in early childhood was associated with various adult functioning, for example, 34% decreased odds of having stable employment and 54% increase in the number of years on medication for mental health conditions.[5] Although a direct comparison is difficult, their results suggest that, persistently greater difficulties across childhood leading to a 0.32 SD difference at age 14 for the VP group could have a prolonged influence on their social and emotional functioning in adulthood.

The MLP and early-term groups showed greater difficulties compared with the full-term children at around age 7; however, the gap was no longer significant at age 14, which offers partial support to the studies reporting higher SCD among children born MLP.[11-13] Different from the previous studies, our estimates are based on a population-representative sample rather than hospital-based samples, and observations extended into adolescence.

Interestingly, the developmental trajectory of SCD was u-shaped. Our results correspond with studies exploring the developmental trajectory of social competence in the general population which suggest an inverted u-shape trajectory (i.e., increase during early-childhood,[29] stability during mid-childhood,[30] and a decline during adolescence).[31] Further, as these prior studies suggest that social competence may rebound and increase in late adolescence towards early-adulthood,[31] future studies extending the observation to adulthood would elaborate how the gap in SCD across gestational groups observed in this study could continue to evolve.

In our study, maternal psychological distress during infancy mediated 20% of the association between VP birth and SCD in adolescence. Early psychological distress among parents of preterm children may affect parental perceptions of the child (e.g., regard the child as more vulnerable),[32] parenting behaviours such as less responsive or overprotective parenting[32 33] and parent-child interactions,[21] all of which may impact on the child's subsequent social development. Although the magnitude of the observed mediation was limited, given the time-gap between our variables, even a small effect may be meaningful. Our results support the importance of providing interventions to reduce maternal psychological distress during infancy, particularly among mothers of the VP children.[19 20 33] This approach may help reduce the long-term SCD in these children.

Our study has many strengths, especially the use of nationally-representative cohort data in the contemporary UK, which enabled us to establish dose-response associations between finer-grained gestational age groups and SCD than previously possible. The longitudinal design of the MCS with repeated measurements of the child's SCD over five waves allowed us to identify the curvilinear u-shaped trajectories across childhood and into mid-adolescence.

There are some limitations to our study. First, our SCD were measured based on parental report. While parental report is valuable in identifying children's behavioural difficulties, it could bias results by reflecting parental views or expectations.[34] Second, although we used a population-representative sample, children from disadvantaged families were more likely to be excluded from our analysis. Since low socioeconomic position is associated with both preterm birth and SCD, this could have led to conservative estimates. Third, in our mediation analysis, the child's SCD and maternal psychological distress were measured mostly by the same person (i.e., the mother). This could have inflated the estimates as distressed mothers are more likely than non-distressed mothers to report their child's behaviour negatively.[32] However, there was up to a 13-year time-lag between the measurement of our mediator and SCD. Previous studies report that increased psychological distress during infancy among mothers of VP children are likely to resolve with time.[35] Fourth, other factors, such as the child's cognitive ability or neonatal complications related to preterm birth could also be a mediator on the pathway between gestational age and SCD, as shown in a different study.[36] However, we did not have valid information on specific neonatal complications and our focus was on the role of a potentially modifiable mediator.

Our results suggest a dose-response association between gestational age and developmental trajectories of SCD. Given the increased SCD across development for children born VP, it is important to monitor aspects of social development and provide continuous support into adolescence for these children. Providing social skills training to the child and interventions to reduce maternal psychological distress during infancy may help these preterm at-risk children. Further research is needed to understand how social competence developmental trajectories evolve into adulthood, and to explore the lasting influence of increased SCD not

only for children born VP but also for children born MLP and early-term. This information

would help improve long-term care for all children born earlier than ideal.

Ethics approval The MCS is approved by the UK National Health Service Research Ethics Committee and written consent was obtained from all participating parents at each survey; MCS1: South West MREC (MREC/01/6/19); MCS2, MCS3: London MREC (MREC/03/2/022, 05/MRE02/46); MCS4:Yorkshire MREC (07/MRE03/32), MCS5: Yorkshire and The Humber-Leeds East (11/YH/0203), MCS6:London MREC(13/LO/1786). The use of anonymized data for academic purposes did not require additional ethical approval.

Data Sharing: Millennium Cohort Study is available via the UK Data Archive. Further information about the study is found at https://cls.ucl.ac.uk/cls-studies/millennium-cohort-study/.

Contributors MH designed the study, carried out analysis and drafted the initial manuscript. NC, YK and AS provided support on the design of the study, interpretation of the results and revised the manuscript.

What is already known
- Very preterm birth (VP, < 32 weeks gestation) is associated with increased risk of social competence difficulties.
- For moderate-to-late preterm (MLP, 32–36 weeks), evidence followed into adolescence is scarce with inconsistent results, and evidence is lacking for early-term (37-38 weeks).
- The role of early maternal psychological distress, which could be a modifiable mediator on the above association, has yet to be studied.

What this study adds
- There was a dose-response association between gestational age and the trajectories of social competence difficulties from early childhood into mid-adolescence.
- VP showed pronounced difficulties throughout, MLP and early-term showed slightly greater difficulties around age 7 compared with the full-term which resolved by age 14.
- Maternal psychological distress during infancy explained 20% of the association between VP and social competence difficulties at age 14.

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Table 1: Descriptive characteristics of the multiply imputed sample, by gestational age groups

	Full-term (n =11,286, 71.2%)	Early-term (n = 3,232, 20.4%)	MLP (n =1,130, 7.3%)	VP (n = 173, 1.1%)	p^a
	%	%	%	%	
Gestational age (wks), mean (95% CI)	40.2 (40.1, 40.2)	37.9 (37.9, 37.9)	35.1 (35.0, 35.2)	29.1 (28.7, 29.5)	< .001
Birth weight (kg), mean (95% CI)	3.5 (3.5, 3.5)	3.2 (3.1, 3.2)	2.5 (2.5, 2.5)	1.3 (1.2, 1.4)	< .001
Sex (Male)	50.5	52.5	54.4	54.7	.06
Multiple birth	0.3	5.3	18.6	22.7	< .001
Low maternal education[b]	49.5	53.9	55.6	52.9	< .001
Low household income[c]	26.7	28.0	28.0	29.3	.53
Maternal age at childbirth (years), mean (95% CI)	29.0 (28.7, 29.2)	29.4 (29.1, 29.8)	29.4 (28.9, 29.9)	28.5 (27.4, 29.6)	< .001
Maternal psychological distress, mean (95% CI)[d]	1.6 (1.5, 1.6)	1.7 (1.6, 1.7)	1.7 (1.6, 1.8)	2.4 (2.1, 2.7)	< .001

MLP = moderate-to-late preterm; VP = very preterm. Weighted means and percentages are shown.
[a]p values for group difference. [b]Below A-level (a qualification required to enter university) or not. [c]Below 60% of UK national median household income. [d] Measured when the child was 9 months.

Table 2: Mean social competence difficulties scores for each age interview, by gestational age groups

	Full-term (n = 11,286)			Early-term (n = 3,232)			MLP (n = 1,130)			VP (n = 173)		
	n	Mean	SD	n	Mean	SD	n	Mean	SD	N	Mean	SD
Age 3	9,609	4.14	2.75	2,733	4.25	2.83	917	4.28	2.81	144	5.12	3.14
Age 5	9,768	2.69	2.47	2,728	2.80	2.49	961	2.82	2.52	151	3.51	3.07
Age 7	8,950	2.61	2.56	2,503	2.82	2.71	871	2.87	2.80	123	3.19	2.56
Age 11	8,512	2.65	2.68	2,324	2.79	2.79	785	3.06	3.05	117	3.38	2.58
Age 14	7,545	3.63	3.08	2,090	3.66	3.02	726	4.01	3.17	110	4.79	3.36

MLP = moderate-to-late preterm; VP = very preterm; SD = standard deviation. Unweighted counts and weighted means are shown.

Table 3 Fixed estimates of latent growth curve models of social competence difficulties from age 3 to 14

	Model 1 gestational age adjusted		Model 2 confounder adjusted[a]		Model 3 mediator included[b]	
	b	95%CI	b	95%CI	b	95%CI
Intercept	3.296[***]	(3.216, 3.377)	3.331[***]	(3.259, 3.403)	3.336[***]	(3.265, 3.407)
Slope	0.454[***]	(0.433, 0.475)	0.459[***]	(0.438, 0.481)	0.460[***]	(0.439, 0.481)
Quadratic slope	0.048[***]	(0.046, 0.050)	0.048[***]	(0.046, 0.050)	0.048[***]	(0.046, 0.050)
Full-term	Ref	-	Ref	-	Ref	-
Early-term	0.048[c]	(-0.104, 0.199)	0.026[c]	(-0.118, 0.170)	0.012[c]	(-0.129, 0.153)
MLP	0.235[d]	(-0.012, 0.483)	0.195[d]	(-0.05, 0.440)	0.187	(-0.054, 0.427)
VP	1.031[**c,d]	(0.275, 1.786)	0.943[*c,d]	(0.229, 1.657)	0.760[*c]	(0.023, 1.497)
Full-term*slope	Ref	-	Ref	-	Ref	-
Early-term*slope	-0.037	(-0.079, 0.006)	-0.038	(-0.081, 0.004)	-0.039	(-0.082, 0.003)
MLP*slope	-0.014	(-0.076, 0.047)	-0.016	(-0.078, 0.046)	-0.016	(-0.079, 0.046)
VP*slope	0.133	(-0.084, 0.350)	0.123	(-0.090, 0.336)	0.117	(-0.098, 0.331)
Full-term*quadratic	Ref	-	Ref	-	Ref	-
Early-term*quadratic	-0.003	(-0.007, 0.001)	-0.003	(-0.007, 0.001)	-0.003	(-0.007, 0.001)
MLP*quadratic	-0.002	(-0.008, 0.003)	-0.002	(-0.008, 0.003)	-0.003	(-0.008, 0.003)
VP*quadratic	0.010	(-0.007, 0.028)	0.010	(-0.007, 0.027)	0.010	(-0.008, 0.027)

MLP = moderate-to-late preterm; VP = very preterm $^*p < .05$, $^{**}p < .01$, $^{***}p < .001$. All models adjusted for sex and multiple birth status. [a]Further adjusted for maternal education, household income, maternal age at childbirth. [b]Adjusted for maternal psychological distress at 9months of child age. [c]Significant difference between early-term and VP groups at 5 % levels. [d]Significant difference between MLP and VP groups at 5 % levels.

Table 4 Estimates of direct and indirect effect for intercepts (mediated through maternal psychological distress) of association between gestational age groups and social competence difficulties

Effect size	Indirect effect b (95%CI)	Direct effect b (95%CI)	Total effect b (95%CI)
Full-term	Ref	Ref	Ref
Early-term	0.022 (0.004, 0.041)[*]	0.012 (-0.129, 0.153)	0.034 (-0.11, 0.179)
MLP	0.024 (-0.006, 0.054)	0.187 (-0.054, 0.427)	0.211 (-0.033, 0.454)
VP	0.188 (0.109, 0.268)[***]	0.760 (0.023, 1.497)[*]	0.949 (0.231, 1.666)[*]

MLP = moderate-to-late preterm; VP = very preterm [*]$p < .05$, [***]$p < .001$. Mediating effect for the intercept of latent growth curve model in Mplus adjusted for sex, multiple birth status, maternal education, household income and maternal age at childbirth are shown.

Figure 1 legend
Predicted plot and trajectory of social competence difficulties by gestational age groups from the confounder adjusted model (Model 2).
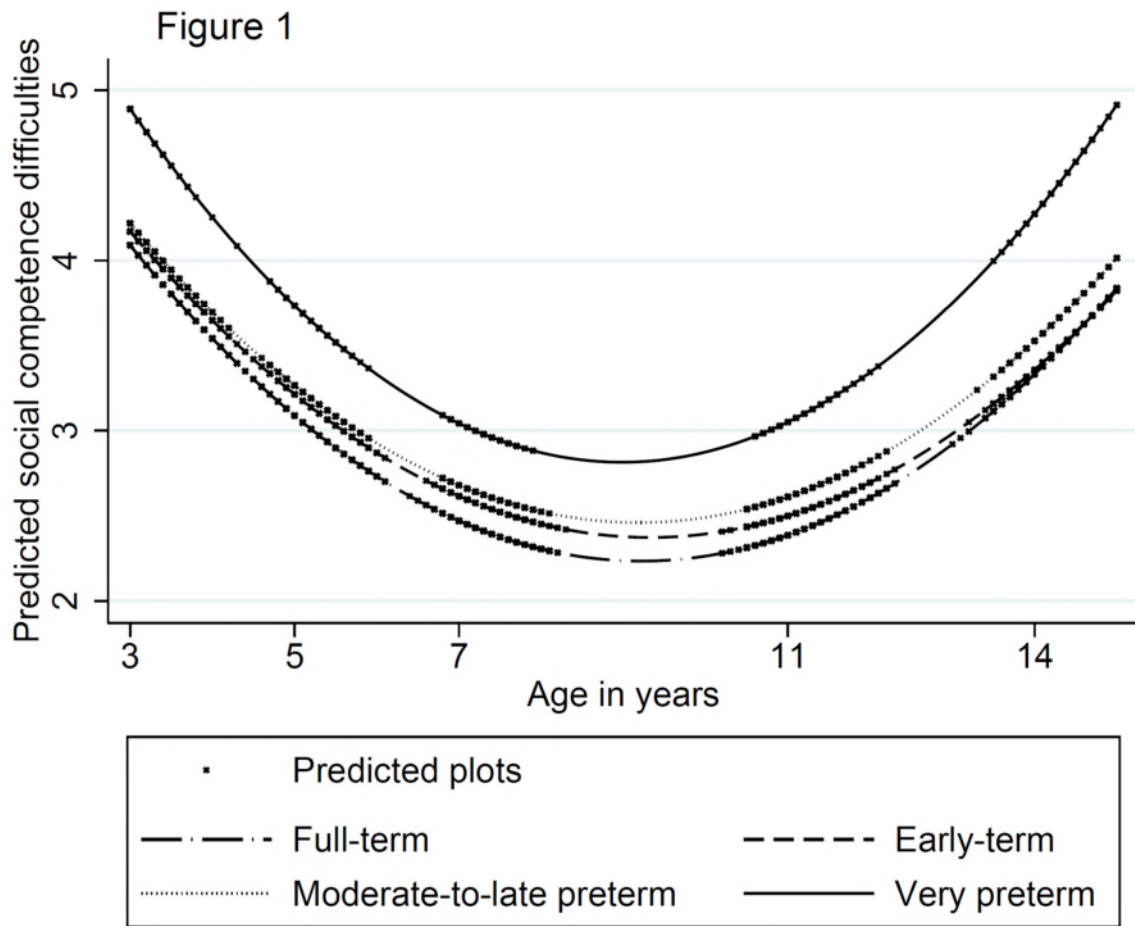

Figure 1

Figure S1 legend
A flow-chart for sample selection.
[a]Implausible for birth weight was defined as birth weight lying outside of ± 4 SD based on gender-segregated birth weight for gestational age centile charts.

Supplementary Table S1 Descriptive characteristics of the study sample, by gestational age groups

	Full-term (n =11,286, 71.2%)		Early-term (n = 3,232, 20.4%)		MLP (n =1,130, 7.3%)		VP (n = 173, 1.1%)		p [a]
	n	%	n	%	n	%	n	%	
Descriptive characteristics									
Gestational age (wks), mean (SD)	11,286	40.2 (0.8)	3,232	37.9 (0.5)	1,130	35.1 (1.2)	173	29.0 (2.0)	<.001
Birth weight (kg), mean (SD)	11,286	3.5 (0.5)	3,232	3.2 (0.5)	1,130	2.5(0.5)	173	1.3(0.5)	<.001
Sex									
Male	5,704	50.5	1,702	52.5	603	54.4	100	54.7	.06
Female	5,582	49.5	1,530	47.5	527	45.6	73	45.3	
Multiple birth									
No	11,238	99.7	3071	94.7	934	81.4	140	77.4	<.001
Yes	48	0.4	161	5.3	196	18.6	33	22.7	
Low maternal education[b]									
No	5,147	50.5	1,377	46.1	464	44.4	75	47.1	<.001
Yes	6,126	49.5	1,854	53.9	664	55.6	98	52.9	
Low household income[c]									
No	7,370	73.3	2,035	72.0	703	72.0	107	70.7	.57
Yes	3,892	26.8	1,188	28.0	425	28.0	66	29.3	
Maternal age at childbirth (years), mean (SD)	11,285	29.0 (5.7)	3,232	29.4 (5.8)	1,130	29.4 (6.3)	173	28.5 (5.7)	<.001
Maternal psychological distress, mean (SD)[d]	10,910	1.6 (1.7)	3,119	1.7 (1.7)	1,094	1.7 (1.7)	159	2.4 (1.9)	<.001

MLP = moderate-to-late preterm; VP = very preterm; SD = standard deviation. Unweighted counts and weighted means and percentages are shown. N varies due to missing data. [a]p values for group difference obtained from chi-square tests for categorical variables and from Wald tests for continuous variables. [b]Below A-level (a qualification required to enter university) or not. [c]Below 60% of UK national median household income. [d]Measured when the child was 9 months.

Supplementary Table S2: Sample bias analysis

	Analytic sample (n = 15,821)		Non-analytic sample[a] (n = 1,931)		p[b]
	n	%	N	%	
Sex					
Male	8,109	51.2	1,048	54.2	.04
Female	7,712	48.8	883	45.9	
Multiple birth					
No	15,383	97.1	1,871	96.7	.60
Yes	438	2.9	60	3.3	
Low maternal education					
No	7,063	49.1	642	37.2	<.001
Yes	8,742	50.9	1,278	62.8	
Low household income					
No	10,215	72.9	1,004	59.6	<.001
Yes	5,571	27.1	910	40.4	
Gestational age group					
Full-term	11,286	71.3	1,349	70.5	.12
Early-term	3,232	20.4	418	21.0	
MLPT	1,130	7.3	129	6.7	
VP	173	1.1	35	1.8	
Maternal age at childbirth (years), mean (SD)	29.1	5.8	27.8	6.5	<.001
Maternal psychological distress, mean (SD)	1.6	1.7	1.6	1.8	.70

MLP = moderate-to-late preterm; VP = very preterm; SD = standard deviation. Unweighted counts and weighted means and percentages are shown. N varies due to missing data. [a]Consists of children who were eligible for this study but were excluded due to missing outcome data. [b]p values for group difference.

Supplementary Table S3: Full estimates of latent growth curve models of social competence difficulties from age 3 to 14

	Model 0 crude model	Model 1 gestational age adjusted	Model 2 confounder adjusted[a]	Model 3 mediator adjusted[b]
	b (95% CI)	b (95% CI)	b (95% CI)	b (95% CI)
Fixed effects				
Intercept	3.681 (3.587, 3.775)***	3.296 (3.216, 3.377)***	3.331 (3.259, 3.403)***	3.336 (3.265, 3.407)***
Slope	0.436 (0.412, 0.460)***	0.454 (0.433, 0.475)***	0.459 (0.438, 0.481)***	0.460 (0.439, 0.481)***
Quadratic slope	0.046 (0.044, 0.048)***	0.048 (0.046, 0.050)***	0.048 (0.046, 0.050)***	0.048 (0.046, 0.050)***
Full-term		Ref (-)	Ref (-)	Ref (-)
Early-term		0.048 (-0.104, 0.199)[c]	0.026 (-0.118, 0.170)[c]	0.012 (-0.129, 0.153)[c]
MLP		0.235 (-0.012, 0.483)[d]	0.195 (-0.05, 0.440)[d]	0.187 (-0.054, 0.427)
VP		1.031 (0.275,1.786)**[c,d]	0.943 (0.229, 1.657)*[c,d]	0.760 (0.023, 1.497)*[c]
Sex	-0.722 (-0.831,-0.614)***	-0.717 (-0.825, -0.608)***	-0.731 (-0.838, -0.624)***	-0.719 (-0.826, -0.612)***
Multiple birth	0.200 (-0.278, 0.677)	0.012 (-0.482, 0.507)	0.173 (-0.329, 0.675)	0.153 (-0.346, 0.653)
Low maternal education			0.348 (0.231, 0.464)***	0.307 (0.191, 0.423)***
Low household income			0.790 (0.634, 0.946)***	0.689 (0.534, 0.844)***
Maternal age at childbirth			-0.041 (-0.052, -0.030)***	-0.039 (-0.050, -0.028)***
Maternal distress				0.229 (0.194, 0.265)***
Full-term*slope		Ref (-)	Ref (-)	Ref (-)
Early-term*slope		-0.037 (-0.079, 0.006)	-0.038 (-0.081, 0.004)	-0.039 (-0.082, 0.003)
MLP*slope		-0.014 (-0.076, 0.047)	-0.016 (-0.078, 0.046)	-0.016 (-0.079, 0.046)
VP*slope		0.133 (-0.084, 0.350)	0.123 (-0.090, 0.336)	0.117 (-0.098, 0.331)
Sex*slope	0.023 (-0.008, 0.053)	0.023 (-0.008, 0.053)	0.021 (-0.010, 0.051)	0.021 (-0.010, 0.051)
Multiple birth*slope	0.021 (-0.115, 0.157)	0.021 (-0.121, 0.163)	0.035 (-0.104, 0.174)	0.034 (-0.106, 0.174)
Low maternal education*slope			0.039 (0.004, 0.074)*	0.037 (0.003, 0.072)*
Low household income*slope			-0.002 (-0.051, 0.048)	-0.006 (-0.056, 0.044)
Maternal age at childbirth*slope			-0.005 (-0.008, -0.002)**	-0.005 (-0.008, -0.002)**
Maternal distress*slope				0.009 (-0.002, 0.020)
Full-term*quadratic		Ref (-)	Ref (-)	Ref (-)
Early-term*quadratic		-0.003 (-0.007, 0.001)	-0.003 (-0.007, 0.001)	-0.003 (-0.007, 0.001)
MLP*quadratic		-0.002 (-0.008, 0.003)	-0.002 (-0.008, 0.003)	-0.003 (-0.008, 0.003)

VP*quadratic		0.010 (-0.007, 0.028)	0.010 (-0.007, 0.027)	0.010 (-0.008, 0.027)
Sex*quadratic	0.002 (0.000, 0.005)	0.002 (0.000, 0.005)	0.002 (-0.001, 0.005)	0.002 (-0.001, 0.005)
Multiple birth*quadratic	0.000 (-0.013, 0.014)	0.001 (-0.013, 0.015)	0.001 (-0.012, 0.015)	0.001 (-0.013, 0.015)
Low maternal education*quadratic			0.005 (0.001, 0.008)**	0.004 (0.001, 0.008)**
Low household income*quadratic			-0.002 (-0.006, 0.003)	-0.002 (-0.007, 0.002)
Maternal age at childbirth*quadratic			0.000 (0.000, 0.000)	0.000 (0.000,0.000)
Maternal distress*quadratic				0.001 (0.000, 0.002)

Variance Components				
Intercept	5.624 (5.284, 5.963)***	5.612 (5.272, 5.952)***	5.283 (4.959, 5.608)***	5.138 (4.823, 5.453)***
Slope	0.169 (0.143, 0.196)***	0.169 (0.142, 0.196)***	0.168 (0.141, 0.195)***	0.168 (0.141, 0.194)***
Quadratic	0.001 (0.001, 0.002)***	0.001 (0.001, 0.002)***	0.001 (0.001, 0.002)***	0.001 (0.001, 0.002)***
Intercept-slope covariance	0.378 (0.304, 0.452)***	0.377 (0.302, 0.451)***	0.361 (0.287, 0.434)***	0.354 (0.282, 0.426)***
Intercept-quadratic covariance	0.006 (0.000, 0.013)	0.006 (0.000, 0.013)	0.006 (-0.001, 0.012)	0.005 (-0.001, 0.012)
Slope-quadratic covariance	0.013 (0.011, 0.016)***	0.013 (0.011, 0.016)***	0.013 (0.011, 0.016)***	0.013 (0.011, 0.016)***

Log-likelihood	-142732.232	-142711.189	-142290.583	-142056.728

MLP = moderate-to-late preterm; VP = very preterm. $^*p$ <.05, $^{**}p$ <.01, $^{***}p$ <.001. All models adjusted for sex and multiple birth status. [a]Further adjusted for maternal education, household income, maternal age at childbirth. [b]Adjusted for maternal psychological distress at 9months of child age. [c]Significant difference between early-term and VP groups at 5 % levels. [d]Significant difference between MLP and VP groups at 5 % levels.

Supplementary Table S4: Sensitivity analysis for children with social competence difficulties measured at all five-time points (N = 10,460).

	Model 2 confounder adjusted[a]
	b (95% CI)
Fixed effects	
Intercept	3.238 (3.166, 3.310)[***]
Slope	0.449 (0.428, 0.471)[***]
Quadratic slope	0.047 (0.045, 0.049)[***]
Full-term	Ref (-)
Early-term	0.036 (-0.116, 0.189)[b]
MLP	0.190 (-0.066, 0.446)
VP	0.901 (0.167, 1.634)[*b]
Sex	-0.719 (-0.831, -0.606)[***]
Multiple birth	0.221 (-0.298, 0.741)
Low maternal education	0.338 (0.218, 0.458)[***]
Low household income	0.779 (0.621, 0.937)[***]
Maternal age at child birth	-0.045 (-0.058, -0.033)[***]
Full-term*slope	Ref (-)
Early-term*slope	-0.035 (-0.080, 0.011)
MLP*slope	-0.006 (-0.071, 0.059)
VP*slope	0.157 (-0.061, 0.375)
Sex*slope	0.018 (-0.015, 0.052)
Multiple birth*slope	-0.064 (-0.207, 0.080)
Low maternal education*slope	0.038 (0.003, 0.074)[*]
Low household income*slope	-0.003 (-0.055, 0.049)
Maternal age at child birth*slope	-0.004 (-0.007, 0.000)[*]
Full-term*quadratic	Ref (-)
Early-term*quadratic	-0.003 (-0.007, 0.002)
MLP*quadratic	-0.002 (-0.008, 0.004)
VP*quadratic	0.011 (-0.007, 0.030)
Sex*quadratic	0.002 (-0.001, 0.005)
Multiple birth*quadratic	-0.010 (-0.024, 0.004)
Low maternal education*quadratic	0.005 (0.001, 0.008)[**]
Low household income*quadratic	-0.002 (-0.007, 0.003)
Maternal age at child birth*quadratic	0.000 (0.000, 0.000)
Variance Components	
Intercept	5.229 (4.905, 5.552)[***]
Slope	0.170 (0.145, 0.196)[***]
Quadratic	0.001 (0.001, 0.002)[***]
Intercept-slope covariance	0.405 (0.331, 0.479)[***]
Intercept-quadratic covariance	0.009 (0.003, 0.016)[**]
Slope-quadratic covariance	0.013 (0.011, 0.016)[***]
Log-likelihood	-108761.088

MLP=moderate-to-late preterm; VP=very preterm. [*]$p < .05$, [**]$p < .01$, [***]$p < .001$. [a]Adjusted for sex, multiple birth, maternal education, household income, maternal age at childbirth. [b]Significant difference between early-term and VP groups at 5 % levels.

Supplementary Table S5: Full estimates of confounder adjusted model (Model 2) centred at different age points (N = 15,824)

	Model 2 Centred at age 3	Model 2 Centred at age 7
	b (95% CI)	b (95% CI)
Fixed effects		
Intercept	4.081 (4.018, 4.144)***	2.466 (2.415, 2.516)***
Slope	-0.596 (-0.618, -0.573)***	-0.212 (-0.222, -0.202)***
Quadratic slope	0.048 (0.046, 0.050)***	0.048 (0.046, 0.050)***
Full-term	Ref (-)	Ref (-)
Early-term	0.059 (-0.065, 0.183)[b]	0.137 (0.027, 0.247)*
MLP	0.074 (-0.150, 0.299)[c]	0.187 (0.022, 0.352)*
VP	0.789 (0.213, 1.364)**,[b,c]	0.567 (0.053, 1.080)*
Sex	-0.686 (-0.789, -0.582)***	-0.765 (-0.841, -0.689)***
Multiple birth	-0.044 (-0.474, 0.386)	-0.004 (-0.325, 0.317)
Low maternal education	0.468 (0.361, 0.576)***	0.298 (0.208, 0.387)***
Low household income	0.578 (0.445, 0.712)***	0.709 (0.592, 0.825)***
Maternal age at child birth	-0.005 (-0.014, 0.005)	-0.014 (-0.022, -0.006)**
Full-term*slope	Ref (-)	Ref (-)
Early-term*slope	0.032 (-0.014, 0.079)	0.007 (-0.014, 0.027)
MLP*slope	0.038 (-0.033, 0.109)	0.018 (-0.014, 0.050)
VP*slope	-0.095 (-0.292, 0.101)	-0.016 (-0.101, 0.069)
Sex*slope	-0.029 (-0.065, 0.007)	-0.011 (-0.027, 0.005)
Multiple birth*slope	0.004 (-0.183, 0.192)	0.016 (-0.074, 0.106)
Low maternal education*slope	-0.061 (-0.102, -0.019)**	-0.025 (-0.043, -0.006)**
Low household income*slope	0.040 (-0.013, 0.093)	0.025 (0.003, 0.047)*
Maternal age at child birth*slope	-0.002 (-0.005, 0.002)	-0.003 (-0.004, -0.001)***
Full-term*quadratic	Ref (-)	Ref (-)
Early-term*quadratic	-0.003 (-0.007, 0.001)	-0.003 (-0.007, 0.001)
MLP*quadratic	-0.002 (-0.008, 0.003)	-0.002 (-0.008, 0.003)
VP*quadratic	0.010 (-0.007, 0.027)	0.010 (-0.007, 0.027)
Sex*quadratic	0.002 (-0.001, 0.005)	0.002 (-0.001, 0.005)
Multiple birth*quadratic	0.001 (-0.012, 0.015)	0.001 (-0.012, 0.015)
Low maternal education*quadratic	0.005 (0.001, 0.008)**	0.005 (0.001, 0.008)**
Low household income*quadratic	-0.002 (-0.006, 0.003)	-0.002 (-0.006, 0.003)
Maternal age at child birth*quadratic	0.000 (0.000, 0.000)	0.000 (0.000, 0.000)
Variance Components		
Intercept	4.081 (4.018, 4.144)***	3.291 (3.074, 3.509)***
Slope	-0.596 (-0.618, -0.573)***	0.074 (0.068, 0.080)***
Quadratic	0.048 (0.046, 0.050)***	0.001 (0.001, 0.002)***
Intercept-slope covariance	-0.569 (-0.638, -0.500)***	0.088 (0.061, 0.116)***
Intercept-quadratic covariance	0.032 (0.027, 0.037)***	-0.018 (-0.023, -0.012)***
Slope-quadratic covariance	-0.018 (-0.021, -0.016)***	-0.007 (-0.008, -0.006)***
Log-likelihood	-142290.583	-142290.583

MLP=moderate-to-late preterm; VP=very preterm. *p <.05, **p <.01, ***p <.001. Adjusted for sex, multiple birth, maternal education, household income, maternal age at childbirth. [b]Significant difference between early-term and VP groups at 5 % levels. [c]Significant difference between MLP and VP groups at 5 % levels.

Supplementary Table S6: Full estimates of direct and indirect effect (mediated through maternal psychological distress) of association between gestational age groups and social competence difficulties.

	Intercept			Slope			Quadratic slope		
	Indirect effect	Direct effect	Total effect	Indirect effect	Direct effect	Total effect	Indirect effect	Direct effect	Total effect
Effect size	b (95% CI)	b (95% CI)	b (95% CI)	b (95% CI)	b (95% CI)	b (95% CI)	b (95% CI)	b (95% CI)	b (95% CI)
Full-term	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Early-term	0.022	0.012	0.034	0.001	-0.039	-0.038	0.000	-0.003	-0.003
	(0.004, 0.041)*	(-0.129,0.153)	(-0.110, 0.179)	(0.000, 0.002)	(-0.082, 0.003)	(-0.081, 0.004)	(0.000, 0.000)	(-0.007, 0.001)	(-0.007, 0.001)
MLP	0.024	0.187	0.211	0.001	-0.016	-0.015	0.000	-0.003	-0.002
	(-0.006, 0.054)	(-0.054,0.427)	(-0.033, 0.454)	(-0.001,0.003)	(-0.079, 0.046)	(-0.078, 0.047)	(0.000, 0.000)	(-0.008, 0.003)	(-0.008, 0.003)
VP	0.188	0.760	0.949	0.008	0.117	0.125	0.000	0.010	0.010
	(0.109,0.268)***	(0.023, 1.497)*	(0.231, 1.666)*	(-0.002,0.017)	(-0.098, 0.331)	(-0.089, 0.338)	(0.000, 0.001)	(-0.008, 0.027)	(-0.007, 0.028)

MLP = moderate-to-late preterm; VP = very preterm. *p <.05, ***p <.001. Mediating effect for the intercept, linear and quadratic slope of confounder-adjusted latent growth curve model in Mplus are shown.

Figure S1

Children who participated at the first wave of the MCS (age 9 months, N = 18,818)

Main respondent not the natural mother (n = 57)
Gestational age or birth weight missing (n =210)
Implausible birth weight or birth weight lying outside of ± 4 SD^a (n =134)
Gestational age 42-43 weeks (n = 665)

Eligible for the study (n = 17,752)

Missing outcome for all five waves (age 3,5,7, 11 and 14 interviews, n = 1,931)

Analytic sample (n = 15,821)