Psychological Medicine

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Maternal social support during and after pregnancy and child cognitive ability: examining timing effects in two cohorts

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Original Article

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Cite this article: Lähdepuro A *et al* (2023). Maternal social support during and after pregnancy and child cognitive ability: examining timing effects in two cohorts. *Psychological Medicine* 1–10. https://doi.org/10.1017/S0033291723003550

Received: 15 May 2023
Revised: 1 November 2023
Accepted: 10 November 2023

Keywords:
ALSPAC; cognitive development; PREDO; pregnancy; protective effects; sensitive period; social support

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Abstract

Background. Maternal anxiety, depression, and stress during and after pregnancy are negatively associated with child cognitive development. However, the contribution of positive maternal experiences, such as social support, to child cognitive development has received less attention. Furthermore, how maternal experience of social support during specific developmental periods impacts child cognitive development is largely unknown.
Methods. Using data from the Avon Longitudinal Study of Parents and Children (ALSPAC; $n = 5784$) and the Prediction and Prevention of Preeclampsia and Intrauterine Growth Restriction study (PREDO; $n = 420$), we investigated the associations between maternal perceived social support during and after pregnancy and child's general cognitive ability at 8 years of age, assessed with the Wechsler Intelligence Scale for Children (WISC). Bayesian relevant life course modeling was used to investigate timing effects of maternal social support on child cognitive ability.
Results. In both cohorts, higher maternal perceived social support during pregnancy was associated with higher performance on the WISC, independent of sociodemographic factors and concurrent maternal symptoms of depression and anxiety. In ALSPAC, pregnancy emerged as a sensitive period for the effects of perceived social support on child cognitive ability, with a stronger effect of social support during pregnancy than after pregnancy on child cognitive ability.
Conclusions. Our findings, supported from two prospective longitudinal cohorts, suggest a distinct role of maternal perceived social support during pregnancy for cognitive development in children. Our study suggests that interventions aimed at increasing maternal social support during pregnancy may be an important strategy for promoting maternal and child well-being.

Introduction

The Developmental Origins of Health and Disease (DOHaD)-hypothesis states that prenatal environmental factors may alter the development of the brain and other organs, thereby influencing neurodevelopment across the lifespan (Barker, 2007; O'Donnell & Meaney, 2017; but see Glover, O'Connor, & O'Donnell, 2023). Supporting the DOHaD-hypothesis, ample evidence suggests that maternal psychological distress (i.e. depression, anxiety, and stress) during and after pregnancy associates with poorer neurodevelopmental outcomes in children (Girchenko et al., 2018; Manzari, Matvienko-Sikar, Baldoni, O'Keeffe, & Khashan, 2019; Pearson et al., 2016; Van den Bergh et al., 2020), including lower cognitive performance (Evans et al., 2012; O'Connor et al., 2022; Power, van IJzendoorn, Lewis, Chen, & Galbally, 2021; Rogers et al., 2020; Tarabulsy et al., 2014). Much less attention has been paid to possible protective factors for child cognitive development such as maternal social support during and after pregnancy. Identifying protective factors is important, since cognitive ability in childhood is associated with educational, occupational, and health outcomes later in life (Blair, 2016; Wraw, Deary, Der, & Gale, 2016; Wraw, Deary, Gale, & Der, 2015).

There is evidence that higher perceived maternal social support during and after pregnancy is associated with lower risk of psychopathology in children (Lähdepuro et al., 2023; Parkes & Sweeting, 2018), but data remain scarce on the associations between maternal social support and cognitive outcomes in children. To our knowledge, the Conditions Affecting Neurocognitive Development and Learning in Early Childhood (CANDLE) cohort of ca. 1000 mother-child-dyads is one of the few cohorts to examine the effect of maternal social support on child cognitive ability (Lewinn, Bush, Batra, Tylavsky, & Rehkopf, 2020; Shin et al., 2019). In this cohort, maternal social support network size at 4 weeks postpartum was associated with higher child cognitive ability at 2 years of age (Shin et al., 2019), whereas maternal social support at child age 2 years, but not during pregnancy, was associated with higher child cognitive ability at 4–6 years of age (Lewinn et al., 2020). These studies were limited to investigating cognitive outcomes among preschool-aged children or younger, and findings were equivocal regarding the relative importance of maternal social support during different developmental periods (i.e. during or after pregnancy) coinciding with different developmental windows (e.g. in utero, neonatal period, or beyond). Furthermore, no previous study has investigated whether maternal social support is associated with child cognitive ability independently of concurrent maternal distress (i.e. symptoms of depression or anxiety), or whether maternal social support buffers the effects of maternal distress on child cognitive ability; studies addressing these knowledge gaps are needed to inform effective targeting of interventions.

Using data from two prospective pregnancy cohort studies, we investigated whether higher maternal perceived social support, reported both during and after pregnancy, was associated with higher general cognitive ability among children at 8 years of age, and whether these associations were independent of, or moderated, the effects of maternal depressive and anxiety symptoms, assessed at the same time points as social support, on child cognitive ability. Utilizing a Bayesian relevant life course modeling (BRLM) approach (Madathil, Joseph, Hardy, Rousseau, & Nicolau, 2018), we then investigated whether there were sensitive or critical periods that best explain the potential association between maternal social support and child cognitive ability, or, alternatively, if any effects of maternal social support on child cognitive ability accumulate across time.

Methods

Participants

Alspac

The Avon Longitudinal Study of Parents and Children (ALSPAC) (Boyd et al., 2013; Fraser et al., 2013) is an ongoing population-based cohort study that enrolled pregnant women residing in the Avon area, United Kingdom, with expected dates of delivery between 1st April 1991 and 31st December 1992. In the first phase of data collection, the study comprised 14 541 pregnancies with maternal questionnaires available from the pregnancy period; these pregnancies resulted in 13 988 children who were alive at 1 year of age. Of the participating women with singleton pregnancies ($n = 14\,468$), 10 528 (72.8%) completed a questionnaire assessing their perceived social support during pregnancy. Of them, 9175 (87.1%) assessed their perceived social support again after pregnancy at child age 8 months. Neurocognitive assessment data, at median child age of 8.5 years (range 7.4–10.5) were available for 5784 (54.9%) children of mothers with social support data from pregnancy, and for 5498 (59.9%) children of mothers with social support data from pregnancy and after pregnancy.

The ALSPAC study website contains details of all the data that is available through a fully searchable data dictionary and variable search tool that can be found at http://www.bristol.ac.uk/alspac/researchers/our-data/. Ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committees. Informed consent for the use of data collected via questionnaires and clinics was obtained from participants following the recommendations of the ALSPAC Ethics and Law Committee at the time. Approval for secondary data analyses was obtained from Yale University Institutional Review Board (Protocol ID: 2000036041).

PREDO

Study participants come from the ongoing Prediction and Prevention of Pre-eclampsia and Intrauterine Growth Restriction (PREDO) study (Girchenko et al., 2017). PREDO enrolled 1079 pregnant women to a clinical arm of this prospective longitudinal study. Of these women, 969 (89.8%) had one or more known risk factors for preeclampsia and intrauterine growth restriction. The sample was appended by 89 pregnant women from the control arm of the study who were recruited independently of their risk factor status, resulting in a sample of 1168 pregnant women. The women were recruited when they arrived for their first ultrasound screening at 12 + 0 to 13 + 6 gestational weeks + days, which were conducted at ten study hospitals in Southern and Eastern Finland, and gave birth to a singleton live child between 2006–2010.

Of the 1168 women, 828 (70.9%) completed a questionnaire assessing their perceived social support during pregnancy. Of them, 497 (60.0%) assessed their perceived social support again after pregnancy at child age 8 years. Neurocognitive assessment data at median child age of 8.5 years (range 7.0–11.9) were available for 420 (50.7%) children of mothers with social support data from pregnancy, and for 370 (74.4%) children of mothers with social support data from pregnancy and after pregnancy.

The Ethics committees of the Helsinki and Uusimaa Hospital District and all participating hospitals approved the PREDO study protocol. All mothers gave written informed consent to participate, and parent(s) gave informed consents for their children.

The authors assert that all procedures in both cohorts contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Measures

Maternal social support and distress and child cognitive ability in ALSPAC

Mothers rated their perceived social support during pregnancy at a median gestational week 24 and after pregnancy at child age 8 months with a ten-item questionnaire developed by the ALSPAC team. Each item (e.g. 'I have no one to share my feelings with', 'If I feel tired I can rely on my partner to take over') was rated on a four-point scale (ranging from 'exactly feel' (0) to 'never feel' (3)). For mothers who reported not having a partner, partner-related items were coded as 'never feel'. Positively worded items were reverse-coded so that the sum score ranged from 0–30, higher score indicating higher social support.

Maternal symptoms of depression and anxiety were assessed using the ten-item Edinburgh Postnatal Depression Scale (EPDS) (Cox, Holden, & Sagovsky, 1987), and the eight-item anxiety subscale of the Crown-Crisp Experiential Index (CCEI) (Birtchnell, Evans, & Kennard, 1988), respectively. In our analyses we focus on measures of maternal depression and anxiety at two time points (gestational week 18 during pregnancy and child age 8 months after pregnancy) which we define as 'concurrent' measures of maternal distress at time points most closely aligned with assessments of maternal social support.

Children's general cognitive ability (intelligence quotient; IQ) was assessed during an in-person visit using the short version of the Wechsler Intelligence Scale for Children, 3rd UK edition (WISC-III) (Wechsler, Golombok, & Rust, 1992), the most current WISC version at the time of testing. Scores were age-scaled based on the UK normative data provided by the WISC-III manual with a Total IQ score mean of 100 and a standard deviation (S.D.) of 15.

Maternal social support and distress and child cognitive ability in PREDO

Mothers reported their perceived satisfaction with social support during pregnancy at gestational weeks 12–14 and after pregnancy at child age 8 years with Sarason's six-item Social Support Questionnaire (SSQ6) (Sarason, Sarason, Shearin, & Pierce, 1987). The SSQ6 first asks about the number of people that are available to provide social support (e.g. 'Whom can you really count on to care about you, regardless of what is happening to you?'), followed by questions on satisfaction with social support on a six-point scale (each item ranging from 'not at all satisfied' (1) to 'very satisfied' (6)). We used the SSQ6 satisfaction sum score as an indicator of perceived social support, scores ranging from 6–36 with a higher score indicating higher satisfaction with social support.

Concurrently to completing the SSQ6 at these two time points (gestational weeks 12–14 during pregnancy and child age 8 years after pregnancy), mothers reported their depressive symptoms with the 20-item Center of Epidemiologic Studies Depression Scale (CES-D) (Radloff, 1977), and anxiety symptoms with the 20-item State-Trait Anxiety Inventory-state version (STAI) (Spielberger, 1983).

Children's general cognitive ability (IQ) was assessed during an in-person visit using a short, seven subtest version (Crawford, Anderson, Rankin, & MacDonald, 2010) of the Wechsler Intelligence Scale for Children, 4th Finnish edition (WISC-IV) (Wechsler, 2010), the most current WISC version at the time of testing. The short-version Full-scale IQ score was converted to a scale that has a mean of 100 and S.D. of 15 based on Finnish normative data.

Psychometric properties of the measures

The measures used in ALSPAC and PREDO for maternal social support (the 10-item questionnaire and SSQ-6), depressive (EPDS and CES-D) and anxiety (CCEI and STAI) symptoms and child cognitive ability (WISC-III and WISC-IV) have all shown good psychometric properties in previous studies (Birtchnell et al., 1988; Friedman et al., 2018; Gunning et al., 2010; Park & Kim, 2023; Rascle, Bruchon-Schweitzer, & Sarason, 2005; Thomson et al., 2014; Tracy, Salo, & Appleton, 2018; Vilagut, Forero, Barbaglia, & Alonso, 2016; Wechsler, 2010; Wechsler et al., 1992). Reliability estimates of the scales for maternal social support, depressive and anxiety symptoms in ALSPAC and PREDO in the current study sample are shown in online Supplementary Table S1.

Covariates

In our analyses, we adjusted for the following covariates previously associated with social support and/or cognitive development (Lewinn et al., 2020; O'Connor et al., 2022).

ALSPAC

Mother-related covariates included self-reported age at delivery (years), parity (primiparous, multiparous), educational attainment (based on the UK educational system: none/Certificate of Secondary Education/vocational training, O-levels, A-levels, university degree or higher), household crowding index (the number of people in the household divided by the number of rooms: <0.5, ⩾0.50–0.75, >0.75–1.00, >1.00), marital/cohabiting status during pregnancy (married/cohabiting, not cohabiting), and substance use during early pregnancy (smoking and/or alcohol use). Child-related covariates included sex assigned at birth (male, female), birthweight (grams) and gestational age (weeks) derived from medical records, mother-reported ethnic background (White, non-White), and child age at cognitive assessment (years + months).

PREDO

Mother-related covariates included age at delivery (years) and parity (primiparous, multiparous) derived from the Finnish Medical Birth Register (MBR; Gissler, Louhiala, & Hemminki, 1997), and highest attained education level (primary or secondary, lower tertiary, upper tertiary) and substance use (smoking and/or alcohol use) during early pregnancy based on MBR data and self-reports. Only 2.4% of the mothers were not married/cohabiting at childbirth, therefore marital/cohabiting status was not included as a covariate. Child-related covariates included sex assigned at birth (male, female), birthweight (grams), and gestational age (weeks) derived from the MBR, and age at cognitive assessment (years + months). Furthermore, since the PREDO clinical study sample was enriched for women at elevated risk of preeclampsia (Girchenko et al., 2017), we also adjusted for the presence or absence of maternal hypertensive disorders during the index pregnancy, including preeclampsia, eclampsia, gestational or chronic hypertension, and unspecified hypertension (International Classification of Diseases, 10th revision codes: I10, O10, O12–O16). Hypertensive disorders were derived from the MBR, medical records, and Care Register for Health Care (Sund, 2012) and operationalized as a binary variable (none *v.* one or more). Data on household crowding was unavailable, and ethnicity was not recorded due to European Union legislation.

Statistical analyses

We used linear regression models to examine associations of maternal social support during and after pregnancy with child cognitive ability. Analyses were adjusted for child sex assigned at birth and age at cognitive assessment (Model 1), followed by all other mother- and child-related covariates in ALSPAC and PREDO (Model 2).

Next, we used linear regression models to test if the associations between maternal social support during and after pregnancy and child cognitive ability were independent of maternal concurrent depressive and anxiety symptoms (Model 3), while adjusting also for the covariates of Model 2. We then tested with separate

https://doi.org/10.1017/S0033291723003550 Published online by Cambridge University Press

interaction analyses if social support moderated the impact of concurrent maternal depressive or anxiety symptoms on child cognitive ability. Moderation effects were investigated separately during and after pregnancy.

To investigate timing effects of maternal social support on child cognitive ability, we used the BRLM (Madathil et al., 2018), adjusting for child's sex assigned at birth and age at cognitive assessment. Other covariates were not included in these analyses because data on these covariates were derived only during pregnancy. The BRLM first estimates the presence or absence of a lifetime effect of repeatedly assessed exposures on an outcome of interest. This lifetime effect size is defined as delta (δ) with a corresponding 95% credible interval (CrI). Next, weights (w) for each exposure period are estimated to indicate the proportion of the lifetime effect explained by the exposure at different time points. To facilitate interpretation, we present weights as percentages. The sum of all weights is fixed at 100% (i.e. $w_1 + w_2 = 100$). In our data, we test if maternal social support at two different time points (during and after pregnancy) has comparable or differing effects on child cognitive ability. We used BRLM to evaluate evidence for: (1) a critical period model, where social support at one time point is most relevant for child cognitive ability (e.g. $w_1 = 100$, $w_2 = 0$), (2) a sensitive period model, where social support at one time point has a relatively higher weight (e.g. $w_1 = 66$, $w_2 = 33$), or (3) an accumulation model, where social support at both time points have equal weights ($w_1 = 50$, $w_2 = 50$). We used posterior probabilities and Euclidean distances to evaluate evidence for which life-course model is best supported by the data; the model with the shortest Euclidean distance is considered the best-fitting model (Madathil et al., 2018).

Finally, we conducted sensitivity analyses using the abovementioned linear regression models in which we excluded children with an IQ score below 70 in the WISC assessment, as a proxy for a potential intellectual disability (Wechsler, 2010; Wechsler et al., 1992).

Continuous scales that showed skewness were square root or rank-order transformed, and all continuous independent variables were standardized to facilitate effect size interpretation and cross-cohort comparisons. Regression coefficients are reported in IQ points; we additionally report standardized coefficients (β) as indicators of effect size in s.d. units. We used complete-case analyses. The BRLM analyses were performed with the *rstan* package in R.4.1.0 (R Core Team, 2022; Stan Development Team, 2020); other statistical analyses were performed with SPSS 29 (IBM Corp, 2020).

Results

Table 1 shows the characteristics of the participating mother-child-dyads in the ALSPAC and PREDO cohorts. In ALSPAC, mothers who provided data for this study were older, more likely to be primiparous, married/cohabiting, and with a higher education level than mothers who were not included in this study, and their children were more often female, White and had a higher birthweight and gestational age than children who were not included in this study (online Supplementary Table S2). In PREDO, mothers included in this study had a higher education level than mothers not included, whereas their children did not differ in the studied characteristics (online Supplementary Table S2). These abovementioned group differences, while statistically significant, represent small to moderate effect sizes.

Table 1. Characteristics of the analytic samples of the ALSPAC cohort (*N* = 5784) and the PREDO cohort (*N* = 420)

	ALSPAC	PREDO
	N (%)/Mean (s.d.)	*N* (%)/Mean (s.d.)
Maternal characteristics		
Age at delivery (years), mean (s.d.)	29.23 (4.49)	33.39 (5.41)
Parity, *N* (%)		
Primiparous	2605 (45.0)	145 (34.5)
Multiparous	3051 (52.7)	275 (65.5)
Missing	128 (2.2)	–
Education level, N (%)		
ALSPAC		
Degree	959 (16.6)	
A-levels	1539 (26.6)	
O-levels	2001 (34.6)	
None/CSE/vocational	1179 (20.4)	
Missing	106 (1.8)	
PREDO		
Upper tertiary		167 (39.8)
Lower tertiary		132 (31.4)
Primary/secondary		121 (28.8)
Household crowding (number of people by room), N (%)		N/A
0–0.5	2812 (48.6)	
0.5–0.75	1761 (30.4)	
0.75–1	864 (14.9)	
>1	197 (3.4)	
Missing	150 (2.6)	
Cohabiting status, N (%)		N/A
Married/cohabiting	5326 (92.1)	
Not cohabiting	413 (7.1)	
Missing	45 (0.8)	
Substance use during early pregnancy[a]		
No	2133 (36.9)	329 (78.3)
Yes	3595 (62.2)	86 (20.5)
Missing	56 (1.0)	5 (1.2)
Hypertensive disorders[b]	N/A	
No		282 (67.1)
Yes		138 (32.9)
Depressive symptoms[c]		
During pregnancy, mean (s.d.)	6.61 (4.84)	11.60 (6.90)
Missing, *N* (%)	102 (1.8)	–
After pregnancy, mean (s.d.)	5.19 (4.51)	8.50 (8.74)
Missing, *N* (%)	272 (4.7)	43 (10.2)

(*Continued*)

https://doi.org/10.1017/S0033291723003550 Published online by Cambridge University Press

Table 1. (*Continued.*)

	ALSPAC N (%)/Mean (S.D.)	PREDO N (%)/Mean (S.D.)
Anxiety symptoms[d]		
During pregnancy, mean (S.D.)	4.83 (3.46)	33.52 (8.01)
Missing, N (%)	154 (2.7)	–
After pregnancy, mean (S.D.)	3.49 (3.24)	32.22 (10.15)
Missing, N (%)	273 (4.7)	40 (9.5)
Social support		
During pregnancy[e], mean (S.D.)	20.09 (4.75)	31.02 (4.78)
After pregnancy[f], mean (S.D.)	20.08 (4.97)	29.86 (5.98)
Missing, N (%)	286 (4.9)	50 (11.9)
Child characteristics		
Sex assigned at birth, N (%)		
Male	2895 (50.1)	208 (49.5)
Female	2889 (49.9)	212 (50.5)
Age at assessment (years), mean (S.D.)	8.62 (0.28)	8.68 (0.92)
WISC-III Total IQ (ALSPAC) / WISC-IV Full-scale IQ (PREDO), mean (S.D.)	104.48 (16.42)	100.35 (13.60)
Birth weight (grams), mean (S.D.)	3435.65 (534.18)	3492.68 (554.66)
Missing, N (%)	67 (1.2)	–
Gestational age (weeks), mean (S.D.)	39.49 (1.80)	39.74 (1.55)
Ethnic background, N (%)		N/A
White	5399 (93.3)	
Non-white	198 (3.4)	
Missing	187 (3.2)	

S.D., standard deviation; IQ, intelligence quotient; WISC-III/IV, Wechsler Intelligence Scale for Children, 3th/4th edition.
[a]Any smoking or alcohol use during early pregnancy.
[b]Any hypertensive disorder (preeclampsia, eclampsia, gestational, or chronic hypertension, and unspecified hypertension) v. no hypertensive disorders in current pregnancy.
[c]Edinburgh Postnatal Depression Scale (EPDS) at gestational week 18 (during pregnancy)/child age 8 months (after pregnancy) in ALSPAC. Center for Epidemiologic Studies Depression Scale (CES-D) at gestational week 12 (during pregnancy)/child age 8 years (after pregnancy) in PREDO.
[d]Crown-Crisp Experiential Index (CCEI) at gestational week 18 (during pregnancy)/child age 8 months (after pregnancy) in ALSPAC. State-Trait-Anxiety Inventory (STAI) at gestational week 12 (during pregnancy)/child age 8 years (after pregnancy) in PREDO.
[e]Reported at median gestational week 24 in ALSPAC, and at gestational weeks 12–14 in PREDO.
[f]Reported at child age 8 months in ALSPAC, and at child age 8 years in PREDO.

Online Supplementary Tables S3 and S4 show the associations of covariates with maternal perceived social support and with child cognitive ability, respectively. In ALSPAC, multiparous and non-cohabiting mothers, and mothers with lower education level and substance use during pregnancy reported lower perceived social support. There were no significant associations between maternal social support and covariates in PREDO (online Supplementary Table S3). In ALSPAC, maternal multiparity, younger age, lower education level, non-cohabiting, higher depressive and anxiety symptoms during and after pregnancy, and lower child birthweight and gestational age were associated with lower child cognitive ability, when adjusting for child sex assigned at birth and age (online Supplementary Table S4). In PREDO, lower maternal education level was associated with lower child cognitive ability, when adjusting for child sex assigned at birth and age (online Supplementary Table S4).

Associations between maternal social support and child cognitive ability

Maternal social support showed relatively high continuity across assessment points ($r = 0.61$, $p < 0.001$ in ALSPAC; $r = 0.41$, $p < 0.001$ in PREDO). In both cohorts, higher maternal social support *during* pregnancy was associated with higher child cognitive ability (Table 2). One S.D. unit increase in maternal social support during pregnancy was associated with a 0.79–1.58 child IQ point increase in ALSPAC and 1.50–1.75 IQ point increase in PREDO, when adjusting for sociodemographic and perinatal covariates in Models 1–2. Higher maternal social support *after* pregnancy was associated with higher child cognitive ability in ALSPAC, independently of covariates in Models 1–2, while there was no such association in PREDO (Table 2). In ALSPAC, one S.D. unit increase in maternal social support after pregnancy was associated with a 0.65–1.25 IQ point increase across these adjusted models.

Maternal social support and concurrent maternal distress

Higher maternal social support during and after pregnancy was associated with lower concurrent depressive and anxiety symptoms (online Supplementary Table S5). However, maternal social support during pregnancy was positively associated with child cognitive ability independently of maternal concurrent depressive and anxiety symptoms during pregnancy in both ALSPAC and PREDO (Model 3 in Table 2). In ALSPAC, the positive association between maternal social support after pregnancy with child cognitive ability was also independent of maternal concurrent depressive and anxiety symptoms (Model 3 in Table 2). Maternal social support during or after pregnancy did not moderate the effects of maternal concurrent depressive or anxiety symptoms on child cognitive ability (Table 3).

Timing effects of maternal social support on child cognitive ability

In ALSPAC, BRLM analyses showed that higher maternal social support, assessed during pregnancy and at 8 months after pregnancy, had a lifetime effect (δ) of 1.87 IQ points on child cognitive ability (95% CrI 1.39–2.37). Maternal social support during pregnancy (w_1) contributed to 69.8% and maternal social support after pregnancy (w_2) contributed to 30.2% of the lifetime effect of maternal social support on child cognitive ability (Fig. 1). There was a 92.0% posterior probability that pregnancy was a sensitive period for the effects of maternal social support on child cognitive ability. Pregnancy as a sensitive period provided the best model fit of all life course models tested (online Supplementary Table S6). In PREDO, the BRLM analyses showed no lifetime effect of maternal social support, assessed during pregnancy and at child age 8.5 years, on child cognitive ability ($\delta = 0.50$ IQ points, 95% CrI −0.88 to 1.88). Therefore, we did not estimate weights for maternal social support during or after pregnancy in PREDO.

https://doi.org/10.1017/S0033291723003550 Published online by Cambridge University Press

Table 2. The associations of maternal social support during and after pregnancy with the child's general cognitive ability (IQ) in the ALSPAC cohort and in the PREDO cohort

	ALSPAC			PREDO		
	WISC-III Total IQ			WISC-IV Full-scale IQ		
	B (95%CI)	*β* (95%CI)	*p*	*B* (95%CI)	*β* (95%CI)	*p*
Social support during pregnancy[a]						
Model 1	**1.58 (1.16–2.00)**	**0.10 (0.07–0.12)**	**<0.001**	**1.75 (0.47–3.03)**	**0.13 (0.04–0.22)**	**0.007**
Model 2	**0.79 (0.37–1.20)**	**0.05 (0.02–0.07)**	**<0.001**	**1.50 (0.27–2.74)**	**0.11 (0.02–0.20)**	**0.02**
Model 3	**0.67 (0.23–1.11)**	**0.04 (0.01–0.07)**	**0.003**	**1.62 (0.29–2.95)**	**0.12 (0.02–0.22)**	**0.02**
Social support after pregnancy[b]						
Model 1	**1.25 (0.82–1.67)**	**0.08 (0.05–0.10)**	**<0.001**	0.08 (−1.28 to 1.45)	0.01 (−0.09 to 0.11)	0.90
Model 2	**0.65 (0.23–1.07)**	**0.04 (0.01–0.07)**	**0.002**	0.01 (−1.30 to 1.31)	0.001 (−0.10 to 0.10)	0.99
Model 3	**0.62 (0.16–1.07)**	**0.04 (0.01–0.07)**	**0.01**	0.06 (−1.44 to 1.55)	0.004 (−0.11 to 0.11)	0.94

Model 1 adjusted for child sex assigned at birth and age at cognitive assessment.

Model 2 adjusted for child sex assigned at birth, age at cognitive assessment, birth weight and gestational age, and maternal age, parity, education, and substance use during pregnancy in both cohorts, and additionally for household crowding index, marital/cohabiting status, and child ethnic background in the ALSPAC cohort, and for maternal hypertensive disorders during pregnancy in the PREDO cohort.

Model 3 is adjusted for child sex assigned at birth, age at cognitive assessment, birth weight and gestational age, maternal age, parity, education, and substance use during pregnancy in both cohorts, and for household crowding index, marital/cohabiting status, and child ethnic background in the ALSPAC cohort, and for maternal hypertensive disorders during pregnancy in the PREDO cohort, and additionally for maternal depressive and anxiety symptoms reported concurrently with social support during/after pregnancy.

Statistically significant associations ($p < 0.05$) are bolded. CI, confidence interval; IQ, intelligence quotient; WISC-III/IV, Wechsler Intelligence Scale for Children, 3rd/4th edition.
B represents change in IQ points following one standard deviation (s.d.) increase in social support. β represents the change in child IQ in standard deviation units following one standard deviation increase in social support
[a]Reported at median gestational week 24 in ALSPAC, and at gestational weeks 12–14 in PREDO.
[b]Reported at child age 8 months in ALSPAC, and at child age 8 years in PREDO.

Table 3. Interactions between maternal social support during and after pregnancy and maternal co-occurring depressive and anxiety symptoms when predicting child cognitive ability (IQ)

	ALSPAC		PREDO	
	WISC-III Total IQ		WISC-IV Full-scale IQ	
	B (95%CI)	*p*	*B* (95%CI)	*p*
During pregnancy[a]				
Social support × depressive symptoms	0.33 (−0.05 to 0.72)	0.09	0.16 (−1.09 to 1.40)	0.81
Social support × anxiety symptoms	−0.08 (−0.49 to 0.33)	0.71	−0.03 (−1.28 to 1.22)	0.96
After pregnancy[b]				
Social support × depressive symptoms	0.17 (−0.24 to 0.57)	0.43	0.50 (−0.79 to 1.78)	0.45
Social support × anxiety symptoms	0.02 (−0.38 to 0.42)	0.93	−0.03 (−1.36 to 1.31)	0.97

CI, confidence interval; IQ, intelligence quotient; WISC-III/IV, Wechsler Intelligence Scale for Children, 3rd/4th edition.
[a]Maternal perceived social support and maternal depressive and anxiety symptoms during pregnancy are assessed at median gestational weeks 18–24 in the ALSPAC cohort, and at gestational weeks 12–14 in the PREDO cohort.
[b]Maternal perceived social support and maternal depressive and anxiety symptoms after pregnancy are assessed at child age 8 months in the ALSPAC cohort, and at child age 8 years in the PREDO cohort.

Sensitivity analyses

Online Supplementary Table S7 shows that the associations of maternal social support during and after pregnancy with child cognitive ability remained similar in both cohorts when excluding children with an IQ score below 70.

Discussion

In this cross-cohort analysis of two prospective pregnancy cohort studies, ALSPAC and PREDO, higher maternal social support during pregnancy was associated with higher general cognitive ability among 8-year-old children in both cohorts. These

https://doi.org/10.1017/S0033291723003550 Published online by Cambridge University Press

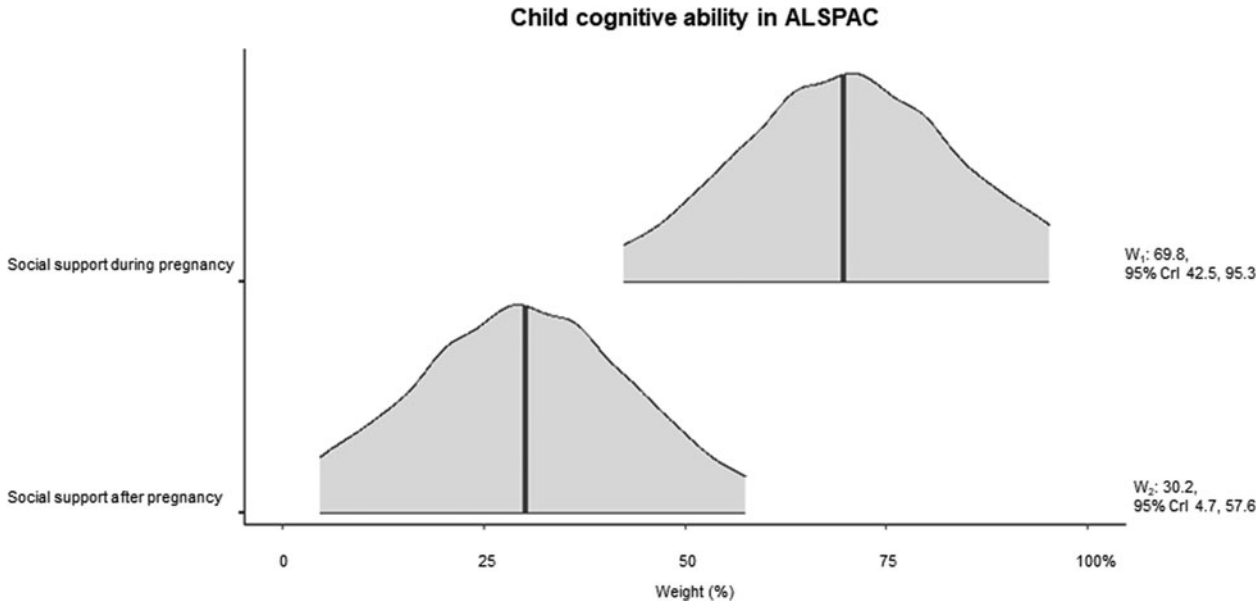

Figure 1. Posterior densities of weights of maternal social support during pregnancy and at child age 8 months in predicting child general cognitive ability (IQ) at 8 years of age in the ALSPAC cohort (n = 5498). Posterior densities are presented as percentages (range 0–100%); the area in gray presents 95% credible interval (CrI) for the mean posterior density.

associations were independent of maternal education level, parity, substance use during pregnancy, child birth weight and gestational age, and, importantly, of maternal concurrent depressive and anxiety symptoms. In ALSPAC, an additional independent positive effect of higher maternal social support after pregnancy with higher cognitive ability in children was also detected. Finally, our BRLM analyses suggested that pregnancy was a sensitive period: maternal social support in pregnancy appeared to carry most benefit for child cognitive ability.

Our findings in the ALSPAC and PREDO cohorts contrast with an earlier study which reported an association of maternal social support network after, but not during pregnancy, with child cognitive ability (Lewinn et al., 2020). The different pattern of results may reflect the use of a social network size as a measure of support, the smaller sample size, or the different analytic approach in the earlier study. On the other hand, the lack of association between social support after pregnancy and child cognitive ability in PREDO in this study was not likely just a matter of a smaller sample size, as the effect size was also much smaller than in ALSPAC. It is possible that differences between ALSPAC and PREDO in social and family context might explain these differences. In addition, maternal social support after pregnancy was reported at different child ages across the two cohorts, at 8 months in ALSPAC and 8 years in PREDO, which may also explain the discrepant findings. Neurodevelopmental processes (e.g. synaptogenesis, synaptic pruning, and white matter development) are especially dynamic during pregnancy and the first 2–3 years of life (Cusick & Georgieff, 2016), and hence maternal social support during this period may have a larger effect on cognitive development than later in childhood. Our finding that maternal social support during pregnancy was consistently associated with child cognitive ability in both PREDO and ALSPAC emphasizes the importance of social support during this period.

Higher maternal social support during and after pregnancy was associated with lower concurrent depressive and anxiety symptoms in both ALSPAC and PREDO, consistent with earlier evidence (Bedaso, Adams, Peng, & Sibbritt, 2021; Racine, Plamondon, Hentges, Tough, & Madigan, 2019). However, we found that, in both cohorts, maternal social support during pregnancy showed beneficial effects on child cognitive ability even when adjusting for maternal concurrent depressive and anxiety symptoms. This suggests that the associations between maternal social support and child cognitive ability are not fully explained by reduced maternal distress, and that there are other mechanisms linking maternal social support to child cognitive development.

Our finding that pregnancy is a sensitive period for the effects of maternal social support on child cognitive ability supports the DOHaD hypothesis (Barker, 2007; O'Donnell & Meaney, 2017), suggesting a long term impact of the prenatal environment on neurodevelopment. Many diverse prenatal mechanisms – including health behaviors, hypothalamic-pituitary-adrenal axis activity, immune activation, autonomic nervous system and others – have been suggested as potential mediators of the link between prenatal maternal psychological distress and child health (Monk, Lugo-Candelas, & Trumpff, 2019; Van den Bergh et al., 2020). Our findings showing a distinct effect of maternal social support during pregnancy underscore the need for mechanism-oriented studies to consider not just adversity but also protective factors in understanding prenatal origins of child development. For example, higher social support during pregnancy has been associated with lower inflammation levels in pregnant women (Coussons-Read, Okun, & Nettles, 2007; Ross et al., 2017). As maternal infections/inflammation during pregnancy are associated with lower cognitive ability among children (Nazzari et al., 2020; O'Connor et al., 2022), the buffering effects of social support on maternal infections/inflammation levels is a potential pathway linking social support during pregnancy to child cognitive ability. Higher perceived social support during pregnancy may also enhance the development of adaptive maternal behaviors and attachment to the child that begins in the prenatal period (Le Bas et al., 2020). Satisfaction with social support has been associated with the quality of mother-child attachment (Hopkins et al., 2018); attachment and mother-child-interactions, in turn, are associated with cognitive development in children (de Mendonça Filho et al., 2022; Ronfani et al., 2015) and may modify the impact of adverse prenatal exposures (Bergman, Sarkar, Glover, & O'Connor, 2010). Mothers with higher social support in the perinatal period may also be more likely to breastfeed their children (Mercan & Selcuk, 2021), and breastfeeding has consistent beneficial effects on child cognitive development (Amiel Castro, Glover, Ehlert, & O'Connor, 2021; Horta, Loret de Mola, & Victora, 2015). After pregnancy, higher maternal social support may enrich the social environment of the child, providing more stimuli to support cognitive development (Tooley, Bassett, & Mackey, 2021). In contrast, in late childhood the child's social environment may be less dependent on maternal social networks; this may explain why maternal social support at child age 8 years was not associated with child cognitive ability in PREDO.

The association between maternal social support during pregnancy and child cognitive ability was consistent and independent of several covariates across cohorts, but the effect sizes were small. In the ALSPAC cohort, the association was similar in magnitude to the associations observed between maternal prenatal depressive or anxiety symptoms and child cognitive ability. Small effects at the population level might nonetheless translate into clinically meaningful findings where interventions may improve social support for those experiencing marked isolation and exclusion.

There may be benefits of screening for maternal social support during pregnancy. Although social support *per se* is not a common specific target in prenatal interventions (by contrast, many intervention options exist for anxiety and depression [Matvienko-Sikar et al., 2021; van Ravesteyn, Van Den Berg, Hoogendijk, & Kamperman, 2017]), it may be that certain, particularly group-based, interventions may promote social support as one pathway for promoting child cognitive development. Further research of this kind is needed given that cognitive ability in childhood and adolescence is positively associated with long-term educational, occupational and health outcomes such as higher educational attainment (Blair, 2016) and better physical and mental health (Wraw et al., 2016, 2015) later in life.

Strengths and limitations

A key strength of our study is utilizing two independent, longitudinal cohorts from two countries. We were able to replicate our key findings on the association between maternal perceived social support during pregnancy and child cognitive ability across both cohorts. Importantly, both cohorts provided objective, independent evaluations using a leading, well-validated measure of children's general cognitive ability (Wechsler, 2010; Wechsler et al., 1992). This precludes the shared method bias of studies using mother-reported outcomes in children. Additionally, child assessments were conducted at the same age in both cohorts, further facilitating cross-cohort comparisons.

Our study also has its limitations. First, we observed selective attrition with mother-child-dyads who continued to participate reporting higher levels of maternal education across both cohorts; this may limit the generalizability of our findings. Second, the number of available participants differed between our cohorts, which may have limited our power to detect a lifetime effect of social support in the smaller PREDO cohort. Third, we were unable to account for maternal IQ in our analyses, which is a strong predictor of child cognitive ability and may confound the association between maternal prenatal depressive symptoms and child cognitive development (Faleschini, Rifas-Shiman, Tiemeier, Oken, & Hivert, 2019); we relied instead on educational attainment as a proxy for the familial and socioenvironmental factors influencing child cognitive development. Nevertheless, earlier studies found associations between maternal social support after pregnancy and child cognitive ability that were independent of maternal IQ (Lewinn et al., 2020). Fourth, our assessment of family socioeconomic status was limited to maternal educational attainment in both cohorts, with household crowding additionally considered in ALSPAC only. While maternal education is among the strongest socioeconomic predictors of cognitive ability in children (Eilertsen et al., 2016; Lewinn et al., 2020), future studies would benefit from more comprehensive evaluation of family socioeconomic status and indicators of social mobility. Fifth, data on paternal perceived social support and IQ were unavailable, and we could thus not take these into account. Future studies would benefit from including the entire parent-child-triad. Sixth, we cannot exclude potential gene-environment correlation as a source of confounding, since maternal polygenic risk scores for psychiatric disorders are associated with poorer maternal mental health also during pregnancy (Havdahl et al., 2022; Rantalainen et al., 2020). Future studies would benefit from more genetically informed designs, including sibling comparisons and the use of polygenic risk scores. Finally, as the mother-child dyads of the ALSPAC cohort were recruited in the beginning of 1990's, there may be some cultural and contextual factors in social support that have changed in the past 30 years, although we note that findings were replicated in PREDO which commenced recruitment in 2006, suggesting that the findings are not dependent on the cultural context.

Conclusions

This cross-cohort comparison of two longitudinal pregnancy cohort studies provides evidence that maternal perceived social support has beneficial effects on child's general cognitive ability, and that pregnancy may be a sensitive period for these effects. Our findings highlight the importance of promoting social support among pregnant women.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0033291723003550

Acknowledgements. We are extremely grateful to all the families who took part in these cohort studies, the midwives for their help in recruiting them, and the whole ALSPAC and PREDO teams, which includes interviewers, computer and laboratory technicians, clerical workers, research scientists, volunteers, managers, receptionists, and nurses.

Funding statement. The UK Medical Research Council and Wellcome (Grant ref: 217065/Z/19/Z) and the University of Bristol provide core support for ALSPAC. This publication is the work of the authors who will serve as guarantors for the contents of this paper. Dr O'Donnell is a CIFAR Fellow (Child and Brain Development Program) and the Pfeil Investigator (Brain and Behavior Research Foundation). Dr O'Donnell has received research support from the Canada First Research Excellence Fund (Healthy Brains for Healthy Lives), the Jacobs Foundation, and the Chamandy Foundation to support this work. Dr Lahti-Pulkkinen has received research support from the Academy of Finland. Prof. O'Connor would like to acknowledge support from the Wynne Center for Family Research and NIH grants R01 UH3 OD023349, R01 MH073842). Ms. Lähdepuro has received research support from University of Helsinki Funds, Doctoral School of Psychology, Learning and Communication. Dr Räikkönen has received research support from the Academy of Finland, from the European Union's Horizon Europe research and innovation program under grant agreement No 101057390

(HappyMums), and from the HiLIFE Helsinki Institute of Life Science Fellows program 2023–2025. Dr Lahti has received research support from the Strategic Research Council (SRC) established within the Academy of Finland (decision number: 352700).

Competing interests. None.

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