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ORIGINAL CONTRIBUTION

Hypertensive disorders of pregnancy and emotional and behavioural problems in children: a longitudinal population-based study

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Abstract

There is evidence that offspring of mothers who have hypertensive disorders of pregnancy (HDP) are at increased risk of adverse health outcomes. This study aims to examine the association between maternal HDP and emotional- and behavioural problems in offspring at age 11 years as reported by teachers and parents. The current study is based on the Avon Longitudinal Study of Parents and Children (ALSPAC), a prospective, population-based study that has followed a cohort of offspring since their mothers were pregnant. Childhood emotional- and behavioural problems were measured using the Strengths and Difficulties Questionnaire (SDQ), completed by parents ($n = 7196$) and the child's teacher ($n = 7411$). Maternal preeclampsia, but not gestational hypertension, was associated with teacher-reported total behavioural difficulties (RR = 1.62; 95% CI 1.03–2.52) and internalising problems in children [peer problems (RR = 1.48; 95% CI 1.06–2.08) and emotional problems (RR = 1.68; 95% CI 1.13–2.51)]. No associations between preeclampsia and/or gestational hypertension and parent-reported emotional- and behaviour problems were observed. Our study showed that children exposed to preeclampsia had higher risk of teacher-reported total behavioural difficulties and internalising problems compared with unexposed children. The findings suggest emotional- and behavioural difficulties may not be evident in all settings, hence the importance of collecting evidence from multiple informants.

Keywords ALSPAC · Behavioural difficulties · Gestational hypertension · Internalising · Preeclampsia · Peer problems

Introduction

Emotional- and behavioural problems, comprising internalising and externalising symptoms affect a substantial proportion of children [1, 2] and often persist into adulthood [3]. They are also associated with an increased risk of adverse outcomes later in life, including physical-health problems and accidental injury [4, 5], poor academic achievement and premature exit from education [6, 7], alcohol and drug use [8], and criminal offences [7, 9]. Thus, prevention of emotional- and behavioural problems in children would not only help children achieve improved development but may also help in reducing other adverse psychosocial outcomes later in life [10].

There has been considerable interest in the pregnancy period as a time that can have long-term influence on health and mental health outcomes in offspring. Amongst other factors, studies have identified gestational complications are risk factors for emotional- and behavioural problems in children [11]. Hypertensive disorders of pregnancy (HDP), including gestational hypertension and preeclampsia, remain

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among the most common prenatal conditions complicating up to 10% of pregnancies globally [12]. HDP, especially preeclampsia, may impair neurodevelopment through compromising blood- and nutrition supply to the foetus [13, 14] and there is a substantial evidence that children diagnosed with neurodevelopmental conditions are at increased risk of behavioural- and emotional problems as a result of the challenges they encounter from difficulties with language, cognition, and social skills [15–18]. However, the available evidence on the relationship between HDP and emotional- and behavioural problems in offspring is limited and inconsistent [19]. While some studies have reported offspring mother with HDP are at an increased risk for emotional- and behavioural outcomes [20, 21], others have found no association [22]. Further, one study found that preeclampsia was associated with decreased risk of internalising problems in children at ages 5 and 8 [19]. Studies to date have had limitations. Most have not consistently accounted for important confounding factors such as maternal depression and anxiety during pregnancy, parity, and gestational diabetes [19–22], and have not examined outcomes beyond 5 years of age [21, 22]. Finally, although teachers are important sources of data on children's emotional- and behavioural functioning in the school setting, most studies have utilised parental reports to examine the association between HDP and behavioural and emotional problems in children [19–22]. Assessments from teachers who observe children in the school setting would provide a different- and useful perspective. To address these limitations, this study aimed to examine the association between maternal HDP and emotional- and behavioural problems in offspring at age 11 years using both parent and teacher reports. Our study was based on a large longitudinal-birth cohort study with the capacity to control for a range of potential confounders.

Methods

Sample and procedure

The study is based on Avon Longitudinal Study of Parents and Children (ALSPAC), a prospective longitudinal population-based study [23, 24]. All pregnant women resident in Avon, UK with expected dates of delivery between 1st April 1991 and 31st December 1992 were invited to take part in the study. The initial ALSPAC cohort consisted of 14,541 pregnancies recruited antenatally. These pregnancies resulted in 14,062 live births and 13,988 children who were alive at 1 year of age. A further 456 children from 452 pregnancies and 257 children from 254 pregnancies were recruited postnatally at age 7 and 8 years, respectively, resulting 15,247 enrolled pregnancies [24, 25]. The current study used data from the offspring sample (singletons only) completing the assessment at 11 years of age ($n = 7196+$). The detailed methodology of ALSPAC has been previously reported [24, 25] and the study website contains information of all the data that is available through a fully searchable data dictionary and variable search tool (https://www.bristol.ac.uk/alspac/researchers/our-data).

Ethics approval for the study was obtained from the ALSPAC Ethics and Law Committee and 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.

Measures

Emotional- and behavioural problems at age 11

Childhood emotional- and behavioural problems were measured using the Strengths and Difficulties Questionnaire (SDQ), completed by parents, usually mothers ($n = 7196$) and the child's teacher ($n = 7411$), when the child was age 11 years [26]. The SDQ is a valid and reliable instrument used to screen emotional- and behavioural problems in children aged 3–16 years and has been widely used in research- and clinical practice [26]. It has a specificity of 95% and sensitivity of 54% [27]. The tool comprising 25 questions, making up five sub-scales: hyperactivity, emotional symptoms, conduct problems, peer problems, and pro-social behaviour (each comprising 5 items) [28]. Scores for the sub-scales range from 0 to 10, and the first four sub-scales are combined to calculate a total difficulties score, ranging from 0 to 40. A higher score indicates higher symptoms, except for pro-social behaviour, where a lower score indicates more difficulties. For the overall score and each of the five sub-scales, children were categorised as 'normal' or as 'borderline/abnormal' if they scored in the 'abnormal' or 'borderline 'ranges, according to cut-offs suggested by Goodman for each SDQ subscale [26]. Sensitivity analyses were also conducted with the continuous SDQ scores.

Hypertensive disorders of pregnancy

Six trained-research midwives extracted all measurements of blood pressure and proteinuria from maternal obstetric records that were documented as part of routine antenatal care by midwives or obstetricians. We applied the International Society for the Study of Hypertension in Pregnancy to determine women with preeclampsia or gestational hypertension [29]. Preeclampsia was defined as systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg, measured on ≥ 2 occasions after 20 weeks of gestation, with proteinuria ($\geq 1+$ on urine dipstick testing occurring at the same time as the elevated blood pressure),

in a mother who did not report having hypertension prior to pregnancy. Gestational hypertension was defined as the same pattern of elevated blood pressure but without proteinuria.

Confounding variables

Data on potential confounders were obtained from obstetric records and questionnaires administered during pregnancy. These included socio-demographic characteristics [child gender, maternal age, maternal education, maternal marital status (never married, widowed/divorced/separated, and married) and ethnicity (white and non-white)] [30–33], maternal smoking and alcohol use during pregnancy [34], parity (nullipara and mutipara) [35, 36], gestational diabetes (yes/no) [37–39], maternal depression and anxiety during pregnancy [40–42], and gestational age at delivery [43].

In the ALSPAC study, maternal education was collected at 32 weeks of pregnancy as a grouped variable according to increasing levels of achievement: CSE (certificate of secondary education), vocational, O-level (ordinary-level: subject-specific qualifications generally obtained at age 16 years), A-level (advanced-level: subject-specific qualifications generally obtained at age 18 years and required for university entry), and university degree. Mothers were asked how often they had consumed alcoholic drinks during the first 3 months of pregnancy (never, less than 1 glass a week, 1 or more glasses a week, and 1 or more glasses every day). Mothers were divided into smokers or non-smokers in response to self-reported smoking status in the first 3 months of pregnancy. Maternal depression was measured at 32 weeks of gestation using Edinburgh Postnatal Depression Scale (EPDS) [44]. Scale scores were dichotomized using the recommended cut-off score for depression [45]. Symptoms of antenatal anxiety at 32 weeks of gestation were measured with the Crown–Crisp Experiential Index (CCEI), a validated self-rating inventory [46]. A score of ≥ 8 was used to indicate maternal anxiety [40, 47].

Statistical analyses

Descriptive statistical analyses were performed to describe the study population. Mean (standard deviation) SDQ scores at ages 11 years were calculated. Unadjusted- and adjusted regression-analyses were used to examine the association between maternal HDP and emotional- and behavioural problems in offspring (for parent and teacher reports separately). A log-binomial model was used to estimate risk ratios (RR) and the corresponding 95% confidence intervals (CI). We ran sensitivity analyses and repeated the analyses with the continuous SDQ scores using linear regression analyses. In multinomial logistic regression models, we estimated the relative risk ratio (RRR) (according to maternal HDP) for the following combinations of SDQ outcomes: rated 'normal' by both informants, rated 'normal' by parent and 'borderline/abnormal' by teacher, rated 'borderline/abnormal' by parent and 'normal' by teacher, and rated 'borderline/abnormal' by both informants. Three thousand eight hundred eighty-one children had total difficulties scores from both informants. Sensitivity analyses were conducted to examine whether attrition might have biased the results. Missing values for covariates were imputed using imputation by chained equations (ICE) with 50 imputation sets [48].

Results

Table 1 shows the characteristics of mothers and children from whom teacher reports were available compared to those with parent reports. Among 7,411 offspring who were assessed for emotional- and behavioural problems using teacher-reported SDQ at the age of 11 years, 50.6% were males and their mean (SD) birth weight (in kg) and length of gestation (in weeks) were 3.42 ($\pm$0.54) and 39.5 ($\pm$1.79), respectively. The mean (SD) age of mothers included in the analysis was 27.9 (4.9) years. Nearly three quarters (76.0%) of the mothers were married and more than half (55.0%) of them were multiparous. In the first 3 months of their pregnancy, 24.8% of mothers smoked tobacco and 13.8% consumed one or more glasses of alcohol per week. The prevalence of antenatal anxiety and depression (measured at 32 weeks of gestation) was 22.7% and 18.9%, respectively. In comparison with those for whom teacher reports were available, mothers of children who had parent reports were older at childbirth, more likely to be white in ethnicity, have higher educational levels, married, less likely to smoke tobacco, and were less likely to be in the clinical range for symptoms of antenatal depression or anxiety (Table 1).

Table 2 shows the mean scores for each SDQ sub-scale and for total difficulties at the age of 11 years. The mean (standard deviation) score of total difficulties was 6.56 (4.98) and 5.83 (5.98) for parent- and teacher reports, respectively. The correlation between parent-reported and teacher-reported SDQ scores was $r = 0.43$ ($p < 0.001$), reflecting a moderate level of agreement. With the exception of peer problems, the mean SDQ scores (for each SDQ sub-scale and for total difficulties) were higher for parent reports compared to teacher reports.

Using Goodman cut-offs, teacher-reported prevalence of children being categorised as 'borderline/abnormal' was higher compared to parents for total difficulties (16.1% vs 9.7%, $p < 0.001$), hyperactivity (14.1% vs 12.1%, $p < 0.001$), and problems with pro-social behaviours (20.3% vs 7.3%, $p < 0.001$). In contrast, the proportion of children scoring in the 'borderline/ abnormal' range for conduct problems (16.0% vs 12.9%, $p < 0.001$), emotional problems (12.5%

Table 1 Characteristics of mothers and children with parent reports compared to those with teacher reports

	Teacher reports ($n=7411$) No. (%)	Parents report ($n=7196$) No. (%)	p* (among groups)
Maternal characteristics			
Maternal age (years)[a]	27.9 (4.9)	29.1 (4.6)	< 0.001
Ethnicity (White)	6130 (97.8)	6573 (98.4)	0.006
Maternal education status			< 0.001
CSE	893 (15.1)	648 (10.0)	
Vocational	623 (10.5)	553 (8.5)	
O-level	2266 (38.3)	2374 (36.6)	
A-level	1411 (23.8)	1764 (27.2)	
Degree	725 (12.3)	1145 (17.7)	
Material status			< 0.001
Never married	1224 (18.5)	895 (13.2)	
Widowed/divorced/separated	365 (5.5)	332 (4.9)	
Married	5038 (76.0)	5533 (81.9)	
Parity			0.08
Nullipara	2936 (45.0)	3111 (46.5)	
Multipara	3595 (55.0)	3581 (53.5)	
Alcohol consumption in pregnancy			0.28
Never	2978 (45.1)	2936 (43.5)	
< 1 glass per week	2602 (39.4)	2769 (41.1)	
1 or more glasses per week	910 (13.8)	925 (13.7)	
1 or more glasses per day	11 1(1.7)	111 (1.7)	
Smoking in pregnancy (smoker)	1649 (24.8)	1207 (17.8)	< 0.001
Gestational diabetes (yes)	28 (0.45)	31 (0.46)	0.88
Antenatal anxiety (yes)	1349 (22.7)	1281 (20.0)	< 0.001
Antenatal depression (yes)	1155 (18.9)	1089 (16.7)	0.001
Gestational hypertension (yes)	1027 (15.1)	943 (14.0)	0.08
Preeclampsia (yes)	135 (1.95)	135 (1.97)	0.93
Child characteristics			
Sex (male)	3747 (50.6)	3603 (50.1)	0.44
Birth weight (kg)[a]	3.42 (0.54)	3.44 (0.52)	0.10
Gestational age at delivery (weeks)[a]	39.5 (1.79)	39.5 (1.74)	0.68

Not all participants recorded data for every characteristic. Missing data were excluded from the analysis

CSE certificate of secondary education

*Chi-square test for categorical variables and *t* test for numerical variables

[a]Values are expressed as mean (standard deviation)

vs 8.2%, $p<0.001$), and peer problems (15.8% vs 12.2%, $p<0.001$) was higher for parent than teacher reports.

Association between HDP and offspring emotional- and behavioural problems

Table 3 shows univariable and multivariable associations between maternal HDP and emotional- and behavioural symptoms at age 11 years. In univariable analyses, children exposed to preeclampsia had nearly a twofold increase in the likelihood of teacher-reported total emotional- and behavioural problems at age of 11 years compared with unexposed children (RR = 1.78; 95% CI 1.11–2.84). Follow-up analyses on the five SDQ symptom sub-scales indicated that preeclampsia was associated with teacher-reported internalising symptoms [peer problems (RR = 1.51; 95% CI 1.05–2.16) and emotional problems (RR = 1.84; 95% CI 1.24–2.73)], but not with externalising [hyperactivity (RR = 1.05; 95% CI 0.59–1.83) and conduct problems (RR = 1.06; 95% CI 0.59–2.1.91)] nor problems with pro-social behaviours (RR = 0.98; 95% CI 0.64–1.51). Gestational hypertension was not associated with teacher-reported emotional- and behavioural problems.

Table 2 The mean scores for each SDQ sub-scale and for total difficulties at the age of 11 years

Behavioural/emotional problems	Parent reports		Teacher reports		$p^{\#}$
	n	Mean (SD)	*n*	Mean (SD)	
Total difficulties[a]	7196	6.56 (4.98)	7411	5.83 (5.98)	< 0.001
Hyperactivity	7182	2.79 (2.24)	7411	2.36 (2.70)	< 0.001
Conduct problems	7199	1.21 (1.43)	7406	0.89 (1.66)	< 0.001
Emotional problems	7182	1.47 (1.73)	7410	1.33 (1.92)	< 0.001
Peer problems	7204	1.12 (1.56)	7411	1.25 (1.86)	< 0.001
Pro-social behaviour	7208	8.32 (1.69)	7411	7.83 (2.42)	< 0.001

SD standard deviation

[#]Using *t* test

[a]Total difficulties score range: 0–40; other domains score range: 0–10. Increasing scores represent increasing problems except for pro-social behaviour, where lower scores represent greater difficulties

Table 3 Association between HDP and offspring behavioural and emotional problems at the age of 11 years

Behavioural/emotional problems	Gestational hypertension		Preeclampsia	
	Unadjusted RR (95% CI)	Adjusted RR[a] (95% CI)	Unadjusted RR (95% CI)	Adjusted RR[a] (95% CI)
Parent-reported SDQ				
Total difficulties	1.06 (0.84–1.33)	1.03 (0.82–1.29)	0.95 (0.53–1.73)	0.88 (0.49–1.61)
Hyperactivity	0.88 (0.71–1.09)	0.87 (0.71–1.09)	0.99 (0.59–1.66)	0.95 (0.56–1.59)
Conduct problems	0.89 (0.74–1.06)	0.88 (0.71–1.09)	1.09 (0.72–1.66)	1.01 (0.69–1.52)
Emotional problems	1.08 (0.86–1.35)	1.07 (0.88–1.30)	1.02 (0.62–1.68)	0.97 (0.59–1.58)
Peer problems	1.18 (1.01–1.39)	1.12 (0.95–1.32)	0.99 (0.64–1.54)	0.97 (0.64–1.49)
Pro-social behaviour	0.91 (0.69–1.20)	0.85 (0.64–1.13)	1.26 (0.69–2.29)	1.19 (0.65–2.18)
Teacher-reported SDQ				
Total difficulties	1.04 (0.82–1.32)	1.08 (0.85–1.36)	1.78 (1.11–2.84)*	1.62 (1.03–2.52)*
Hyperactivity	0.91 (0.73–1.14)	0.95 (0.77–1.18)	1.05 (0.59–1.83)	1.00 (0.58–1.72)
Conduct problems	1.06 (0.85–1.33)	1.13 (0.91–1.40)	1.06 (0.59–1.91)	1.01 (0.57–1.78)
Emotional problems	1.07 (0.87–1.31)	1.04 (0.84–1.27)	1.84 (1.24–2.73)*	1.68 (1.13–2.51)*
Peer problems	1.12 (0.95–1.33)	1.07 (0.91–1.26)	1.51 (1.05–2.16)*	1.48 (1.06–2.08)*
Pro-social behaviour	0.85 (0.71–1.01)	0.82 (0.66–1.01)	0.98 (0.64–1.51)	0.91 (0.59–1.38)

RR risk ratio, *CI* confidence interval

*$p < 0.05$

[a]Adjusted for maternal age, ethnicity, maternal education, marital status, parity, maternal alcohol use during pregnancy, maternal smoking, gestational diabetes, maternal depression, maternal anxiety, child's gender, and gestational age at delivery

In multivariable analyses, after adjusting for a wide range of known confounding factors, the effect of preeclampsia on teacher-reported internalising symptoms [for peer problems (RR = 1.48; 95% CI 1.06–2.08) and emotional problems (RR = 1.68; 95% CI 1.13–2.51)] and total emotional- and behavioural problems remained significant (RR = 1.62, 1.03–2.52) (Table 3). The findings were similar when analyses were repeated using a continuous SDQ score (Table S1). We found no association between HDP (gestational hypertension and preeclampsia) and parent-reported emotional- and behavioural problems in children, both before and after adjustment for potential confounders (Table 3). A sensitivity analysis comparing those retained in this analysis with the imputed data found no substantial difference (Table S2).

Using a multinomial model, we further examined the association between HDP and emotional- and behavioural problems in children by combining parent and teacher reports ($n = 3861$), with children rated as 'normal' by both informants as the reference group. The effect estimates of both preeclampsia and gestational hypertension were stronger when a child was rated 'borderline/abnormal' by both informants or rated 'normal' by a parent and 'borderline/abnormal' by a teacher; although the finding did not reach agreed standards for statistical significance (Table S3).

Discussion

In this study, we examined the association between maternal HDP (gestational hypertension and preeclampsia) and emotional- and behavioural problems in children using both parent and teacher reports of SDQ scores. The moderate level of correlation between parent-reported and teacher-reported SDQ scores was similar or less than that of reported in other studies [49–51].

Our findings demonstrated that preeclampsia, but not gestational hypertension, was associated with a 62% increased risk of teacher-reported total emotional- and behavioural problems in offspring. We found that this association was due to an increased risk of internalising symptoms (peer problems and emotional problems) as opposed to externalising symptoms (hyperactivity and conduct problems) and pro-social behaviours. The associations remained after adjustment for a wide range of socioeconomic, obstetric, and individual factors.

Our findings are consistent with the hypothesis that foetal programming may influence, at least in part, later mental health, by suggesting an effect of early life exposure on later health and disease risk [52–54]. It is plausible prenatal exposure to preeclampsia may affect foetal brain development through utero-placental under-perfusion, placental ischemia, hypoxia, and oxidative stress, which in turn leads to an increased risk of emotional- and behavioural problems later in life [19, 55, 56]. Recent studies from both animal models [57] and human subjects [58, 59] have reported that preeclampsia is associated with altered mental health and behavioural outcomes in offspring.

The discrepancy in the associations between preeclampsia and gestational hypertension and teacher-reported emotional problems in children might be due to the difference in the severity of the condition. Preeclampsia is a serious condition characterized by high blood pressure at or beyond 20 weeks of gestation with proteinuria or other multisystem involvements, whereas gestational hypertension is a more benign elevation in blood pressure arising in pregnancy (at or beyond 20 weeks of gestation) in the absence of proteinuria and is considered to be a transient condition [60, 61]. Reduction in blood supply to the foetus is more severe in preeclampsia than in gestational hypertension and more likely compromise the neurobehavioral development of the offspring [62]. Studies examining the association between maternal HDP (gestational hypertension and preeclampsia) and offspring cognitive impairment [63] and depressive symptoms [36] found similar results, suggesting maternal preeclampsia in particular adversely affects offspring neurodevelopment and mental health.

Previous studies have found a positive association between maternal HDP (gestational hypertension and/or preeclampsia) and parent-reported emotional- and behavioural problems in children [19–21]. However, no studies have examined these associations when reported by teachers. One birth cohort study has found a positive association between HDP (with or without proteinuria) and parent-reported internalising and externalising problems in children ages 2–14 [20]. However, this study did not examine the effect of gestational hypertension and preeclampsia separately. A separate analysis of the same cohort of children conducted by Robinson et al. [19] found that preeclampsia was associated with total behavioural difficulties, internalising- and externalising problems at various follow-up points in child offspring although the increased risk was not consistently apparent. Our findings partially agreed with Robinson et al. [19] results and are in contrast with another study where no association was found [22]. The discrepancy could be attributed to several factors including the tool used to measure emotional- and behavioural problems, assessment age, sample size, and the level of adjustment for confounding factors. While previous studies examined the association in a sample of children with a wide age range (2–14 years) [19, 20], the children in our study were all aged 11. On the other hand, previous studies used relatively small samples, with inadequate power to detect effect, and did not adjust for important confounders such as maternal mental-health problems during pregnancy, parity, and gestational diabetes [19, 20]. In this study, we used data from a large birth-cohort study and were able to consider these confounding factors in our analysis. While previous studies used parent-reported Child Behaviour Checklist (CBCL) to assess children's emotional- and behavioural problems [19, 20], our study used the SDQ. However, both measures are valid and reliable instruments for assessing child emotional- and behavioural problems and have been widely used in research and clinical practice [26, 64].

Parents and teachers observe children in different environments. This can lead to discordance between reported presence and severity of behavioural- and emotional problems [50]. This may be due to internalising symptoms being more obvious in the school setting where there are greater social- and academic demands resulting in discrepancies between parents and teachers [65]. The discrepancy may also be as a result of reporting biases [66, 67]; teachers may have less historical knowledge of the child or having different thresholds from parents for viewing certain behaviours as "problems" [65, 68].

An alternative explanation for the discrepancy in our findings may be attributed to the psychometric properties of the SDQ, which are stronger for the teacher version than the parent questionnaire [10]. Finally, the null association between preeclampsia and parent-reported emotional- and behavioural problems might also be type II error, as previous

publications using the same cohort of children showed strong associations between preeclampsia and parent-reported ADHD [69] and anxiety disorders [70], although these were measured using a diagnostic instrument (Development and Well-Being Assessment; DAWBA), rather than a symptom scale [71].

This study has several important strengths. The study used data on emotional- and behavioural problems from a large prospective cohort. The longitudinal design reduces the likelihood of recall bias. Good measures of exposure and the availability of a wide range of confounders were strengths of our study. Additionally, our study differentiated internalising symptoms from externalising behaviours in children. We were also able to see the effect of gestational hypertension and preeclampsia on offspring emotional- and behavioural problems separately, which provided stronger evidence of a causal relationship.

The following limitations of the study should also be considered. First, there was considerable sample attrition. In comparison with those retained in the analyses, mothers of children who were lost to follow-up or missing data, were younger at childbirth, more likely to be multiparous, smoke tobacco, drink alcohol, and have more antenatal depressive and anxiety symptoms (data not shown). Previous studies have also shown that the ALSPAC cohort attrition is associated with socioeconomic disadvantage [25]. Because these factors are also associated with adverse mental health and behavioural outcomes in offspring, it has been argued this type of loss follow-up is more likely to weaken the point estimates of any observed association between exposures and outcomes [72, 73]. Previous work in ALSPAC has also suggested that selective dropout does not bias prediction of risk of behavioural disorders [74]. Consistent with this, a recent longitudinal study showed that loss to follow-up rarely affects estimates of associations [75]. In addition, the rate of exposure to HDP (gestational hypertension and/or preeclampsia) in offspring who were and were not followed-up did not differ substantively and estimates from multiple imputation and complete case analyses were broadly comparable (Table S2). Hence, we suggested that exclusion of subjects from the cohort because of missing data was unlikely to have biased the results. Second, childhood emotional- and behavioural problems were obtained by parent- and teacher reports of the SDQ. Reliance on self-reports may lead to misclassification bias. Parents may underestimate behavioural problems, although the mean SDQ scores were broadly similar to the national survey [76]. Any such misclassification would tend to weaken the association. Third, we relied on a screening measure of emotional- and behavioural symptoms rather than a diagnostic instrument, although SDQ is valid and reliable for assessing emotional- and behavioural problems in children and early adolescents, and has been widely used in research and clinical practice [26]. Finally, whilst we adjusted for a number of potential confounders including maternal mental-health symptoms during pregnancy, we cannot exclude the possibility of residual confounding.

Conclusion

Our study showed that children exposed to preeclampsia had an increased risk of internalising problems compared with unexposed children, according to teacher but not parental reports. No associations of gestational hypertension and emotional- and behavioural problems were observed. Although, the discrepancy between findings based on parent- and teacher reports warrants further research, our findings suggest that emotional- and behavioural difficulties may not be evident in all settings, hence collecting evidence from multiple informants is recommended. Further research is needed to better understand the neurodevelopmental and mental health outcomes off offspring of mothers with preeclampsia.

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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