Impact of trajectories of maternal postpartum depression on infants' socioemotional development

Subbiah, Gireesh Kumar; Reijneveld, Sijmen A; Hartman, Catharina A; van der Zee-van den Berg, Angarath I; Boere-Boonekamp, Magda M; Almansa, Josué; de Kroon, Marlou L A

Published in:
Pediatric Research

DOI:
10.1038/s41390-023-02697-w

European Society for Paediatric Research
Society for Pediatric Research
www.nature.com/pr

POPULATION STUDY ARTICLE

Check for updates

Impact of trajectories of maternal postpartum depression on infants' socioemotional development

Gireesh Kumar Subbiah[1]✉, Sijmen A. Reijneveld[1], Catharina A. Hartman[2], Angarath I. van der Zee-van den Berg[3], Magda M. Boere-Boonekamp[4], Josué Almansa[1] and Marlou L. A. de Kroon[1,5]

BACKGROUND: We assessed (a) the effects of postpartum depression (PPD) trajectories until 6 months postpartum on infants' socioemotional development (SED) at age 12 months, and (b) the mediating role of maternal self-efficacy (MSE), and the additional effect of postpartum anxiety at age 12 months.
METHODS: We used data from POST-UP trial ($n = 1843$). PPD was assessed using the Edinburgh Postnatal Depression Scale (EPDS) at 1, 3, and 6 months. Infants' SED was assessed at 12 months using the Ages and Stages Questionnaire-Social-Emotional (ASQ-SE). Structural equations were applied to estimate the effect of PPD trajectories on infants' SED and mediation by MSE. The additional effects of postpartum anxiety were assessed with conditional regression.
RESULTS: Higher levels of PPD over time were associated with a lower SED (coefficient for log-EPDS 3.5, 95% confidence interval 2.8; 4.2, e.g., an increase in the EPDS score from 9 to 13 worsens the ASQ-SE by 1.3 points). About half of this relationship was mediated by MSE. Postpartum anxiety had an independent adverse effect on SED.
CONCLUSIONS: PPD and postpartum anxiety have a negative impact on infants' SED. MSE as a mediator may be a potential target for preventive interventions to alleviate the negative effects of maternal psychopathology on infants' SED.

Pediatric Research (2024) 96:519–524; https://doi.org/10.1038/s41390-023-02697-w

IMPACT:

- The trajectories of postpartum depression (PPD) from 1 month to 6 months were negatively related to infants' socioemotional development (SED) at age 12 months, underlining the importance of repeated assessment of PPD.
- Maternal self-efficacy (MSE) mediated the association between PPD and SED, implying MSE could be a potential target for preventive interventions.
- An additional independent negative effect of postpartum anxiety was identified, implying the assessment of postpartum anxiety also has a surplus value to identify mothers at risk.

INTRODUCTION

Maternal postpartum depression (PPD) usually starts between childbirth and 4–6 weeks thereafter and has negative consequences for the mother and her infant.[1–4] However, evidence on the effects of PPD on early childhood socioemotional development (SED) is sparse.[5–7] SED is a continuous process through which humans acquire the skills to express, experience, and regulate emotions as a precursor to develop social competencies and emotional intelligence.[8] SED in the first year of life is sensitive to the caregiver's positive parenting practices that can regulate the infant's stress and contributes to the infant's emotional wellbeing.[8,9] In the long-term, high parenting quality acts as a buffer enhancing the healthy development of neurobiological systems governing stress reactivity and emotion.[10,11]

Mothers are usually the primary caregivers, and their infants can be considerably exposed to the symptoms of PPD.[3,12] The mechanisms by which PPD can negatively influence infants' SED are complex and not fully clarified. Insofar research has focused on direct causal mechanisms including genetic inheritance and indirect mechanisms including the effects of PPD on parenting quality and behaviors.[7,13–15] Besides the uncertainty about the influence of PPD on SED, it is also not clear if the variations in the PPD trajectory, i.e., in the onset, severity, and continuity of PPD are of additional importance for infants' SED.[16–18]

One of the potential mechanisms by which PPD can indirectly impact infants' SED is the influence of maternal self-efficacy (MSE).[19,20] MSE refers to the mother's self-confidence in the organization and execution of tasks dealing with the care of her

[1]Department of Health Sciences, University Medical Center Groningen, University of Groningen, Hanzeplein 1, 9713GZ Groningen, the Netherlands. [2]Department of Psychiatry, Interdisciplinary Center Psychopathology and Emotion Regulation, University Medical Center Groningen, University of Groningen, Hanzeplein 1, 9713 GZ Groningen, the Netherlands. [3]Netherlands School of Public and Occupational Health, P.O. Box 20022, 3503 LA Utrecht, the Netherlands. [4]Department of Health Technology and Services Research, Technical Medical Centre, University of Twente, P.O. Box 217, 7500 AE Enschede, the Netherlands. [5]Department of Public Health and Primary Care, Environment and Health, KU Leuven, Kapucijnenvoer 35P.O. Box 7001, 3000 Leuven, Belgium. ✉email: g.k.subbiah@umcg.nl

Received: 21 March 2023 Accepted: 27 May 2023
Published online: 19 June 2023

child. Depression could lower MSE by altering her cognitions including perceptions of worthlessness and negative self-attribution.[21] Additionally, MSE has been shown to predict the child's adjustment directly, or indirectly via positive parenting practices and behaviors.[22,23] Therefore, we hypothesized that the trajectory of PPD is negatively associated with infants' SED and this association is mediated by MSE.

Finally, PPD often co-occurs with anxiety. Postpartum anxiety by itself is a risk factor for poor SED of infants.[24] However, owing to the comorbid nature of PPD and postpartum anxiety it is difficult to disentangle the distinct impacts of these disorders on infants' SED.[25,26] Evidence lacks on whether anxiety has an independent effect on infants' SED on top of PPD.

Therefore, the main aim of the study was to assess the effects of maternal PPD trajectories until 6 months on infants' SED at age 12 months. In addition, we aimed to assess the mediating role of MSE and the additional effect of postpartum anxiety at 12 months of age.

METHODS

Study design and participants

We used longitudinal data from the *POST-UP* trial.[27,28] *POST-UP* had a prospective, quasi-experimental, comparative design to assess if regular screening for PPD in Preventive Child Healthcare (PCHC) followed by advice on treatment options and referral when indicated improved mental health outcomes at the maternal and child level. The participants of the *POST-UP* trial were mother-child dyads consulting the PCHC between December 1, 2012, and April 1, 2014, during the first month after birth. The participants allotted to the intervention arm ($n = 1843$) were repeatedly screened for PPD during the PCHC consultation, using the Dutch version of the Edinburgh Postnatal Depression Scale (EPDS),[29] whereas the participants allotted to the care as usual arm ($n = 1246$) were not screened for PPD. Since the PPD trajectory is the main independent variable for the current study only mother-child dyads of the intervention arm were included ($n = 1843$).

Procedure and measures

During home visits around 2 weeks postpartum informed consent for participation was obtained from the parents by the PCHC nurse. Baseline data were recorded during the first in-person consultation at the PCHC center 4 weeks after birth. The intervention arm received regular screening of PPD at 1, 3, and 6 months after childbirth. More details on the recruitment and blinding procedure can be found elsewhere.[27] The *POST-UP* trial procedures were in accordance with the protocols of the World Medical Association Declaration of Helsinki and were approved by the Medical Ethics Committee, University of Twente (approval number: 80-82470-98-012).

Socioemotional development (SED) of infants at age 12 months was the primary outcome variable. SED was assessed using the Ages and Stages Questionnaire-Social-Emotional 12-month version (ASQ-SE).[30] The ASQ-SE consists of 25 items related to developmentally appropriate behavior and is completed by the caregiver. The scores of all items are summed up (ranging from 0 to 145): higher scores represent a worse SED. The original and the Dutch version of ASQ-SE have good validity and reliability.[31,32]

Postpartum depression (PPD) was measured at 1, 3, and 6 months postpartum using the EPDS. The EPDS is a widely used measure for screening for PPD in clinical practice and research, and the Dutch version of the EPDS exhibits good internal consistency.[33] It consists of 10 items and the scores are summed up to get a total score (ranging from 0 to 30), with higher scores indicating a higher level of depressive symptoms. Scores on the EPDS ranging from 9 to 12 are indicative of mild depression and scores above 12 indicate major depression.[34] Since both clinical PPD and subclinical symptoms of PPD are associated with infants' SED, we modeled the EPDS scores as a continuous variable instead of as a categorical variable.[16]

Maternal self-efficacy (MSE) was assessed using the postnatal version of the Self-Efficacy in the Nurturing Role (SENR) questionnaire at age 12 months of the infant,[35] which includes 16 items representing basic parenting competencies. Negatively formulated items were scored inversely so that higher scores reflect higher MSE. The SENR has shown good internal reliability for the postpartum period.[22,36]

Postpartum anxiety was measured using the short version of the state form of the Spielberger State-Trait Anxiety Inventory (STAI-6) at 12 months after birth.[37] The STAI-6 has been widely used for the screening of anxiety in pregnant women and mothers during the perinatal period.[38,39] The Dutch version of the STAI-6 has shown good psychometric properties.[40]

Other covariates regarded maternal education level (high versus low), gestational age (in weeks), lifetime history of depression (yes or no), having experienced stressful life events before or after childbirth, defined by at least 2 or more stressful life events at either time periods i.e., stressful life events including an accident, illness, death of family or friends, losing a job, financial, housing and relationship problems (more details can be found in Appendix 1).[41]

Statistical analyses

For an optimal estimation of the effects, multiple imputation was carried out to resolve the missingness of data (Table 1 provides details on missing data). The multiple imputation method was based on the method of chained equations, with the assumption of missingness at random over 20 imputed data sets, and 75 iterations to ensure convergence.[42] Imputations were based on variables potentially associated with the main variables of the study i.e., PPD, postpartum anxiety, MSE, and SED. These included age of the mother (in years), maternal education level (high versus low), first pregnancy (yes or no), method of delivery (cesarean section versus vaginal delivery), alcohol consumption (yes or no), social support (assessed using the Social Support List-Interactions questionnaire[43]), quality of life of the mother (assessed using the Medical Outcome Study-Short Form[44]), stressful life events before and after childbirth, birth weight (in grams), breast-feeding status (yes or no), physical health problems of the child (yes or no), hospitalization of the child (yes or no), and infants' temperament (assessed using the Infant-Toddler Quality Of Life questionnaire-Short Form-47[45]). Binary variables were imputed using logistic regression, and continuous variables using predictive mean matching.[42,46]

For the first aim i.e., to assess the effects of the PPD trajectory on infants' SED, firstly, the individual EPDS trajectories over the three measurement points were estimated using multilevel regression analysis with a random intercept and slope. Given the skewed count-type nature of the EPDS scores, these were modeled using Poisson regression.[47] Due to the low variability of the random slopes, the longitudinal trends of the EPDS score were estimated with a random intercept model and a fixed slope. The ASQ-SE at 12 months was regressed on the random intercept of the PPD trajectory, to assess the effects of overall variations in the levels of the EPDS scores on the ASQ-SE scores using structural equation modeling (SEM) (Total effects model).

For the second aim, i.e., to assess the mediating role of MSE, the values of MSE at 12 months were added in the pathway between PPD and SED to test mediation using SEM (Mediation model). To study the additional independent effect of postpartum anxiety, we applied conditional regression analysis to obtain a measure of anxiety independent of PPD[48] conditional values of anxiety i.e., the residuals of the linear regression of the STAI-6 scores at 12 months on the EPDS scores at 6 months (hereafter referred to as 'postpartum anxiety variable'). ASQ-SE scores were adjusted by the postpartum anxiety variable in the mediation models. Finally, all covariates were included in the model (as adjusting variables for the mediator and outcome variables).

The descriptive analyses were carried out in IBM SPSS 27.0. Multiple imputations were done in R (package mice, version 3.13.0).[49] Trajectories of PPD and SEM were performed in M-Plus version 8 and estimated using maximum likelihood estimation with robust standard errors.[50,51]

RESULTS

Background characteristics

The sample ($n = 1843$) consisted of mothers who were Dutch citizens by birth (95.3%) and were generally highly educated (88.7%). Other characteristics of the mother-child dyads are presented in Table 1.

The effects of PPD trajectories on SED of infants

The initial level of the EPDS scores among the mothers varied, but generally decreased slightly from the first month to the sixth month postpartum (Fig. 1). Higher levels of PPD over time were associated with a lower SED (coefficient for log-EPDS 3.5, 95% confidence interval (95% CI) 2.8; 4.2, e.g., an increase in the EPDS score from 9 to 13 was related to a decrease of 1.3 points on the ASQ-SE (Table 2, model 1). To make this association better

Table 1. Characteristics of the mothers and infants in the study; source is *POST-UP* trial ($n = 1843$).

Mother's characteristics	Type of measure	Values[a]	Missing *n* (%)
Age of the mother	in years, mean (SD)	30.6 (4.1)	Nil
Single parenthood	yes, *n* (%)	17 (0.9)	Nil
Education of mother	low education, *n* (%)	208 (11.3)	Nil
First pregnancy	yes, *n* (%)	721 (39.1)	Nil
Complications during pregnancy	yes, *n* (%)	442 (24)	Nil
Smoking during pregnancy	yes, *n* (%)	174 (9.5)	Nil
Alcohol during pregnancy	yes, *n* (%)	28 (1.6)	Nil
Self-efficacy (SENR[b]) at 12 months	mean (SD)	100.9 (8.9)	378 (20.5)
Lifetime history of depression	yes, *n* (%)	327 (17.7)	Nil
Postpartum depression (EPDS[c]) at	mean (SD)		
1 month		3.71 (3.4)	291 (15.8)
3 months		2.99 (3.3)	420 (22.8)
6 months		2.70 (3.3)	724 (39.3)
Anxiety (STAI-6[d]) at 12 months	≥cut-off 42, *n* (%)	265 (17.7)	345 (18.7)
Stressful life event			
Before pregnancy	2 or more, yes, *n* (%)	344 (18.7)	330 (17.9)
After childbirth		211 (13.9)	330 (17.9)
Infant's characteristics	Type of measure	Values	Missing *n* (%)
Gestational age	in weeks, mean (SD)	39.7 (1.7)	123 (6.8)
Birth weight	in grams, mean (SD)	3486 (525)	Nil
Sex	male, *n* (%)	933 (50.6)	Nil
Breastfeeding at 1 month	yes, *n* (%)	904 (49.1)	Nil
Socioemotional development (ASQ-SE[e]) at 12 months	median, (IQR)	10 (5–20)	382 (20.7)

SD Standard deviation, *IQR* Interquartile range.
[a]Descriptive values were computed on valid cases from original sample (not the imputed samples).
[b]Self-Efficacy in Nurturing Roles questionnaire for maternal self-efficacy (SENR).
[c]Edinburgh Postnatal Depression Scale (EPDS).
[d]State form of State-Trait Anxiety Inventory short form for maternal postpartum anxiety (STAI-6).
[e]Ages and Stages Questionnaire-Social-Emotional for socioemotional development (ASQ-SE).

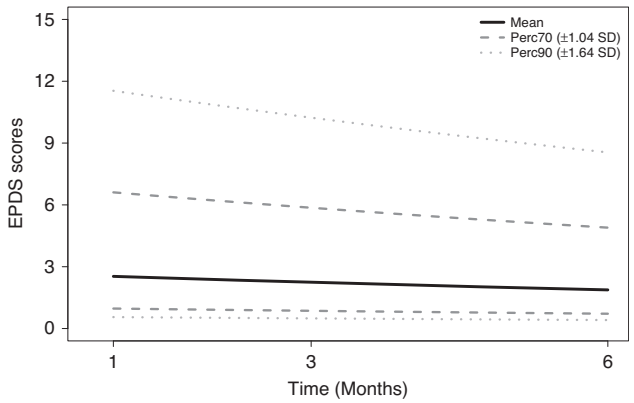

Fig. 1 Trends of the Edinburgh Postnatal Depression Scale trajectories from 1 to 6 months after birth representing the random intercepts and its variance ($n = 1843$). Areas within the dotted lines include 70% and 90% of the trajectories, respectively.

interpretable, the predicted values of ASQ-SE based on EPDS scores in the original scale are presented in Appendix 2.

Mediating role of MSE and additional effect of postpartum anxiety

MSE mediated the relationship between PPD and SED (indirect effect 1.7, 95% CI: 1.2; 2.1) as seen in Table 2, model 2. The addition of the postpartum anxiety variable and other covariates reduced all effects marginally, but these remained statistically significant (Table 2, model 4, and Fig. 2). About 50% of the total effects of the PPD on SED were mediated via MSE (indirect effect 1.4, 95% CI: 1.0; 1.9). Postpartum anxiety had a small but significant additional negative effect on SED (B 0.17, 95% CI: 0.10; 0.24).

DISCUSSION

We found a negative association of PPD trajectories with infants' SED. Moreover, we found that MSE mediated this relationship. Furthermore, postpartum anxiety had a small additional negative effect on infants' SED.

Higher PPD levels during the first 6 months postpartum were associated with a worse SED of infants at 12 months of age. Our findings are in line with a study by Porter et al. among 282 mother-child dyads which showed negative effects of the trajectories of perinatal depression on infants' SED at the age of 12 months.[52] Porter et al. also assessed the effects of the changes in perinatal depression over time (random slopes). We could not assess this association due to the small variability of the changes in PPD over time, whereas this was much larger in the study by Porter et al. The difference in the variability of PPD between both studies could be due to the differences between the study samples; Porter et al. assessed a clinical sample whereas we assessed a community sample.

We found that MSE mediated the association between PPD and infants' SED. To our knowledge, this is the first study to examine the role of MSE as a mediator of the relationship between the course of

Table 2. The direct, indirect (i.e., mediated), and total effects of postpartum depression trajectory, based on the EPDS values at 1, 3, and 6 months of age on infants' socioemotional development as assessed with the ASQ-SE score ($n = 1843$).

Models[a]	Direct Effect B (SE)	Indirect Effect B (SE)	Total Effect B (SE)	Mediation Effect (%)
1. The relationship between the EPDS[b] trajectory and ASQ-SE[c] score	NA	NA	3.5 (0.4)	NA
2. Model 1 with inclusion of MSE[d] as a potential mediator	1.8 (0.4)	1.7 (0.2)	3.5 (0.4)	47.7
3. Model 2 with inclusion of conditional postpartum anxiety	1.8 (0.4)	1.4 (0.2)	3.1 (0.4)	46.0
4. Model 3 with inclusion of other covariates*	1.6 (0.4)	1.4 (0.2)	2.9 (0.4)	48.5

*Covariates include maternal education, history of depression before childbirth, stressful life events before or after the birth of the child, and gestational age.
[a]All the associations were significant at $p < 0.001$. Estimates pooled over the 20 multiple imputed datasets.
[b]*EPDS* - Edinburgh Postnatal Depression Scale.
[c]*ASQ-SE* - Ages and Stages Questionnaire-Social-Emotional.
[d]*MSE* - maternal self-efficacy.

PPD and infants' SED at age 12 months. A possible explanation is that depressive states could negatively affect the mother's parenting abilities which in turn might lead to a negative appraisal of her infant's behavior.[53] However, PPD and MSE have been shown to have a bidirectional relationship in which MSE is a predictor as well as a consequence of PPD;[54] It is also possible that they have a shared psychological, neurobiological, or genetic background rather than being mutual causes.[55] Therefore, our results reiterate the importance of recognizing both PPD and MSE as important targets for preventive interventions to improve infants' SED.

Finally, our finding that postpartum anxiety had a small additional negative effect on top of PPD on infants' SED, is in line with the study by Prenoveau et al. that demonstrated moderate effects of postpartum anxiety on infants' SED at age 2 years.[56] However, in that study anxiety did not independently predict SED problems beyond PPD. Postpartum anxiety is associated with intrusive parenting practices which could explain the impact of anxiety on infants' SED.[24]

Strengths and limitations

Our study has several strengths. First, our study had a longitudinal design with a representative sample of 1843 mother-child dyads from the general Dutch population. Second, PPD has been assessed repeatedly at three time points (1, 3, and 6 months after birth), which allowed for studying the effects of the course of PPD on infants' SED precisely. Finally, we used a Poisson-based regression approach to handle the skewed PPD scores that provide robustness to the model and results.

However, some limitations should be mentioned as well. The main limitation of our study regards the use of self-reported maternal mental health and infants' SED which may have introduced information bias. For instance, mothers who are depressed may be more likely to rate their infants having more socioemotional problems as well as rate their self-efficacy lower. However, all three questionnaires used in the study have been validated among the population of mothers with PPD and anxiety.[29,35,57] Second, we did not assess prenatal depression and prenatal anxiety whereas these could be important confounders in the association between PPD and SED of infants.[1,24] However, including 'lifetime depression' and 'stressful life events' as covariates is likely to reduce potential bias here. Third, due to the design of the study, the other direction of the association between PPD and MSE was not tested.

Implications

The strong associations of PPD trajectories with infants' SED in our data emphasize the need for effective and regular screening of PPD during the postpartum period. In addition, also screening for postpartum anxiety should be considered because of its independent, additional negative effect on infants' SED. Furthermore, the mothers with PPD, as well as their infants, may benefit from interventions that focus on both decreasing the duration and level of the PPD and improving maternal self-efficacy via interventions such as peer parenting support groups.[58]

Future studies are needed to assess the effects of the duration of all types of mental health problems before and after giving birth, including repeated measures of other mental health problems including perinatal depression and anxiety. Additionally, more insight is needed into protective factors affecting bonding between mother and child, into the effects of paternal mental health, and into biological mechanisms such as epigenetic changes or changes to the morphology of the brain in order to obtain further evidence enabling to develop and offer effective personalized preventive interventions.[59,60]

CONCLUSIONS

The levels of the PPD trajectory between birth and 6 months after birth are negatively associated with infants' SED. Moreover, MSE

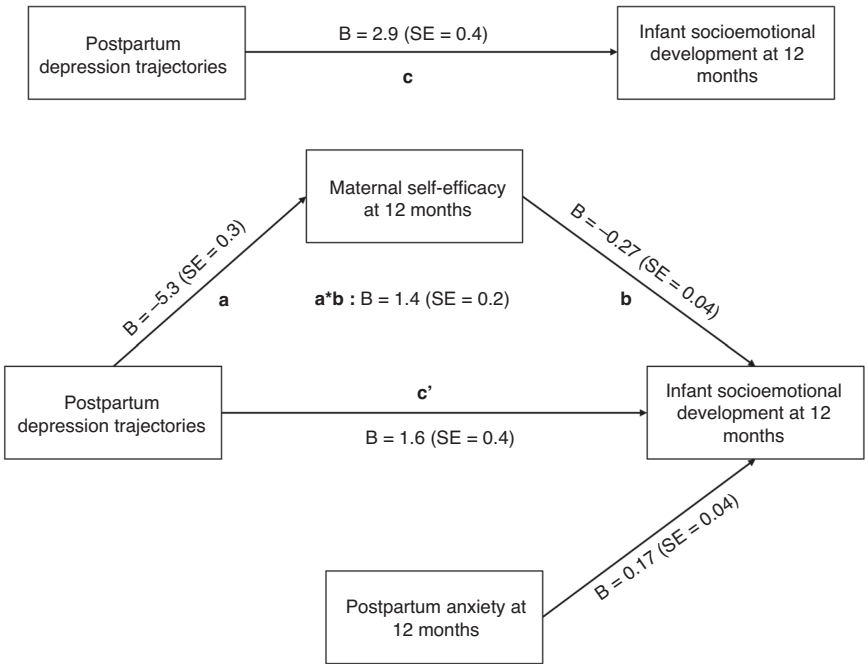

Fig. 2 Mediation model demonstrating the associations (B) and their standard errors (SE); "*c*" is the total effects model, where c is the total effect of postpartum trajectories (log transformed) on infants' socioemotional development. For the mediation model, a*b is the indirect, i.e., the mediated, effect and c- is the direct, i.e., not-mediated, effect. The effects are adjusted for postpartum anxiety and for other covariates (maternal education, history of depression before childbirth, stressful life events during or after birth of the child, and gestational age). Estimates were pooled over 20 multiple imputed datasets. All paths indicated in the figure were statistically significant at $p < 0.001$.

significantly mediated the relationship between PPD and SED, indicating MSE as a potential target for preventive interventions to alleviate the negative effects of PPD on children's SED. Additionally, our findings show the importance of the (repeated) assessment of PPD and anxiety among mothers in the postpartum period in order to offer preventive interventions in an early phase.

DATA AVAILABILITY

Data for the current study is not publicly available. Reasonable requests for data can be made to the principal investigator of the *Post-Up* trial, Dr. Magda M. Boere-Boonekamp; m.m.boere-boonekamp@utwente.nl.

REFERENCES

1. Aktar, E. et al. Fetal and infant outcomes in the offspring of parents with perinatal mental disorders: earliest influences. *Front. Psychiatry* **10**, 391 (2019).
2. Stewart, D. E. & Vigod, S. N. Postpartum depression: pathophysiology, treatment, and emerging therapeutics. *Annu. Rev. Med.* **70**, 183–196 (2019).
3. Pearlstein, T., Howard, M., Salisbury, A. & Zlotnick, C. Postpartum depression. *Am. J. Obstet. Gynecol.* **200**, 357–364 (2009).
4. Slomian, J., Honvo, G., Emonts, P., Reginster, J. Y. & Bruyère, O. Consequences of maternal postpartum depression: a systematic review of maternal and infant outcomes. *Women's Health* **15**, 1745506519844044 (2019).
5. Moehler, E. et al. Childhood behavioral inhibition and maternal symptoms of depression. *Psychopathology* **40**, 446–452 (2007).
6. Feldman, R. et al. Maternal depression and anxiety across the postpartum year and infant social engagement, fear regulation, and stress reactivity. *J. Am. Acad. Child Adolesc. Psychiatry* **48**, 919–927 (2009).
7. Carter, A. S., Garrity-Rokous, F. E., Chazan-Cohen, R., Little, C. & Briggs-Gowan, M. J. Maternal depression and comorbidity: predicting early parenting, attachment security, and toddler social-emotional problems and competencies. *J. Am. Acad. Child Adolesc. Psychiatry* **40**, 18–26 (2001).
8. Thompson, R. A. & Virmani, E. A. Socioemotional development. in *Encyclopedia of Human Behavior* 2nd edn, 504–511 (Elsevier Inc., 2012).
9. Vertsberger, D. & Knafo-Noam, A. Mothers' and fathers' parenting and longitudinal associations with children's observed distress to limitations: From pregnancy to toddlerhood. *Dev. Psychol.* **55**, 123–134 (2019).
10. Edwards, D. M., Gibbons, K. & Gray, P. H. Relationship quality for mothers of very preterm infants. *Early Hum. Dev.* **92**, 13–18 (2016).
11. Sarfi, M., Smith, L., Waal, H. & Sundet, J. M. Risks and realities: dyadic interaction between 6-month-old infants and their mothers in opioid maintenance treatment. *Infant Behav. Dev.* **34**, 578–589 (2011).
12. Paulson, J. F., Dauber, S. & Leiferman, J. A. Individual and combined effects of postpartum depression in mothers and fathers on parenting behavior. *Pediatrics* **118**, 659–668 (2006).
13. Bosquet Enlow, M. et al. Differential effects of stress exposures, caregiving quality, and temperament in early life on working memory versus inhibitory control in preschool-aged children. *Dev. Neuropsychol.* **44**, 339–356 (2019).
14. Vaiserman, A. M. Epigenetic programming by early-life stress: evidence from human populations. *Dev. Dyn.* **244**, 254–265 (2015).
15. O'Donnell, K. J. & Meaney, M. J. Epigenetics, development, and psychopathology. *Annu Rev. Clin. Psychol.* **16**, 327–350 (2020).
16. Van Der Waerden, J. et al. Maternal depression trajectories and children's behavior at age 5 years. *J. Pediatr.* **166**, 1440–1448.e1 (2015).
17. Kettunen, P., Koistinen, E. & Hintikka, J. Is postpartum depression a homogenous disorder: time of onset, severity, symptoms and hopelessness in relation to the course of depression. *BMC Pregnancy Childbirth* **14**, 1–9 (2014).
18. Vliegen, N., Casalin, S. & Luyten, P. The course of postpartum depression: a review of longitudinal studies. *Harv. Rev. Psychiatry* **22**, 1–22 (2014).
19. Bandura, A. Self-efficacy mechanism in human agency. *Am. Psychol.* **37**, 122–147 (1982).
20. Coleman, P. K. & Karraker, K. H. Maternal self-efficacy beliefs, competence in parenting, and toddlers' behavior and developmental status. *Infant Ment. Health J.* **24**, 126–148 (2003).
21. Jones, T. L. & Prinz, R. J. Potential roles of parental self-efficacy in parent and child adjustment: a review. *Clin. Psychol. Rev.* **25**, 341–363 (2005).
22. Wernand, J. J., Kunseler, F. C., Oosterman, M., Beekman, A. T. F. & Schuengel, C. Prenatal changes in parenting self-efficacy: linkages with anxiety and depressive symptoms in primiparous women. *Infant Ment. Health J.* **35**, 42–50 (2014).
23. Bates, R. A. et al. Relations of maternal depression and parenting self-efficacy to the self-regulation of infants in low-income homes. *J. Child Fam. Stud.* **29**, 2330–2341 (2020).
24. Rees, S., Channon, S. & Waters, C. S. The impact of maternal prenatal and postnatal anxiety on children's emotional problems: a systematic review. *Eur. Child Adolesc. Psychiatry* **28**, 257–280 (2019).

25. Aktar, E. & Bögels, S. M. Exposure to parents' negative emotions as a developmental pathway to the family aggregation of depression and anxiety in the first year of life. *Clin. Child Fam. Psychol. Rev.* **20**, 369–390 (2017).
26. Murray, L., Creswell, C. & Cooper, P. J. The development of anxiety disorders in childhood: an integrative review. *Psychol. Med.* **39**, 1413–1423 (2009).
27. van der Zee-Van Den Berg, A. I. et al. Post-up study: postpartum depression screening in well-child care and maternal outcomes. *Pediatrics* **140**, e20170110 (2017).
28. van der Zee-Van den Berg, A. I., Boere-Boonekamp, M. M., Groothuis-Oudshoorn, C. G. M. & Reijneveld, S. A. The Edinburgh Postpartum Depression Scale: Stable structure but subscale of limited value to detect anxiety. *PloS One* **14**, e0221894 (2019).
29. Cox, J. L., Holden, J. M. & Sagovsky, R. Detection of postnatal depression. *Br. J. Psychiatry* **150**, 782–786 (1987).
30. Squires, J., *et al*. *Ages and Stages Questionnaires, Social-Emotional: A Parent-Completed, Child-Monitoring System for Social-Emotional Behaviors* (Paul H. Brookes Publishing Company, 2002).
31. McCrae, J. S. & Brown, S. M. Systematic review of social–emotional screening instruments for young children in child welfare. *Res. Soc. Work Pr.* **28**, 767–788 (2018).
32. De Wolff, M. S., Theunissen, M. H. C., Vogels, A. G. C. & Reijneveld, S. A. Three questionnaires to detect psychosocial problems in toddlers: a comparison of the BITSEA, ASQ:SE, and KIPPPI. *Acad. Pediatr.* **13**, 587–592 (2013).
33. Pop, V. J., Komproe, I. H. & van Son, M. J. Characteristics of the Edinburgh postnatal depression scale in The Netherlands. *J. Affect Disord.* **26**, 105–110 (1992).
34. Matthey, S., Henshaw, C., Elliott, S. & Barnett, B. Variability in use of cut-off scores and formats on the Edinburgh Postnatal Depression Scale – Implications for clinical and research practice. *Arch. Women's Ment. Health* **9**, 309–315 (2006).
35. Pedersen, F. A., Bryan, Y., Huffman, L. & Del Carmen, R. Constructions of self and offspring in the pregnancy and early infancy periods. In *the Biennial Meeting of the Society for Research in Child Development* (1989).
36. Porter, C. L. & Hsu, H. C. First-time mothers' perceptions of efficacy during the transition to motherhood: Links to infant temperament. *J. Fam. Psychol.* **17**, 54–64 (2003).
37. Marteau, T. M. & Bekker, H. The development of a six-item short-form of the state scale of the Spielberger State—Trait Anxiety Inventory (STAI). *Br. J. Clin. Psychol.* **31**, 301–306 (1992).
38. Tendais, I., Costa, R., Conde, A. & Figueiredo, B. Screening for depression and anxiety disorders from pregnancy to postpartum with the EPDS and STAI. *Span. J. Psychol.* **17**, e7 (2014).
39. Gunning, M. D. et al. Assessing maternal anxiety in pregnancy with the State-Trait Anxiety Inventory (STAI): issues of validity, location and participation. *J. Reprod. Infant Psychol.* **28**, 266–273 (2010).
40. van der Bij, A. K., de Weerd, S., Cikot, R. J. L. M., Steegers, E. A. P. & Braspenning, J. C. C. Validation of the Dutch short form of the state scale of the Spielberger State-Trait Anxiety Inventory: Considerations for usage in screening outcomes. *Community Genet* **6**, 84–87 (2003).
41. Grote, N. K. et al. A meta-analysis of depression during pregnancy and the risk of preterm birth, low birth weight, and intrauterine growth restriction. *Arch. Gen. Psychiatry* **67**, 1012–1024 (2010).
42. White, I. R., Royston, P. & Wood, A. M. Multiple imputation using chained equations: Issues and guidance for practice. *Stat. Med.* **30**, 377–399 (2011).
43. Kempen, G. I. J. M. & Van Eijk, L. M. The psychometric properties of the SSL12-I, a short scale for measuring social support in the elderly. *Soc. Indic. Res.* **35**, 303–312 (1995).
44. Ware, J. E., Kosinski, M. & Keller, S. D. A 12-item short-form health survey: construction of scales and preliminary tests of reliability and validity. *Med. Care* **34**, 220–233 (1996).
45. Landgraf, J. M., Vogel, I., Oostenbrink, R., van Baar, M. E. & Raat, H. Parent-reported health outcomes in infants/toddlers: Measurement properties and clinical validity of the ITQOL-SF47. *Qual. Life Res.* **22**, 635–646 (2013).
46. Morris, T. P., White, I. R. & Royston, P. Tuning multiple imputation by predictive mean matching and local residual draws. *BMC Med. Res. Methodol.* **14**, 1–13 (2014).
47. Gupta, P. L., Gupta, R. C. & Ong, S. H. Modelling count data by random effect poisson model. *Sankhya Indian J. Stat.* **66**, 548–565 (2003).
48. de Kroon, M. L. A., Renders, C. M., van Wouwe, J. P., van Buuren, S. & Hirasing, R. A. The Terneuzen Birth Cohort: BMI change between 2 and 6 years is most predictive of adult cardiometabolic risk. *PloS One* **5**, e13966 (2010).
49. van Buuren, S. & Groothuis-Oudshoorn, K. mice: Multivariate Imputation by Chained Equations in R. *J. Stat. Softw.* **45**, 1–67 (2011).
50. Muthén, L. K. & Muthén, B. O. *Mplus: Statistical Analysis with Latent Variables: User's Guide*. (Muthén & Muthén, 2017).
51. Schermelleh-Engel, K., Moosbrugger, H. & Müller, H. Evaluating the fit of structural equation models: tests of significance and descriptive goodness-of-fit measures. *MPR Online* **8**, 23–74 (2003).
52. Porter, E., Lewis, A. J., Watson, S. J. & Galbally, M. Perinatal maternal mental health and infant socio-emotional development: a growth curve analysis using the MPEWS cohort. *Infant Behav. Dev.* **57**, 101336 (2019).
53. Atkins, R. Self-efficacy and the promotion of health for depressed single mothers. *Ment. Health Fam. Med.* **7**, 155–168 (2010).
54. Kunseler, F. C., Willemen, A. M., Oosterman, M. & Schuengel, C. Changes in parenting self-efficacy and mood symptoms in the transition to parenthood: a bidirectional association. *Parenting* **14**, 215–234 (2014).
55. Leerkes, E. M. & Crockenberg, S. C. The development of maternal self-efficacy and its impact on maternal behavior. *Infancy* **3**, 227–247 (2002).
56. Prenoveau, J. M. et al. Maternal postnatal depression and anxiety and their association with child emotional negativity and behavior problems at two years. *Dev. Psychol.* **53**, 50–62 (2017).
57. Squires, J., Bricker, D., Heo, K. & Twombly, E. Identification of social-emotional problems in young children using a parent-completed screening measure. *Early Child Res. Q* **16**, 405–419 (2001).
58. Schwab-Reese, L. M., Schafer, E. J. & Ashida, S. Associations of social support and stress with postpartum maternal mental health symptoms: Main effects, moderation, and mediation. *Women Health* **57**, 723–740 (2017).
59. Kvalevaag, A. L. et al. Paternal mental health and socioemotional and behavioral development in their children. *Pediatrics* **131**, e463–e469 (2013).
60. Jawahar, M. C., Murgatroyd, C., Harrison, E. L. & Baune, B. T. Epigenetic alterations following early postnatal stress: a review on novel aetiological mechanisms of common psychiatric disorders. *Clin. Epigenetics* **7**, 1–13 (2015).

AUTHOR CONTRIBUTIONS

G.K.S. drafted the initial manuscript, carried out the data analyses and revised the manuscript. M.L.A.d.K. conceptualized and supervised the study, supervised the data analyses and reviewed and revised the manuscript. S.A.R. and C.A.H. supervised the study, reviewed and revised the manuscript. J.A. carried out and supervised data analyses, and revised the manuscript. A.I.v.d.Z.-v.d.B. and M.M.B.-B. conceptualized and designed the *POST-UP* trial, and coordinated and supervised data collection, and critically reviewed the manuscript. All authors have read and approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

FUNDING

Funded by the Netherlands Organization for Health Research and Development (grant number 80-82470-98-012).

COMPETING INTERESTS

The authors declare no competing interests.

INFORMED CONSENT

Informed consent was obtained from all the participants for this study.

ADDITIONAL INFORMATION

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s41390-023-02697-w.

Correspondence and requests for materials should be addressed to Gireesh Kumar Subbiah.