Original Article

# Association of Postpartum Depression with Maternal Serum Magnesium Levels, Infant Growth, and Neurodevelopmental Indices

**Mohammad A. Pourmirzaiee, Seyede S. Daniali[1], Roya Riahi[2], Sepideh Majidi[3], Roya Kelishadi[1]**

*Pediatrics Department, Research Institute for Primordial Prevention of Non-Communicable Disease, Child Growth and Development Research Center, Isfahan University of Medical Sciences, Isfahan, Iran, [1]Child Growth and Development Research Center, Research Institute for Primordial Prevention of Non-Communicable Disease, Isfahan University of Medical Sciences, Isfahan, Iran, [2]Department of Epidemiology and Biostatistics, School of Public Health, Isfahan University of Medical Sciences, Isfahan, Iran, [3]Clinical Research Development Unit, Hajar Hospital, Shahrekord University of Medical Sciences, Shahrekord, Iran*

## Abstract

**Background:** Postpartum depression (PPD) can exert both short-term and long-term effects on a child's health. Offspring born to mothers who suffer from PPD face an elevated susceptibility to encountering psychological disturbances and developmental delays. Moreover, there has been conjecture surrounding a plausible connection between maternal magnesium (Mg) levels and psychiatric manifestations. This study aims to investigate the relationship between maternal Mg levels and PPD and the correlation between PPD and an infant's growth and neurodevelopment at 6 and 12 months. **Methods:** This longitudinal study is a sub-study derived from the "PERSIAN Birth Cohort Study," encompassing 224 mother–infant pairs randomly enlisted during 2019–2020 in Isfahan. Maternal serum magnesium (Mg) levels were measured at 38 weeks of gestation. PPD was evaluated employing the Edinburgh Postpartum Depression Scale (EPDS) four weeks postpartum. Measurements of birth size were undertaken, adhering to standardized protocols at birth, 6 months, and 12 months. Anthropometric parameters and the Persian version of the validated Ages and Stages Questionnaires (ASQ) were employed to assess infant neurodevelopmental status at 6 and 12 months. **Results:** Overall, 22.3% of mothers grappled with PPD. The mean (standard deviation) maternal magnesium levels (Mg) were 1.95 ± 0.23 mg/dL. No statistically significant association was detected between maternal serum magnesium (Mg) levels and the incidence of PPD. Correspondingly, no significant association emerged between PPD and indices of growth. However, a noteworthy distinction materialized in the communication scores of offspring born to depressed and non-depressed mothers following adjustments for confounding variables at 12 months ($\beta = 1.81$; 95% confidence interval: 0.32-3.30). Furthermore, a substantial regression in communication skills became apparent between 6 and 12 months. **Conclusions:** This study failed to establish a significant association between maternal serum magnesium (Mg) levels and PPD. Nevertheless, research lends credence to an inverse correlation between maternal depression and subsequent behavioral difficulties in offspring, such as communication skills. Thus, the imperative nature of screening for PPD should be underscored to facilitate its early detection and intervention, thereby enhancing infant well-being.

**Keywords:** *Child development, infant, magnesium, postpartum depression*

## Introduction

Postpartum depression (PPD), a subtype of major depressive disorder, manifests as persistent and severe low mood occurring within four weeks after childbirth and potentially extending up to 30 weeks postpartum. Symptoms encompass crying episodes, insomnia, despondency, fatigue, anxiety, impaired concentration, diminished interest or pleasure in activities, reduced energy levels, and feelings of worthlessness or guilt.[1] PPD's prevalence is estimated to range between 10% and 15% in North America,[2] 27% in the Middle East, and 23.7%–34.8% in Iran.[3,4]

The role of trace elements in the pathophysiology of PPD, including magnesium (Mg), has garnered attention.[5] Magnesium, the body's fourth most abundant cation ($Mg^{2+}$), is pivotal in activating enzyme systems. Magnesium deficiency is associated with psychiatric symptoms such as depression, headaches, tremors, anxiety, and mood swings.[6,7] The substantial transfer of magnesium ($Mg^{2+}$) from the mother to the fetus can lead to issues in PPD.[8] Magnesium (Mg) supplementation has shown efficacy in treating depression.[6,7]

Conversely, untreated maternal depression can have short-term and long-term repercussions on the child's well-being.



**How to cite this article:** Pourmirzaiee MA, Daniali SS, Riahi R, Majidi S, Kelishadi R. Association of postpartum depression with maternal serum magnesium levels, infant growth, and neurodevelopmental indices. Int J Prev Med 2024;15:16.

***Address for correspondence:***
*Dr. Sepideh Majidi, Clinical Research Development Unit, Hajar Hospital, Shahrekord University of Medical Sciences, Shahrekord, Iran.*
*E-mail: sh_daniali@yahoo.com*

**Access this article online**
**Website:** www.ijpvmjournal.net/www.ijpm.ir
**DOI:** 10.4103/ijpvm.ijpvm_30_24
**Quick Response Code:**

Neonates born to depressed mothers are less likely to be breastfed and are more prone to immune problems, sleep disturbances, impaired fetal and postnatal development, and increased hospitalizations.[1,9,10]

The first year of a child's life is a critical period for growth and development, influenced by the mother's emotional state. There have been conflicting findings regarding the association between PPD and anthropometric measures. Avan *et al*.'s[11] study highlighted an association between PPD and stunting in Africa or a higher height-for-age z-score and adiposity in depressed women in the United States.[12] Conversely, Grote *et al*.'s[13] study concluded that postnatal depression does not significantly affect offspring growth in European countries.

Moreover, several studies have demonstrated a substantial impact of maternal PPD on infant development at various stages. A systematic review indicated that a mother's mood in the first year of a child's life can negatively influence four domains of the child's development: behavior, psychomotor skills, cognition, and social–emotional development.[14] Consequently, children born to mothers with PPD are at risk of cognitive and language developmental delays.[9,15] Some studies have also highlighted developmental delays across multiple domains in children due to maternal mood, encompassing problem-solving, communication, personal–social skills, and motor skills.[14,16]

PPD represents a relatively prevalent mood disorder following childbirth, and many sufferers refrain from seeking treatment from mental health professionals. Furthermore, while magnesium (Mg) has been posited as a contributing factor, the available data remain inconclusive. In light of PPD's adverse impact on maternal responsibilities and interaction with infants, the current study aimed to investigate two hypotheses: first, whether there exists an association between maternal magnesium ($Mg^{2+}$) levels and PPD, and second, whether there is a relationship between PPD and infants' growth and neurodevelopmental indicators.

## Methods

### Study population

This longitudinal study was conducted as a sub-study within the framework of the Prospective Epidemiological Research Studies in Iran (PERSIAN Birth Cohort) at the Isfahan Center, known as the "Isfahan Birth Cohort" (IBC). Detailed information regarding the study's design, participants, and data collection methods has been previously published.[17]

Sample size estimation for this study was determined using the correlation coefficient formula, with a significance level of 5% and a statistical power of 80%.[18] Initially, the minimum required sample size for this study was calculated to be 199 subjects. However, considering the potential for a reduction in sample size, it was conservatively increased to 219. Ultimately, data from 224 mother-infant pairs were included and subjected to analysis.

All participants were selected through a random process utilizing random table numbers. These participants were provided with comprehensive information about the study's objectives, protocols, and subsequent follow-up stages. To participate, they willingly provided their informed consent by signing consent forms and completing relevant questionnaires. Furthermore, participants were informed about the necessity of blood sampling during the later stages of pregnancy, with an assurance that their personal information would be kept strictly confidential.

### Inclusion criteria

The pregnant women enrolled in this study were Iranian residents of Isfahan for at least one year, with no prior history of infertility and the intention to deliver their babies in hospitals within Isfahan City.

### Exclusion criteria

Women who had relocated to another city or country or those who had consumed alcohol or cigarettes during pregnancy were ineligible for participation in this study. Furthermore, the study excluded mothers experiencing preterm labor, preeclampsia, a history of unfortunate events such as divorce or the death of a relative, those taking psychotropic medication, or individuals undergoing other stressful life experiences.

### Ethical consideration

The study protocol, which adhered to the criteria of the Helsinki Declaration, was submitted to the Ethics Committee of the Isfahan University of Medical Science and received approval under the ethical code IR.MUI.MED.REC.1398.331. Participation in this study was entirely voluntary, and participants retained the right to withdraw from the study at any point.

### Sample collection

Maternal blood samples, totaling 2 ml and collected in Heparinized tubes, were obtained at the 38th week of pregnancy. Following blood preparation, serums were stored in a refrigerator at temperatures ranging from 2 to 8°C using a xylidyl blue calorimeter. Serum magnesium levels were subsequently determined at the laboratory of Amin Hospital, affiliated with Isfahan University of Medical Science, utilizing the absorbance photometry method with the Mindray BS-600 Analyzer.

### Birth size measurements

A proficient interviewer gathered general, medical, and socioeconomic data, including education, income, parental occupations, and smoking habits. Subsequently, a skilled midwife employed standardized techniques to obtain neonatal anthropometric measurements, encompassing weight (in grams), head circumference, and height (in centimeters), conducted at least two hours post-birth. Birth weight was assessed using a precision instrument that could measure within 10 grams (Seca mobile digital baby scale 334; UK). Birth length was determined using a stadiometer, with the neonate lying supine and their knees extended while the soles of their feet were securely positioned against the measurement board. Head circumference was measured at the maximal occipitofrontal circumference (OFC) using a standard measuring tape that was accurate to 1 mm. The mid-upper arm circumference, defined as the circumference of the upper left arm, was measured at the midpoint between the shoulder and elbow at 6 and 12 months of age using colored plastic tape.[19]

### Data collection

Gestational age, neonatal sex, gravidity (the number of pregnancies a woman has had), parity (the number of viable children a woman has given birth to), maternal weight (in kg), maternal height (in cm), maternal supplementation during pregnancy (yes or no), delivery method (vaginal, cesarean, or other), maternal employment status (housewife or employed), breastfeeding status, and socioeconomic status (SES) categorized as low, moderate, or high were meticulously recorded.

Furthermore, the initial demographic information questionnaire administered to mothers upon entry into the birth cohort was utilized to gather essential details and evaluate SES.

Gestational age was determined based on the mother's regular menstrual cycle or the first-trimester fetal ultrasound (performed at or before 16 weeks of gestation), employing crown-rump length as the measurement criterion.

Additionally, maternal body mass index (BMI) at enrollment was calculated by dividing body weight (in kg) by the square of height (in $m^2$), maternal education level (<12 years, 12 years [high school diploma], or >12 years), monthly household income (in Iranian Rials [IRR]), and exposure to second-hand smoke during pregnancy (yes or no) were documented.

### Outcome measures

#### *Study questionnaire*

The EPDS comprises ten questions, each offering four response options to assess maternal moods and feelings. It is administered during the fourth week following delivery. Every question is allocated a score ranging from 0 to 3, resulting in a total score ranging from 0 to 30. A score of 12 or higher indicates the presence of PPD.[20,21] Existing evidence supports the sufficient validity and reliability of the EPDS in the Iranian population for diagnosing PPD.[22] Information concerning maternal dietary supplements, including magnesium, was documented during the third trimester of pregnancy.

The Persian version of the validated Questionnaires of Ages and Stages (ASQ) is employed to evaluate the neurodevelopmental status of the child at 6 and 12 months.[23] It screens for developmental delays in children utilizing 20 age-specific developmental questionnaires, commencing at 2 months and concluding at 60 months. These questionnaires encompass five domains: Fine Motor, Gross Motor, Communication, Problem-Solving, and Personal-Social. Each domain consists of six questions, with response options of yes (10 points), sometimes (5 points), or not yet (0 points). This study utilized the questionnaires designed for the 6- and 12-month age groups.[24] The test's validity ranges from 76% to 88%, rendering it a reliable tool with a Cronbach's alpha coefficient of 0.86 and a reliability coefficient of 0.93 for Iranian children. Its specificity and sensitivity were 95% and 90%, respectively, for the high-risk group and 100% and 75% for the community group.[25]

### Statistical analysis

Descriptive statistics, encompassing frequency (%) and mean (SD), were utilized to illustrate participants' categorical and continuous data. The two-independent sample *t*-test (in instances of non-normal data, the Mann-Whitney test was employed), along with the Chi-square test, was employed to ascertain disparities in maternal and/or infant demographic characteristics between infants born to postpartum depressed and non-depressed mothers. Logistic regression analysis was employed to explore the association between maternal serum magnesium levels and the risk of PPD. The model underwent adjustments for maternal weight, height, delivery method, maternal age at delivery, SES gravidity, parity, household income, and infant gender. The researchers utilized repeated measures analysis of variance to assess changes in anthropometric measurements (z-scores) and skill measurements from 6 to 12 months among infants born to postpartum depressed and non-depressed mothers.

Additionally, correlation and multivariate regression analyses were conducted to evaluate the association between PPD and anthropometric (z-scores) and neurodevelopmental skills at 12 months while controlling for 6-month scores and other covariates. These covariates encompassed delivery type, maternal age, SES, parity, maternal education, maternal employment, breastfeeding at 12 months, exclusive breastfeeding, supplementation, infant gender, and birth weight. Statistical significance was established for all analyses at a $P$ value less than 0.05. All statistical analyses were executed using IBM SPSS Statistics V. 22.0 (SPSS Inc., Chicago, IL).

## Results

The frequency of PPD among the participants stood at 22.3%. The mean age of the participants in our study was 28.23 ± 4.34 years. The mean maternal serum magnesium level was 1.95 ± 0.23 mg/dl. No significant association was observed between maternal serum magnesium levels and the risk of PPD (odds ratio [OR]: 0.29, 95% confidence interval [CI]: 0.04 to 1.77). This statistical model was adjusted for maternal weight, height, delivery type, maternal age at delivery, SES, number of previous deliveries, previous children, maternal education, and infant gender. Comprehensive characteristics of mothers and their children, stratified by PPD, can be found in Table 1.

There were no significant differences detected in infants' weight-for-height, weight-for-age, height-for-age, and mid-upper arm circumference-for-age at 6 and 12 months, based on PPD status ($P > 0.05$) [Table 2]. Furthermore, there was no significant depression-by-time effect (interaction effect) on infants' weight-for-height, weight-for-age, height-for-age,

**Table 1: Characteristics of mothers and children according to postpartum depression**

| Demographic characteristics | Non-depressed (*n*=174) | Depressed (*n*=50) | *P* |
|---|---|---|---|
| Maternal magnesium level (mg/dl), mean (SD) | 1.97 (0.25) | 1.91 (0.18) | 0.64 |
| Maternal weight (kg), mean (SD) | 65.67 (11.57) | 64.81 (11.10) | 0.63 |
| Maternal height (cm), mean (SD) | 161.38 (5.20) | 161.80 (5.49) | 0.09 |
| Gravidity (number of pregnancy) | | | |
| The first labor | 78 (75.7%) | 25 (24.3%) | 0.64 |
| Second | 66 (81.5%) | 15 (18.5%) | |
| Third or more | 30 (76.9%) | 9 (23.1%) | |
| Socioeconomic status (SES) | | | |
| Low | 58 (68.2%) | 27 (31.8%) | 0.02* |
| Moderate | 93 (83.8%) | 18 (16.2%) | |
| High | 22 (84.6%) | 4 (15.4%) | |
| Parity (number of labor with live child) | | | |
| None | 78 (75.7%) | 26 (24.3%) | 0.91 |
| One | 70 (78.7%) | 15 (21.3%) | |
| Two or more | 24 (80.0%) | 9 (20.0%) | |
| Type of delivery | | | |
| Vaginal | 84 (80.0%) | 21 (20.0%) | 0.76 |
| Cesarean | 82 (76.6%) | 25 (23.4%) | |
| Other | 8 (72.7%) | 3 (27.3%) | |
| Maternal employment | | | |
| Housewife | 162 (76.8%) | 49 (23.2%) | - |
| Employee | 11 (100%) | - | |
| Maternal education | | | |
| Illiterate/under 12th education | 21 (56.8%) | 16 (43.2%) | 0.004* |
| Twelfth education | 74 (81.3%) | 17 (18.7%) | |
| Academic | 78 (82.1%) | 17 (17.9%) | |
| Children | | | |
| Newborn weight (gr) | 3161.79 (379.29) | 3161.84 (399.81) | 0.99 |
| Newborn height (cm) | 50.20 (2.44) | 50.53 (2.59) | 0.41 |
| Newborn head circumference (cm) | 34.60 (1.33) | 34.69 (1.21) | 0.67 |
| Breastfeeding at 12 months | | | |
| No | 14 (82.4%) | 3 (17.6%) | 0.6 |
| Yes | 158 (77.8%) | 45 (22.2%) | |
| Exclusive breastfeeding | | | |
| No | 74 (76.3%) | 23 (23.7%) | 0.55 |
| Yes | 98 (79.9%) | 25 (20.3%) | |
| Supplementation | | | |
| No | 54 (83.1%) | 11 (16.9%) | 0.22 |
| Yes | 120 (75.5%) | 39 (24.5%) | |

*$P<0.05$ is considered statistically significant. Data are shown as mean (SE) or frequency (%). Results were reported from an two-independent sample *t*-test and Chi-square test

or mid-upper arm circumference-for-age ($P > 0.05$) [Table 3]. The overall change in anthropometric measurements from 6 to 12 months did not exhibit a significant difference between depressed and non-depressed mothers ($P > 0.05$) [Table 2]. However, a significant depression-by-time effect (interaction effect) was observed in communication skills, indicating a poorer progression in communication skills for children of depressed mothers compared to non-depressed mothers ($P = 0.02$) [Table 3].

Furthermore, as depicted in Table 4, a multivariate linear model demonstrated a significant association between PPD status and 12-month communication skills in both models a (β: 1.89; 95% CI: 0.44-3.34) and model b (β: 1.81; 95% CI: 0.32-3.30) [Table 4].

## Discussion

The present study assessed the associations between maternal magnesium levels and PPD. Additionally, the association between PPD and a child's growth and neurodevelopment at 6 and 12 months was investigated. Findings indicate no significant differences in the growth of children born to depressed mothers compared to non-depressed mothers at birth, 6 months, or 12 months. However, a significant association between PPD status and communication skills at 12 months was observed after controlling for confounding variables. The response rate for this study was 93.4%.

The rate of PPD in our study was lower than in previous studies conducted in our country[4,26] but higher than reported in North America.[2] This disparity may be attributed to various influential factors on depression before and after childbirth, such as obstetric, pediatric, personality, socioeconomic, and cultural factors. Additionally, using different validated questionnaires and cut-off values for assessing depression has led to inconsistent results.[26,27] Furthermore, in alignment with a study by Smorti *et al*.,[28] it was observed that the likelihood of experiencing depression was higher among mothers with lower SES and less education than their higher socioeconomic and more educated counterparts. Poverty and socioeconomic hardships are recognized as risk factors for depression.[29]

Our study's mean maternal magnesium levels were comparable to those observed in pregnant women without magnesium deficiency.[30,31] However, no significant association was found between maternal serum magnesium levels and PPD. This finding aligns with a randomized controlled trial by Edalati Fard, which showed that the prescription of magnesium supplements did not reduce postpartum depressive symptoms.[32] The association between decreased magnesium levels and depression in various groups has not been substantiated.[33] Several factors, including hormonal, physiological, and psychological changes, appear to play a more significant role in the etiology of depression, particularly during the prenatal period, than maternal serum magnesium levels.[27,34]

Our study revealed no differences in child growth between infants born to depressed and non-depressed mothers at birth, 6 months, or 12 months. Although the weight-for-age z-score at 12 months was slightly higher in infants of depressed women compared to non-depressed women, this difference did not reach statistical significance. In line with our findings, a study involving 4745 children

**Table 2: Anthropometric measurement according to postpartum depression at 6 and 12 months**

| Measurement | Time | | | | | | Time* Depression status, *P* |
|---|---|---|---|---|---|---|---|
| | Depression status at 6 months | | *P* | Depression status at 12 months | | *P* | |
| | No Depressed | Depressed | | No Depressed | Depressed | | |
| W-F-A, z-score | 6.59 (0.30) | 6.37 (0.37) | 0.39 | 8.85 (0.36) | 9.04 (0.44) | 0.55 | 0.08 |
| Wfh, z-score | 0.15 (0.31) | 0.09 (0.38) | 0.83 | 0.43 (0.33) | 0.56 (0.40) | 0.63 | 0.46 |
| Hfa, z-score | 7.83 (0.40) | 7.66 (0.49) | 0.62 | 11.26 (0.49) | 11.21 (0.60) | 0.90 | 0.72 |
| Mfa, z-score | -0.07 (0.24) | -0.09 (0.29) | 0.93 | 0.38 (0.24) | 0.48 (0.30) | 0.640 | 0.48 |

Results were reported from repeated measures ANOVA. Data are shown as mean (SE). Wfh: weight-for height, W-F-A: weight-for-age, Hfa: height-for-age, and Mfa: MUAC-for-age

**Table 3: Neurodevelopmental Skill measurement score according to postpartum depression at 6 and 12 months**

| Measurement | Time | | | | | | Time* Depression status, *P* |
|---|---|---|---|---|---|---|---|
| | Depression status at 6 months of age | | *P* | Depression status at 12 months of age | | *P* | |
| | Not depressed | Depressed | | Not depressed | Depressed | | |
| Communication | 53.02 (2.41) | 53.55 (2.64) | 0.64 | 54.99 (2.64) | 53.47 (2.89) | 0.22 | 0.02* |
| Gross motor | 58.91 (2.08) | 58.10 (2.27) | 0.41 | 58.93 (2.27) | 57.40 (2.48) | 0.14 | 0.27 |
| Fine motor | 55.95 (1.95) | 55.22 (2.13) | 0.42 | 54.87 (1.91) | 54.60 (2.09) | 0.73 | 0.51 |
| Problem Solving | 59.31 (1.67) | 59.35 (1.83) | 0.96 | 58.24 (1.86) | 57.67 (2.03) | 0.51 | 0.33 |
| Personal–Social | 56.96 (2.84) | 57.30 (3.11) | 0.79 | 53.67 (3.34) | 53.12 (3.65) | 0.72 | 0.22 |

*$P<0.05$ is considered as statistically significant. Results were reported from repeated measures ANOVA. Data are shown as mean (SE)

**Table 4: Association of postpartum depression and neurodevelopment at 12 months**

| Skill Variables | Parameter | Model a | | | | Model b | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Beta | 95% CI | | *P* | Beta | 95% CI | | *P* |
| | | | Lower | Upper | | | Lower | Upper | |
| Communication (12 months) | Communication (6 months) | 0.76 | 0.66 | 0.87 | <0.001* | 0.77 | 0.67 | 0.88 | <0.001* |
| | Gross movements (6 months) | 0.06 | -0.08 | 0.20 | 0.38 | 0.09 | -0.05 | 0.23 | 0.19 |
| | Fine movements (6 months) | -0.01 | -0.16 | 0.14 | 0.90 | 0.02 | -0.13 | 0.17 | 0.80 |
| | Problem solving (6 months) | 0.12 | -0.05 | 0.28 | 0.16 | 0.13 | -0.04 | 0.29 | 0.13 |
| | Personal–Social (6 months) | 0.04 | -0.05 | 0.13 | 0.37 | 0.04 | -0.05 | 0.13 | 0.43 |
| | Depression | 1.89 | 0.44 | 3.34 | 0.01* | 1.81 | 0.32 | 3.30 | 0.02* |
| Gross movements (12 months) | Communication (6 months) | -0.02 | -0.11 | 0.06 | 0.60 | -0.03 | -0.12 | 0.06 | 0.53 |
| | Gross movements (6 months) | 0.80 | 0.68 | 0.91 | <0.001* | 0.79 | 0.67 | 0.91 | <0.001* |
| | Fine movements (6 months) | 0.08 | -0.05 | 0.20 | 0.23 | 0.07 | -0.06 | 0.20 | 0.27 |
| | Problem solving (6 months) | 0.03 | -0.10 | 0.17 | 0.61 | 0.04 | -0.10 | 0.17 | 0.62 |
| | Personal–Social (6 months) | 0.01 | -0.06 | 0.09 | 0.69 | 0.02 | -0.06 | 0.10 | 0.60 |
| | Depression | 0.77 | -0.42 | 1.95 | 0.20 | 0.47 | -0.78 | 1.72 | 0.46 |
| Fine movements (12 months) | Communication (6 months) | 0.03 | -0.04 | 0.11 | 0.39 | 0.01 | -0.06 | 0.09 | 0.74 |
| | Gross movements (6 months) | 0.06 | -0.04 | 0.16 | 0.22 | 0.04 | -0.07 | 0.14 | 0.49 |
| | Fine movements (6 months) | 0.65 | 0.54 | 0.76 | <0.001* | 0.63 | 0.52 | 0.74 | <0.001* |
| | Problem solving (6 months) | 0.01 | -0.11 | 0.13 | 0.91 | 0.00 | -0.12 | 0.12 | 0.96 |
| | Personal–Social (6 months) | 0.07 | 0.00 | 0.13 | 0.04* | 0.07 | 0.00 | 0.13 | 0.04* |
| | Depression | 0.13 | -0.94 | 1.19 | 0.81 | 0.27 | -0.79 | 1.34 | 0.62 |
| Problem solving (12 months) | Communication (6 months) | 0.04 | -0.03 | 0.11 | 0.27 | 0.00 | -0.07 | 0.08 | 0.95 |
| | Gross movements (6 months) | 0.03 | -0.07 | 0.12 | 0.58 | 0.01 | -0.08 | 0.11 | 0.80 |
| | Fine movements (6 months) | 0.18 | 0.07 | 0.28 | <0.001* | 0.15 | 0.04 | 0.26 | 0.01* |
| | Problem solving (6 months) | 0.66 | 0.55 | 0.77 | <0.001* | 0.65 | 0.54 | 0.77 | <0.001* |
| | Personal–Social (6 months) | 0.05 | -0.01 | 0.11 | 0.10 | 0.06 | 0.00 | 0.12 | 0.07 |
| | Depression | 0.40 | -0.61 | 1.41 | 0.44 | 0.74 | -0.29 | 1.76 | 0.16 |
| Social Personality (12 months) | Communication (6 months) | 0.03 | -0.06 | 0.13 | 0.50 | 0.03 | -0.07 | 0.13 | 0.55 |
| | Gross movements (6 months) | 0.03 | -0.09 | 0.15 | 0.63 | 0.04 | -0.09 | 0.16 | 0.56 |
| | Fine movements (6 months) | -0.02 | -0.16 | 0.12 | 0.77 | 0.01 | -0.13 | 0.15 | 0.91 |
| | Problem solving (6 months) | 0.06 | -0.09 | 0.21 | 0.42 | 0.06 | -0.09 | 0.21 | 0.42 |
| | Personal–Social (6 months) | 1.01 | 0.93 | 1.09 | <0.001* | 1.03 | 0.94 | 1.11 | <0.001* |
| | Depression | 0.93 | -0.39 | 2.24 | 0.17 | 1.09 | -0.25 | 2.44 | 0.11 |

Model b adjusted for delivery type, maternal age at delivery, SES, number of previous children, maternal education, maternal employment, breastfeeding at 12 months, exclusive breastfeeding, supplementation, infant's gender, and birth weight. *$P<0.05$ is considered statistically significant. Results were reported from the multivariate linear regression model

found no association between weight-for-length below the 10th percentile, while a significant association was observed with length, particularly in low/middle-income contexts.[35] However, contrary to earlier research, there was no confirmed increase in the likelihood of underweight or stunted growth among children of depressed mothers during the first year of life in developed countries.[12,36] This discrepancy may be attributed to similar rates of breastfeeding, exclusive breastfeeding, and gestational weight gain in depressed and non-depressed women in our study.

According to recent study findings, a decline and poor progression in communication skills from 6 to 12 months were observed, particularly at the 12 months. Other studies have also reported disruptions in communication skills among infants of depressed mothers at various ages, ranging from 12 months[37,38] to 18 months.[39]

Furthermore, a longitudinal birth cohort study by Avan *et al*.[11] demonstrated a significant association between maternal postnatal depression and child behavior problems, including concentration difficulties and impaired social relationships, at the age of 2 years. Some studies have even suggested that children whose mothers suffer from PPD are at risk of emotional and psychological issues and delays in cognitive and language development.[9,15]

Additionally, the findings of a systematic review by Sohr-Preston and Scaramella suggest that late maternal depression (occurring between 5 and 12 weeks postpartum), but not early-onset maternal PPD (within 4 weeks after childbirth), was associated with reduced expressive language scores during infancy. Their study evaluated recipient and expressive communication skills at ages 10, 14, 18, 24, 32, and 40 months in infants with depressed mothers.[40]

Language development is a critical skill for effective communication, consisting of two facets: recipient and expressive language. Expressive language, which involves conveying a message, appears to be more indirectly influenced by maternal behavior than recipient skills, which encompasses receiving and comprehending messages from a caregiver. In line with our study, a descriptive investigation in Tehran involving 1036 mothers and their offspring has revealed delays in a child's communication skills when the mother experiences depression.[25]

A literature review supports the hypothesis that depressed mothers may manifest heightened irritability and diminished responsiveness to their infant's emotional and physical needs.[40]

Furthermore, interactions involving play, vocal communication, and explanations between depressed mothers and their infants tend to be minimized.[41,42] Additionally, parenting styles, including intrusive and passive behaviors,[42] insecure attachment,[14,43] reduced storytelling, and diminished verbal communication by depressed mothers,[44] expedite adverse effects on infant communication. Conversely, maternal depression can give rise to unhealthy behaviors that impact neurodevelopment.

In a study by Ibanez *et al*.,[45] antenatal depression was correlated with children's development at 3 years of age, but only in the presence of antenatal anxiety. In other words, psychological disorders may significantly impact infants' neurodevelopmental delays more than maternal depression alone. No disparities were observed in other domains of the child's neurodevelopmental scores between depressed and non-depressed mothers. Nevertheless, study results indicated that the persistence of PPD would augment developmental delay in most[46] or some ASQ domains at 24 months. These discrepancies could be ascribed to methodological limitations and different assessment tools for infants' neurodevelopment, including the Bayley, ASQ, and Mullen Scales of Early Learning questionnaires. Furthermore, assessments of maternal depression were conducted at various time points.

Despite prior research findings, no definitive evidence has emerged concerning the specific domains of child neurodevelopmental delay. As mentioned previously, this inconsistency may be attributed to disparities in methodological approaches.

The present study possesses several strengths. Our data stem from a prospective birth cohort study that accounts for various confounding factors. However, there are limitations to our research. It should be noted that depression levels were assessed only in the fourth week post-delivery, disregarding potential variations over time, and other influential factors affecting both infant birth size and PPD may have been overlooked.

## Conclusions

The current study has elucidated a noteworthy correlation between Postpartum Depression (PPD), a prevalent health concern, and the neurodevelopmental scores of children. The evaluation of depression as a postpartum screening tool can prove to be a valuable asset for parents and caregivers, facilitating the identification of mothers who are susceptible and affording them early treatment and essential support services, thus alleviating potential detrimental impacts on their offspring.

### Abbreviations

ASQ: Ages and Stages Questionnaires
BMI: Body Mass Index
EPDS: Edinburgh Postpartum Depression Scale
IBC: Isfahan Birth Cohort
MDI: Mental Development Index
OFC: Occipitofrontal Circumference
PPD: Postpartum Depression
SES: Socioeconomic Status.

### Declarations ethics approval and consent to participate

This study adhered to the principles of the Declaration of Helsinki and received approval from the Research Ethics Committees of the Medical University of Isfahan under the reference number IR.MUI.RESEARCH.REC.1398.331. All participants were duly informed that their participation was voluntary and that their responses would remain confidential. Informed written consent was obtained from all questionnaire respondents, and participants were assured they could withdraw from the study without incurring any penalties. No compensation was provided for participation in the relevant guidelines and regulations conducted in all methods and experiments.

### Availability of data and materials

The corresponding authors are prepared to disclose the acquired data upon receiving reasonable requests.

### Financial support and sponsorship

This study was part of project number 298200 and received support from Isfahan University of Medical Sciences (Research Ethics code: IR.MUI.RESEARCH.REC.1398.331).

### Conflicts of interest

There are no conflicts of interest.

**Received:** 22 Jan 24 **Accepted:** 26 Jan 24
**Published:** 28 Mar 24

## References

1. Stewart DE, Vigod S. Postpartum depression. N Engl J Med 2016;375:2177-86.
2. Faisal-Cury A, Menezes PR, d'Oliveira AF, Schraiber LB, Lopes CS. Temporal relationship between intimate partner violence and postpartum depression in a sample of low income women. Matern Child Health J 2013;17:1297-303.
3. Khorramirad A, Lotfi MM, Bidgoli AS. Prevalence of postpartum depression and related factors in Qom. J Pajoohande 2010;15:62-6.
4. Taherifard P, Delpisheh A, Shirali R, Afkhamzadeh A, Veisani Y. Socioeconomic, psychiatric and materiality determinants and risk of postpartum depression in border city of ilam, Western Iran. Depress Res Treat 2013;2013:653471. doi: 10.1155/2013/653471.
5. Etebary S, Nikseresht S, Sadeghipour HR, Zarrindast MR. Postpartum depression and role of serum trace elements. Iran J Psychiatry 2010;5:40-6.
6. Serefko A, Szopa A, Poleszak E. Magnesium and depression. Magnes Res 2016;29:112-9.
7. Eby GA, Eby KL. Rapid recovery from major depression using magnesium treatment. Med Hypotheses 2006;67:362-70.
8. Serefko A, Szopa A, Wlaź P, Nowak G, Radziwoń-Zaleska M, Skalski M, *et al*. Magnesium in depression. Pharmacol Rep 2013;65:547-54.
9. Brummelte S, Galea LA. Postpartum depression: Etiology, treatment and consequences for maternal care. Horm Behav 2016;77:153-66.
10. Pearlstein T, Howard M, Salisbury A, Zlotnick C. Postpartum depression. Am J Obstet Gynecol 2009;200:357-64.
11. Avan B, Richter LM, Ramchandani PG, Norris SA, Stein A. Maternal postnatal depression and children's growth and behaviour during the early years of life: Exploring the interaction between physical and mental health. Arch Dis Child 2010;95:690-5.
12. Ertel KA, Koenen KC, Rich-Edwards JW, Gillman MW. Maternal depressive symptoms not associated with reduced height in young children in a US prospective cohort study. PloS One 2010;5:e13656. doi: 10.1371/journal.pone.0013656.
13. Grote V, Vik T, von Kries R, Luque V, Socha J, Verduci E, *et al*. Maternal postnatal depression and child growth: A European cohort study. BMC Pediatr 2010;10:14.
14. Kingston D, Tough S, Whitfield H. Prenatal and postpartum maternal psychological distress and infant development: A systematic review. Child Psychiatry Hum Dev 2012;43:683-714.
15. Moe V, Braarud HC, Wentzel-Larsen T, Slinning K, Vannebo UT, Guedeney A, *et al*. Precursors of social emotional functioning among full-term and preterm infants at 12 months: Early infant withdrawal behavior and symptoms of maternal depression. Infant Behav Dev 2016;44:159-68.
16. Folger AT, Eismann EA, Stephenson NB, Shapiro RA, Macaluso M, Brownrigg ME, *et al*. Parental adverse childhood experiences and offspring development at 2 years of age. Pediatrics 2018;141:e20172826. doi: 10.1542/peds.2017-2826.
17. Sakhvidi MJZ, Danaei N, Dadvand P, Mehrparvar AH, Heidari-Beni M, Nouripour S, *et al*. The prospective epidemiological research studies in IrAN (PERSIAN) birth cohort protocol: Rationale, design and methodology. Longit Life Course Stud 2021;12:241-62.
18. Gress-Smith JL, Luecken LJ, Lemery-Chalfant K, Howe R. Postpartum depression prevalence and impact on infant health, weight, and sleep in low-income and ethnic minority women and infants. Matern Child Health J 2012;16:887-93.
19. Marshall SK, Monárrez-Espino J, Eriksson A. Performance of mid-upper arm circumference to diagnose acute malnutrition in a cross-sectional community-based sample of children aged 6–24 months in Niger. Nutr Res Pract 2019;13:247-55.
20. Thombs BD, Benedetti A, Kloda LA, Levis B, Riehm KE, Azar M, *et al*. Diagnostic accuracy of the Edinburgh Postnatal Depression Scale (EPDS) for detecting major depression in pregnant and postnatal women: Protocol for a systematic review and individual patient data meta-analyses. BMJ Open 2015;5:e009742. doi: 10.1136/bmjopen-2015-009742.
21. Ahmadi kani Golzar A, GoliZadeh Z. Validation of Edinburgh postpartum depression scale (EPDS) for screening postpartum depression in Iran. Iran J Psychiatr Nurs 2015;3:1-10.
22. Rahmani Ivary F, Fanaei S, Ghahremani S, Falah Ardizi N, Abdollahpour N, Khorsandi F, *et al*.: A systematic review of psychometric properties of the Edinburgh postnatal depression scale in Iranian population. Int J Pediatr 2019;7:9497-505.
23. Vameghi R, Sajedi F, Mojembari AK, Habiollahi A, Lornezhad HR, Delavar B. Cross-cultural adaptation, validation and standardization of ages and stages questionnaire (ASQ) in Iranian children. Iran J Public Health 2013;42:522.
24. Lamsal R, Dutton DJ, Zwicker JD. Using the ages and stages questionnaire in the general population as a measure for identifying children not at risk of a neurodevelopmental disorder. BMC Pediatrics 2018;18:1-9.
25. Doulabi MA, Akbarzadeh AR. Relationship of mothers' psychological status with development of kindergarten children. Iran J Child Neurol 2016;10:61-72.
26. Afshari P, Tadayon M, Abedi P, Yazdizadeh S. Prevalence and related factors of postpartum depression among reproductive aged women in Ahvaz, Iran. Health Care for Women Int 2020;41:255-65.
27. Thurgood S, Avery DM, Williamson L. Postpartum depression (PPD). Am J Clin Med 2009;6:17-22.
28. Smorti M, Ponti L, Pancetti F. A comprehensive analysis of post-partum depression risk factors: The role of socio-demographic, individual, relational, and delivery characteristics. Front Public Health 2019;7:295. doi: 10.3389/fpubh.2019.00295.
29. Parsons CE, Young KS, Rochat TJ, Kringelbach ML, Stein A. Postnatal depression and its effects on child development: A review of evidence from low-and middle-income countries. Br Med Bull 2012;101:57-79.
30. Djanas D, Farnas H, Sriyanti R, Ambelina S. Differences post delivery of term pregnancy mean maternal serum magnesium level with low versus normal birth weight. Bioscientia Med J Biomed Transl Res 2022;6:1708-14.
31. Tavana Z, Hosseinmirzaei S. Comparison of maternal serum magnesium level in pre-eclampsia and normal pregnant women. Iran Red Crescent Med J 2013;15:e10394.
32. Fard FE, Mirghafourvand M, Mohammad-Alizadeh Charandabi S, Farshbaf-Khalili A, Javadzadeh Y, Asgharian H. Effects of zinc and magnesium supplements on postpartum depression and anxiety: A randomized controlled clinical trial. Women Health 2017;57:1115-28.
33. You HJ, Cho S-E, Kang S-G, Cho S-J, Na K-S. Decreased serum magnesium levels in depression: A systematic review and meta-analysis. Nord J Psychiatry 2018;72:534-41.
34. Soares CN, Zitek B. Reproductive hormone sensitivity and risk for depression across the female life cycle: A continuum of vulnerability? J Psychiatry Neurosci 2008;33:331-43.

35. Strobino DM, Ahmed S, Mistry K, Wasserman E, Hossain MB, Minkovitz C. Maternal depressive symptoms and attained size among children in the first 2 years of life. Acad Pediatr 2016;16:75-81.
36. Farías-Antúnez S, Xavier MO, Santos IS. Effect of maternal postpartum depression on offspring's growth. J Affect Disord 2018;228:143-52.
37. Quevedo LA, Silva RA, Godoy R, Jansen K, Matos MB, Tavares Pinheiro KA, *et al*. The impact of maternal post-partum depression on the language development of children at 12 months. Child Care Health Dev 2012;38:420-4.
38. Kaplan PS, Danko CM, Everhart KD, Diaz A, Asherin RM, Vogeli JM, *et al*. Maternal depression and expressive communication in one-year-old infants. Infant Behav Dev 2014;37:398-405.
39. Koutra K, Chatzi L, Bagkeris M, Vassilaki M, Bitsios P, Kogevinas M. Antenatal and postnatal maternal mental health as determinants of infant neurodevelopment at 18 months of age in a mother-child cohort (Rhea Study) in Crete, Greece. Soc Psychiatry Psychiatr Epidemiol 2013;48:1335-45.
40. Sohr-Preston SL, Scaramella LV. Implications of timing of maternal depressive symptoms for early cognitive and language development. Clin Child Fam Psychol Rev 2006;9:65-83.
41. Stein A, Craske MG, Lehtonen A, Harvey A, Savage-McGlynn E, Davies B, *et al*. Maternal cognitions and mother-infant interaction in postnatal depression and generalized anxiety disorder. J Abnorm Psychol 2012;121:795-809.
42. Field T. Postpartum depression effects on early interactions, parenting, and safety practices: A review. Infant Behav Dev 2010;33:1-6. doi: 10.1016/j.infbeh.2009.10.005.
43. Tomlinson M, Cooper P, Murray L. The mother-infant relationship and infant attachment in a South African peri-urban settlement. Child Dev 2005;76:1044-54.
44. Paulson JF, Dauber S, Leiferman JA. Individual and combined effects of postpartum depression in mothers and fathers on parenting behavior. Pediatrics 2006;118:659-68.
45. Ibanez G, Bernard JY, Rondet C, Peyre H, Forhan A, Kaminski M, *et al*. Effects of antenatal maternal depression and anxiety on children's early cognitive development: A prospective cohort study. PloS One 2015;10:e0135849. doi: 10.1371/journal.pone.0135849.
46. Prenoveau JM, Craske MG, West V, Giannakakis A, Zioga M, Lehtonen A, *et al*. Maternal postnatal depression and anxiety and their association with child emotional negativity and behavior problems at two years. Dev Psychol 2017;53:50.