Effect of postpartum depression and role of infant feeding practices on relative weight of child at 1 and 3 years of age

Drishti Shrestha[1*†], Aliza K C Bhandari[1,2,3†], Kohei Ogawa[4,5], Hisako Tanaka[4], Chiharu Miyayama[6], Reiko Horikawa[7], Kevin Y. Urayama[1,4] and Naho Morisaki[4*]

Abstract

Background Childhood obesity has increased and is considered one of the most serious public health challenges of the 21st century globally, and may be exacerbated by postpartum depression (PPD). The purpose of this study was to examine the association between PPD at 1st and 6th month postpartum, infant feeding practices, and body mass index (BMI) z-score of the child at one and three years of age.

Methods This study used data from an ongoing prospective maternal-child birth cohort performed at the National Center for Child Health and Development (NCCHD) in suburban Tokyo, Japan with the period of recruitment from May 13, 2010 to November 28, 2013. Out of 2,309 total number of mothers, 1,279 mother–child dyads were assessed in the study. We performed multivariable linear regression analysis to examine the association between PPD and child's BMI z-score stratified by the child's age at 1 year and 3 years of age.

Results The prevalence of PPD at 1 month postpartum (17%) was found to be higher than at 6 months (12%). In multivariable linear regression analysis we observed that children at 3 years who had mothers with PPD at 6 months had, on average, a BMI z-score 0.25 higher than children of mothers who did not have PPD at 6 months (ß coefficient 0.25, 95% CI [0.04 to 0.46], p value 0.02), holding all other covariates constant. Also, initiation of weaning food when child is at six months of age was associated with higher BMI z-score of the child at 3 years after adjusting for all covariates (ß coefficient = 0.18, 95% CI [0.03 to 0.34], p-value < 0.05).

Conclusion The significant association between PPD at 6 months and child's BMI z-score at 3 years of age, in conjunction with birth trends and high prevalence of PPD, can add to the body of evidence that there is need for multiple assessment across the first postpartum year to rule out PPD as early screening and early interventions may benefit both maternal health and child development outcomes. These findings can indicate the need for establishing support systems for care-giving activities for mothers with PPD.

Keywords Postpartum, Maternal depression, Infant feeding practices, BMI, Japan

†Drishti Shrestha and Aliza K C Bhandari are first authors and contributed equally to this work.

*Correspondence:
Drishti Shrestha
21MP217@slcn.ac.jp
Naho Morisaki
morisaki-n@ncchd.go.jp
Full list of author information is available at the end of the article

Shrestha *et al. BMC Pregnancy and Childbirth* (2024) 24:336

Page 2 of 13

Background

Obesity is increasing at an alarming rate throughout the world. Childhood obesity is considered one of the most serious public health challenges of the 21st century globally [1], and is associated with more deaths than childhood underweight conditions [2]. Since 1971, increasing trends have been reported in body mass index (BMI) among children in both high-income countries and low-income countries [3]. The global prevalence of overweight in children aged 5 years or under has increased modestly, along with increase in obesity in children aged 5 to 19 years between 1975 and 2016 [4]. According to the World Health Organization (WHO), the prevalence of overweight and obesity among children and adolescents aged 5 to 19 years has risen dramatically from 4% in 1975 to 18% in 2016 [5]. In Japan, the prevalence of overweight in children under 5 years is 1.5% which is less compared to that in the United States (9.4%) [6]. However, high prevalence of low birth weight (LBW) infants (9.5%) and increasing percentages of overweight/obese women aged 20 years or older (19.2%) in recent years [7] may have some lasting effects on the weight status in children of future generations in Japan.

Childhood obesity can lead to a course for an unhealthy adult life as it has been linked with a range of adverse physical and mental health outcomes. Previous studies have reported several factors associated with childhood overweight and/or obesity in children under 5 years of age such as maternal education, age at marriage, marital status, mother's BMI, maternal depression, socio-economic status, child's sex, birth weight, birth order, number of children, media exposure, high dietary diversity, etc. [8–11]. In addition, postpartum depression (PPD) is a common and serious mental health problem that is associated with maternal suffering and numerous negative consequences for the offspring [12, 13]. The prevalence of PPD has been reported to range from 10 to 15% in western countries to about 18% in the lower-middle income countries [14] with a prevalence of 13.7% in Japan [13]. PPD can compromise care-giving activities and performance of parenting roles including feeding practices such as breastfeeding, disruptions in sleep routines, decreases in post-natal health checkups and also decreases in vaccination rates among children [15], which may affect the child's early development [16]. Attachment theory, and its application to parenting behavior, suggests that depression may influence caregiving through (a) reduced understanding of infants' needs, (b) reduced sensitivity in responding to infant cues, and/or (c) reduced ability to comply with infant care guidance [17, 18]. Studies have shown that depressive symptoms are associated with reduced odds of continued breastfeeding, with increased practice of adding cereal to a bottle of formula or breastmilk, and higher bread/cereal and total energy intake at 2 months, but not associated with early introduction of complementary foods [19, 20].

A Brazilian cohort study showed a more rapid weight gain in children of mothers affected by PPD and suggested that disturbances in feeding behavior of depressed mothers could affect both tails of the growth distribution, leading either to stunting or obesity [11]. A study conducted in the United States (US) showed a small but significantly greater average weight gain at six months in infants of mothers with PPD, but PPD was not associated with infant feeding practices especially concerning early introduction of complementary foods [21]. There is a need to further understand the effect of PPD on weight status in early childhood and the role of feeding practices in influencing this relationship. Hence, our study aims to examine the association between maternal PPD at one and six months postpartum and the relative weight of a child measured by BMI z-score at age one and three years. The effect of infant feeding practices in influencing PPD and BMI z-score relationship will also be examined.

Methods

Study design

This study utilized data from an ongoing prospective birth cohort study performed at the National Center for Child Health and Development (NCCHD) in suburban Tokyo, Japan with the period of recruitment from May 13, 2010 to November 28, 2013. The pregnant women were recruited during their first antenatal visits, which usually took place during 6–14 weeks of gestation. During the first year of the postnatal period, follow-up was performed at one month, three months, and at 3-month intervals thereafter. The follow-up was conducted on an annual basis after the first year [22].

Study population

Of 2,309 women who participated in the birth cohort at pregnancy, we included 1,855 participants who re-consented at the postnatal follow-up and 1,395 participants had performed at least one follow-up of their child when they were one or three years of age. Among them, we excluded participants with multiple births ($n=72$), participants whose child did not have BMI measures at both one and three years ($n=22$) and participants who had missing information for Edinburgh Postnatal Depression Scale (EPDS) at both 1 and 6 months postpartum. Hence, the final number of participants included in the analysis was 1,279 mother–child dyads (Fig. 1).

Data collection

Data were collected through self-administered questionnaires at recruitment, including information on basic
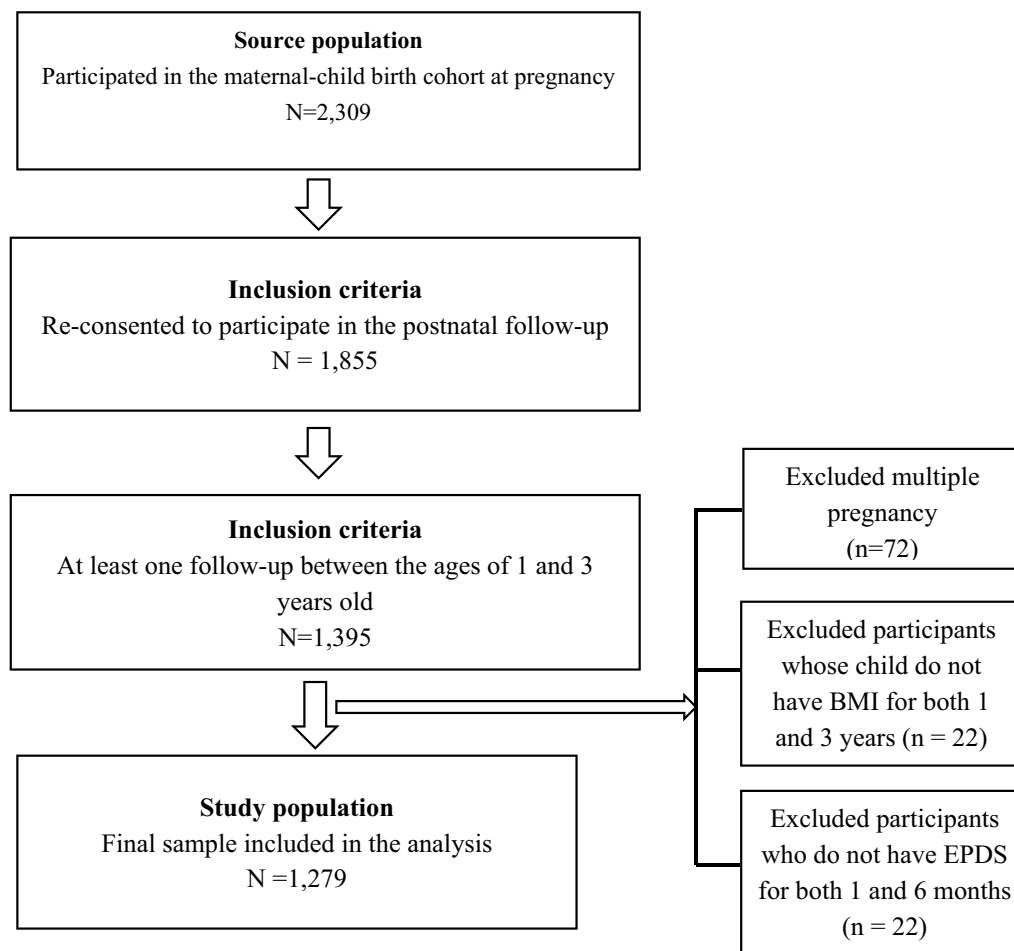
Fig. 1 Flow diagram for study population

sociodemographics, pregnancy characteristics and child characteristics. Information related to the pregnancy, delivery, and birth outcomes was obtained from the electronic medical records. Data collection at follow-up included a combination of self-administered questionnaires and requests for visits to the hospital for in-person anthropometric measurements by medical staff [23].

Dependent variable
We used relative weight of child as the outcome variable, measured using BMI z-scores of children at one and three years of age. BMI z-score is a measure of weight (kg) adjusted for height (cm), age (months) and sex, relative to a smoothed reference distribution and represents the standard deviations from the mean of the population standard [24]. Thus, BMI z-score provides a numeric estimate of how far the measured value is from the average. In this study, the BMI z-score estimates were calculated using the Excel-based Clinical Tools for Growth Evaluation of Children sourced from The Japanese Society for Pediatric Endocrinology (JSPE) [25], which was created based on the "Infant Physical Growth Survey Report" published by the Ministry of Health, Labor and Welfare in 2000 and used as a continuous outcome [26, 27].

Explanatory variables
Postpartum depression (PPD) was the primary exposure for this study, which is a major depressive disorder with a postpartum onset in the early months after childbirth. PPD was assessed using a Japanese version of the Edinburgh Postnatal Depression Scale (EPDS) at 1 month and 6 months postpartum. The EPDS is a 10-item self-report screening tool designed to screen women for symptoms of emotional distress during pregnancy and the postnatal period in which each item is scored on a 4-point scale ranging from 0 to 3 [28]. Total scores can range from 0 to 30, and the cut-off value of ≥ 9 has been shown to indicate good sensitivity and specificity for depression among Japanese women [29]. We derived a binary variable in which an EPDS score of ≥ 9 was defined as having

Shrestha *et al. BMC Pregnancy and Childbirth* (2024) 24:336

Page 4 of 13

symptoms of PPD. Since EPDS was only used to collect information and not as a clinical screening tool for PPD, no intervention was done among mothers who were identified to have PPD in this cohort.

In terms of assessment timing, childbirth is a difficult and exhausting process in which a female goes through a lot of hormonal, physical, emotional, and psychological changes throughout pregnancy and tremendous changes occur in the mother's familial and interpersonal world which can lead to stress in earlier months of postpartum [30]. Two Japanese studies concluded the earlier months postpartum as risk factors for PPD showing the prevalence of PPD to be higher at 1-month postpartum than other times [31, 32]. Hence, we assessed PPD at two different points of time i.e. at 1-month and 6-months. In addition, we also assessed the proportion of mothers with PPD at 1-month only, 6-months only, PPD at both 1 and 6 months, and PPD at either 1 month or 6 months. In addition, we also assessed the information on sociodemographic characteristics of mothers stratified by PD.

Similarly, the information on exclusive breastfeeding (EBF) until 6 months and initiation of weaning food after 6 months was collected by a self-administered questionnaire during the follow-up period. We created a binary yes/no variable for both defined as practiced EBF vs did not practice EBF, and weaning started before or after six months vs at 6 months. We coded additional variables including maternal age (≤ 29, 30–34, 35–39, ≥ 40 years), maternal education (university, community college, training school, high school or less), marital status (single, married), annual household income (> 8 million yen, 4–8 million yen, < 4 million yen), occupation (unemployed, employed), pre-pregnancy BMI (18.5 to 25 kg/ m^2, < 18.5 kg/m^2, ≥ 25 kg/m^2) [27], complications during pregnancy (at least one complications such as gestational diabetes, pregnancy induced hypertension, preeclampsia, placenta accreta, placenta previa coded as yes and no), delivery method (vaginal delivery, cesarean section), primiparity (yes, no), preterm (gestational age at birth < 37 weeks, ≥ 37 weeks), and birth weight (categorization 1: < 2500gm, ≥ 2500gm and categorization 2: < 2500gm as low, 2500–4000 gm as normal and ≥ 4000gm as obese).

Statistical analysis

The frequency and percentage of maternal characteristics, paternal characteristics, child characteristics and infant feeding practices were examined for the overall population. The mean with standard deviation of BMI z-score at 1 year and 3 years were assessed in relation to these characteristics. The student t-test or ANOVA were performed to assess the association between the explanatory variables and outcome.

We performed linear regression analysis to examine the association between PPD at 1 month and 6 months postpartum and BMI z-score of the child at ages 1 and 3 years. Hence, we pursued separate linear regression analyses to address four associations based on the timing of the maternal PPD and follow-up of the child at age 1 year and 3 years for outcome assessment. The model 1 represented a simple linear regression analysis examining the association between PPD at 1 or 6 months with child's BMI z-score at 1 and 3 years of age separately. Model 2 included model 1 adjusted for sociodemographic variables of mother (maternal age, maternal education, marital status, income, occupation) and child characteristics (child gender, gestational age, birth weight) as potential confounders. Model 3 included model 2 adjusted for additional potential confounders (complications during pregnancy, delivery method, pre-pregnancy BMI, primiparity). Model 4 included model 3 adjusted for variables related to infant feeding practices (exclusive breastfeeding until 6 months and initiation of weaning food at 6 months). The prevalence of depression among women with multiple pregnancy has been repeatedly reported to be higher than those with singleton pregnancies hence, we dropped women with multiple pregnancy to avoid high-risk population [33]. Mediation analysis was considered based on the method by Baron and Kenny [34] to assess the hypothesis that PPD at 6 months postpartum would influence child's BMI z-score at 3 years of age mediated by infant feeding practices like EBF and weaning. Infant feeding practices were also assessed for potential interaction with PPD at 6 months postpartum in influencing child's BMI z-score at 3 years of age. For all statistical tests, a two-sided *p*-value of 0.05 was considered statistically significant. Statistical analysis were conducted using Stata BE 17.0.

Ethical approval

Written informed consent was obtained from the participants to enroll into the original cohort study which was approved by the Institutional Review Board of the National Center for Child Health and Development. The data was obtained from the same institution upon the careful evaluation of the current study proposal.

Results

Of the 1,279 eligible participants, 1,198 participants had information on BMI at 1 year of age and 914 at 3 years of age. Majority of the mothers (46.29%) were of age 35–39 years at delivery with mean age of 36.2 ± 4.12 years. Majority of the mothers (59.11%) had educational level up to university, were married (94.45%), and more than half were employed (53.79%) and had an annual household income of less than 4 million yen (53.17%). In

Shrestha *et al. BMC Pregnancy and Childbirth*   (2024) 24:336

Page 5 of 13

addition, only about 5% of the mothers had a pre-pregnancy BMI of over 25 kg/m^2 and 22.6% had complications during pregnancy. About 221 mothers (17%) had PPD at 1 month postpartum, 155 mothers (12%) had PPD at 6 months postpartum, 153 mothers (12.0%) had PPD at 1 months only, 87 mothers had PPD at 6 months only, 68 mothers (5.32%) had PPD at both 1 and 6 months and 186 mothers (14.54%) had PPD at either 1 or 6 months. When we stratified the study population by PPD, there were not much statistical difference in the population with PPD and without PPD except for their annual income and parity (Supplementary Table 1). More than half of mothers (56.92%) breastfed exclusively and started weaning at 6 months (53.24%). Based on crude analyses, the child's BMI z-score was significantly associated with maternal age, pre-pregnancy BMI, birth weight, PPD at 6 months, EBF, and initiation of weaning food at 6 months during our univariable analysis (Table 1).

The results of multivariable linear regression model examining the association between PPD at 1 month and child's BMI z-score at 1 year and 3 years are shown in Table 2. In the unadjusted analysis (Model 1), PPD at 1 month was not significantly associated with child's BMI z-score at the age of 1 year (ß coefficient -0.08, 95% CI [0.21 to 0.05]) and at the age of 3 years (ß coefficient -0.11, 95% CI [-0.06 to 0.27]). However, the adjusted analysis additionally accounting for pregnancy characteristics (Model 3) showed a significant association between PPD at 1 month and BMI z-score at 3 years (ß coefficient 0.20, 95% CI [0.02 to 0.37]). Additionally adjusting for infant feeding practices (Model 4) slightly attenuated the association (ß coefficient 0.16, 95% CI [-0.04 to 0.36]).

The results of multivariable linear regression model examining the association between PPD at 6 months and child's BMI z-score at 1 year and 3 years are shown in Table 3. In the unadjusted analysis (Model 1), PPD at 6 months was not significantly associated with child's BMI z-score at the age of 1 year (ß coefficient 0.05, 95% CI [-0.11 to 0.21]) showing similar results for the adjusted analyses. However, a statistically significant association was observed for child's BMI z-score at the age of 3 years in model 1 (ß coefficient 0.20, 95% CI [0.01 to 0.39]), and adjusted analysis did not considerably alter the results for BMI z-score at both 1 year and 3 years. Including infant feeding practices into the model showed a statistically significant independent effect of PPD at 6 months on child's BMI z-score at the age of 3 years (ß coefficient 0.25, 95% CI [(0.04 to 0.46)]. Several covariates also appeared to be independently associated with BMI z-score at 3 years independent of the association for PPD at 6 months, including gestational age, birth weight, pre-pregnancy BMI, exclusive breastfeeding until 6 months and initiation of weaning food at 6 months.

We also considered the infant feeding practices as a potential mediator of the association between PPD at 6 months and child's BMI z-score at 3 years. Based on the results of the primary associations observed in the multivariable analysis applied to the criteria described by Baron and Kenny, evidence of mediation was not observed in our study. However, PPD and infant feeding practices were independently associated with child's BMI z-score at 3 years. Regarding potential effect modification, the statistical interaction between PPD at 6 months and exclusive breastfeeding until 6 months were tested and was not found to be statistically significant (*p* value 0.09).

Furthermore, we also performed sensitivity analysis by including overall population (not excluding multiple births) however, the results remain unchanged (Supplementary Table 2).

Discussion

The current study examined the association between PPD and BMI z-score of the child at 1 and 3 years of age and assessed the role of infant feeding practices in influencing this association. We found that PPD at 6 months postpartum was positively associated with child's BMI z-score at 3 years of age. Examination of infant feeding practices did not appear to mediate or modify the effect of PPD on child's BMI z-score at 3 years. Characteristics such as maternal age, maternal education, pre-pregnancy BMI, birth weight of the child and infant feeding practices appeared to be independently associated with child's BMI z-score.

In the context of the assessment for the timing of PPD, Suzumiya et al. (2004) in their Japanese study showed the prevalence of PPD at one month postpartum to be 1 to 2 times higher compared to other postpartum periods [32] which was consistent with our study with the prevalence of PPD at 1 month being higher than that of PPD at 6 months postpartum. In a U.S. study conducted among 1,359 women, the prevalence of PPD was about 34% in the first 6 months postpartum which is comparable to the results of studies conducted outside Japan [35]. In this study, we found an association between PPD at 6 months and child's BMI z-score at 3 years of age. However, we did not find any association between PPD at 1 month and child's BMI z-score at 1 and 3 years. The reasons behind this result might be the high rate of infant and mother health checkups 1 month after childbirth (83.6%) [36] and father's child care leave up to 8 weeks postpartum in Japan [37] which may have helped mothers to receive care and support. As a result, the effect of PPD at 1 month may not be distinct within this period. However, with the increase in the employment rate of women in Japan, the burden might have increased for

Table 1 Characteristics of the study population and relationship with child's BMI z-score at 1 and 3 years of age

Variables	Overall population (*N* = 1279)	Population with BMI z-score at 1 year (*N* = 1198)			Population with BMI z-score at 3 years (*N* = 914)		
	Frequency (%)	Frequency	Mean (sd)	*P* value	Frequency	Mean (sd)	*P* value
Maternal age (in years)							
Mean (sd)	36.2 (4.12)						
≤ 29	88 (6.88)	83	-0.002 (0.88)	0.66	56	-0.16 (1.00)	0.001**
30–34	320 (25.02)	300	0.12 (0.82)		215	0.04 (0.92)	
35–39	592 (46.29)	553	0.13 (0.94)		423	0.26 (0.95)	
≥ 40	279 (21.81)	262	0.10 (0.92)		220	0.22 (0.93)	
Maternal education							
High school or less	75 (5.86)	73	-0.14 (0.90)	0.06	48	0.003 (1.08)	0.17
CT or VS or JC	387 (30.26)	366	0.12 (0.90)		281	0.12 (0.95)	
University	756 (59.11)	705	0.13 (0.90)		544	0.22 (0.93)	
Missing	61 (4.77)	54	0.19 (0.85)		41	0.17 (1.10)	
Marital status							
Single	11 (0.86)	11	0.01 (0.76)	0.72	7	-0.07 (0.63)	0.49
Married	1208 (94.45)	1133	0.11 (0.91)		867	0.17 (0.94)	
Missing	60 (4.69)	54	0.20(0.85)		40	0.19 (1.11)	
Household annual income (in Japanese yen)							
< 4 million	680 (53.17)	635	0.12 (0.88)	0.41	57	-0.02 (1.11)	0.10
4–8 million	400 (31.27)	382	0.14 (0.92)		290	0.14 (1.01)	
> 8 million	90 (7.04)	82	-0.001 (0.9)		490	0.23 (0.89)	
Missing	109 (8.52)	99	0.04 (0.96)		77	0.06 (0.93)	
Occupation							
Unemployed	527 (41.20)	495	0.12 (0.91)	0.65	367	0.10 (0.97)	0.04*
Employed	688 (53.79)	646	0.10 (0.90)		503	0.23 (0.92)	
Missing	64 (5.00)	57	0.20 (0.84)		44	0.17 (1.06)	
Pre-pregnancy BMI (in kg/m^2)							
18.5–25	948 (74.12)	889	0.15 (0.87)	< 0.001***	676	0.21 (0.91)	< 0.001***
< 18.5	249 (19.47)	230	-0.14 (0.93)		179	-0.05 (0.98)	
≥ 25	68 (5.32)	66	0.47 (1.00)		50	0.50 (1.19)	
Missing	14 (1.09)	13	0.02 (1.10)		9	0.15 (0.66)	
Complications during pregnancy [a] (at least one complications)							
No	990 (77.4)	929	0.10 (0.90)	0.47	693	0.16 (0.93)	0.35
Yes	289 (22.6)	269	0.15 (0.93)		221	0.23 (1.02)	
Delivery method							
Vaginal delivery	878 (68.65)	827	0.10 (0.92)	0.56	616	0.18 (0.93)	0.97
CS section	364 (28.46)	338	0.14 (0.87)		276	0.18 (0.97)	
Missing	37 (2.89)	33	0.06 (0.86)		22	0.02 (1.17)	
Primiparity							
Yes	815 (63.72)	773	0.11 (0.87)	0.90	570	0.18 (0.95)	0.69
No	464 (36.28)	425	0.12 (0.96)		344	0.16 (0.94)	
Paternal education							
University	981 (76.70)	917	0.10 (0.91)	0.95	696	0.16 (0.94)	0.84
CT or VS Or JC	6 (0.47)	6	0.13 (0.81)		4	0.33 (0.44)	
High school or less	225 (17.59)	215	0.14 (0.90)		171	0.20 (0.96)	
Missing	67 (5.24)	60	0.20 (0.83)		43	0.19 (1.07)	
Child's sex							
Female	630 (49.26)	588	0.14 (0.91)	0.21	441	0.13 (0.90)	0.20
Male	649 (50.74)	610	0.08 (0.89)		473	0.21 (0.99)	

Table 1 (continued)

Variables	Overall population (N = 1279)	Population with BMI z-score at 1 year (N = 1198)			Population with BMI z-score at 3 years (N = 914)		
	Frequency (%)	Frequency	Mean (sd)	P value	Frequency	Mean (sd)	P value
Gestational age (in weeks)							
Preterm < 37 weeks	68 (5.32)	61	0.07 (0.90)	0.71	47	0.29 (1.19)	0.37
Fullterm ≥ 37 weeks	1210 (94.61)	1137	0.11 (0.90)		866	0.17 (0.94)	
Missing	1 (0.08)	0	0.00		1	-1.15	
Birth weight (in grams)							
Mean	2982.79						
Categorization 1 (< 2500, ≥ 2500)							
< 2500	131 (10.24)	122	-0.08 (0.83)	0.01*	90	-0.18 (1.06)	< 0.001***
≥ 2500	1148 (89.76)	1076	0.13 (0.91)		824	0.21 (0.93)	
Categorization 2 (< 2500, 2500—4000, ≥ 4000)							
< 2500 (Low)	131 (10.24)	122	-0.08 (0.83)	0.02*	90	-0.18 (1.06)	< 0.001***
2500–4000 (Normal)	1137 (88.90)	1065	0.13 (0.91)		817	0.21(0.93)	
≥ 4000 (Obese)	11 (0.86)	11	0.46 (0.73)		7	0.63 (0.63)	
PPD at 1 month							
No	942 (73.65)	877	0.12 (0.87)	0.24	668	0.15 (0.94)	0.19
Yes	221 (17.28)	208	0.05 (0.94)		157	0.25 (0.98)	
Missing	116 (9.07)	113	0.13 (1.04)		89	0.24 (0.997)	
PPD at 6 months							
No	945 (73.89)	901	0.10 (0.89)	0.54	672	0.14 (0.93)	0.04*
Yes	155 (12.12)	148	0.15 (0.96)		115	0.34 (1.04)	
Missing	179 (14)	149	0.14 (0.93)		127	0.20 (0.94)	
PPD							
PPD at 1 month only	153 (12.0)	144	0.04 (0.90)	0.30	102	0.20 (0.94)	0.50
PPD at 6 months only	87 (6.8)	84	0.22 (0.91)	0.33	60	0.32 (1.03)	0.16
PPD both at 1 and 6 months	68 (5.32)	64	0.07 (1.03)	0.66	55	0.36 (1.05)	0.18
PPD either at 1 month and 6 months	186 (14.54)	180	0.06 (0.90)		128	0.21 (0.98)	
No	730 (57.08)	692	0.12 (0.86)		515	0.13 (0.92)	
Exclusive breastfeeding until 6 months							
No	335 (26.19)	315	0.19 (0.87)	0.02*	246	0.30 (0.96)	0.001**
Yes	728 (56.92)	695	0.06 (0.90)		513	0.07 (0.91)	
Missing	216 (16.89)	188	0.19 (0.96)		155	0.32 (1.0)	
Initiation of weaning food at 6 months							
No	393 (30.73)	371	0.02 (0.92)	0.08	278	0.01 (0.93)	0.02*
Yes	681 (53.24)	651	0.13 (0.90)		487	0.22 (0.92)	
Missing	205 (16.03)	176	0.23 (0.85)		149	0.31 (1.03)	

sd Standard deviation, *PPD* Postpartum depression, *CT or VS or JC* College of technology or vocational school or junior college

* *P*-value < 0.05, ** *p*-value < 0.01, *** *p* value < 0.001

[a] Presence of at least one of the following complications: gestational diabetes mellitus, pregnancy induced hypertension, pre-eclampsia, placenta accreta and placenta previa

the PPD mothers which may compromise care-giving activities and performance of parenting roles affecting child's growth and development [15, 16]. The association between PPD at 6 months and child's BMI z-score at 3 years of age found is consistent with the result of a Brazilian cohort study showing an increased risk of overweight in infants aged 6-months to two years by 1.7 times among mothers with depressive symptoms compared to those without depressive symptoms [11]. In contrast, some studies performed in the USA and UK have shown PPD to be associated with slower growth of the infants [38, 39].

In this study, we also found that children who were exclusively breastfed had lower BMI z-score at 3 years

Shrestha *et al. BMC Pregnancy and Childbirth*   (2024) 24:336

Page 8 of 13

Table 2 Multivariable linear regression model examining the association between PPD at 1 month and child's BMI z-score at the age of 1 year and 3 years

Variables	Model 1		Model 2		Model 3		Model 4	
	ß coefficient (95% CI)							
	1 year (*N* = 1198)	3 years (*N* = 914)	1 year (*N* = 999)	3 years (*N* = 754)	1 year (*N* = 960)	3 years (*N* = 728)	1 year (*N* = 807)	3 years (*N* = 601)
PPD at 1 month (ref. No)								
Yes	-0.08 (-0.21 to 0.05)	0.11 (-0.06 to 0.27)	-0.06 (-0.21 to 0.08)	0.14 (-0.03 to 0.32)	-0.02 (-0.17 to 0.13)	0.20* (0.02 to 0.37)	-0.05 (-0.22 to 0.12)	0.16 (-0.04 to 0.36)
Maternal age (in years) (ref. ≤ 29)								
30–34			0.07 (-0.16 to 0.33)	0.27 (-0.05 to 0.58)	0.003 (-0.25 to 0.25)	0.26 (-0.06 to 0.57)	-0.02 (-0.30 to 0.26)	0.16 (-0.19 to 0.53)
35–39			0.10 (-0.14 to 0.33)	0.50*** (0.20 to 0.80)	0.003 (-0.24 to 0.24)	0.45** (0.14 to 0.75)	(-0.03) (-0.30 to 0.24)	0.31 (-0.05 to 0.66)
≥ 40			0.07 (-0.18 to 0.32)	0.43* (0.12 to 0.74)	-0.03 (-0.28 to 0.23)	0.41* (0.09 to 0.73)	-0.10 (-0.39 to 0.19)	0.25 (-0.11 to 0.62)
Maternal education (ref. high school or less)								
CT or VS or JC			0.28* (0.03 to 0.53)	0.07 (-0.24 to 0.39)	0.33** (0.08 to 0.58)	0.10 (-0.22 to 0.42)	0.30* (0.02 to 0.58)	0.13 (-0.23 to 0.49)
University			0.29* (0.04 to 0.53)	0.20 (-0.11 to 0.51)	0.36** (0.11 to 0.60)	0.24 (-0.08 to 0.55)	0.31* (0.03 to 0.58)	0.22 (-0.13 to 0.58)
Marital status (ref. single)								
Married			0.04 (-0.53 to 0.60)	0.48 (-0.28 to 1.23)	0.01 (-0.58 to 0.60)	0.49 (-0.26 to 1.24)	-0.01 (-0.61 to 0.59)	0.36 (-0.39 to 1.11)
Occupation (ref. unemployed)								
Employed			0.01 (-0.11 to 0.12)	0.12 (-0.03 to 0.26)	0.01 (-0.11 to 0.13)	0.12 (-0.03 to 0.27)	0.03 (-0.10 to 0.17)	0.08 (-0.08 to 0.24)
Income (ref. < 4 million yen)								
4–8 million			0.06 (-0.17 to 0.29)	0.04 (-0.24 to 0.32)	0.09 (-0.14 to 0.32)	0.03 (-0.26 to 0.31)	0.05 (-0.21 to 0.31)	-0.02 (-0.33 to 0.29)
> 8 million			0.03 (-0.19 to 0.26)	0.05 (-0.23 to 0.33)	0.07 (-0.16 to 0.30)	0.04 (-0.25 to 0.33)	0.02 (-0.24 to 0.27)	0.05 (-0.26 to 0.36)
Child's sex (ref. female)								
Male			0.11 (-0.004 to 0.22)	0.004 (-0.13 to 0.14)	0.11 (-0.01 to 0.22)	0.01 (-0.13 to 0.14)	0.10 (-0.03 to 0.22)	0.02 (-0.13 to 0.17)
Gestational week (ref. Preterm < 37 weeks)								
Full term ≥ 37 weeks			-0.21 (-0.50 to 0.08)	-0.39 * (-0.73 to -0.04)	- 0.07 (-0.37 to 0.24)	-0.28 (-0.36 to 0.08)	-0.11 (-0.14 to 0.18)	-0.35 (-0.73 to 0.03)
Birth weight (in grams) (ref. < 2500)								
≥ 2500			0.30** (0.10 to 0.52)	0.50*** (0.25 to 0.75)	0.27* (0.05 to 0.48)	0.48*** (0.22 to 0.74)	0.26* (0.03 to 0.49)	0.39** (0.12 to 0.67)
Complications (ref. No)								
Yes					-0.01 (-0.15 to 0.15)	0.05 (-0.11 to 0.23)	0.02 (-0.14 to 0.18)	0.03 (-0.16 to 0.22)
Delivery method (ref. Vaginal Delivery)								
CS section					0.03 (-0.10 to 0.16)	-0.06 (-0.22 to 0.09)	0.0002 (-0.15 to 0.15)	-0.10 (-0.26 to 0.07)
Pre pregnancy BMI (in kg/m²) (ref. 18.5 to 25)								
< 18.5					-0.28*** (0.43 to -0.13)	-0.22* (-0.40 to -0.04)	-0.33*** (-0.50 to -0.17)	-0.30** (-0.50 to -0.11)
≥ 25					0.27* (0.20 to 0.52)	0.17 (-0.13 to 0.47)	0.23 (-0.04 to 0.49)	0.04 (-0.27 to 0.36)
Primiparity (ref. Yes)								
No					0.03 (-0.10 to 0.15)	0.05 (-0.09 to 0.20)	0.06 (-0.08 to 0.19)	0.01 (-0.15 to 0.18)

Table 2 (continued)

Variables	Model 1		Model 2		Model 3		Model 4	
	ß coefficient (95% CI)							
	1 year (N = 1198)	3 years (N = 914)	1 year (N = 999)	3 years (N = 754)	1 year (N = 960)	3 years (N = 728)	1 year (N = 807)	3 years (N = 601)
Exclusive breastfeeding until 6 months (ref. No)								
Yes							-0.16* (-0.30 to -0.02)	-0.19* (-0.36 to -0.03)
Initiation of Weaning Food at 6 months (ref. No)								
Yes							0.04 (-0.10 to 0.17)	0.15 (-0.01 to 0.31)

CI Confidence Interval, *BMI* Body Mass Index, *PPD* Postpartum depression, *CT or VS or JC* College of technology or vocational school or junior college

* P-value < 0.05, ** p-value < 0.01, *** p value < 0.001

of age, independent of the effect of PPD at 6 months. George et al. concluded that mothers with depressive symptoms were prone to have a less healthy lifestyle, and different feeding practices were provided to their infants [40]. Mothers with depressive symptoms were more likely to stop breastfeeding earlier than mothers who were non-depressed [41] which can be explained by the evidence from previous studies that the decrease in breastfeeding rates among depressed mothers may affect the child's weight status [42–44]. The role of breastfeeding has been positively associated with child's adequate growth and development, but studies have not consistently shown a relationship between exclusive breastfeeding and weight of child [45]. Thus, mother's postpartum depression was speculated to affect negatively children feeding practices, especially for children less than 2 years of age. In a cross-sectional study conducted in nine Greek rural and urban regions, children who were exclusively breastfed showed a significantly lower prevalence of overweight and obesity at the age of 2–5 years [43]. This might suggest that exclusively breastfeeding an infant will help to maintain a healthy body weight as they grow.

Additionally, children who are not exclusively breastfed were reported to be at higher risk of being introduced to complementary feeding before the age of six months [46]. The findings of the Infant Feeding Practices Study II found an association of PPD with the early introduction to solid foods which had negative effect on child's developmental outcomes [45]. Also, a study done examining the role of complementary foods on childhood obesity revealed that children who initiated weaning food before the age of four months and after six months of age were more likely to be overweight and obese in their later childhood [47]. This was also consistent with the current study as child's BMI z-score was higher if their weaning was started before and after six months of their life.

In addition to PPD at 6 months and infant feeding practices, we were able to confirm the independent effect of other factors that influence higher BMI trajectories such younger gestational age, higher birthweight, and higher pre-pregnancy BMI. A study conducted in Poland reported a relationship between higher birth weight and higher BMI percentile of children aged 4–15 years [48]. A Chinese study showed the odds of childhood overweight to be significantly higher in children born to mothers who were overweight/obesity during the pre-pregnancy period than in those born to mothers with normal weight [49]. Similarly, findings from a longitudinal study showed an association between pre-pregnancy BMI and the obesity in children aged 2 years [50]. The findings from these studies were consistent with the results of our study suggesting that mothers should take good care of their diet and nutrition even before pregnancy. Taken together, the results of our multivariable analyses confirm the multi-factorial nature of early life factors in contributing to the weight status of children, of which our study has confirmed the role of PPD at 6 months, infant feeding practices, and several characteristics of the mother and child.

The availability of pregnancy-related factors, birth characteristics, psychosocial status, and longitudinal follow-up data in this cohort study provided the unique opportunity to perform one of the first studies of its kind in a Japanese population. The prospective design allowed us to minimize potential recall bias issues, such as those related to feeding practices. However, despite these strengths, there are important limitations to acknowledge. As with most longitudinal studies, there was loss to follow-up of the children over the 3 years leading to a reduced sample size which may have weakened our ability to examine potential interaction effects. Loss to follow-up was balanced between the PPD categories and characteristics of these participants were not markedly different from those who remained in the study.

Shrestha *et al. BMC Pregnancy and Childbirth* (2024) 24:336

Page 10 of 13

Table 3 Multivariable linear regression model examining the association between PPD at 6 months and child's BMI z-score at the age of 1 year and 3 years

	Model 1		Model 2		Model 3		Model 4	
	ß coefficient (95% CI)							
	1 year (N = 1198)	**3 years (N = 914)**	**1 year (N = 956)**	**3 years (N = 713)**	**1 year (N = 918)**	**3 years (N = 689)**	**1 year (N = 800)**	**3 years (N = 600)**
PPD at 6 months (ref. No)								
Yes	0.05 (-0.11 to 0.21)	0.20* (0.01 to 0.39)	0.06 (-0.10 to 0.23)	0.23* (0.03 to 0.42)	0.09 (-0.07 to 0.26)	0.24* (0.04 to 0.44	0.07 (-0.11 to 0.25)	0.25* (0.04 to 0.46)
Maternal age (in years) (ref. ≤ 29)								
30–34			0.05 (-0.20 to 0.30)	0.11 (-0.23 to 0.45)	-0.02 (-0.27 to 0.24)	0.10 (-0.25 to 0.44)	-0.03 (-0.31 to 0.25)	0.13 (-0.24 to 0.50)
35–39			0.10 (-0.14 to 0.34)	0.36* (0.03 to 0.68)	0.002 (-0.25 to 0.25)	0.30 (-0.04 to 0.64)	-0.06 (-0.33 to 0.21)	0.27 (-0.10 to 0.63)
≥ 40			0.01 (-0.24 to 0.26)	0.21 (-0.11 to 0.57)	-0.07 (-0.33 to 0.19)	0.17 (-0.16 to 0.55)	-0.16 (-0.45 to 0.12)	0.20 (-0.18 to 0.58)
Maternal education (ref. high school or less)								
CT/ VS or JC			0.23 (-0.20 to 0.48)	0.06 (-0.27 to 0.39)	0.30* (0.05 to 0.55)	0.09 (-0.25 to 0.42)	0.31* (0.03 to 0.58)	0.08 (-0.28 to 0.44)
University			0.27* (0.03 to 0.52)	0.16 (-0.17 to 0.49)	0.36** (0.12 to 0.61)	0.19 (-0.14 to 0.52)	0.37* (0.10 to 0.64)	0.19 (-0.16 to 0.55)
Marital status (ref. single)								
Married			0.08 (-0.45 to 0.62)	0.26 (-0.45 to 0.97)	0.06 (-0.49 to 0.62)	0.26 (-0.44 to 0.97)	0.02 (-0.54 to 0.58)	0.14 (-0.56 to 0.83)
Occupation (ref. unemployed)								
Employed			-0.01 (-0.13 to 0.11)	0.10 (-0.04 to 0.24)	-0.003 (-0.13 to 0.12)	0.10 (-0.05 to 0.25)	0.02 (-0.11 to 0.15)	0.09 (-0.06 to 0.25)
Income (ref. < 4 million yen)								
4–8 million			0.08 (-0.15 to 0.32)	0.08 (-0.22 to 0.38)	0.10 (-0.14 to 0.33)	0.07 (-0.23 to 0.38)	0.07 (-0.18 to 0.32)	-0.02 (-0.33 to 0.29)
> 8 million			0.03 (-0.13 to 0.11)	0.10 (-0.20 to 0.40)	0.05 (-0.18 to 0.29)	0.10 (-0.21 to 0.40)	0.05 (-0.20 to 0.30)	0.05 (-0.26 to 0.36)
Child's sex (ref. female)								
Male			0.10 (-0.01 to 0.22)	-0.02 (-0.16 to 0.12)	0.10 (-0.02 to 0.21)	-0.03 (-0.17 to 0.12)	0.09 (-0.03 to 0.22)	-0.03 (-0.18 to 0.12)
Gestational week (ref. Preterm < 37 weeks)								
Full term ≥ 37 weeks			-0.22 (-0.51 to 0.07)	-0.48** (-0.82 to -0.13)	-0.07 (-0.37 to 0.22)	-0.40* (-0.75 to -0.04)	-0.09 (-0.40 to 0.23)	-0.22 (-0.51 to 0.07)
Birth weight (in grams) (ref. < 2500)								
≥ 2500			0.31** (0.11 to 0.52)	0.46*** (0.20 to 0.72)	0.27* (0.06 to 0.48)	0.43*** (0.17 to 0.69)	0.22 (0.01 to 0.44)	0.31* (0.04 to 0.58)
Complications (ref. No)								
Yes					-0.01 (-0.15 to 0.14)	-0.02 (-0.20 to 0.16)	0.004 (-0.15 to 0.16)	0.02 (-0.17 to 0.20)
Delivery method (ref. Vaginal Delivery)								
CS section					0.04 (-0.10 to 0.17)	-0.03 (-0.19 to 0.13)	-0.002 (-0.15 to 0.14)	-0.08 (-0.25 to 0.09)
Pre pregnancy BMI (in kg/m^2) (ref. 18.5 to 25)								
< 18.5					0.28*** (-0.43 to -0.13)	-0.21* (-0.39 to -0.02)	-0.28** (-0.45 to -0.12)	-0.25 * (-0.44 to -0.05)
≥ 25					0.27* (0.20 to 0.52)	0.17 (-0.13 to 0.47)	0.23 (-0.04 to 0.49)	0.04 (-0.27 to 0.36)
Primiparity (ref. Yes)								
No					0.01 (-0.12 to 0.13)	0.01 (-0.14 to 0.16)	0.04 (-0.09 to 0.18)	0.01 (-0.15 to 0.17)

Table 3 (continued)

	Model 1		Model 2		Model 3		Model 4	
	ß coefficient (95% CI)							
	1 year (*N*=1198)	3 years (*N*=914)	1 year (*N*=956)	3 years (*N*=713)	1 year (*N*=918)	3 years (*N*=689)	1 year (*N*=800)	3 years (*N*=600)
Exclusive breastfeeding until 6 months (ref. No)								
Yes							-0.18* (-0.32 to -0.05)	-0.22* (-0.38 to -0.06)
Initiation of Weaning Food at 6 months (ref. No)								
Yes							0.07 (-0.06 to 0.20)	0.18* (0.03 to 0.34)

CI Confidence Interval, *BMI* Body Mass Index, *PPD* Postpartum depression, *CT or VS or JC* College of technology or vocational school or junior college

* *P*-value < 0.05, ***p*-value < 0.01, ****p* value < 0.001

Self-reported data from mothers may have weaken the accuracy due to general reporting bias, we would expect this bias to be non-differential in nature and effect results towards the null. Finally, despite the high-quality data from this cohort study, this was a single center study with study subjects primarily residing in the same region of Tokyo. Thus, generalizability of the study findings may not be extendable into other sub-populations with vastly different characteristics. Additional studies are necessary to confirm these study findings in a wider range of populations. Nevertheless, results of our study highlight the importance of considering PPD as factor which should be considered in future preventative efforts.

Conclusions

The study examined the association of PPD and infant feeding practices on relative weight of child at 1 year and 3 years of age. We found a significant association between PPD at 6 months postpartum and child's BMI z-score at 3 years of age with infant feeding practices, maternal age, maternal education, pre-pregnancy BMI, birth weight of the child as likely confounders. Infant feeding practices did not appear to mediate or modify the association, but was found to be independently associated with child's BMI z-score at 3 years. The significant relation of PPD at 6 months to child's BMI z-score at 3 years, in conjunction with birth trends and high prevalence of PPD, can add to the body of evidence that there is need for multiple assessment across the first postpartum year to rule out PPD since early screening and early interventions may benefit both maternal health and child development outcomes. These findings can indicate the need for establishing support systems for appropriate mental health services, and also suggestive of health promotion initiatives providing support to continue breastfeeding practices for recommended duration and in care-giving activities for PPD mothers.

Abbreviations

US	United States
IRB	International Review Board
UK	United Kingdom
CI	Confidence Interval
SE	Standard Error

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12884-024-06483-2.

> **Supplementary Material 1.**
>
> **Supplementary Material 2.**

Authors' contributions

Conceptualization DS, AKCB, KU; Methodology DS, AKCB, KU; Validation DS, AKCB; Formal analysis DS, AKCB; Investigation DS, AKCB; Resources DS, AKCB, KU; Data curation DS, AKCB, HT, NM; Writing - original draft preparation DS, AKCB; Writing – review DS, AKCB, KU, KO, HT, CM, RH, NM and Writing - editing DS, AKCB, KU; Visualization DS, AKCB; Supervision AKCB, KU; Project administration DS, AKCB, KU, KO, HT, CM, RH, NM. All authors have read and approved the final manuscript.

Availability of data and materials

The datasets generated during and analyzed during the current study are not publicly available as it is a cohort data maintained by the National Center for Child Health and Development, Japan but are available from the institute itself on reasonable request. Authors Naho Morisaki and Hisako Tanaka could be contacted regarding any information on data sharing and availability.

Shrestha *et al. BMC Pregnancy and Childbirth*   (2024) 24:336

Page 12 of 13

Declarations

Ethics approval and consent to participate
This is a secondary analysis based on a cohort study which got the ethical approval from the Ethical Review Board of National Center for Child Health and Development, Japan. Written informed consent was obtained from the participants. We obtained consent on data curation, validation and analysis from the same institution to conduct this study. The participants from the cohort were not involved in the design or conduct or reporting or dissemination plans of this research. The intervention and all methods were performed in accordance with relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Graduate School of Public Health, St. Luke's International University, Tokyo, Japan. [2]Department of Health Policy, National Center for Child Health and Development, Tokyo, Japan. [3]Division of Prevention, National Cancer Center Institute for Cancer Control, Tokyo, Japan. [4]Department of Social Medicine, National Center for Child Health and Development, Tokyo, Japan. [5]Center for Maternal-Fetal, Neonatal and Reproductive Medicine, National Center for Child Health and Development, Tokyo, Japan. [6]Department of Pediatrics, Juntendo University Faculty of Medicine, Tokyo, Japan. [7]Division of Endocrinology and Metabolism, National Center for Child Health and Development, Tokyo, Japan.

References
1. Sahoo K, Sahoo B, Choudhury AK, Sofi NY, Kumar R, Bhadoria AS. J Family Med Prim Care. 2015;4(2):187–92. https://doi.org/10.4103/2249-4863.154628.
2. GBD Obesity Collaborators. Health effects of overweight and obesity in 195 countries over 25 years. N Engl J Med. 2017;377:13–27.
3. Abarca-Gómez L, Abdeen ZA, Hamid ZA, et al. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. Lancet. 2017;390(10113):2627–42. https://doi.org/10.1016/S0140-6736(17)32129-3.
4. Di Cesare M, Sorić M, Bovet P, et al. The epidemiological burden of obesity in childhood: a worldwide epidemic requiring urgent action. BMC Med. 2019;17:212. https://doi.org/10.1186/s12916-019-1449-8.
5. Balasundaram P, Krishna S. Obesity effects on child health. [Updated 2022 Sep 3]. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2022. Accessed from: https://www.ncbi.nlm.nih.gov/books/NBK570613/#_NBK570613_pubdet_.
6. Global nutrition report by NCD Risk Factor Collaboration. NCD Risk Factor Collaboration. Available online: http://ncdrisc.org/data-downloads.html. Accessed 30 Dec 2022.
7. Shinsugi C, Kurotani K, Miyoshi M, Takimoto H. Trends in maternal and child malnutrition indicators in Japan. Jpn J Nutr Diet. 2020;78(Supplement):S39–49. https://doi.org/10.5264/eiyogakuzashi.78.S39.
8. Saha J, Chouhan P, Ahmed F, Ghosh T, Mondal S, Shahid M, Fatima S, Tang K. Overweight/obesity prevalence among under-five children and risk factors in India: a cross-sectional study using the national family health survey (2015–2016). Nutrients. 2022;14:3621. https://doi.org/10.3390/nu14173621.
9. Sorrie MB, Yesuf ME, GebreMicha TG. Overweight/obesity and associated factors among preschool children in Gondar City, Northwest Ethiopia: a cross-sectional study. 2017;12:e0182511. https://doi.org/10.1371/journal.pone.0182511.
10. Gebrie A, Alebel A, Zegeye A, Tesfaye B, Ferede A. Prevalence and associated factors of overweight/obesity among children and adolescents in Ethiopia: a systematic review and meta-analysis. BMC obesity. 2018;5:1–12. https://doi.org/10.1186/s40608-018-0198-0.
11. Surkan PJ, Kawachi I, Peterson KE. Childhood overweight and maternal depressive symptoms. J Epidemiol Community Health. 2008;62:e11. https://doi.org/10.1136/jech.2007.065664.
12. O'Hara MW, McCabe JE. Postpartum depression: current status and future directions. Ann Rev Clin Psychol. 2013;9:379–407. https://doi.org/10.1146/annurev-clinpsy-050212-185612.
13. Muchanga SMJ, Yasumitsu-Lovell K, Eitoku M, Mbelambela EP, Ninomiya H, Komori K, Tozin R, Maeda N, Fujieda M, Suganuma N. Preconception gynecological risk factors of postpartum depression among Japanese women: the Japan Environment and Children's Study (JECS). J Affect Disord. 2017;217:34–41. https://doi.org/10.1016/j.jad.2017.03.049.
14. Wang Z, Liu J, Shuai H, et al. Mapping global prevalence of depression among postpartum women. Transl Psychiatry. 2021;11:543. https://doi.org/10.1038/s41398-021-01663-6.
15. Field T. Postpartum depression effects on early interactions, parenting, and safety practices: a review. Infant Behav Dev. 2010;33(1):1–6. https://doi.org/10.1016/j.infbeh.2009.10.005.
16. Herba CM, Glover V, Ramchandani PG, Rondon MB. Maternal depression and mental health in early childhood: an examination of underlying mechanisms in low-income and middle-income countries. Lancet Psychiatry. 2016;3(10):983–92. https://doi.org/10.1016/S2215-0366(16)30148-1.
17. Postpartum depression effects on early interactions, parenting, and safety practices: a review. Infant Behav Dev. 2010;33:1-6.https://doi.org/10.1016/j.infbeh.2009.10.005.
18. Coyne LW, Low CM, Miller AL, et al. Mothers' empathic understanding of their toddlers: associations with maternal depression and sensitivity. J Child Fam Stud. 2007;16:483–97. https://doi.org/10.1007/s10826-006-9099-9.
19. McLearn KT, Minkovitz CS, Strobino DM, Marks E, Hou W. Maternal depressive symptoms at 2 to 4 months post partum and early parenting practices. Arch Pediatr Adolesc Med. 2006;160:279–84. https://doi.org/10.1001/archpedi.160.3.279.
20. Savage JS, Birch LL. WIC mothers' depressive symptoms are associated with greater use of feeding to soothe, regardless of perceived child negativity. Pediatr Obes. 2017;12(2):155–62. https://doi.org/10.1111/ijpo.12122. Epub 2016 Feb 29 PMID: 26923811.
21. Gaffney KF, Kitsantas P, Brito A, Swamidoss CSS. Postpartum depression, infant feeding practices, and infant weight gain at six months of age. J Pediatr Health Care. 2014;28(1):43–50. https://doi.org/10.1016/j.pedhc.2012.10.005.
22. Ogawa K, Morisaki N, Sago H, et al. Association between women's perceived ideal gestational weight gain during pregnancy and pregnancy outcomes. Sci Rep. 2018;8:11574. https://doi.org/10.1038/s41598-018-29936-z.
23. Miyayama C, Morisaki N, Ogawa K, et al. Evaluating the association between caesarean delivery and weight status in early childhood in a Japanese birth cohort study. Sci Rep. 2023;13:19612. https://doi.org/10.1038/s41598-023-45316-8.
24. Flegal KM, Ogden CL. Childhood obesity: are we all speaking the same language? Adv Nutr. 2011;2(2):159S–166S. https://doi.org/10.3945/an.111.000307.
25. Endocrinology, T. J. S. f. P. Anthropometric index calculation file. 2011. Retrieved Nov 8 from: http://jspe.umin.jp/medical/chart_dl.html.
26. Ministry of Health, L. a. W., Child and Family Policy Bureau. National growth survey report on preschool children in 2000. 2002. https://www.mhlw.go.jp/houdou/0110/h1024-4.html.
27. Committee, J. S. f. P. E. J. G. S. A. J. S. Basic concept regarding the evaluation of the physique of Japanese children [日本人小児の体格の評価に関する基本的な考え方]. J Jpn Soc Growth. 2011;17(2), 84–89. http://mol.medicalonline.jp/library/journal/download?GoodsID=dh6auxol/2011/001702/005&name=0084-0099j&UserID=202.21.163.142.
28. Cox JL, Holden JM, Sagovsky R. Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. Br J Psychiatry. 1987;150:782–6. https://doi.org/10.1192/bjp.150.6.782. PMID: 3651732.

Shrestha *et al. BMC Pregnancy and Childbirth*   (2024) 24:336

Page 13 of 13

29. Okano TMM, Masuji F, Tamaki R, Nomura J, Miyaoka H. Validation and reliability of Japanese version of the EPDS. Arch Psychiatric Diagn Clin Eval. 1996;7:523–33.

30. Mughal S, Azhar Y, Siddiqui W. Postpartum depression. [Updated 2022 Oct 7]. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2024. Available from: https://www.ncbi.nlm.nih.gov/books/NBK519070/.

31. Ishikawa N, Goto S, Murase S, Kanai A, Masuda T, Aleksic B, Usui H, Ozaki N. Prospective study of maternal depressive symptomatology among Japanese women. J Psychosom Res. 2011;71(4):264–9. https://doi.org/10.1016/j.jpsychores.2011.02.001.

32. Suzumiya H, Yamashita Y, Yoshida K. An investigation into support methods for perinatal psychiatric health using a self-recorded questionnaire on depressed feelings seen in postpartum mothers and the inability to bond. Arch Psychiatric Diagn Clin Eval. 2003;14:49–57 (in Japanese).

33. Choi Y, Bishai D, Minkovitz CS. Multiple births are a risk factor for postpartum maternal depressive symptoms. Pediatrics. 2009;123(4):1147–54. https://doi.org/10.1542/peds.2008-1619.

34. Baron RM, Kenny DA. The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. J Personal Soc Psychol. 1986;51:1173–82.

35. O'Hara MW, Wisner KL. Perinatal mental illness: definition, description and aetiology. Best Pract Res Clin Obstet Gynaecol. 2014;28(1):3–12. https://doi.org/10.1016/j.bpobgyn.2013.09.002. ISSN 1521-6934.

36. Ministry of Health, Labour and Welfare: Heisei 24 nendo chiiki hoken kenkozoshin jigyo hokoku no gaiyo. https://www.mhlw.go.jp/toukei/saikin/hw/c-hoken/12/. Accessed15 Mar 2024.

37. Ministry of Health, Labour and Welfare (MHLW). https://www.mhlw.go.jp/bunya/koyoukintou/pamphlet/dl/02_en.pdf. Accessed 15 Mar 2024.

38. Hendrick V, Smith LM, Hwang S, Altshuler LL, Haynes D. Weight gain in breastfed infants of mothers taking antidepressant medications. J Clin Psychiatry. 2003;64(4):410–2. https://doi.org/10.4088/jcp.v64n0409.

39. O'Brien LM, Heycock EG, Hanna M, Jones PW, Cox JL. Postnatal depression and faltering growth: a community study. Pediatrics. 2004;113(5):1242–7. https://doi.org/10.1542/peds.113.5.1242. PMID: 15121936.

40. George GC, Milani TJ, Hanss-Nuss H, Freeland-Graves JH. Compliance with dietary guidelines and relationship to psychosocial factors in low-income women in late postpartum. J Am Diet Assoc. 2005;105(6):916–26. https://doi.org/10.1016/j.jada.2005.03.009.

41. Adewuya AO, Ola BO, Aloba OO, Mapayi BM, Okeniyi JA. Impact of postnatal depression on infants' growth in Nigeria. J Affect Disord. 2008;108(1–2):191–3. https://doi.org/10.1016/j.jad.2007.09.013.

42. Dennis CL, McQueen K. Does maternal postpartum depressive symptomatology influence infant feeding outcomes? Acta Paediatr. 96(4):590–594. https://doi.org/10.1111/j.1651-2227.2007.00184.x.

43. Gaffney KF, Kitasantas P, Cheema J. Clinical practice guidelines for feeding behaviors and weight-for-age at 12 months: a secondary analysis of the Infant Feeding Practices Study II. 2012. https://doi.org/10.1111/j.1741-6787.2011.00236.x.

44. Aktar K. The association between exclusive breastfeeding and nutritional status among infants under six months of age in Bangladesh: a secondary analysis of Bangladesh Demographic and Health Survey, 2017–18. https://www.diva-portal.org/smash/get/diva2:1569670/FULLTEXT01.pdf.

45. Mantzorou M, Papandreou D, Vasios GK, Pavlidou E, Antasouras G, Psara E, Taha Z, Poulios E, Giaginis C. Exclusive breastfeeding for at least four months is associated with a lower prevalence of overweight and obesity in mothers and their children after 2–5 years from delivery. Nutrients. 2022;14(17):3599. https://doi.org/10.3390/nu14173599.

46. Kramer MS, Kakuma R. The optimal duration of exclusive breastfeeding: a systematic review. Adv Exp Med Biol. 2004;554:63–77.

47. Papoutsou S, Savva SC, Hunsberger M, et al. Timing of solid food introduction and association with later childhood overweight and obesity: the IDEFICS study. Matern Child Nutr. 2018;14:e1247. https://doi.org/10.1111/mcn.12471.

48. Baran J, Weres A, Czenczek-Lewandowska E, Leszczak J, Kalandyk-Osinko K, Mazur A. Relationship between children's birth weight and birth length and a risk of overweight and obesity in 4–15-year-old children. Medicina. 2019;55(8):487. https://doi.org/10.3390/medicina55080487.

49. Liu LGJ, Ye R, Liu J, Zhuang Z, Ren A. J Epidemiol. 2015;25(8):536–43. https://doi.org/10.2188/jea.JE20140149.

50. Łoniewska B, Michalczyk K, Podsiadło K, Adamek K, Michalczyk B, Tousty P, Kaczmarczyk M, Łoniewski I. Analysis of the influence of pre-pregnancy BMI and weight gain during pregnancy on the weight of healthy children during the first 2 years of life: a prospective study. Children. 2022;9:1431. https://doi.org/10.3390/children9101431.

51. Fifth Global Nepali Health Conference. Book of abstracts. Non-resident Nepali Association. 2023,9,53. https://nrna.org/wp-content/uploads/2023/09/Final-draft-for-compendium-5th-GNHC.pdf. Accessed 22 Sept 2023.

Publisher's Note