STATISTICS IN TRANSITION-new series, Spring 2013
Vol. 14, No. 1, pp. 107–128

MATERNAL NUTRITIONAL STATUS AND LACTATIONAL AMENORRHEA IN INDIA: A SIMULATION ANALYSIS

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ABSTRACT

Apart from breast-feeding, socio-economic and biological factors, maternal health also influences the length or distribution of waiting time to conception. The main objective of this paper is to examine the linkages between maternal nutritional status (measured by body mass index-BMI) and postpartum amenorrhea among currently breast-feeding women in India and its region. Further, the probability to remain amenorrheic through simulative approach has been estimated to get better understanding of the impact of maternal nutritional status on postpartum amenorrhea. Using National Family Health Survey-2 data, women who were not pregnant, who were breast-feeding and who were not using any hormonal contraceptives at the time of the survey were included in the analysis. Missing cases for body mass index and child nutritional status were imputed by fitting the linear regression equation. There was no significant difference existing between mean BMI of each region of India before and after imputation of missing cases. The interaction term between maternal nutritional status and duration of breast-feeding (child's age) was significantly associated with the likelihood of having resumed menstruation after controlling for breast-feeding practices, child nutritional status and socio-economic and demographic covariates. The effect of maternal nutritional status on lactational amenorrhea was not found to be significant when women were breast-feeding since last 12 months except in the northern region of India. However, after 12 months of breast-feeding, the probability of undernourished women to remain amenorrheic was likely to be greater and this trend was highly consistent across all the six regions included in the analysis.

Key words: simulative approach, maternal nutritional status, body mass index, postpartum amenorrhea, India.

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1. Introduction

The interval between birth of a child and subsequent return of menstrual cycle is known as lactational amenorrhea. There are number of important factors which affect lactational amenorrhea either directly or through breast-feeding and its complete understanding is somewhat a complex phenomenon. Apart from breast-feeding, socio-economic and biological factors, maternal health also influences the length or distribution of waiting time to conception. It is easily visualized that maternal health affects the duration/frequency of breast-feeding. For instance, an undernourished woman might think that her milk is not sufficient and/or nutritious or she will not be competent enough to breast-feed for a longer duration and ultimately it adversely affects the duration of amenorrhea. The other possibility is that an undernourished woman may prefer to increase the frequency as well as duration of breast-feeding because she might be not capable to produce sufficient nutritious milk for her child.

However, nutritionists argued that the nutritional status of woman is also directly linked with the quality and duration of breast-feeding. Frisch (1983) found that nutritional intake influences fecundity. Further, Frisch *et al.* (1973) and Frisch and McArthur (1974) investigated the effect of nutrition on ovarian function and they have formulated the "critical body composition hypothesis." This hypothesis suggests that a minimal amount of fat as percentage of body weight is necessary for attaining menarche and for maintaining ovarian cycles. However, it still remains controversial and some researchers have suggested that nutritional status of women has a strong impact on postpartum amenorrhea (PPA).

The arguments that shorter duration of breast-feeding results in short duration of birth interval may deteriorate the nutritional status of mother. The term 'maternal depletion syndrome' in the literature refers to "the effect of a rapid succession of pregnancies and periods of lactation which erode the nutritional status of the mother" (Cleland and Sathar, 1984). There have been a few studies dealing with the effects of birth interval on maternal mortality (measurement of maternal health) due to non-availability of data. It is very difficult to measure the health effect of high fertility or short birth intervals on mothers. However, it is also argued that longer duration of breast-feeding has a negative impact on health. It is not easy to measure maternal health due to intense and longer breast-feeding in the analyses of reproductive performance and health from currently available data.

India and the central region in particular are well known for high fertility leading to the burden on women who already have poor nutritional status. Therefore, it is felt that the duration of amenorrhea might change for well-nourished and undernourished women. Huffman *et al.* (1987) suggested maternal nutrition is not likely to shorten the length of PPA significantly. Moreover, the relationship between maternal nutritional status and lactational amenorrhea is not clearly understood. Some researchers have argued that undernourished women have less chance of maintaining the ovarian cycle (Frisch *et al.*, 1973; Frisch and

McArthur, 1974). But some researchers have also argued that this relationship is biologically insignificant (Diaz *et al*., 1988). Therefore, the specific objective of this chapter is to examine the independent impact of maternal nutritional status on lactational amenorrhea among breast-feeding women.

2. Method and materials

This study uses National Family Health Survey (NFHS) data conducted in the years 1998-99. The analysis was carried out for India and its six regions, namely - the northern region includes Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab and Rajasthan; the central region consists of Chhattisgarh, Madhya Pradesh, Uttaranchal and Uttar Pradesh; the eastern region comprises of Bihar, Jharkhand, Orissa and West Bengal; the northeastern region consists of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura; the western region includes Goa, Gujarat and Maharashtra; and finally the southern region includes Andhra Pradesh, Karnataka, Kerala and Tamil Nadu.

Regions follow the classification scheme contained in the NFHS published report (IIPS and ORC Macro, 2000). Region specific analysis was carried out after assigning a proper weight to adjust for the differences in sample size across states. Sample weights were calculated to provide region-wide estimates, for example, for the northeastern region (which contains eight states):

$1/[8*(n_s/ n_p)]$ where n_s is the sample size for each state and n_p is the sample size for pooled data. Whenever it is required, values for missing cases have been imputed using linear regression equation and results have compared before and after imputing the missing values.

Women who were not pregnant, not using any hormonal contraceptives and were currently breast-feeding at the time of the survey were selected for the study. The NFHS-2 data obtained information from 90,303 ever married women in the age group of 15-49 years. There were 22,597 women who were currently breast-feeding at the time of the survey, of whom 959 women who were currently pregnant and 737 women who were using modern contraceptive pills were dropped from the analysis. The analysis was carried out for 20,901 currently breast-feeding women. At the time of the survey, women were asked if their menstruation had returned since the birth of their youngest child. The lactational amenorrhea is defined as a dichotomous variable. The dependent variable was the women who reported not to have resumed menstruation after the delivery of the last child and were coded as amenorrheic or as non-amenorrheic if women resumed menstruation.

An anthropometric measurement, body mass index (BMI) has been used as an indicator for measuring nutritional status of women. Chronic energy deficiency in women is usually indicated by BMI of less than 18.5 kg/m^2. BMI is a valid indicator for assessment of nutritional status of women as literature suggests that

BMI is consistently highly correlated with body weight and is relatively independent of the stature or height of the individual. Such type of measurement is very highly reliable than the measurement which is solely based on reporting. However, child weight-for-age is identified as an indicator for child's nutritional status.

The combined variables, namely maternal nutrition and duration of breast-feeding (equivalent to the age of the child) is considered as an independent variable. The four categories of this variable are:

undernourished (BMI<18.5 kg/m^2) women and child aged <=12 months;
undernourished (BMI<18.5 kg/m^2) women and child aged 13-35 months;
well-nourished (BMI>=18.5 kg/m^2) women and child aged <=12 months;
and well-nourished (BMI>=18.5 kg/m^2) women and child aged 13-35 months.

The other independent variables are: region (north/central/east/northeast/west/south); place of residence (rural/urban); respondent's education (illiterate/middle school complete/high school complete and above); standard of living (low/medium/high); sex of index child (female/male); maternal age (in years) (15-24/25-34/35-49); parity (1/2/>=3); child's weight-for-age Z-score (>=-2/<-2); and breast-feeding status (breast-feeding with supplements/exclusive breast-feeding/breast-feeding with plain water only). Analyses were also carried out in India and for six regions, separately.

The information on maternal body mass index (BMI) for 1795 women and child's weight-for-age for 4130 cases was found to be missing. The missing values of maternal BMI and child's weight-for-age were imputed with the help of multiple linear regression analysis. The significance level of coefficients in the multivariate framework was compared before and after imputing the missing values. The independent variables used for imputing the missing values of maternal BMI are region (north/central/east/northeast/west/south), place of residence (rural/urban), respondent's education (illiterate/middle school complete/high school complete and above), standard of living (low/medium/high), parity (continuous), current age of woman (continuous), and breast-feeding status (breast-feeding with supplements/exclusive breast-feeding/breast-feeding with plain water only). In addition to the above mentioned covariates, current age of child was also included for imputing the missing values of child weight-for-age in the regression analysis.

The mean value of maternal nutritional status (BMI) was computed by selected characteristics of women. Further, the survival probability of the pattern of PPA was estimated using the non-parametric method of Kaplan-Meier (K-M). Log-rank test has been applied to determine whether there were significant differences in the median duration of PPA between undernourished and well-nourished women.

Since we have controlled the duration of breast-feeding by creating the combined variable of maternal nutritional status and duration of breast-feeding, we have preferred multiple logistic regression analysis over Cox hazards model.

A simulative approach has been adopted in this paper to find out the adjusted effects of maternal nutritional status on lactational amenorrhea. It is decided to compute the adjusted proportion of amenorrheic women by maternal nutritional status on the assumption that all women in the sample were having undernourished child and also by considering all women in the sample were having well-nourished child, separately. From this approach, an attempt was made to obtain the important information of proportion of remaining amenorrheic for a particular variable by keeping other variables at the mean level. Similarly, these probabilities for a particular combination of variables may also be computed by holding the remaining variables at the mean level (Dwivedi, 2006; Dwivedi *et al.*, 2007).

3. Results

3.1. Kaplan-Meier (K-M) survival analysis

Kaplan-Meier (K-M) survival analysis was carried out to find the median duration of PPA according to maternal nutritional status. The technique also helps in proper categorization of duration of breast-feeding (child's age) as a categorical predictor in the multivariate analysis.

The results of K-M survival probability of PPA in relation to BMI for those women who were currently breast-feeding, not pregnant and were not using any hormonal contraceptives at the time of the survey for India and its regions are presented in the Figure 1. It is evident that at the first month of PPA period, 88 percent of better-nourished women and 90 percent of malnourished women in case of India were still amenorrheic, whereas at the end of six months, 57 percent of better-nourished and 63 percent of malnourished women in case of all India were still amenorrheic. However, at the end of 12 months, these rates for two different categories of women declined to about half of the previous values, i.e., to 26 percent and 32 percent, respectively. Later, at the end of 32 months, the corresponding figures were eight percent and six percent, respectively. It is clear from the present analysis that undernourished women were more likely to be found in amenorrheic state than better-nourished women (Figure 1).

In the case of better-nourished women, the percentage of women who were still amenorrheic at the end of first month was highest in the northeastern region and lowest in the northern region. But for undernourished women, the percentage of women who were still amenorrheic at the end of first month was highest in the southern region and lowest in the northern region. The percentage of women who remained amenorrheic at the end of first month was found to be relatively higher among malnourished women in the entire region except in the northeastern region where the corresponding percentage was equal for both better-nourished and malnourished women. But, the percentage of women who were amenorrheic at the end of 12 months was considerably higher among malnourished in the entire region of India. At the end of 20 months also, a similar pattern was observed. But, the difference in percentages to remain amenorrheic between better-nourished and malnourished women was remarkably higher in the western and southern regions. For example, at the end of 12 months, the percentages of women remaining amenorrheic among undernourished was 31 percent compared to 18 percent who were well-nourished in the western region of India. Kaplan-Meier estimates show that there has been a sharp decline in the percentages of amenorrheic women during 11 to 12 month of the postpartum period in all the regions of India, irrespective of maternal nutritional status.

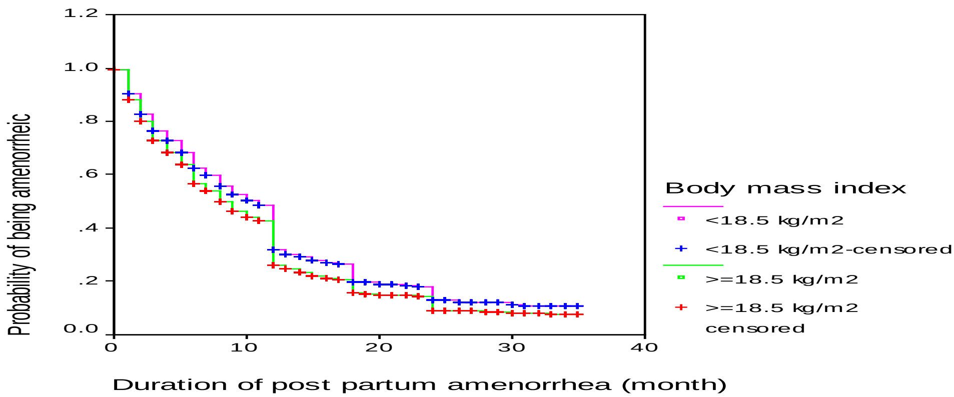
The median duration of PPA and its 95 percent confidence interval estimates for women who were currently breast-feeding, not pregnant and were not using any hormonal contraceptives at the time of the survey with respect to their body mass index in case of India and its regions have also been calculated and are presented in Table 1. Log-rank test showed that there was a significant difference in the duration of amenorrhea between the two groups under study. Undernourished women had a significantly longer duration of PPA than well-nourished women in India ($p<0.00001$).

Table 1. Median duration of postpartum amenorrhea and its 95% confidence interval (CI) estimates for women who were currently breast-feeding, not pregnant and were not using any hormonal contraceptives at the time of the survey with respect to body mass index of women in India and its regions-1998-99.

Country/Regions	BMI>=18.5 kg/m^2			BMI<18.5 kg/m^2			Log-rank test
	Median	95% CI		Median	95% CI		
		L	U		L	U	Test-statistic
India	**9.00**	**8.68**	**9.32**	**11.00**	**10.79**	**11.21**	**76.90***
North	7.00	6.49	7.51	8.00	7.14	8.86	5.38***
Central	12.00	11.73	12.27	12.00	11.85	12.15	2.86
East	10.00	9.56	10.44	12.00	11.59	12.41	14.18**
Northeast	8.00	7.48	8.52	9.00	8.01	9.99	3.64
West	6.00	5.36	6.64	11.00	10.39	11.61	45.53*
South	7.00	6.54	7.46	9.00	8.16	9.84	35.62*

Note: *p<=0.00001; ** p<=0.0002; ***p<=0.0204

Figure 1. Survival curve based on Kaplan-Meier method for India



The median duration of PPA was significantly longer for undernourished women in the northern, eastern, western and southern regions and difference was significantly more apparent in the western and southern regions. However, there was no significant difference in the median duration of PPA between better-nourished and malnourished women in the central and northeastern regions. The survival curves based on Kaplan-Meier method for all the regions of India presented in the figures, also indicates more clearly the same findings (Figure 1).

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Figure 1.1. Survival curve based on Kaplan-Meier method for Northern region of India

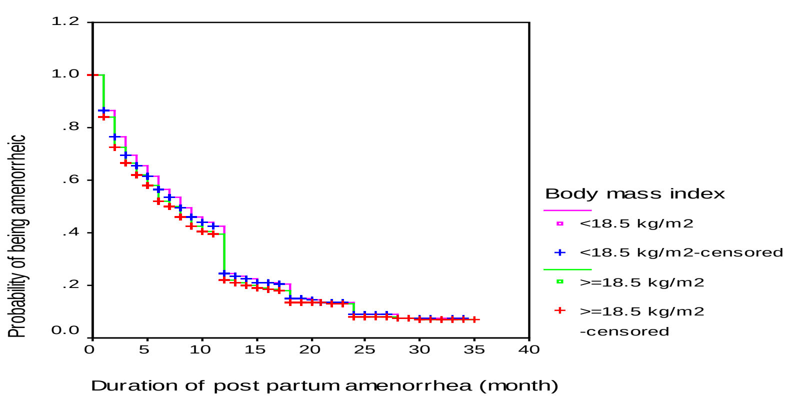

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Figure 1.2. Survival curve based on Kaplan-Meier method for Central region of India

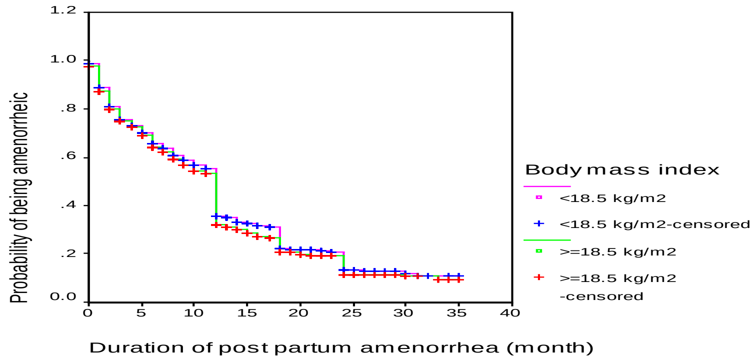

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Figure 1.3. Survival curve based on Kaplan-Meier method for Eastern region of India

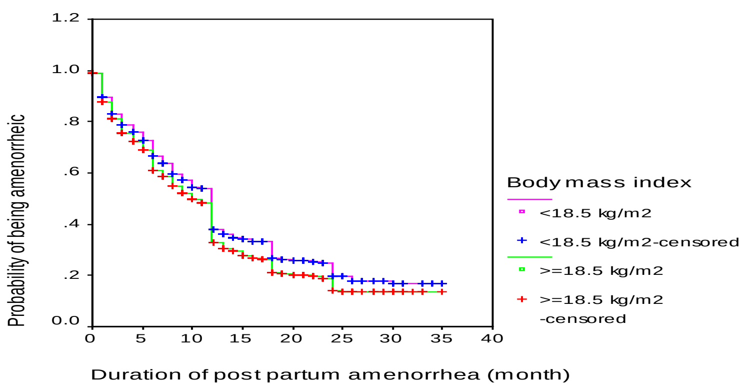

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Figure 1.4. Survival curve based on Kaplan-Meier method for Northeastern region of India

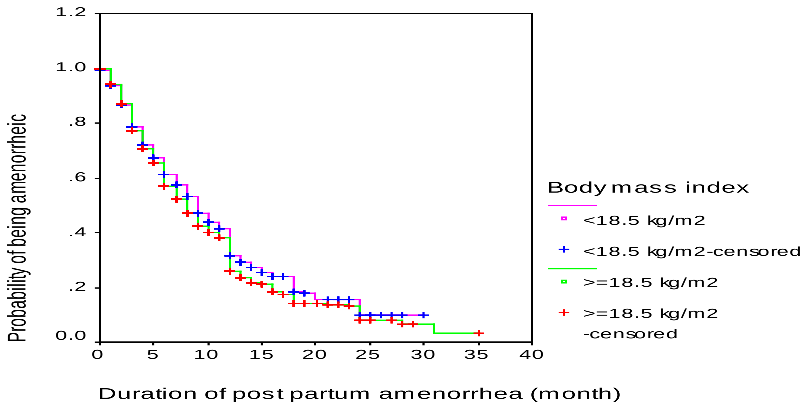

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Figure 1.5. Survival curve based on Kaplan-Meier method for Western region of India

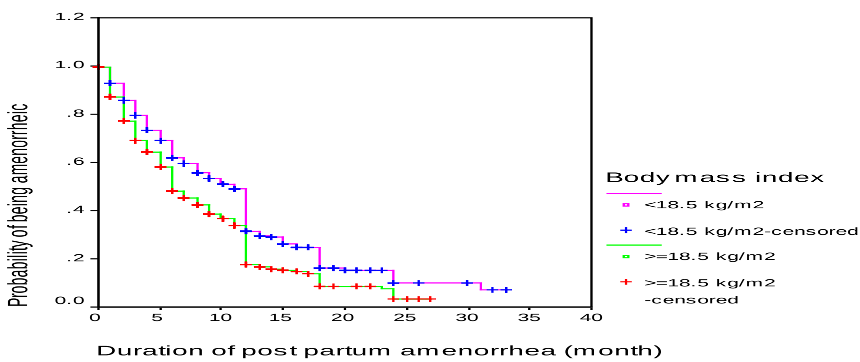

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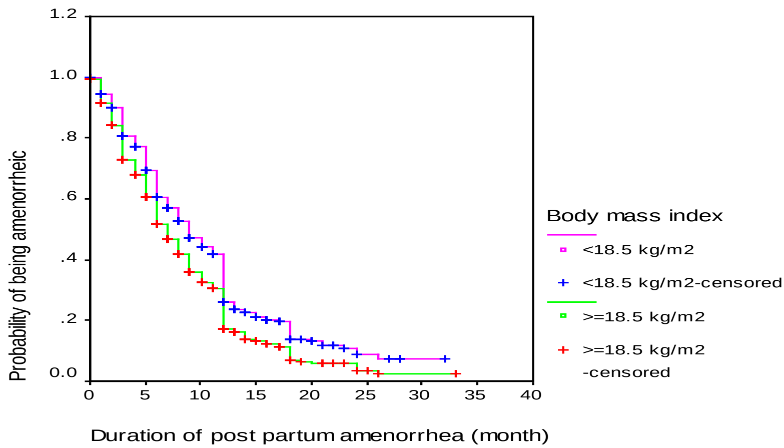
Figure 1.6. Survival curve based on Kaplan-Meier method for Southern region of India



3.2. Multivariate analysis

To identify the independent effect of maternal nutritional status on lactational amenorrhea among breast-feeding women, all the important determinants were considered in the multivariate logistic regression analysis. The choice of the explanatory variables included in the logistic model was governed by two considerations: first, its relation with the dependent variable should be statistically significant in the bivariate analysis; and second, the inclusion of that variable could also be theoretically justified.

The adjusted odds ratio and its 95 percent confidence interval estimates of amenorrheic versus non-amenorrheic women who were currently breast-feeding, not pregnant and were not using any hormonal contraceptives at the time of the survey for India by selected characteristics are presented in Table 2. The results presented in the table clearly show that the adjusted chance to remain amenorrheic was more evident among women of all regions of India except in the southern region, although the odds ratio was found to be significant only in the central and eastern regions. There was no variation in the magnitude as well as significance level of odds ratio after imputing the missing values. However, the magnitude of the adjusted odds ratio increased slightly compared to the unadjusted odds ratio in the eastern region. This indicates that after controlling the other important factors, women from the eastern region had strong positive tendency to remain amenorrheic than those in the northern region of India.

Women who were from urban areas belonged to educated category and had medium or high standard of living, were significantly less likely to be amenorrheic. This pattern was almost similar after imputing the missing values. Women with a male child were more likely to be amenorrheic, but the relationship was not statistically significant. Maternal age was also inversely associated with lactational amenorrhea. However, parity was positively associated with the chance that the woman will be in the state of PPA. The adjusted chance to remain amenorrheic increases significantly with an increase in parity. For example, women who were at parity three or above had greater likelihood of being found in amenorrheic state at the time of the survey; the chance was double than that for women of parity one. The result was statistically significant. After imputing the missing values of maternal BMI and child weight-for-age, the magnitude of odds ratio for parity and maternal age remained unchanged for the same level of significance. Women who had undernourished children were significantly less likely to remain amenorrheic than women with well nourished children. The likelihood was almost similar but the level of significance was changed after imputing the missing values. Among women who did not report their child's weight-for-age the chances to remain amenorrheic increased significantly. Further, the direction of the regression coefficient was the same as it was in the case of unadjusted coefficient. Women who were exclusively breast-feeding or breast-feeding as well as giving plain water were significantly more likely to remain amenorrheic, but the odds ratio was relatively higher among those women who were exclusively breast-feeding.

Table 2. Adjusted odds ratio and 95% confidence interval (CI) estimates of amenorrheic versus non-amenorrheic women who were currently breast-feeding, not pregnant and were not using any hormonal contraceptives at the time of the survey, India by selected characteristics-1998-99.

Variables	India			India*		
	Exp (β)	95% CI for Exp (β)		Exp (β)	95% CI for Exp (β)	
		Lower	Upper		L	U
Region of residence						
North®	1.00	-	-	1.00	-	-
Central	1.15	1.03	1.27	1.15	1.04	1.28
East	1.28	1.15	1.43	1.30	1.16	1.45
Northeast	1.06	0.94	1.20	1.04	0.92	1.17
West	1.05	0.93	1.20	1.05	0.92	1.20
South	0.94	0.83	1.06	0.94	0.83	1.06
Place of residence						
Rural®	1.00	-	-	1.00	-	-
Urban	0.81	0.75	0.89	0.79	0.73	0.87
Respondent's education						
Illiterate®	1.00	-	-	1.00	-	-
Middle school complete	0.79	0.73	0.86	0.77	0.71	0.84
High school complete and above	0.74	0.66	0.84	0.72	0.64	0.82
Standard of living						
Low®	1.00	-	-	1.00	-	-
Medium	0.74	0.69	0.80	0.72	0.67	0.78
High	0.54	0.48	0.61	0.52	0.46	0.59
Sex of child						
Female®	1.00	-	-	1.00	-	-
Male	1.06	1.00	1.14	1.07	1.00	1.14
Maternal age (in years)						
15-24®	1.00	-	-	1.00	-	-
25-34	0.88	0.81	0.96	0.89	0.82	0.97
35-49	0.77	0.66	0.88	0.78	0.67	0.90
Parity						
1 Child	1.00	-	-	1.00	-	-
2 Children	1.44	1.31	1.58	1.44	1.31	1.59
>=3 Children	2.11	1.91	2.34	2.16	1.95	2.39
Child wt-for-age						
Z-score >=-2®	1.00	-	-	1.00	-	-
Z-score < -2	0.99	0.91	1.08	0.91	0.84	0.99
Missing	1.25	1.12	1.40	NA	NA	NA
Breast-feeding status						
Breast-feeding+supplements®	1.00	-	-	1.00	-	-
Exclusive breast-feeding	5.32	4.74	5.98	4.51	4.01	5.08
Breast-feeding+ plain water only	2.45	2.22	2.69	2.27	2.06	2.51
Maternal BMI & Child age						
<18.5Kg/m^2 and 13-35 months®	1.00	-	-	1.00	-	-
<18.5Kg/m^2 and <=12 months	6.10	5.43	6.86	6.14	5.46	6.90
>=18.5Kg/m^2 and <=12 months	6.71	6.01	7.49	6.78	6.08	7.57
>=18.5Kg/m^2 and 13-35 months	0.76	0.68	0.86	0.77	0.70	0.86
Missing BMI and 0-35 months	1.91	1.63	2.25	NA	NA	NA

Note: *Odds ratio includes imputed values for missing cases of body mass index and child wt-for-age.

Table 3. Adjusted odds ratio and 95% confidence interval (CI) estimates of amenorrheic versus non-amenorrheic women who were currently breast-feeding, not pregnant and were not using any hormonal contraceptives at the time of the survey for India and its regions by maternal body mass index (BMI) & child age-1998-99.

Variables	India			India*			North*			Central*		
	Exp (β)	95% CI for Exp (β)		Exp (β)	95% CI for Exp (β)		Exp (β)	95% CI for Exp (β)		Exp (β)	95% CI for Exp (β)	
		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
Maternal BMI & Child age												
<18.5Kg/m^2 and <=12 months®	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-
<18.5Kg/m^2 and 13-35 months	0.16	0.15	0.18	0.16	0.15	0.18	0.17	0.13	0.22	0.15	0.12	0.20
>=18.5Kg/m^2 and <=12 months	1.10	1.00	1.21	1.11**	1.00	1.22	1.34	1.10	1.64	1.02	0.83	1.26
>=18.5Kg/m^2 and 13-35 months	0.13	0.11	0.14	0.13	0.11	0.14	0.14	0.11	0.18	0.14	0.11	0.18
Missing BMI and 0-35 months	0.31	0.27	0.37	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note: *Odds ratio includes imputed values for missing cases of body mass index and child wt-for-age.
** Results significant at P<=0.05. It includes 1 in 95% confidence interval because of rounding.
All other considered variables in the Table 2 have been controlled.

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Table 3.1. Adjusted odds ratio and 95% confidence interval (CI) estimates of amenorrheic versus non-amenorrheic women who were currently breast-feeding, not pregnant and were not using any hormonal contraceptives at the time of the survey for different regions of India by maternal body mass index (BMI) & child age-1998-99.

Variables	East			Northeast			West			South		
	Exp (β)	95% CI for Exp (β)		Exp (β)	95% CI for Exp (β)		Exp (β)	95% CI for Exp (β)		Exp (β)	95% CI for Exp (β)	
		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
Maternal BMI & Child age												
<18.5Kg/m^2 and <=12 months®	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-
<18.5Kg/m^2 and 13-35 months	0.20	0.16	0.26	0.18	0.12	0.26	0.15	0.11	0.22	0.11	0.08	0.16
>=18.5Kg/m^2 and <=12 months	1.16	0.92	1.46	1.23	0.93	1.62	0.81	0.60	1.09	0.96	0.74	1.24
>=18.5Kg/m^2 and 13-35 months	0.15	0.12	0.19	0.12	0.09	0.17	0.09	0.06	0.13	0.07	0.05	0.10

Note: Odds ratio includes imputed values for missing cases of body mass index and child wt-for-age.
All other considered variables in the Table 3.5.1 have been controlled.

Women who had a child of age less than 13 months were significantly more likely to remain amenorrheic, irrespective of their nutritional status, than undernourished women who had a child of age 13 to 35 months and the odds ratio was found to be similar after imputing the missing values. On the other hand, the adjusted chance to remain amenorrheic was found to be lower among women who were better-nourished and had a child of age 13 to 35 months compared to their undernourished counterparts who had a child of the same age. The result was consistent after imputation of missing values of maternal BMI and child weight-for-age.

A possible reason for this finding may be that the duration of breast-feeding (child's age) is one of the important predictors in determining the lactational amenorrhea among breast-feeding women. Therefore, for comparison purpose, we have taken undernourished women with the age of the child less than 13 months as a reference category in the multivariate analysis (Table 3). Results clearly revealed that there was no significant difference in postponing the return of ovulation after birth of a child between undernourished and better-nourished women with the age of the child less than 13 months in all the regions of India except the northern region. In the northern region, the probability to remain amenorrheic was high among better-nourished women with the age of the child less than 13 months as opposed to undernourished women with the same age of the child.

3.3. Simulation analysis

The predicted probabilities to remain amenorrheic were calculated for a particular variable by holding all remaining variables at their average level in the model. These results are presented in the Table 4.

Some selected variables and a combination of variables considered in the present prediction analysis are: (i) breast-feeding status, (ii) place of residence, (iii) respondent's education, (iv) standard of living, (v) sex of child, (vi) child nutritional status, (vii) maternal BMI and child age (duration of breast-feeding), (viii) maternal BMI and child age with breast-feeding status, (ix) maternal BMI and child age with child nutritional status, (x) maternal BMI and child's age with breast-feeding status and child's nutritional status.

The results indicate that the probability to remain amenorrheic was comparatively higher among those women who were exclusively breast-feeding. By assuming that all women in India were exclusively breast-feeding, the chance to remain amenorrheic has increased to around 13 percent than among those women who were breast-feeding and giving only plain water. The probability to remain amenorrheic was more than average among those women who were breast-feeding and giving only plain water, whereas the corresponding probability for women who were breast-feeding as well as giving supplements was lower in comparison to the average value (0.418).

A similar pattern was found in all the regions of India where the percentage of amenorrheic women who were breast-feeding and giving some supplements was lower than the average value of the respective regions. The gain in terms of percentage of women who continued PPA period due to practice of exclusive breast-feeding was high in the western region followed by the eastern and the southern parts of the country and it was lowest in the northeastern region.

Living in urban areas was inversely associated with amenorrhea compared with living in rural areas and the rural-urban differentials were more pronounced in the northern and the eastern parts of the country. The probability to remain amenorrheic among rural women was comparatively high in the western regions followed by those in the eastern and central regions and was lowest in the southern region. As education and standard of living increases, the percentage of amenorrheic women decreases. However, the pattern was not consistent with respect to education of women in the western and the eastern regions of India. By assuming that all women in the sample were educated up to high school and above, the chance to remain amenorrheic has reduced considerably in all the regions of India except the northeastern, the southern and the western regions of the country. This change in the probability was more apparent in the western region followed by the north and the northeast regions of India. Similarly, the chance to remain amenorrheic has reduced in the entire region on the assumption that all women have a higher standard of living, and this change was more manifested in the central and eastern regions. Women with male child were slightly more likely to be amenorrheic than women with girl child except in the western region. However, if it is assumed that all women in India had only male child, the percentage of women with lactational amenorrhea has reduced by around five percent from the mean value.

The percentage of amenorrheic women was higher among those with malnourished children than their counterparts with well-nourished children in all the regions of India except the south India. However, this difference was almost negligible in the southern region. The probability to remain amenorrheic was highest among those women who were better-nourished and had a child of age less than 13 months in the central, east, north and northeast regions of India, whereas in the southern and western regions, the chance was found to be highest among those women who were undernourished and had a child of age less than 13 months. Further, more undernourished women with a child of age 13-35 months were amenorrheic than better-nourished women with a child of the same age in all the regions of India. If it is assumed that all women in the sample had a child of age less than 13 months, the probability to remain amenorrheic was higher than the average value, irrespective of their maternal nutritional status. This result is true for all the regions of India. In addition, there was a substantial reduction in the percentage of amenorrheic women among better-nourished women with a child of age 13-35 months in all the regions of India from their respective mean values. The reduction in probability was more apparent in the central parts of the country followed by the southern region.

The percentage of amenorrheic women was found to be highest among those who were exclusively breast-feeding regardless of their BMI and child's age. Further, the probability to remain amenorrheic was found to be highest in the western region among those undernourished women who had a child of age less than 13 months. If it is assumed that all women in the sample were exclusively breast-feeding a child of age 13-35 months then the probability to remain amenorrheic increases from the average value among undernourished women in all the regions of India. Whereas, this probability was lower than the average value among better-nourished women with a child at the same age of 13-35 months in all the regions of India except the central, eastern and western parts of the country. Moreover, after keeping the age of the child as 13-35 months, the probability to remain amenorrheic was high among undernourished women than their well-nourished counterparts in all the regions of India.

If it is assumed that all women were exclusively breast-feeding a child of age less than 13 months, the probability to remain amenorrheic was higher among those women who were malnourished than well-nourished women with a child of the same age in the southern and western regions. The result has become inverted in other regions of India. However, after making unvarying the age of a child as less than 13 months, the chance to remain amenorrheic was not consistent across the different regions of India by maternal nutritional status.

The percentage of amenorrheic women was found to be relatively higher among those who were breast-feeding and giving plain water compared to those women who were breast-feeding and giving supplements, irrespective of maternal BMI and child's age, in all the regions of India. If it is considered that all women were breast-feeding with plain water only, the probability to remain amenorrheic increases from the average value when women had a child of age less than 13 months regardless of their BMI in the entire region. However, it decreases from the average value when women had a child of age 13-35 months in all the regions of India. On the other hand, the level of corresponding probability decreases but the pattern was the same if it is considered that all women were breast-feeding and giving supplements. With regard to women who were breast-feeding with plain water or any supplements, the probability was relatively higher for well-nourished women who had a child of age less than 13 months in the entire region except in the southern and western regions where the corresponding highest figure was for undernourished women with the age of the child less than 13 months.

When child's weight-for-age and maternal BMI with child age are taken into consideration, it is evident that the chance of remaining amenorrheic was comparatively higher among women whose children were better-nourished, regardless of maternal BMI and child's age except in the southern region. On assuming the age of the child as 13-35 months, the percentage of amenorrheic women was found highest among those undernourished who had a well-nourished child in all the regions of India. If it is considered that all women in India had malnourished children of age less than 12 months, the probability of remaining amenorrheic increases from the average value among all women regardless of their nutritional status. This pattern was consistent in all the regions of India (table not shown).

Once child's weight-for-age, maternal BMI with child's age and breast-feeding status are considered together, the probability was found to be highest among women who were exclusively breast-feeding and had better-nourished children regardless of their BMI and child's age. The pattern was found to be the same in all the regions except in the southern region where the chance was comparatively higher among women who were exclusively breast-feeding and had undernourished children regardless of their BMI and child's age. The chance of remaining amenorrheic was highest among better-nourished women who were exclusively breast-feeding and had better-nourished children of less than 13 months in all the regions of India except the southern region, and lowest among better-nourished women who were breast-feeding and giving supplements and had better-nourished children of age 13-35 months in all the regions of India. When it is assumed that all women in India were undernourished with malnourished children of age 13-35 months and were exclusively breast-feeding, the probability of remaining amenorrheic increases around four points from the average value. This increase in probability was found to be highest (13 points) in the eastern region and lowest in the northern region (one point). However, for the central and northeastern regions, the figure was lower than the average value of the respective regions (table not shown).

Table 4. Estimated probabilities of remaining amenorrheic by selected combinations of characteristics for India and its regions-1998-99.

Variable	Probability ± Standard Deviation						
	India	North	Central	East	Northeast	West	South
Average	0.418±0.282	0.388±0.284	0.457±0.283	0.445±0.275	0.392±0.266	0.406±0.301	0.394±0.296
Breast-feeding status							
Breast-feeding+supplements	0.359±0.222	0.329±0.220	0.399±0.232	0.390±0.216	0.357±0.228	0.320±0.213	0.321±0.217
Exclusive breast-feeding	0.642±0.222	0.620±0.235	0.619±0.226	0.688±0.189	0.590±0.246	0.702±0.219	0.652±0.245
Breast-feeding+ plain water only	0.514±0.240	0.486±0.248	0.536±0.239	0.533±0.221	0.495±0.253	0.555±0.246	0.471±0.257
Place of residence							
Rural	0.524±0.239	0.505±0.246	0.541±0.238	0.542±0.219	0.503±0.253	0.562±0.245	0.476±0.258
Urban	0.479±0.239	0.431±0.241	0.512±0.240	0.474±0.222	0.459±0.250	0.548±0.246	0.458±0.255
Respondent's education							
Illiterate	0.502±0.238	0.450±0.242	0.529±0.237	0.494±0.219	0.476±0.253	0.582±0.242	0.499±0.261
Middle school complete	0.452±0.236	0.409±0.236	0.480±0.238	0.427±0.216	0.449±0.250	0.511±0.245	0.442±0.252
High school complete and above	0.439±0.235	0.340±0.233	0.436±0.234	0.437±0.217	0.439±0.248	0.540±0.245	0.410±0.244
Standard of living							
Low	0.490±0.237	0.466±0.242	0.490±0.236	0.460±0.218	0.473±0.253	0.607±0.238	0.459±0.256
Medium	0.427±0.231	0.407±0.233	0.419±0.229	0.416±0.214	0.417±0.244	0.533±0.244	0.393±0.238
High	0.364±0.217	0.336±0.213	0.347±0.211	0.363±0.205	0.409±0.242	0.455±0.239	0.351±0.223
Sex of child							
Female	0.357±0.215	0.326±0.209	0.338±0.208	0.358±0.203	0.397±0.240	0.476±0.241	0.339±0.217
Male	0.369±0.218	0.344±0.216	0.354±0.213	0.369±0.206	0.420±0.245	0.437±0.236	0.362±0.227
Child wt-for-age							
Z-score >=-2	0.375±0.217	0.351±0.214	0.368±0.210	0.370±0.206	0.425±0.243	0.454±0.231	0.362±0.227
Z-score < -2	0.358±0.212	0.326±0.205	0.334±0.199	0.367±0.205	0.398±0.237	0.407±0.222	0.364±0.228
Maternal BMI & Child age							
<18.5Kg/m^2 and 13-35months	0.169±0.043	0.132±0.033	0.148±0.034	0.215±0.048	0.204±0.049	0.216±0.068	0.134±0.028
<18.5Kg/m^2 and <=12 months	0.546±0.078	0.472±0.076	0.525±0.072	0.566±0.071	0.580±0.075	0.627±0.100	0.569±0.060
>=18.5Kg/m^2 and <=12 months	0.570±0.077	0.543±0.077	0.530±0.072	0.601±0.070	0.628±0.073	0.578±0.103	0.560±0.060
>=18.5Kg/m^2 and 13-35 months	0.136±0.036	0.112±0.028	0.140±0.033	0.170±0.040	0.150±0.038	0.134±0.046	0.088±0.020
Maternal BMI & Child age with Breast-feeding status							
Breast-feeding with supplements							
+ <18.5Kg/m^2 and 13-35months	0.176±0.072	0.140±0.062	0.202±0.073	0.240±0.080	0.173±0.058	0.154±0.080	0.116±0.050
+ <18.5Kg/m^2 and <=12 months	0.543±0.129	0.472±0.133	0.600±0.119	0.589±0.115	0.525±0.102	0.509±0.150	0.510±0.122
+ >=18.5Kg/m^2 and <=12 months	0.566±0.128	0.540±0.134	0.605±0.118	0.623±0.113	0.573±0.100	0.461±0.149	0.500±0.122
+ >=18.5Kg/m^2 and 13-35 months	0.143±0.061	0.120±0.054	0.191±0.070	0.192±0.068	0.127±0.045	0.094±0.052	0.076±0.034
Exclusive breast-feeding							
+ <18.5Kg/m^2 and 13-35months	0.471±0.128	0.422±0.129	0.433±0.116	0.576±0.116	0.416±0.099	0.561±0.149	0.438±0.120
+ <18.5Kg/m^2 and <=12 months	0.831±0.079	0.796±0.095	0.818±0.080	0.861±0.064	0.789±0.070	0.880±0.067	0.859±0.062
+ >=18.5Kg/m^2 and <=12 months	0.844±0.074	0.837±0.081	0.821±0.079	0.877±0.059	0.820±0.063	0.857±0.077	0.854±0.064

Variable	Probability ± Standard Deviation						
	India	North	Central	East	Northeast	West	South
+ >=18.5Kg/m^2 and 13-35 months	0.412±0.123	0.380±0.124	0.417±0.114	0.508±0.116	0.333±0.090	0.428±0.147	0.332±0.108
Breast-feeding with plain water only							
+ <18.5Kg/m^2 and 13-35months	0.319±0.109	0.271±0.102	0.335±0.103	0.387±0.107	0.302±0.086	0.374±0.141	0.227±0.085
+ <18.5Kg/m^2 and <=12 months	0.719±0.109	0.665±0.124	0.748±0.099	0.740±0.097	0.694±0.088	0.770±0.110	0.696±0.105
+ >=18.5Kg/m^2 and <=12 months	0.738±0.105	0.723±0.114	0.752±0.098	0.766±0.092	0.734±0.082	0.733±0.120	0.688±0.107
+ >=18.5Kg/m^2 and 13-35 months	0.269±0.099	0.237±0.093	0.321±0.101	0.324±0.098	0.232±0.072	0.258±0.116	0.157±0.065

4. Discussion and conclusions

Analyses are very much in line with the previous finding that breast-feeding practices affect the likelihood of resumption of menstrual cycle after birth. Mothers who breast-feed their child exclusively were less likely to have resumed menstruation. Socio-economic status and education of women were found to be inversely associated with duration of lactational amenorrhea. Living in urban areas of the north and the east regions and higher level of maternal education except the east, northeast and west regions were all associated with a lower likelihood of remaining amenorrheic. It is clear that mother needs a balanced diet based on a variety of nutritious food items especially during pregnancy and lactation. Women from low socio-economic status will not be able to manage the nutritious food. Thus, they may breast-feed their child more frequently or spend more time per day doing it, and as a result have a higher likelihood of remaining amenorrheic. Parity was found to be positively associated with the likelihood of remaining amenorrheic. The reason may be that higher parities women preferred longer duration of breast-feeding as compared to those women who were at lower parities. Mothers who had underweight children were poorly (p>0.05) associated with lactational amenorrhea except in the central region. Moreover, mothers who had underweight children were more likely to remain amenorrheic in the central region. There is a possibility that poorly nourished children are those who are not receiving adequate weaning foods after six months of age and are more likely to breast-feeding more intensively (Kurz *et al.*, 1993; Dewey *et al.*, 1997). Child gender did not have significant impact on the return of ovulation period. It shows that there is no change in the breast-feeding behaviour of mothers by sex of the child.

The interaction term between maternal nutritional status and duration of breast-feeding (child's age) was significantly associated with the likelihood of having resumed menstruation after controlling for breast-feeding practices, child nutritional status and socio-economic and demographic covariates. The effect of maternal nutritional status on lactational amenorrhea was not found to be significant when women were breast-feeding since last 12 months except in the northern region of India. However, after 12 months of breast-feeding, the probability of undernourished women remaining amenorrheic was likely to be greater and this trend was highly consistent across all the six regions included in the analysis. The possibility is that undernourished women have less body fat to support the return of menses after giving birth. As Kurz *et al.* (1993) came out with the findings that poorly nourished women may experience greater inhibition of the ovulatory hormones than better-nourished women, given the same amount of suckling, and so they were found to be more amenorrheic. At the same time, other researchers have also argued that undernourished women produce less milk per nourishing episode (Delgado *et al.*, 1982 and Lunn *et al.*, 1984), and their children need to suck longer or more intensely than children of better-nourished mothers to obtain the amount of milk that they require. This increase in sucking frequency or intensity might be associated with an increase in plasma prolactin level and thus increase the likelihood of being amenorrheic (Loudon *et al.*, 1983).

Thus, the result clearly shows that maternal nutritional status has not had an independent impact on lactational amenorrhea. Gournis *et al.* (1997) have tried to explain the specific biological mechanisms that explain such type of findings. They found that unrestricted access to food (well-nourished) to ovariectomized rats during lactation was associated with higher levels of luteinizing hormone and follicle stimulating hormone. Therefore, these rats had shorter postpartum anestrus period. However, in this seminal study, it was not possible to separate the influence of maternal body composition from behaviours leading to less sucking behaviour on the metabolic/physiologic changes determining the duration of the anestrus period.

In addition to human epidemiologic studies, there is accumulating evidence strongly suggesting that maternal nutritional status does exercise an independent role in the return of menstruation. Leptin, a protein hormone released from adipocytes, appears to play an important role in reproductive performance (Frübeck, 1997). Studies show that there is a crucial link in leptin, maternal nutritional status and postpartum amenorrhea (Kopp *et al.*, 1997). Kurz *et al.* (1993) reported a significant negative relation between maternal nutritional status and postpartum amenorrhea. Further, they have stated that after controlling the infant supplementation, the association became only marginally significant and this study has little biological importance.

However, Loudon *et al.* (1983) has suggested that changes in sucking behaviour are more likely than maternal nutrition per se to influence the duration of postpartum amenorrhea. This study also supports the argument; otherwise the results should be very much consistent across all the six regions of India. Moreover, NFHS-3 data shows that the mean number of day and night time feeds was found to be low in the north and the central regions as compared to rest of the regions of the country. Further, the biologically significant role of maternal nutritional status on postpartum amenorrhea has never been contested, but it is argued that when undernourished women had certain level of duration and intensity of breast-feeding then they were found to be more likely to remain amenorrheic.

Moreover, one could not fully breakdown the effect of socio-economic status on all intermediate and proximate determinants explaining lactational amenorrhea. The fact that socio-economic status remained significantly associated with lactational amenorrhea in India and in countries` all six regions has been considered. It is important for future studies to include the factors such as breast-feeding duration, that is, minutes breast-feeding per day and intensity in the analysis of postpartum amenorrhea, which is not available in NFHS. An attempt should also be made to collect the duration of PPA from those women who were not interested to breast-feed their child but they could not do so because of child loss.

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