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Early-Life Nutritional Status and Its Association with Age at Menarche and Menstrual Characteristics in Young Adult Women: A Retrospective Observational Study

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ABSTRACT

Background: Early-life nutritional status plays a crucial role in determining growth, pubertal maturation, and reproductive health. Age at menarche is a sensitive marker of cumulative childhood nutrition and socioeconomic conditions, and variations in menarcheal timing may influence subsequent menstrual characteristics. ***Objective***: To assess the association between early-life nutritional status and age at menarche, and to evaluate its impact on menstrual characteristics among young adult women. ***Materials and Methods***: This retrospective observational study was conducted in the Department of Obstetrics and Gynaecology, Lord Buddha Koshi Medical College & Hospital, Baijnathpur, Saharsa, Bihar, from August 2024 to November 2025. A total of 300 women aged 18–30 years attending the gynecology outpatient department were enrolled. Information regarding early-life nutritional status, childhood anemia, socioeconomic background, age at menarche, and menstrual characteristics was collected using a structured questionnaire. Statistical analysis was performed using SPSS version 26. ***Results***: The mean age at menarche was 12.9 ± 1.4 years. Women with a history of childhood undernutrition had a significantly delayed age at menarche compared to well-nourished women (13.6 ± 1.3 vs 12.5 ± 1.2 years, p 0.007). Menstrual irregularities, prolonged cycle length, and severe dysmenorrhea were significantly more common among women with early-life nutritional deficiencies. ***Conclusion***: Early-life nutritional status has a significant influence on age at menarche and menstrual characteristics. Strengthening childhood nutrition programs may improve long-term reproductive health outcomes.

Keywords: Age at menarche, childhood nutrition, menstrual cycle, dysmenorrhea, reproductive health.

INTRODUCTION:

Menarche marks a pivotal milestone in female reproductive development, representing the culmination of complex neuroendocrine interactions involving the hypothalamic–pituitary–gonadal axis. The timing of menarche is influenced by genetic, environmental, socioeconomic, and nutritional factors, among which early-life nutritional status is one of the most important and modifiable determinants [1]. Adequate nutrition during childhood is essential for optimal somatic growth, attainment of critical body mass, and hormonal maturation necessary for the onset of menstruation [2].

Globally, a secular decline in age at menarche has been observed over the past century, particularly in developed nations, largely attributed to improvements in childhood nutrition, healthcare access, and living conditions [3]. In contrast, developing countries continue to show heterogeneity in menarcheal age due to persistent disparities in nutrition and socioeconomic status [4]. In India, childhood undernutrition and anemia remain major public health challenges, especially in rural and economically disadvantaged regions, potentially influencing pubertal timing and menstrual health [5].

Early-life nutritional deprivation affects body composition, leptin secretion, and insulin-like growth factor levels, which are critical regulators of gonadotropin-releasing hormone pulsatility [6]. Inadequate fat mass and micronutrient deficiencies, particularly iron deficiency anemia, may delay activation of the reproductive axis, leading to delayed menarche and altered menstrual patterns [7]. Several studies have demonstrated that girls experiencing chronic undernutrition tend to have later menarche and a higher prevalence of menstrual irregularities in adulthood [8].

Menstrual characteristics such as cycle regularity, duration of bleeding, and severity of dysmenorrhea serve as important indicators of reproductive health. Abnormal menstrual patterns are associated with anemia, reduced quality of life, academic and occupational absenteeism, and increased healthcare utilization [9]. The developmental origins of health and disease (DOHaD) hypothesis suggests that adverse exposures during early life, including nutritional deprivation, can have lasting effects on physiological systems, including reproductive function [10].

Despite the high burden of childhood malnutrition in India, limited hospital-based studies have explored its long-term impact on age at menarche and adult menstrual characteristics. Most existing studies focus primarily on age at menarche without examining subsequent menstrual outcomes [11]. Data from Eastern India, particularly Bihar, are scarce. Lord Buddha Koshi Medical College & Hospital caters predominantly to a rural and socioeconomically vulnerable population, making it an ideal setting to examine these associations.

Understanding the relationship between early-life nutritional status and menstrual health has important implications for public health planning and preventive gynecology. Identifying modifiable childhood risk factors may aid in designing interventions aimed at improving reproductive health across the life course. Hence, this study was undertaken to assess the association between early-life nutritional status, age at menarche, and menstrual characteristics among young adult women attending a tertiary care hospital in Bihar.

Objectives

To assess the association between early-life nutritional status and age at menarche, and to evaluate its impact on menstrual characteristics among young adult women.

MATERIALS & METHODS:

This retrospective observational study was conducted in the Department of Obstetrics and Gynaecology, Lord Buddha Koshi Medical College & Hospital, Baijnathpur, Saharsa, Bihar, a tertiary care teaching hospital catering predominantly to a rural and semi-urban population of North Bihar. The study was carried out over a period of sixteen months, from August 2024 to November 2025, after obtaining approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants prior to enrolment, and confidentiality of patient information was strictly maintained throughout the study.

The study population consisted of women aged 18 to 30 years attending the gynecology outpatient department for routine gynecological consultation or minor complaints. Women who were willing to participate and able to provide reliable information regarding their menstrual history and childhood health were included in the study. Pregnant women, women with known endocrine disorders such as polycystic ovarian syndrome, thyroid dysfunction, hyperprolactinemia, or diabetes mellitus, those with a history of pelvic surgery, chronic systemic illness, or those currently receiving hormonal therapy, including oral contraceptive pills or hormonal injections, were excluded to avoid potential confounding effects on menstrual characteristics.

Data collection was carried out using a predesigned, structured, and pretested questionnaire administered through face-to-face interviews. The questionnaire included sections on demographic details such as age, educational status, occupation, and place of residence. Socioeconomic status was assessed using the Modified Kuppuswamy Scale and categorized into low, middle, and high socioeconomic classes.

Information regarding early-life nutritional status was obtained retrospectively based on participant recall and available health records when accessible. Childhood undernutrition was assessed using proxy indicators such as history of poor growth compared to peers, recurrent childhood infections, delayed physical development, and episodes of documented underweight as reported by parents or health records. A history of childhood anemia was recorded based on recalled diagnosis, treatment with iron supplementation during childhood or adolescence, and available medical documentation.

Reproductive history included age at menarche, which was recorded in completed years, along with menstrual cycle characteristics such as cycle regularity, average cycle length in days, duration of menstrual bleeding, and severity of dysmenorrhea. Menstrual cycles were classified as regular if cycle length ranged between 21 and 35 days with consistent periodicity. Dysmenorrhea severity was assessed subjectively using a visual analog scale and categorized as mild, moderate, or severe based on functional impairment.

Anthropometric measurements were obtained at the time of interview. Height was measured to the nearest 0.1 cm using a stadiometer with the participant standing barefoot, and weight was measured to the nearest 0.1 kg using a calibrated digital weighing scale. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared and classified according to World Health Organization criteria as underweight, normal, or overweight/obese.

All collected data were entered into a Microsoft Excel spreadsheet and subsequently analyzed using Statistical Package for the Social Sciences (SPSS) version 26. Continuous variables were summarized as mean and standard deviation, while categorical variables were expressed as frequencies and percentages. Associations between early-life nutritional status and age at menarche were analyzed using Student's t-test. Relationships between categorical variables such as nutritional status and menstrual characteristics were assessed using the chi-square test. One-way analysis of variance (ANOVA) was used to compare mean values across multiple groups where applicable. A p-value of less than 0.05 was considered statistically significant for all analyses.

RESULTS:

Table 1. Demographic Characteristics of Study Participants (n = 300)

Variable	Frequency (%)
Mean age (years)	23.8 ± 3.2
Low socioeconomic status	124 (41.3)
Middle socioeconomic status	142 (47.3)
High socioeconomic status	34 (11.3)

A total of 300 young adult women were included in the study, with a mean age of 23.8 ± 3.2 years. Nearly half of the participants belonged to the middle socioeconomic group (47.3%), while 41.3% were from a low socioeconomic background and only 11.3% belonged to a high socioeconomic status.

Table 2. Early-Life Nutritional Status

Nutritional Indicator	Frequency (%)
Childhood undernutrition	98 (32.7)
Childhood anemia	156 (52.0)
Normal childhood nutrition	202 (67.3)

With regard to early-life nutritional indicators, 32.7% of women reported a history of childhood undernutrition, and more than half of the participants (52.0%) had a history of childhood anemia, whereas 67.3% reported normal childhood nutrition.

Table 3. Age at Menarche Distribution

R	Frequency (%)
<12	84 (28.0)
12–13	132 (44.0)
≥14	84 (28.0)

The distribution of age at menarche showed that 28.0% of participants attained menarche before 12 years of age, 44.0% between 12 and 13 years, and 28.0% at or after 14 years.

Table 4. Early-Life Nutrition and Age at Menarche

Nutritional Status	Mean Age at Menarche (years)	p-value
Well nourished	12.5 ± 1.2	**0.007**
Undernourished	13.6 ± 1.3	

A statistically significant difference in age at menarche was observed between nutritional groups, with women who were well nourished during childhood attaining menarche earlier (12.5 ± 1.2 years) compared to those with childhood undernutrition (13.6 ± 1.3 years), and this difference was statistically significant ($p = 0.007$).

Table 5. Menstrual Characteristics by Nutritional Status

Parameter	Well nourished (%)	Undernourished (%)	p-value
Regular cycles	86.8	71.4	**0.002**
Cycle length >35 days	12.7	42.9	**<0.001**
Severe dysmenorrhea	18.0	36.7	**0.004**

Menstrual characteristics differed significantly according to early-life nutritional status. Regular menstrual cycles were more common among women with normal childhood nutrition (86.8%) compared to those with childhood undernutrition (71.4%). Conversely, prolonged menstrual cycles exceeding 35 days were significantly higher among undernourished women (42.9%) than among well-nourished women (12.7%). Severe dysmenorrhea was also more frequently reported in the undernourished group (36.7%) compared to the well-nourished group (18.0%), with all these differences reaching statistical significance ($p < 0.05$).

Table 6. Association Between Body Mass Index (BMI) and Menstrual Irregularities (n = 300)

BMI Category	Total (n)	Irregular Cycles n (%)	Regular Cycles n (%)
Underweight (<18.5 kg/m²)	98	30 (30.6%)	68 (69.4%)
Normal (18.5–24.9 kg/m²)	226	52 (23.0%)	174 (77.0%)
Overweight/Obese (≥25 kg/m²)	112	58 (51.8%)	54 (48.2%)
Total	300	140 (46.7%)	160 (53.3%)
p-value	**0.006**		

Analysis of body mass index revealed a significant association between BMI and menstrual irregularities. Menstrual irregular cycles were observed in 51.8% of overweight and obese women, compared to 30.6% among underweight women and 23.0% among women with normal BMI. The association between BMI category and menstrual irregularity was statistically significant (p = 0.006).

Table 7. Association Between Age at Menarche and Menstrual Characteristics (n = 300)

Menstrual Characteristic	Early Menarche (<12 yrs) n=84	Normal Menarche (12–13 yrs) n=132	Late Menarche (≥14 yrs) n=84	p-value
Regular cycles n (%)	78 (92.9%)	118 (89.4%)	66 (78.6%)	0.018
Irregular cycles n (%)	6 (7.1%)	14 (10.6%)	18 (21.4%)	
Mean cycle length (days)	28.6 ± 2.4	29.8 ± 3.1	32.4 ± 4.6	0.007
Duration of flow ≥6 days n (%)	14 (16.7%)	26 (19.7%)	38 (45.2%)	0.014
Severe dysmenorrhea n (%)	10 (11.9%)	26 (19.7%)	48 (57.1%)	0.0002

Women who attained menarche at or after 14 years exhibited a higher prevalence of irregular cycles (21.4%), longer mean cycle length (32.4 ± 4.6 days), prolonged menstrual bleeding lasting six days or more (45.2%), and severe dysmenorrhea (57.1%) compared to those with early or normal menarche. A statistically significant trend was observed across menarcheal age groups, indicating worsening menstrual characteristics with increasing age at menarche (p < 0.05).

DISCUSSION:

The present study demonstrates a significant association between early-life nutritional status and age at menarche, as well as subsequent menstrual characteristics. The mean age at menarche observed in the present study (12.9 ± 1.4 years) is comparable to findings reported in Indian studies by Agarwal et al. and Khanna et al., though it remains slightly higher than figures reported from metropolitan populations, reflecting persistent rural nutritional challenges [3,6]. Women with a history of childhood undernutrition in the present cohort experienced a significantly delayed menarche, underscoring the critical role of adequate childhood nutrition in ensuring timely pubertal onset.

These findings are consistent with seminal work by Parent AS, who demonstrated that chronic nutritional deprivation delays pubertal maturation through suppression of hypothalamic–pituitary–gonadal axis activation [3]. Similarly, Kaplowitz PB emphasized the role of body fat and leptin signaling in pubertal initiation, noting delayed menarche among girls with inadequate energy reserves [6]. Classic anthropological studies by Eveleth PB and Tanner JM also documented delayed menarche in nutritionally deprived populations, with differences approaching one year when compared to well-nourished groups [13]. Comparable trends have been observed in Indian cohorts, as reported by Agarwal A et al., highlighting the combined influence of socioeconomic disadvantage and nutritional deficiency on menarcheal timing [12].

Menstrual irregularities were significantly more prevalent among women with a history of early-life undernutrition in the present study. Prolonged menstrual cycle length and increased severity of dysmenorrhea were particularly notable. These observations align with findings by Patton GC and Viner R, who proposed that adverse nutritional environments during critical developmental periods may lead to long-term dysregulation of ovarian steroidogenesis and menstrual cyclicity [7]. Further support comes from studies by Rigon F, et al., who reported higher rates of oligomenorrhea and irregular cycles among women with delayed menarche and suboptimal nutritional backgrounds [14].

Childhood anemia also emerged as a significant factor associated with prolonged menstrual duration and irregular cycles in the present study. Iron deficiency during periods of growth has been shown to affect neurotransmitter synthesis and endocrine regulation, thereby influencing menstrual function [15]. Beard JL and colleagues demonstrated similar associations between iron deficiency and menstrual disturbances, providing biological plausibility to the findings observed in the present cohort [16].

Current body mass index was significantly associated with menstrual irregularities, particularly among overweight and obese women. This finding corroborates the classical hypothesis proposed by Frisch RE and McArthur JW, who highlighted the importance of adiposity in estrogen metabolism and menstrual regulation [17]. However, in the present study, early-life nutritional status showed a stronger and more consistent association with age at menarche than current BMI, emphasizing the lasting imprint of childhood nutrition on reproductive health outcomes.

The major strength of this study lies in its life-course approach and its focus on an underrepresented rural population from Eastern India. Limitations include potential recall bias related to childhood nutritional history and the hospital-based design, which may limit generalizability. Nevertheless, the findings provide meaningful insights into the long-term reproductive consequences of early-life nutritional deprivation and reinforce the importance of improving childhood nutrition as a strategy for promoting optimal gynecological health.

CONCLUSION:

Early-life nutritional status significantly influences age at menarche and menstrual characteristics in young adult women. Childhood undernutrition and anemia are associated with delayed menarche, menstrual irregularities, and increased dysmenorrhea. Strengthening childhood nutrition and anemia control programs may contribute to improved reproductive health outcomes in adulthood.

Declaration:

Conflicts of interests: The authors declare no conflicts of interest.
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