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DECLINING AGE AT MENARCHE IN INDIA: SECULAR TRENDS, DETERMINANTS AND HEALTH IMPLICATIONS – A NARRATIVE REVIEW

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ABSTRACT

Menarche is an important marker of female reproductive maturation and reflects the cumulative effects of genetic, neuroendocrine, metabolic, nutritional, social and environmental influences. Evidence from India indicates that age at menarche has decreased across successive birth cohorts, although the magnitude of change differs between regions and population groups. This narrative review synthesizes recent Indian and international evidence concerning secular changes in menarcheal timing, determinants of earlier maturation, associated health outcomes and implications for adolescent and community health practice. A recent NFHS-based analysis of 578,790 women reported a weighted mean age at menarche of 13.49 years and a decline from 13.78 years in the oldest birth cohort to 13.34 years in the youngest birth cohort examined. Regional differences remain substantial. Childhood adiposity, growth patterns and nutritional transition appear to be among the most consistent modifiable correlates of earlier menarcheal timing. Socioeconomic and lifestyle changes may contribute through multiple pathways, while evidence concerning endocrine-disrupting chemicals and psychosocial stress remains less consistent. Earlier menarche has been associated with later life obesity, metabolic abnormalities, cardiovascular outcomes and some hormone related cancers, although these relationships are influenced by adiposity and other life course factors. The public health response should therefore emphasize healthy growth, prevention of excessive childhood weight gain, menstrual preparedness, supportive school environments, psychosocial support and surveillance of pubertal timing rather than treating early menarche as an isolated disease condition.

Keywords: Early Menarche; Age at Menarche; Puberty; Secular Trend; Adolescent Health; India

1 INTRODUCTION

Menarche the first menstrual bleeding is a readily recognized milestone within female pubertal development. It occurs after progressive activation of the hypothalamic–pituitary–gonadal axis and follows earlier pubertal events such as

breast development. The timing of puberty is shaped by interactions among inherited biological characteristics, neuroendocrine regulation, energy availability, adiposity, childhood growth, psychosocial circumstances and environmental exposures [1]. Age at menarche should be interpreted as the endpoint of a developmental process rather than as the result of one isolated factor. Menarche occurs relatively late in the pubertal sequence changes in menarcheal age may not fully capture changes in the timing of pubertal onset.

Across populations menarcheal timing has historically shifted with changes in nutrition, infectious disease burden, living conditions and socioeconomic circumstances. More recent evidence suggests that the direction and speed of this secular change are not uniform. Some populations continue to show earlier maturation whereas others show stabilization or a slower rate of change. Studies of breast development indicate that shifts in pubertal onset may precede changes detectable through menarcheal age alone [2].

India is undergoing simultaneous nutritional, demographic and lifestyle transitions. Improvements in food availability and living standards coexist with childhood overweight, sedentary behaviour, dietary change and persistent undernutrition. These contrasting conditions provide a complex context for interpreting changes in pubertal timing. Recent national and regional studies have strengthened the evidence base and provide an opportunity to examine the Indian trend without attributing it prematurely to a single cause [3,5].

Aim

This narrative review aims to synthesize current evidence on secular trends in age at menarche in India, examine biological, nutritional, socioeconomic, environmental and psychosocial factors associated with menarcheal timing, summarize the potential health implications of earlier menarche, and discuss implications for adolescent health, nursing practice and public health.

2 SECULAR TRENDS IN MENARCHEAL AGE

The NFHS-based analysis reported a weighted mean age at menarche of 13.49 ± 1.21 years. Approximately 66.2% of women experienced menarche between 13 and 14 years of age while 17.2% were classified as having early menarche and 16.7% as having late menarche according to the operational definitions used in the study. In this analysis early menarche referred to menarche occurring before 13 years of age. This population level classification should not be equated with clinically defined precocious puberty, which refers to the unusually early onset of pubertal development. Marked regional variation was also observed with the lowest mean age in the Northeast and higher values in several other regions [3].

A prospective study of North Indian girls estimated a decline of approximately 0.41 years per decade during the contemporary period and also showed that Tanner stage provided useful information about pubertal maturation [4]. A three-generation study from Chandauli district, Uttar Pradesh, reported a reduction of about 1.66 years in mean age at menarche between women older than 40 years and participants younger than 20 years. Dietary and lifestyle characteristics including frequent junk-food consumption and leisure patterns were associated with differences in menarcheal age in that population [5]. These regional findings should not be interpreted as national estimates but they illustrate the heterogeneity underlying the overall Indian trend.

Population analyses suggest that environmental and demographic conditions may interact with menarcheal timing. An analysis comparing Indian survey data from 1992–1993 and 2019–2021 found modest decreases in menarcheal age across most states and reported associations with educational attainment and climatic variables such as specific humidity and temperature [6]. These findings should be interpreted as contextual associations rather than evidence of causal effects of climate on menarcheal timing

International evidence is broadly compatible with continued movement toward earlier pubertal timing but the magnitude of change differs between populations. A large pooled analysis of more than half a million women from Asian cohorts demonstrated differences in menarcheal age across birth cohorts and countries [7]. Contemporary studies therefore support a model of secular change that is population-specific rather than a uniform global decline.

Table 1: Recent evidence on changes in menarcheal timing

Population/study	Design/source	Main finding	Interpretation
India	NFHS-based population analysis, 2024	Mean age 13.49 years; 13.78 to 13.34 years across birth cohorts	Long-term decline with marked regional variation [3]
North India	Prospective study, 2023	Estimated decline of about 0.41 years/decade	Recent advancement in a regional cohort [4]
Chandauli, Uttar Pradesh	Primary three-generation study, 2025	Mean age 14.89 years in >40-year group versus 13.23 years in <20-year group	Generational differences associated with dietary, lifestyle and socioeconomic factors [5]
India	Survey and climate analysis, 2025	Slight decrease across most states with demographic and climatic associations	Suggests multiple contextual influences; causality remains uncertain [6]
Asia	Pooled cohort analysis, 2024	548,830 women across six Asian countries	Demonstrates heterogeneous cohort patterns across Asia [7]

3 DETERMINANTS OF EARLIER MENARCHE

3.1 Genetic and neuroendocrine influences

Pubertal timing has a substantial inherited component, but genetic susceptibility does not mean that the timing of menarche is genetically fixed. The hypothalamic–pituitary–gonadal axis is activated through coordinated neuroendocrine signaling, including regulation of gonadotropin-releasing hormone neurons. Metabolic information and peripheral signals interact with this system to determine whether sufficient biological conditions for reproductive maturation are present [1]. Genetic variation therefore provides a background susceptibility on which nutritional and environmental conditions act.

3.2 Nutrition, adiposity and childhood growth

Among modifiable influences, body composition and childhood growth have some of the most consistent associations with earlier pubertal development. Indian evidence indicates that changing dietary and lifestyle patterns are associated with differences in menarcheal age, while international evidence supports the role of childhood adiposity and growth in pubertal timing [5,8].

Adipose tissue is metabolically active and communicates with the hypothalamic and peripheral endocrine systems through leptin, insulin and other metabolic signals. Thus, excess adiposity may facilitate conditions associated with earlier maturation. The traditional concept that puberty begins after attainment of a single critical percentage of body fat is overly simplistic. [1,8].

India's coexistence of undernutrition and excess weight is particularly relevant. Chronic undernutrition and severe illness may delay maturation whereas excess childhood adiposity may be associated with earlier timing. Catch-up growth may add another layer of complexity. Consequently, the appropriate public-health goal is healthy growth across childhood rather than weight reduction as an isolated strategy.

3.3 Socioeconomic, urban and lifestyle influences

Socioeconomic conditions can influence pubertal timing through diet, healthcare access, infection exposure, educational opportunity, housing and other living conditions. The recent NFHS analysis demonstrated socioeconomic and geographic patterning of menarcheal age in India [3]. The Chandauli study also identified associations with dietary and leisure behaviours [5]. These findings indicate that socioeconomic variables should be interpreted as pathways that shape exposure and opportunity rather than as direct biological causes.

Sedentary behaviour energy-dense diets and changes in sleep or screen use are biologically plausible contributors, particularly when they affect energy balance. The evidence is less consistent for sleep duration, screen exposure and artificial light as independent predictors of menarche. These variables should therefore be described as possible contributors rather than established primary determinants.

3.4 Environmental and psychosocial influences

3.4.1 Endocrine-disrupting chemicals

Endocrine-disrupting chemicals have attracted attention because some compounds can interact with estrogenic, androgenic, thyroid or metabolic pathways. A longitudinal cohort study in China involving 546 girls aged 6–8 years followed for two years found that selected phthalate metabolites were associated with earlier pubertal progression. Similarly a European multi-cohort study reported associations between exposure to endocrine-disrupting chemicals, including bisphenol A (BPA) and parabens and pubertal development, although the direction of the associations varied across chemicals, exposure periods, sex and pubertal outcomes [9,10]. In addition, a follow-up study of adolescent girls reported associations between prenatal phthalate exposure and selected reproductive hormones and ovarian characteristics at 16 years of age. Taken together these findings suggest that endocrine-disrupting chemicals may influence pubertal development through multiple pathways but their contribution to changes in age at menarche remains uncertain. Longitudinal research particularly in Indian populations, is needed to clarify the effects of specific chemicals and critical windows of exposure[11].

At present there is insufficient evidence to attribute the secular decline in age at menarche in India to exposure to endocrine-disrupting chemicals. Differences in exposure mixtures, timing and levels of exposure as well as methods used to assess pubertal development make comparisons across studies difficult. Longitudinal studies in India incorporating repeated exposure measurements and standardized assessment of pubertal outcomes are needed before causal relationships can be established.

3.4.2 Psychosocial stress and adversity

Psychosocial conditions may influence developmental timing through interactions between stress physiology, behaviour, nutrition and metabolic pathways. A cohort study involving more than 14,000 children examined maternal stress during pregnancy in relation to pubertal timing and explored childhood BMI and psychosocial stress as possible pathways [12]. Such findings support continued investigation but do not justify treating stress as an independent universally applicable cause of earlier menarche.

3.5 Psychological consequences of early menarche

Early menarche may be associated with psychological vulnerability because physical maturation can occur before adolescents have developed corresponding emotional and social resources. Recent meta-analyses published in 2025 reported an association between earlier menarche and depressive outcomes, although heterogeneity and the predominantly observational nature of the evidence limit causal interpretation [13,14]. The appropriate clinical response is therefore awareness and proportionate psychosocial support rather than assuming that every early-maturing girl will develop a mental health disorder.

3.6 Menstrual preparedness and social environment

The experience of early menarche is shaped by whether adolescents have received accurate information and whether their schools provide privacy, water, sanitation and appropriate menstrual support. Recent Indian study from Odisha examined menstrual health and hygiene practices and their predictors among adolescent girls and women of reproductive age [15]. These findings reinforce the importance of preparing girls before menarche rather than waiting until menstruation has begun.

4 HEALTH IMPLICATIONS OF EARLIER MENARCHE

Age at menarche should be considered a marker within a life-course pattern rather than a direct, isolated cause of adult disease. Associations may arise through shared pathways involving childhood adiposity, insulin resistance, reproductive hormone exposure, socioeconomic circumstances and other cumulative influences.

4.1 Obesity and metabolic health

Earlier menarche has repeatedly been associated with higher adiposity in adulthood, but recent evidence also demonstrates that the relationship with diabetes is not uniform. Importantly for India, a prospective analysis from the CARRS cohort followed 3,654 women free of diabetes for a median of 9.2 years and found no significant association between age at menarche and incident type 2 diabetes after multivariable adjustment (HR 1.04, 95% CI 0.95–1.14) [16]. The finding argues against presenting early menarche as an independent and inevitable cause of diabetes.

Contemporary research continues to identify associations between menarcheal timing and metabolic risk factors. A study of women participating in the Tehran Lipid and Glucose Study examined age at menarche in relation to metabolic

syndrome and its components across birth cohorts [17]. The evidence supports monitoring of healthy growth and cardiometabolic risk without overstating causality.

4.2 Cardiovascular health

The association between menarcheal age and cardiovascular disease appears complex and may be nonlinear. An analysis combining observational and Mendelian-randomization approaches reassessed the relationship and highlighted the importance of distinguishing association from causation [18]. A contemporary cohort study also examined menarcheal age in relation to cardiovascular risk factors [19]. These findings support viewing pubertal timing as one component of a broader risk profile rather than as a stand-alone cardiovascular diagnosis.

4.3 Breast and hormone-related cancers

Earlier menarche is associated with breast cancer risk in large epidemiological evidence. The Collaborative Group on Hormonal Factors in Breast Cancer pooled individual-level data from 117 studies and found that breast cancer risk increased with younger age at menarche [20]. More recent genetic and epidemiological analyses continue to examine whether this relationship reflects a causal effect of pubertal timing or shared biological pathways [21]. In adolescent health practice early menarche should therefore be regarded as a life-course marker rather than interpreted as a prediction that an individual girl will develop cancer.

4.4 Reproductive and psychosocial health

Earlier pubertal development may coincide with psychosocial challenges, earlier exposure to reproductive health risks and greater need for age-appropriate counselling. These associations are strongly influenced by social context. Nursing care should focus on accurate puberty education, confidential communication, safeguarding, menstrual support and access to adolescent-friendly services rather than labelling girls on the basis of menarcheal age alone.

5 PUBLIC-HEALTH AND NURSING IMPLICATIONS

5.1 Promote healthy childhood growth

Health promotion should encourage balanced nutrition, adequate micronutrient intake, regular physical activity and prevention of excessive weight gain while avoiding weight stigma. Programmes should recognize India's double burden of undernutrition and overweight.

5.2 Provide menstrual education before menarche

Puberty and menstrual education should begin before the expected age of menarche. Essential content includes the physiology of puberty, expected menstrual patterns, menstrual pain management, hygiene, product choices, safe disposal, common myths and warning signs requiring professional assessment. Early education can reduce fear and improve preparedness.

5.3 Strengthen menstrual-friendly schools

Schools should combine education with practical facilities, including water, sanitation, privacy, safe disposal and access to menstrual products. Menstrual-health programmes should also address pain, stigma, restrictions and absenteeism. Nurses can coordinate education, screening, referral and school-health advocacy.

5.4 Recognize abnormal pubertal development

A population-level reduction in menarcheal age does not mean that every early presentation is normal. The appearance of early secondary sexual characteristics, rapid progression or other concerning features warrant clinical assessment. Nurses can contribute by documenting pubertal history, recognizing atypical patterns, providing reassurance and facilitating referral.

5.5 Provide psychosocial support

Girls who mature earlier may benefit from additional attention to body image, emotional wellbeing, peer relationships and menstrual stigma. Screening should be confidential and proportionate. Current evidence supports awareness of depressive symptoms but does not justify assuming psychopathology on the basis of early menarche alone [13,14].

5.6 Strengthen surveillance and research

India would benefit from standardized monitoring of pubertal timing alongside nutrition and adolescent-health indicators. Future studies should distinguish thelarche from menarche, use prospective measurements where feasible,

document anthropometry and socioeconomic conditions and incorporate environmental exposures. Regional surveillance would help determine whether the decline is continuing, stabilizing or diverging among population groups.

6 DISCUSSION

Recent evidence strengthens the conclusion that menarcheal age has declined in India across generations, but the change is gradual, heterogeneous and dependent on the population and time period studied. The 2024 NFHS-based analysis provides the strongest recent national evidence while regional studies demonstrate that local trends can be considerably different [3,5]. The Indian literature also illustrates why a single explanation is inadequate. Nutritional transition, childhood adiposity, socioeconomic change and lifestyle patterns interact, while environmental and psychosocial influences remain areas of active investigation.

The health significance of earlier menarche is similarly multifaceted. Associations with adiposity and cardiometabolic risk are supported by a substantial literature, but the recent Indian CARRS findings demonstrate that an association observed in other populations should not automatically be assumed to apply to Indian women [16]. Cardiovascular evidence is also evolving, with contemporary analyses suggesting that the relationship may be nonlinear and potentially confounded by broader life-course factors [18,19].

The most important implication is not avoid medicalizing normal variation in pubertal development. Earlier menarche should provide an opportunity for anticipatory guidance, menstrual preparedness, healthy-growth promotion, psychosocial support and appropriate assessment when puberty appears unusually early or progresses rapidly. School and community nurses are particularly well placed to integrate these functions.

Limitations

It is a narrative rather than a registered systematic review and therefore does not provide a formal risk-of-bias assessment or quantitative meta-analysis. The included studies use different definitions of early menarche and different methods for measuring pubertal timing. Much Indian evidence is based on retrospective recall which can introduce measurement error. Associations between early menarche and adult outcomes may also reflect residual confounding by adiposity, socioeconomic circumstances and other life-course exposures. The availability of recent Indian studies remains uneven across regions limiting national generalizability of some local findings.

7 CONCLUSION

Current evidence indicates a continuing but heterogeneous decline in age at menarche in India. Recent national and regional studies support important contributions from nutritional transition, childhood adiposity, growth, socioeconomic circumstances and lifestyle, while environmental and psychosocial pathways remain less certain. Earlier menarche is associated with several later-life health outcomes, but these associations should be interpreted in the context of confounding and population differences. Public-health and nursing strategies should focus on healthy childhood growth, anticipatory menstrual education, supportive school environments, psychosocial wellbeing, recognition of atypical pubertal development and improved surveillance of pubertal timing.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare that they have no competing interests.

Declaration of originality

This manuscript has been newly prepared for submission and is not being considered simultaneously by another journal. The text has been independently rewritten and synthesized from the cited literature; source material has been paraphrased rather than reproduced verbatim.

Author Contributions

Contributor	Concept	Study design	Data collection	Statistical Analysis	Literature Review	Discussion	Fund Generation
Ms.Saru Krishna A	√	√	-	-	√	√	-
Ms.Neethu M	√	√	-	-	√	√	-

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