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Age at menarche in South Asia: an interplay of sociodemographic, nutritional, lifestyle, anthropometric, biological, and environmental factors—a systematic review

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ADMINISTRATIVE INFORMATION

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INTRODUCTION

Review question / Objective The present review aims to examine evidence on sociodemographic, nutritional, lifestyle, anthropometric, biological, and environmental factors associated with age at menarche among females aged 8-21 years in South Asia.

Rationale An early or late age at menarche is associated with significant long-term health complications Evidence suggests that early age at menarche is associated with an increased risk of breast and endometrial cancers, obesity, and cardiometabolic disorders such as type 2 diabetes While delayed onset is associated to long-term health problems such as osteoporosis-sis, poor bone mineral density, subfertility, and psychosocial stress Subsequently, the trajectory of healthy aging can be affected by these factors. The co-occurrence of early age at menarche among over-nourished females and delayed menarche in undernourished females exacerbates the dual burden of malnutrition. This pattern is distinct in South Asia, highlighting the nutritional transition and related challenges faced by this region. In addition to social, nutritional, and lifestyle transition, biological factors, specifically heredity, are also identified as a strong influencing factor that determines the age at menarche. The early life environment, particularly during the developmental phase, is influenced by certain factors, including maternal age, nutritional status, prenatal nutrition, and birth order, which significantly impact birth weight and fetal development, and eventually influence the age at menarche. Additionally, Exposure to poor environmental factors, including household use of smoking, alcohol, and tobacco; climate change; exposure to environmental toxins, and endocrine-disturbing chemicals are recognized as a key driver of menarcheal timings. Despite growing evidence, a wide range of differences in the age at menarche without any specific pattern has been observed across South Asia. These disparities are attributed to the complex interplay of sociodemographic factors,

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nutritional, lifestyle, biological, and environmental factors. The sociodemographic, nutritional, lifestyle, anthropometric, biological, and environmental factors associated with age at menarche among females aged 8-21 years remained underexplored, especially in the South Asian context. The patterns and gaps observed in the review will help build adolescent health and nutrition strategies and support future research.

Condition being studied All included studies examined to evaluate the association between increasing or decreasing trends in menarcheal age among adolescent females aged 8–21 years, with factors including 1). sociodemographic characteristics (parental education, socioeconomic status, place of residence) 2). Nutrition & lifestyle factors (physical activity, dietary patterns, sleep habits, stress) 3). Anthropometric parameter: Nutritional status parameter (Height, weight, BMI, waist circumference, hip circumference, waist to hip ratio, Body frame assessment parameter such as bi-acromial width, bi-iliac width, and arm span; malnutrition indicators: stunting/HAZ score, wasting/WHZ scores, underweight/WAZ scores, overweight or obese (Z score of BMI-for-age>-2SD) 4).Biological factors (Birth weight, maternal or sibling's age at menarche, birth order); and 5). environmental factors. Trends in the age at menarche over time were also assessed.

METHODS

Search strategy The search strategy utilized a combination of well-defined key words or MeSH terms as follows: [“child, female” OR “adolescents, female” OR “adolescent, female” OR “female adolescent” OR “female adolescents”] AND [“menarche” OR “age factors” OR “age at onset of menarche” OR “secular trend” OR “puberty” OR “pubertal maturation”] AND [“malnourishment” OR “malnourishments” OR “undernutrition” OR “nutritional deficiency” OR “nutritional deficiencies” OR “under-nutrition” OR “underweight” OR “stunting” OR “nutritional Status” OR “anthropometry” OR “overnutrition” OR “overweight” OR “obesity” OR “body weights and measure” OR “body mass index” OR “waist-hip ratio” OR “factor, Sociodemographic” OR “factors, sociodemographic” OR “sociodemographic Factor” OR “exposure, environ-mental” OR “environmental exposures” OR “exposures, environmental” OR “dietary Patterns” OR “dietary habits” OR “food habits” OR “habit, food” OR “eating habits” OR “eating habit” OR “habit, eating” OR “dietary habits” OR “ultra-processed foods” OR “food, ultra-Processed” OR “environmental exposure” OR “drug effect” OR “radiation exposure” OR “lifestyle factors” OR “factor, lifestyle” OR “stress, psychological” OR “physical Activity” OR “activities, physical” OR “activity, physical” OR “physical activities” OR “exercise, physical” OR “exercises, physical” OR “sedentary lifestyle” OR “life-style, sedentary” OR “physical inactivity” OR “inactivity, physical” OR “lack of physical activity”] AND [“Afghanistan” OR “Bangladesh” OR “Bhutan” OR “India” OR “Maldives” OR “Nepal” OR “Pakistan” OR “Sri Lanka” OR “South Asia”]. The search strategy utilized a combination of well-defined keywords and MeSH terms (where applicable) for each database, ensuring comprehensive coverage of the research question

Participant or population Preadolescent, adolescent, and late adolescent females (8 - 21 years old) residing in South Asian countries, including India, Pakistan, Bangladesh, Nepal, Bhutan, Sri-Lanka, Maldives, and Afghanistan, whose age of menarche was reported.

Intervention Not applicable.

Comparator South Asian countries (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka).

Study designs to be included Observational study (cross-sectional study, case control, and cohort study).

Eligibility criteria The eligibility criteria for the review were structured according to the PICOS (Population, Intervention, Comparison, Outcome, Study design, Timeframe) framework to ensure clarity and consistency in the selection of studies.
Inclusion Criteria: Preadolescent, adolescent, and late adolescent (8 - 21 years old) residing in South Asian countries, including India, Pakistan, Bangladesh, Nepal, Bhutan, Sri-Lanka, Maldives, and Afghanistan, whose age of menarche was reported.
Exclusion Criteria: Studies involving male participants, females younger than 8 years, populations outside the 8–21-year age range, or clinical populations with specific health conditions known to significantly influence age at menarche (e.g., Turner’s syndrome, polycystic ovarian syndrome [PCOS], chronic illnesses, or genetic disorders) were excluded.

Information sources An extensive and structured literature search was carried out in four databases, including PubMed, Web of Science, Science Direct, and Google Scholar, to identify appropriate full-text research articles published in the English

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language across the period of 1st January 2014 and 31st May 2025. The final search was conducted on 15 July 2025. Additionally, manual screening of the reference lists of included articles was conducted to identify other eligible studies.

Main outcome(s) All included studies were examined to evaluate the association between increasing or decreasing trends in menarcheal age among adolescent females aged 8–21 years and factors, including 1). sociodemographic characteristics (parental education, socioeconomic status, place of residence) 2). Nutrition & lifestyle factors (physical activity, dietary patterns, sleep habits, stress) 3). Anthropometric parameter: Nutritional status parameter (Height, weight, BMI, waist circumference, hip circumference, waist to hip ratio, Body frame assessment parameter such as bi-acromial width, bi-iliac width, and arm span; malnutrition indicators: stunting/HAZ score, wasting/WHZ scores, underweight/WAZ scores, overweight or obese (Z score of BMI-for-age>-2SD) 4).Biological factors (Birth weight, maternal or sibling's age at menarche, birth order); and 5). environmental factors. Trends in the age at menarche over time were also assessed.

Additional outcome(s) None.

Data management All identified records were imported into the COVIDENCE 2.0 systematic review software (Veritas Health Innovation, Melbourne, Australia) in RIS file format from Science Direct as well as Web of Science, and in PubMed file format from the PubMed databases. All duplicate articles were removed. The study selection process was conducted in two stages. In the first step, title and abstract screening were conducted independently by two reviewers. In case of any uncertainty or disagreement, the study was retained for the next phase. In the next stage same two reviewers independently screened the full-text research articles to include the eligible studies in the review. Any discrepancies or disagreements at every stage of the review process were resolved through discussion with a third reviewer. The full-text articles published in the English language were retained for the review.

Quality assessment / Risk of bias analysis We assessed the methodological quality of the eligible studies using tools developed by the Joanna Briggs Institute (JBI), Australia (36). An appropriate JBI checklist, based on study design (cross-sectional or case-control), was utilized to assess the studies (Supplementary Tables S3, S4—JBI Checklist). Two reviewers (RTW and AAM) appraised the studies independently and rated each question as “yes,” “no,” “unclear,” or “not applicable.

Strategy of data synthesis Data were systematically extracted from all included full-text articles and organized in a Microsoft Excel spreadsheet. The data on mean age at menarche and prevalence, as reported in the studies, were extracted. Furthermore, the variables were recorded in a standardized format as follows: author(s), year, country, data collection method, sample size, the reported mean age at menarche, predictors of the age at menarche onset, and overall findings. All included studies were reviewed to assess the reported age at menarche and the factors influencing this age. The analysis focused exclusively on modifiable risk factors that influence the timing of menarche. These factors were grouped into categories as follows:

i. Sociodemographic factors: Place of residence (rural/urban), economic status, wealth index, parental educational and occupational status, birth order, caste, and religion.

ii. Nutritional & Lifestyle factors: Dietary factors, including dietary habits and dietary pattern, history of complementary or breastfeeding practices; screen time, sleep, physical activity, and stress.

iii. Anthropometric factors: Nutritional status indicators, including undernutrition (stunting, wasting, underweight) and overnutrition (overweight and underweight, body mass index, other nutritional deficiencies, and any other anthropometric measurements such as skeletal frame, bi-acromial width, bi-iliac width, and arm span.

iv. Biological factors: Mother’s or sister’s age at menarche, birth weight.

v. Environmental factors: Exposure to medicine, chemicals, or any other environmental toxins, such as household or parental use of smoking, alcohol, or any other substance.

Subgroup analysis Not applicable.

Sensitivity analysis Not applicable.

Language restriction Study published in the English language only.

Country(ies) involved India.

Other relevant information This systematic review encompassing 18 selected research articles critically examined the association between sociodemographic, nutritional, lifestyle, anthropometric, biological, and environmental factors and the age at menarche among females aged 8–21 years in the underexplored South Asian

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region. The mean age at menarche across most South Asian studies lies within 12–13 years, aligning well with global averages. However, the reported mean age of menarche in studies from Bhutan, Bangladesh, and Nepal was under 12 years, whereas the prevalence of late menarche after 14 years of age was reported in some Indian studies, indicating significant sub-regional variation in mean age at menarche..Menarche occurring before the age of 12 years was consistently associated with sociodemographic factors such as urban residence, and a higher standard of living; lifestyle factors, including higher BMI, sleep, and physical activity, higher consumption of fruits and vegetables and non-vegetarian diet, excessive screen time, and biological/environmental factors like low birth weight, absence of biological father, mothers' age at menarche, and exposure to environmental factors. Conversely, menarche occurring after 14 years of age was associated with rural residence, lower socioeconomic status, and undernutrition (stunting and underweight).

Keywords female adolescent; age at menarche; undernutrition; overnutrition; stunting; anthropometry; sociodemographic factors; nutrition and lifestyle factors; South Asia.

Dissemination plans This review underlines the multifactorial role of various determinants of age of menarche, including socio-demographic, nutritional, and lifestyle patterns, and the health implications associated with early and late menarche among adolescents. Early menarche was observed consistently among urban adolescents in higher socioeconomic families, while late menarche was common in rural settings. However, mixed results across studies suggest regional, cultural, and contextual differences affecting menarche timing. While undernutrition and stunted growth led to delayed menarche. The early menarche was a result of obesity, high adiposity among girls, along with a sedentary lifestyle, stress, and a high-calorie dietary pattern. Although biological factors such as maternal nutritional status, early nutrition, and birth weight are non-modifiable for the individual, they are crucial factors in the growth and development trajectories in the future. Thus, an intergenerational approach to optimise the age at menarche should be highlighted. By addressing the modifiable factors such as dietary patterns, physical activity, stress, and lifestyle, the timing of menarche can be balanced. This review generates evidence specifically for the South Asian population on menarcheal timing and its influencing factors to apprise and tailor the public health and nutritional interventions for better health outcomes in adolescence and womanhood.

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