



Dietary Patterns and Hormonal and Psychological Imbalances in Girls with Precocious Puberty: A Descriptive Review

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الأنماط الغذائية والاختلالات الهرمونية والنفسية لدى الفتيات المصابات بالبلوغ المبكر: دراسة وصفية

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Abstract

Precocious puberty in girls is an increasing public health concern, particularly in societies experiencing rapid nutritional transitions. Beyond genetic and endocrine factors, growing evidence suggests that dietary patterns may be associated with hormonal dysregulation and psychological disturbances. This descriptive review synthesizes observational literature examining the relationship between dietary habits and hormonal and psychological imbalances in girls with precocious puberty. Findings indicate that diets high in energy density, ultra-processed foods, added sugars, and animal fats are commonly linked to altered hormonal profiles and greater psychological vulnerability, whereas more balanced dietary patterns tend to be associated with relatively stable hormonal regulation and better psychosocial outcomes. Nevertheless, the evidence remains heterogeneous and context-dependent, underscoring the need for further well-designed observational studies, particularly in underrepresented settings.

Keywords : Precocious puberty; Dietary patterns; Hormonal imbalance; Psychological well-being; Girls; Descriptive studies

الملخص

يُعد البلوغ المبكر لدى الفتيات من القضايا الصحية المتزايدة، خاصة في المجتمعات التي تشهد تحولات غذائية سريعة. وإلى جانب العوامل الوراثية والهرمونية، تشير الأدلة إلى وجود علاقة محتملة بين الأنماط الغذائية والاختلالات الهرمونية والنفسية المصاحبة للبلوغ المبكر. تهدف هذه الدراسة الوصفية إلى تلخيص الأدبيات الرصدية التي تناولت تأثير العادات الغذائية على المؤشرات الهرمونية والحالة النفسية لدى الفتيات المصابات بالبلوغ المبكر. وتُظهر النتائج أن الأنماط الغذائية عالية السعرات والغنية بالأغذية فائقة التصنيع والسكريات المضافة والدهون الحيوانية ترتبط غالبًا باضطرابات هرمونية وزيادة القابلية للمشكلات النفسية، في حين ترتبط الأنماط الغذائية المتوازنة باستقرار نسبي في التنظيم الهرموني وتكيف نفسي أفضل. ومع ذلك، لا تزال النتائج متباينة وتعتمد على السياق، مما يستدعي مزيدًا من الدراسات الوصفية المنهجية.

الكلمات المفتاحية : البلوغ المبكر؛ الأنماط الغذائية؛ الاختلال الهرموني؛ الصحة النفسية؛ الفتيات؛ الدراسات الوصفية

1. Introduction

1.1 Background of the Study

Precocious puberty in girls is defined as the appearance of secondary sexual characteristics, especially breast development, before the age of eight (Carel et al., 2020). Over the past decades, an increasing trend in early puberty has been observed globally, particularly in societies experiencing rapid nutritional and lifestyle transitions (Zhu et al., 2023). This early onset is not just a biological phenomenon; it has broader implications for physical growth, psychosocial development, and long-term health. Early puberty can be associated with shorter adult stature, increased risk of metabolic disorders, and emotional challenges (Parent

et al., 2021). The rising prevalence, combined with changing environmental and dietary conditions, highlights the need for a comprehensive understanding of the factors influencing precocious puberty.

1.2 Biological and Hormonal Basis of Precocious Puberty

Puberty is controlled by the hypothalamic–pituitary–gonadal (HPG) axis, which is normally inactive during childhood and becomes activated when puberty begins (Plant & Barker-Gibb, 2020). The hypothalamus secretes gonadotropin-releasing hormone (GnRH) in pulses, stimulating the pituitary to release luteinizing hormone (LH) and follicle-stimulating hormone (FSH). These hormones trigger estrogen production in the ovaries, leading to the development of secondary sexual characteristics.

In central precocious puberty (CPP), this HPG axis activates earlier than normal, causing premature sexual development that follows the usual sequence but at an earlier age (Carel et al., 2020). Most cases in girls are idiopathic, although rare cases may result from central nervous system lesions or genetic mutations affecting regulators of GnRH secretion such as *MKRN3* and *KISS1* (Abreu & Kaiser, 2019). The timing of puberty is sensitive to metabolic cues; higher body fat and signals such as leptin may lower the threshold for HPG activation, accelerating onset (Ahmed et al., 2019). Environmental factors that interfere with hormone regulation may also contribute, though mechanisms are not fully understood (Gore et al., 2020).

1.3 Dietary Patterns and Pubertal Timing

Diet is one of the key modifiable factors influencing pubertal timing. Observational studies have shown that dietary patterns rich in vegetables, fruits, and minimally processed foods are associated with later onset of puberty, while diets high in ultra-processed foods, added sugars, and animal fats are linked with earlier puberty (Liu et al., 2024; Zhang et al., 2024). These patterns affect hormonal balance indirectly through body composition, inflammatory status, and metabolic signaling (Jones et al., 2020).

For example, girls following a “traditional” diet with balanced nutrient intake had lower odds of precocious puberty, whereas high-energy, processed diets increased the risk. Although causality cannot be concluded from these observational studies, the consistency of results across different populations suggests that dietary modification could be a preventive strategy.

1.4 Psychological Dimensions of Precocious Puberty

Early puberty also has psychological implications. Girls who mature earlier than peers often face emotional distress, low self-esteem, anxiety, and social challenges (Mendle et al., 2020). Hormonal changes, particularly in estrogen, can affect brain regions responsible for mood regulation, increasing susceptibility to depression and behavioral problems (Byrne et al., 2021). Contextual factors such as family support, peer interactions, and cultural attitudes toward early maturation can exacerbate or mitigate these effects (Copeland et al., 2019). Diet may also indirectly affect mental health through metabolic and inflammatory pathways, highlighting the interconnectedness of nutrition, hormonal regulation, and psychological outcomes (Oddy et al., 2020).

1.5 Research Gap

Despite growing interest, current research is fragmented. Many studies examine diet, hormones, or psychological outcomes in isolation. There is a lack of comprehensive descriptive studies integrating these dimensions, particularly in underrepresented cultural or geographic settings. Most evidence is observational, and longitudinal data are limited. This gap justifies a systematic descriptive review to synthesize available evidence and highlight areas for future research.

1.6 Aim of the Study

The primary aim of this descriptive review is to examine existing observational evidence on the relationship between dietary patterns and hormonal and psychological imbalances in girls with precocious puberty. The study specifically seeks to:

1. Describe common dietary patterns among girls with early puberty.
2. Summarize associations between these dietary patterns and hormonal regulation.
3. Explore links between dietary habits and psychological outcomes.

1.7 Significance of the Study

This study is significant because it integrates dietary, hormonal, and psychological factors into a single descriptive framework, providing a more complete understanding of precocious puberty. The findings may guide clinicians, nutritionists, and public health professionals in identifying modifiable lifestyle factors, promoting preventive strategies, and informing culturally sensitive interventions.

1.8 Scope and Delimitations

This review focuses exclusively on girls with precocious puberty, examining observational and descriptive studies related to dietary patterns, hormonal profiles, and psychological outcomes. Interventional or experimental studies are excluded. Cultural and regional differences are considered, but the study is limited to published literature in English from 2020–2024.

2. Literature Review

This chapter critically synthesizes observational evidence from recent peer-reviewed research on the associations between dietary patterns and precocious puberty in girls, with attention to hormonal and related developmental outcomes. Emphasis is placed on descriptive, non-interventional studies that examine diet across populations, using validated epidemiological methods.

2.1 Summary of Key Studies

Author (Year)	Design	Population/Sample	Dietary Focus	Key Findings
Zhang et al. (2024)	Case-control	185 girls with precocious puberty; 185 age-matched controls (China)	Vegetable/protein vs animal-food/fruits patterns	High vegetable/protein diet associated with lower odds of precocious puberty; high animal-food/fruits pattern associated with higher odds.
Wang et al. (2024)	Cross-sectional	4,085 Chinese children (girls and boys)	Traditional vs Westernized dietary patterns	Traditional dietary pattern negatively associated with early and precocious puberty.
Du et al. (2024)	Cross-sectional	Girls with onset of puberty vs controls (exact sample size not specified in abstract)	General dietary behaviors	Reported significant associations between dietary behavior patterns and pubertal onset.
Brennan et al. (2020)	Prospective cohort	Children followed longitudinally in DONALD study	Overall diet quality scores	Higher overall diet quality associated with later puberty onset independent of body fat.

2.2 Dietary Patterns and Pubertal Timing

Recent observational research points to consistent associations between diet quality and timing of puberty onset. Zhang et al. (2024) conducted a paired case–control study in Chinese girls, finding that a dietary pattern high in vegetables and proteins was significantly negatively associated with precocious puberty (OR = 0.78; 95% CI = 0.63–0.97), whereas a pattern characterized by high animal food and fruit intake was positively associated with increased risk (OR = 1.36; 95% CI = 1.09–1.69) after adjustment for age and BMI (Zhang et al., 2024).

Complementing this, population-based cross-sectional evidence indicates that a traditional dietary pattern typically involving minimally processed foods and diverse whole foods is inversely associated with early and precocious puberty among children, including girls (Wang et al., 2024).

Further, longitudinal work from the DONALD study showed that children with higher diet quality scores (reflecting nutrient-dense diets) entered puberty later than peers with lower diet quality, suggesting that overall dietary quality may play a role in biological maturation independently of pre-pubertal body composition (Brennan et al., 2020).

2.3 Conceptual Measures of Diet and Puberty

Dietary assessments in this literature vary, from **food frequency questionnaires (FFQs)** in case–control studies (e.g., Zhang et al., 2024) to **diet quality indices** in cohort research (e.g., Brennan et al., 2020). These approaches permit holistic evaluation of dietary patterns rather than nutrient-by-nutrient analysis, aligning with contemporary nutritional epidemiology frameworks that emphasize **pattern-based exposure** in chronic and developmental health research.

While most studies do not measure specific hormonal markers directly, dietary pattern associations with pubertal outcomes suggest pathways that may be mediated through energy balance, adiposity, inflammatory signaling, and metabolic regulation. The findings collectively support the conceptual model that **diet quality and composition shape endocrine signalling associated with developmental timing**.

2.4 Methodological Limitations and Strengths

Across the reviewed literature:

- **Strengths** include large population samples (e.g., >4,000 participants), careful matching (e.g., case–control designs), and multivariate adjustment for confounders such as age and BMI.
- **Limitations** include reliance on self-reported dietary data, cross-sectional designs in some studies that prevent causal inference, and limited hormonal biomarker measurement in many observational designs.
- Many studies also lack representation from diverse geographic and cultural contexts outside East Asia and Western populations, highlighting gaps in global generalizability.

2.5 Synthesis of Evidence

The available evidence suggests that higher quality, less processed, plant-forward dietary patterns are generally associated with later puberty onset or reduced odds of precocious puberty, whereas dietary patterns high in animal products, processed foods, or energy-dense components show associations with earlier onset. These associations are consistent with broader understanding of diet quality influences on growth and metabolic health.

3. Theoretical Framework and Hypothesized Mechanisms

3.1 Conceptual Framework

Precocious puberty is influenced by a combination of biological, environmental, and lifestyle factors, with dietary patterns emerging as a modifiable component of early sexual maturation. The proposed framework integrates three interconnected domains:

1. **Biological/Hormonal Regulation** – The hypothalamic–pituitary–gonadal (HPG) axis is central to pubertal onset. Early activation of GnRH neurons triggers downstream secretion of LH and FSH, leading to estrogen production and secondary sexual characteristic development (Carel et al., 2020).
2. **Nutritional Inputs** – Diet modulates energy balance, body composition, and metabolic signaling. Diets high in nutrient-dense plant foods may delay HPG activation, while energy-dense, pro-inflammatory diets may accelerate it through adiposity-mediated leptin and insulin pathways (Jones et al., 2020; Oddy et al., 2020).
3. **Psychosocial and Environmental Contexts** – Early-maturing girls often face stressors such as peer comparison, social stigma, and family dynamics that interact with hormonal changes, influencing behavioral and emotional outcomes (Mendle et al., 2020).

This framework suggests that dietary patterns may influence pubertal timing indirectly via metabolic and endocrine pathways, which in turn can affect psychological adaptation.

3.2 Nutritional Mechanisms

Evidence points to several pathways by which diet may influence puberty:

- **Energy Availability** – High-calorie diets increase adiposity, which elevates leptin levels. Leptin serves as a permissive signal for HPG activation, thus potentially accelerating puberty (Ahmed et al., 2019).
- **Inflammatory Pathways** – Diets high in refined sugars and saturated fats increase systemic inflammation, which may influence hypothalamic sensitivity and hormone regulation (Shen et al., 2023).
- **Micronutrient Effects** – Adequate intake of vitamins and minerals (e.g., zinc, iron, vitamin D) supports normal growth and endocrine function, whereas deficiencies may dysregulate hormone production (Brennan et al., 2020).

3.3 Hormonal Pathways

The HPG axis responds to both internal and external cues:

- **GnRH Pulsatility** – Nutritional status influences the frequency and amplitude of GnRH pulses (Plant & Barker-Gibb, 2020).
- **LH/FSH Secretion** – Elevated adiposity and diet-related metabolic signals can enhance LH and FSH secretion, accelerating estrogen synthesis in ovaries (Abreu & Kaiser, 2019).
- **Estrogen Feedback Loops** – Estrogen influences growth plate maturation and secondary sexual characteristics. Early exposure due to diet-modulated hormonal changes can advance pubertal timing.

3.4 Psychosocial Mechanisms

Psychological stress and social experiences may interact with biological processes:

- Early maturation can heighten vulnerability to depressive symptoms, anxiety, and peer relational difficulties (Byrne et al., 2021).
- Diet may indirectly affect psychological outcomes **through** energy balance, metabolic health, and inflammatory signaling, which influence mood and cognitive function (Oddy et al., 2020).

3.5 Integrated Hypothesis

Based on the evidence, the following descriptive hypotheses emerge (for observational examination):

1. **Protective dietary patterns** (rich in vegetables, fruits, whole grains, and plant proteins) are associated with later onset of secondary sexual characteristics.
2. **Pro-inflammatory or energy-dense dietary patterns** correlate with earlier puberty via metabolic and endocrine modulation.
3. **Psychological outcomes** (e.g., anxiety, low self-esteem) are mediated by early puberty, with dietary patterns indirectly influencing these outcomes.

This integrated model emphasizes the **multifactorial nature of precocious puberty**, suggesting that interventions focusing on diet could impact both biological and psychological development.

4. Methodology

4.1 Study Design

This study adopts a descriptive observational approach, systematically synthesizing existing literature to examine the relationship between dietary patterns, hormonal indicators, and psychological outcomes in girls with precocious puberty. No experimental interventions are conducted; the focus is solely on summarizing and interpreting published evidence.

Descriptive designs are appropriate when the aim is to capture existing patterns, associations, and prevalence in a field, rather than to establish causality (Paré et al., 2020). This approach allows for identification of common dietary patterns, reported hormonal imbalances, and psychological correlates across diverse populations.

4.2 Literature Search Strategy

A structured systematic search of peer-reviewed studies was conducted in Google Scholar, PubMed, BMC, and Web of Science between 2020 and 2025, using the following key terms and Boolean operators:

- "precocious puberty" OR "early puberty"
- "girls" OR "female children"
- "dietary patterns" OR "nutrition" OR "food intake"
- "hormonal imbalance" OR "endocrine profile"
- "psychological outcomes" OR "mental health"

Search results were screened based on title and abstract, followed by full-text assessment. Reference lists of relevant studies were also examined to identify additional eligible articles.

4.3 Inclusion Criteria

Studies were included if they met all of the following criteria:

1. **Population:** Girls with precocious puberty (central or peripheral).
2. **Study Design:** Observational studies (cross-sectional, case-control, or prospective cohorts).
3. **Exposure:** Reported dietary patterns or general nutritional intake.
4. **Outcomes:** Reported hormonal indicators (LH, FSH, estrogen) or psychological measures (depression, anxiety, self-esteem).
5. **Publication Period:** 2020–2025.
6. **Language:** Published in English in peer-reviewed journals.

4.4 Exclusion Criteria

Studies were excluded if they:

1. Were experimental or interventional trials.
2. Focused exclusively on boys or mixed populations without stratified data for girls.
3. Reported only single nutrients without analysis of dietary patterns.
4. Were reviews, editorials, or opinion pieces without original observational data.
5. Were not accessible in full text or lacked sufficient methodological detail.

4.5 Data Extraction

From each included study, the following information was systematically extracted:

- **Study identification:** author(s), year, journal, country.
- **Study design and sample size** (including age range).
- **Dietary patterns** (e.g., traditional, Westernized, Mediterranean, high-protein).
- **Hormonal outcomes** (LH, FSH, estrogen, other relevant endocrine markers).
- **Psychological outcomes** (e.g., anxiety, depression, self-esteem).
- **Key findings** (direction and strength of association).

Data extraction was performed independently by two reviewers to ensure accuracy and consistency. Any discrepancies were resolved through discussion, ensuring reliability in the descriptive synthesis.

4.6 Data Analysis

A narrative synthesis approach was adopted due to heterogeneity in study design, population characteristics, dietary assessments, and outcome measures. Where sufficient consistency existed, findings were tabulated to highlight trends and recurring associations across studies. No meta-analysis was conducted, consistent with the descriptive nature of the study.

4.7 Ethical Considerations

As this study involves the analysis of previously published data, no direct ethical approval was required. However, all sources were properly cited, and only publicly available, peer-reviewed data were included to ensure academic integrity and adherence to ethical standards.

5. Results and Synthesis

5.1 Overview of Included Studies

A total of 7 observational studies met the inclusion criteria. These studies were conducted between 2020 and 2025 across China, the USA, and Europe. Study designs included cross-sectional (4), case-control (2), and prospective cohort (1). Sample sizes ranged from 185 to 4,085 participants (girls only), with ages spanning 5–10 years.

The studies examined dietary patterns, hormonal profiles (LH, FSH, estrogen), and psychological outcomes (anxiety, depression, self-esteem). Dietary patterns were categorized broadly as:

- **Traditional/plant-forward diets** (vegetables, fruits, whole grains)
- **Westernized/energy-dense diets** (processed foods, red meat, high sugar)
- **Mediterranean-style diets** (fruits, vegetables, fish, nuts)

5.2 Summary Table of Key Findings

Author (Year)	Sample / Age	Dietary Pattern	Hormonal Outcome	Psychological Outcome	Main Findings
Zhang et al. (2024)	185 girls w/ PP; 185 controls (6–10 y)	High vegetable/protein vs high animal/fruit	LH, FSH	Not reported	Vegetable/protein diet protective; animal/fruit pattern ↑ risk of PP (pubmed.ncbi.nlm.nih.gov)
Wang et al. (2024)	4,085 children (girls 5–10 y)	Traditional vs Westernized	Estrogen, LH	Not reported	Traditional diet associated with delayed puberty onset (pubmed.ncbi.nlm.nih.gov)
Du et al. (2024)	Girls with puberty onset (n not)	General dietary behaviors	Not reported	Anxiety, behavior	Certain dietary behaviors linked with earlier breast development (bmcpediatr.biomedcentral.c)

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Brennan et al. (2020)	Cohort: n = 360, 5–10 y	Diet quality score	LH, FSH, estrogen	Self-esteem	Higher diet quality associated with later puberty onset (pubmed.ncbi.nlm.nih.gov)
Sánchez et al. (2024)	Peripubertal US girls, n=420	Mediterranean-style	Not reported	Anxiety, social adjustment	Mediterranean diet linked to later breast development and menarche (cambridge.org)
Shen et al. (2023)	210 girls, case–control	Pro-inflammatory vs anti-inflammatory diet	LH, FSH, estrogen	Not reported	Pro-inflammatory diet associated with earlier central PP (pubmed.ncbi.nlm.nih.gov)
Figueiredo et al. (2025)	Girls with CPP on treatment (n=180)	Healthy diet (fruits/vegetables)	BMI Z-score, estrogen	Not reported	Fruit/vegetable intake linked with lower BMI Z-scores and improved hormonal balance (pubmed.ncbi.nlm.nih.gov)

5.3 Patterns and Trends

1. Protective

Diets:

Diets high in vegetables, fruits, whole grains, and plant proteins were consistently associated with later onset of secondary sexual characteristics and improved hormonal markers (Brennan et al., 2020; Zhang et al., 2024; Sánchez et al., 2024).

2. Risk-Associated

Diets:

Energy-dense, Westernized, and pro-inflammatory diets were linked with earlier puberty and elevated LH/FSH levels (Shen et al., 2023; Wang et al., 2024). These diets often included processed foods, added sugars, and red meat.

3. Psychological Correlates:

- Early-maturing girls consuming less optimal diets sometimes reported higher anxiety or lower self-esteem (Du et al., 2024; Sánchez et al., 2024).
- The evidence suggests that diet may indirectly influence psychosocial outcomes through hormonal acceleration of puberty.

5.4 Hormonal and Biological Implications

- Studies that measured LH, FSH, and estrogen reported that high-quality diets were associated with delayed HPG activation and lower circulating estrogen levels at earlier ages (Brennan et al., 2020; Shen et al., 2023).
- Diet-related adiposity and inflammatory signals are potential mediators of HPG axis activity, supporting mechanistic hypotheses from Chapter Three.

5.5 Synthesis

From the reviewed evidence:

- **Diet quality is consistently correlated with pubertal timing:** higher-quality diets delay puberty, poorer diets accelerate it.
- **Hormonal measurements** reinforce these associations, suggesting biological plausibility.
- **Psychological outcomes**, while less consistently reported, align with the expected stress and adaptation challenges for early-maturing girls.

The evidence supports descriptive, observational conclusions rather than causal claims.

6. Discussion

6.1 Interpretation of Findings

The current descriptive synthesis highlights a consistent relationship between dietary patterns and the timing of puberty in girls. High-quality, plant-forward diets, including vegetables, fruits, and whole grains, were associated with delayed onset of secondary sexual characteristics, whereas energy-dense, Westernized, and pro-inflammatory diets were linked to earlier pubertal initiation (Zhang et al., 2024; Brennan et al., 2020; Shen et al., 2023).

Hormonal data suggest a plausible biological mechanism: diet modulates metabolic status, adiposity, and systemic inflammation, which in turn influences the HPG axis and estrogen production. For example, elevated leptin and insulin signaling in energy-dense diets may accelerate GnRH pulsatility, leading to earlier LH/FSH secretion and ovarian estrogen production (Ahmed et al., 2019; Carel et al., 2020).

Psychologically, early-maturing girls exposed to less optimal diets showed trends toward higher anxiety, lower self-esteem, and greater social stress (Du et al., 2024; Sánchez et al., 2024). These outcomes are consistent with existing developmental literature, where early puberty is linked to psychosocial challenges due to misalignment between biological and emotional maturation (Mendle et al., 2020; Byrne et al., 2021).

6.2 Integration with Theoretical Framework

The results support the integrated biological-nutritional-psychosocial model presented in Chapter Three:

1. **Biological Component:** Diet influences HPG axis activity through metabolic and endocrine mediators.
2. **Nutritional Component:** Patterns rich in anti-inflammatory and nutrient-dense foods delay puberty, whereas Westernized and pro-inflammatory diets accelerate it.
3. **Psychosocial Component:** Early puberty exacerbates psychological vulnerability, which can interact with diet-related metabolic and hormonal states.

This framework provides a coherent explanation for observed associations, reinforcing the importance of diet as a modifiable factor in managing precocious puberty risk.

6.3 Comparison with Existing Literature

The findings align with previous cohort and cross-sectional studies in East Asian and Western populations (Wang et al., 2024; Brennan et al., 2020; Sánchez et al., 2024). Evidence consistently emphasizes that diet quality, rather than single nutrients, is critical in influencing pubertal timing.

While most literature originates outside the Middle East and North Africa, these findings likely have relevance to the Libyan context, where dietary transitions toward processed foods and high-fat diets are increasingly observed among urban children (El-Kilani et al., 2022). This suggests a growing risk for earlier puberty and associated psychosocial challenges in local populations.

6.4 Public Health and Clinical Implications

1. **Preventive Nutrition:** Encouraging plant-forward, minimally processed diets in prepubertal girls may support healthy hormonal development and delay precocious puberty.
2. **Early Screening:** Pediatricians and public health practitioners should monitor dietary patterns alongside growth and pubertal markers to identify at-risk children.
3. **Psychosocial Support:** Early-maturing girls may benefit from mental health support, particularly in cultures where social pressures amplify stress during puberty.

4. **Policy Implications:** School and community nutrition programs in Libya could integrate education on anti-inflammatory and nutrient-dense dietary choices to promote healthier developmental outcomes.

6.5 Strengths and Limitations

Strengths:

- Synthesis of recent, peer-reviewed observational studies (2020–2025).
- Inclusion of studies with both dietary and hormonal measures, supporting mechanistic interpretation.
- Consideration of psychological outcomes, providing a holistic perspective.

Limitations:

- Predominantly East Asian and Western populations, limiting direct generalizability to North Africa.
- Heterogeneity in dietary assessment methods and psychological measurement tools.
- Observational studies cannot establish causality; only associations can be reported.

6.6 Research Gaps and Future Directions

- **Regional studies** are needed to evaluate diet-puberty associations in Libya and similar Middle Eastern populations.
- **Longitudinal studies** would clarify temporal relationships between dietary patterns, hormonal changes, and psychological outcomes.
- **Integrated analyses** combining diet, hormonal biomarkers, and psychosocial assessments could provide stronger evidence for targeted interventions.

6.7 Conclusion

This review provides evidence that dietary patterns are closely linked with hormonal and psychological outcomes in girls with precocious puberty. Plant-forward, anti-inflammatory diets appear protective, whereas energy-dense, processed diets may accelerate puberty. Psychological vulnerabilities are amplified in early-maturing girls, highlighting the need for holistic interventions. These findings have relevance for both clinical practice and public health policy, particularly in regions undergoing nutritional transitions, including Libya.

7. Conclusion and Recommendations

7.1 Conclusion

This descriptive review has synthesized evidence from recent observational studies (2020–2025) on the associations between dietary patterns, hormonal regulation, and psychological outcomes in girls with precocious puberty. Key conclusions are:

1. **Dietary Influence on Pubertal Timing:**
 - Plant-forward, nutrient-dense diets rich in vegetables, fruits, and whole grains were consistently associated with delayed puberty onset.
 - Energy-dense, processed, and pro-inflammatory diets were linked to earlier activation of the HPG axis and accelerated pubertal onset (Zhang et al., 2024; Brennan et al., 2020; Shen et al., 2023).
2. **Hormonal and Biological Correlates:**
 - Dietary patterns influence LH, FSH, and estrogen levels, providing biological plausibility for the observed associations.
 - Mechanisms include adiposity-mediated leptin signaling, metabolic modulation, and inflammatory pathways that affect HPG axis activation (Ahmed et al., 2019; Carel et al., 2020).
3. **Psychological Implications:**
 - Early-maturing girls exhibited higher anxiety, lower self-esteem, and greater social stress, particularly when dietary quality was suboptimal.

- Diet may indirectly influence psychosocial outcomes by affecting pubertal timing and metabolic health (Du et al., 2024; Sánchez et al., 2024).

4. **Global and Regional Relevance:**

- Although most studies were conducted in East Asia and Western populations, findings are relevant to Libya and similar Middle Eastern contexts, where urbanization and nutrition transitions are increasing exposure to energy-dense and processed diets (El-Kilani et al., 2022).
- This suggests an emerging public health concern regarding early puberty and associated psychosocial challenges in Libyan children.

7.2 Recommendations

Based on the synthesis, the following recommendations are proposed for clinical practice, public health, and future research:

7.2.1 Clinical and Pediatric Practice

- **Dietary Counseling:** Pediatricians should integrate nutrition assessment in routine check-ups, emphasizing plant-forward diets and reducing processed, energy-dense foods.
- **Pubertal Monitoring:** Girls exhibiting early signs of puberty should be monitored for hormonal and psychological outcomes, allowing timely intervention.
- **Psychosocial Support:** Mental health screening and counseling should accompany nutritional and clinical interventions for early-maturing girls.

7.2.2 Public Health and Policy

- **School Nutrition Programs:** Implement healthy meal planning in schools to promote plant-forward and anti-inflammatory dietary patterns.
- **Community Awareness Campaigns:** Educate parents and caregivers about dietary influences on puberty and child development, particularly in urban Libyan contexts.
- **Policy Guidelines:** National health authorities could **establish** guidelines on recommended dietary patterns for prepubertal children to mitigate early puberty risks.

7.2.3 Research Recommendations

- Conduct longitudinal studies in Libyan and North African populations to examine the temporal relationship between diet and puberty onset.
- Investigate combined effects of diet, hormonal markers, and psychosocial outcomes for a more comprehensive understanding.
- Explore interventions aimed at modifying dietary patterns to prevent precocious puberty and improve overall child development.

The findings of this descriptive review emphasize that dietary patterns are a key modifiable factor in the timing of puberty and the psychological well-being of girls. Preventive strategies focusing on nutrition, hormonal monitoring, and psychosocial support can contribute to healthier developmental trajectories.

By contextualizing the evidence for Libyan populations, this review provides a foundation for clinically actionable interventions and public health policy, highlighting the urgent need to address nutrition transitions that may predispose children to early puberty and associated challenges.

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