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Research Article

THE ROLE OF BIOTIN ON METABOLIC HEALTH AND NUTRITIONAL STATUS IN ADOLESCENTS: A SYSTEMATIC LITERATURE REVIEW

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Deviyah Chailatul Lutfiyani[1#], Naila Khurriyatul Friskya Afsokhah Nabilah[1], Muhamat Ferry Ardiansyah[1], Dwi Nur Hikmatul Amaliyah[1], Azhwa Nayla Salsabilla[1], Auliya Savira Az Zahra[1], I'anatul Wiqoyah[1], Dwi Rukma Santi[1]

Abstract:

Background: Biotin (vitamin B7) serves as an indispensable coenzyme for essential carboxylases governing gluconeogenesis, fatty acid synthesis, and amino acid catabolism. Although critical for energy homeostasis, comprehensive evaluations exploring its systemic impact on adolescent metabolic health, obesity dynamics, and the clinical risks of indiscriminate high-dose supplementation remain fragmented

Objective: To systematically synthesize and analyze the empirical evidence regarding the physiological role of biotin in metabolic health, nutritional status, and potential safety hazards among adolescents. Methods: A Systematic Literature Review (SLR) was executed adhering to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Literature searches were conducted across PubMed, ScienceDirect, and Google Scholar for peer-reviewed studies published between 2022 and 2026. Applying stringent inclusion and exclusion criteria, 16 articles were selected for qualitative synthesis.

Results: Adolescent daily biotin requirements are established at an Adequate Intake (AI) of 20–40 µg/day. Observational data reveal that adolescents particularly females and individuals with obesity frequently exhibit suboptimal intake (< 22 µg/day) or depressed serum concentrations. Biotin insufficiency impairs carboxylase gene expression, disrupts insulin sensitivity, and is exacerbated by gut microbial dysbiosis in obesity. Conversely, empirical clinical trials demonstrate that high-dose biotin supplementation (2,500 µg/day) confers no therapeutic benefit for cosmetic hair or skin conditions in the absence of verified deficiency. More critically, supra-physiological intake induces nephrometabolic disturbances (proximal renal tubular acidosis) and severe laboratory immunoassay interference (falsely altered thyroid hormones, troponin, and hCG).

Conclusion: Biotin is crucial for metabolic equilibrium in growing adolescents; however, adequacy should be achieved through balanced dietary patterns rather than unmonitored commercial supplementation.

Keywords: Adolescents; Biotin; Immunoassay interference; Metabolic health; Nutritional status; Systematic review; Vitamin B7

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1. INTRODUCTION

Biotin, also designated as vitamin B7 or vitamin H, is a water-soluble micronutrient belonging to the B-complex family that plays a fundamental biochemical role in cellular

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metabolism across human physiology. Biotin functions as an obligatory prosthetic group covalently bound to five carboxylase enzymes: acetyl-CoA carboxylase 1 and 2, pyruvate carboxylase, propionyl-CoA carboxylase, and 3-methylcrotonyl-CoA carboxylase (Karachaliou & Livaniou, 2024). Through these catalytic complexes, biotin governs primary intermediary metabolism, including gluconeogenesis (the de novo synthesis of glucose from non-carbohydrate substrates), fatty acid biosynthesis, and the mitochondrial catabolism of branched-chain amino acids and odd-chain fatty acids (Khoso et al., 2025). Furthermore, emerging molecular research indicates that biotin regulates gene expression, chromatin remodeling through histone biotinylation, and the transcription of critical metabolic and immunological signaling pathways (Karachaliou & Livaniou, 2024).

Adolescence represents an extraordinary phase of human ontogeny, marked by the second-fastest period of somatic growth, sexual maturation, and neurodevelopment following infancy. During this developmental transition, metabolic demands for macro- and micronutrients surge dramatically to support lean tissue accretion, skeletal elongation, and expanding blood volumes (Azahra et al., 2025; Santoso et al., 2025). Concurrently, this age group is increasingly characterized by lifestyle transformations, sedentary routines, and erratic dietary practices such as skipping breakfast, high consumption of ultra-processed fast foods, and inadequate intake of fresh vegetables and whole grains (Azahra et al., 2025). These suboptimal eating behaviors not only impair immediate nutritional status but also destabilize metabolic health, increasing susceptibility to adolescent adiposity, insulin resistance, dyslipidemia, and systemic cardiometabolic complications in adulthood (Aguilera-Méndez et al., 2024; Santoso et al., 2025).

In recent years, biomedical interest surrounding biotin's therapeutic and systemic utility has expanded substantially. Emerging clinical and pre-clinical studies demonstrate that biotin adequacy is intimately tied to glycemic control, lipid homeostasis, gut microbial ecology, and neurocognitive resilience (Belda et al., 2022; Kong et al., 2026). In contrast, severe biotin deficiency precipitates alopecia, peri-orificial erythematous scaling dermatitis, lethargy, hypotonia, and neurological deficits (Ahmad et al., 2026; Karachaliou & Livaniou, 2024). However, the popularization of biotin within social media and commercial wellness industries has driven a surge in the unsupervised consumption of supra-physiological biotin supplements (often containing 2,500 to 10,000 µg exceeding physiological needs by up to 500-fold) under the unverified premise of enhancing hair growth, nail thickness, and metabolic rate (Falotico & Lipner, 2022; Khoso et al., 2025).

Despite this widespread consumption, critical empirical gaps persist. Most available scientific literature focuses narrowly on either dermatology (such as adult telogen effluvium) or severe inborn errors of metabolism (biotinidase deficiency), leaving the specific relationship between biotin adequacy, adolescent metabolic health, and nutritional status poorly characterized. Furthermore, high-dose commercial supplementation poses recognized clinical perils, including immunoassay analytical interference that falsely distorts endocrine and cardiac laboratory results (Angelopoulos et al., 2023; Kahraman et al., 2025), alongside rare but severe nephrometabolic toxicities (Ahmad et al., 2026).

Therefore, this systematic literature review aimed to comprehensively synthesize and evaluate empirical research concerning the role of biotin in metabolic health and nutritional status among adolescents, while elucidating the metabolic risks and diagnostic hazards of unsupervised high-dose supplementation. The findings are intended to supply healthcare providers, public health nutritionists, and school health authorities with evidence-based guidance to promote balanced dietary habits and curb irrational supplement misuse.

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2. METHODS

2.1 Research Design

This study employed a Systematic Literature Review (SLR) methodology, adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. This approach was selected to provide a systematic and structured examination of previously published scientific evidence related to biotin in adolescent populations. Through this methodology, the study aimed to collate, critically evaluate, and integrate empirical findings addressing the metabolic, nutritional, and pharmacological dimensions of biotin.

A systematic qualitative synthesis was adopted to facilitate the identification and interpretation of relevant findings across the selected literature. This approach enabled the researchers to examine the available evidence comprehensively while considering the different aspects of biotin discussed in previous empirical studies. The synthesis focused on integrating the reported findings to develop an overall understanding of the relationship between biotin and metabolic health, nutritional status, and pharmacological considerations among adolescents. The use of the PRISMA 2020 guidelines also provided a structured reporting framework to support transparency and consistency in presenting the systematic review process.

2.2 Search Strategy and Database Selection

A comprehensive literature search was conducted across three major electronic databases: PubMed, ScienceDirect, and Google Scholar, capturing peer-reviewed scientific studies published between January 2022 and February 2026. The search utilized specific Boolean keyword strings in both English and Indonesian: ('biotin' OR 'vitamin B7') AND ('metabolic health' OR 'glucose metabolism' OR 'insulin resistance') AND ('nutritional status' OR 'obesity') AND ('adolescents' OR 'youth' OR 'teenagers').

2.3 Eligibility Criteria

Inclusion criteria comprised: (1) original research articles (randomized controlled trials, prospective/retrospective cohort studies, cross-sectional surveys, case-control studies, and documented clinical reports) or official nutritional authority consensus guidelines; (2) studies examining the metabolic functions, dietary intake, serum status, or adverse effects of biotin; (3) studies focusing on adolescents or generating direct physiological and clinical relevance to adolescent metabolic health; (4) publications in English or Indonesian; and (5) open-access full-text availability. Exclusion criteria included: (1) duplicate records; (2) studies published outside 2022–2026; (3) non-peer-reviewed commentaries or popular media articles; and (4) articles without accessible empirical methodologies.

2.4 Study Screening and PRISMA Flow

The study selection followed four PRISMA stages: identification, screening, eligibility, and inclusion. Following electronic database queries, initial records were screened based on title and abstract relevance. Full-text articles were subsequently retrieved and appraised independently against eligibility criteria. Ultimately, 16 core scientific articles met all criteria and were incorporated into qualitative data extraction.

2.5 Data Extraction and Synthesis

Data extraction was performed using a standardized matrix capturing author/year, study title, research design, sample size/characteristics, specific intervention or evaluation metric, and key metabolic/nutritional findings. Data synthesis followed a qualitative narrative approach, structuring findings into four core thematic domains: (1) biotin dietary requirements and adolescent nutritional status; (2) metabolic mechanisms in glucose, lipid,

and gut microbiome regulation; (3) clinical evidence regarding dermatological and mental health outcomes; and (4) safety risks and diagnostic immunoassay interference.

2.6 Methodological Quality Appraisal

The methodological quality appraisal considered the diversity of research designs represented in the synthesized evidence. The included studies encompassed human cross-sectional surveys, randomized clinical trials, animal metabolic models, and retrospective case evaluations. These different study designs provided varied empirical perspectives on the metabolic, nutritional, and pharmacological dimensions of biotin.

The diversity of methodological approaches was taken into consideration when examining and synthesizing the findings from the selected studies. Each study contributed evidence according to its respective research design and methodological characteristics. This consideration was important to ensure that the interpretation of the synthesized findings remained consistent with the nature and scope of the available evidence.

2.7 Scope and Limitations of the Research Used

The scope of this review was restricted to peer-reviewed scientific literature published within the last five years (2022–2026), focusing on the metabolic, nutritional, and pharmacological dimensions of biotin in adolescent populations. One of the main limitations was the scarcity of clinical trials conducted exclusively among adolescent human participants. Consequently, the interpretation of certain metabolic mechanisms required extrapolation from studies involving adult populations and pre-clinical animal models, which may limit the direct applicability of those findings to adolescents.

Regarding ethical considerations, this study synthesized previously published secondary data and did not involve direct experimentation or intervention involving human participants. Therefore, formal approval from an institutional research ethics committee was not required. Nevertheless, the review maintained adherence to publication ethics principles, including appropriate acknowledgment of original authors, accurate citation of scientific sources, and respect for established academic integrity standards.

3. RESULTS AND DISCUSSION

3.1. Result

Table 1. Systematic Matrix Literature on Biotin, Metabolic Health, and Nutritional Status (N=16)

No.	Author (Year)	Study Title & Design	Key Findings & Clinical Implications
1	Kotnik et al. (2023)	Advisability of dietary supplement use in adolescents (Cross-sectional)	Adolescent biotin intake was often below D-A-CH recommendations, emphasizing the importance of a balanced diet.
2	Khoso et al. (2025)	Addition of oral biotin to PRP for alopecia (Randomized Controlled Trial)	Biotin supplementation (2,500 µg/day) provided no additional hair growth benefit when combined with PRP.
3	Karachaliou & Livaniou (2024)	Biotin homeostasis and human disorders (Biochemical narrative review)	Biotin supports cellular division, myelin synthesis, and carboxylase activity, contributing to normal growth and development.
4	Turkoglu et al. (2024)	Biochemical status in telogen effluvium patients (Case-control study)	Biotin levels did not differ significantly between patients and healthy controls, questioning routine supplementation without deficiency.

5	Kong et al. (2026)	Dietary biotin intake on anxiety and depression (Prospective cohort study)	Higher biotin intake was associated with lower depression and anxiety risks, with a potential optimal intake of 45–48 µg/day.
6	Aguilera-Méndez et al. (2024)	Prenatal biotin supplementation in caloric restriction (Animal model)	Biotin supplementation mitigated metabolic complications associated with prenatal caloric restriction in offspring.
7	Almasi et al. (2024)	Biotin and exercise on cognitive impairment (Experimental rat model)	Biotin demonstrated neuroprotective effects by reducing oxidative stress and improving learning and memory.
8	Raveendran et al. (2024)	Detection of biotin deficiency from dried blood spots (LC-MS assay)	DBS coupled with LC-MS enabled minimally invasive detection of early biotin deficiency using specific biomarkers.
9	Angelopoulos et al. (2023)	Low-dose biotin supplements in hypothyroidism (Clinical trial)	Adolescent biotin intake was often below D-A-CH recommendations, emphasizing the importance of a balanced diet.
10	Jungert et al. (2022)	Revised D-A-CH reference values for biotin intake (Nutritional consensus)	Biotin supplementation (2,500 µg/day) provided no additional hair growth benefit when combined with PRP.
11	Nugraha et al. (2023)	Vitamin B intake and overweight in adolescent females (Cross-sectional)	Biotin supports cellular division, myelin synthesis, and carboxylase activity, contributing to normal growth and development.
12	Güder & Eker (2023)	Laboratory evaluation of dermatology patients' biotin levels (Retrospective)	Biotin levels did not differ significantly between patients and healthy controls, questioning routine supplementation without deficiency.
13	Ahmad et al. (2026)	Biotin-induced proximal renal tubular acidosis (Case report with rechallenge)	Higher biotin intake was associated with lower depression and anxiety risks, with a potential optimal intake of 45–48 µg/day.
14	Kahraman et al. (2025)	Biotin interference in pediatric obesity-related ELISA (Laboratory study)	Biotin supplementation mitigated metabolic complications associated with prenatal caloric restriction in offspring.
15	Belda et al. (2022)	Gut microbial biotin metabolism in severe obesity (Metagenomic trial)	Biotin demonstrated neuroprotective effects by reducing oxidative stress and improving learning and memory.
16	Falotico & Lipner (2022)	Biotin beware: Perils of supplementation (Clinical dermatological survey)	DBS coupled with LC-MS enabled minimally invasive detection of early biotin deficiency using specific biomarkers.

Source: Systematic data extraction from synthesized peer-reviewed literature, 2026.

The qualitative synthesis of Table 1 confirms that biotin is biologically indispensable for adolescent metabolic homeostasis, yet indiscriminate exogenous supplementation poses multi-organ safety risks.

Biotin requirements in adolescents are established using the Adequate Intake (AI) standard due to limited experimental evidence. The recommended AI is 20 µg/day for ages 9–13 and 25–40 µg/day for ages 14–18 (Jungert et al., 2022; Kahraman et al., 2025). Balanced diets containing eggs, legumes, nuts, dairy, whole grains, and vegetables generally meet these requirements. However, poor dietary diversity and meal skipping may contribute to inadequate intake, particularly among adolescent females (Kotnik et al., 2023; Nugraha et

al., 2023). Adolescents with obesity may also have lower circulating biotin levels than those with normal weight (Güder & Eker, 2023).

Biotin functions as an essential cofactor for enzymes involved in glucose and lipid metabolism, particularly pyruvate carboxylase and acetyl-CoA carboxylase (Karachaliou & Livaniou, 2024). Adequate biotin supports insulin sensitivity, glucose regulation, and lipid metabolism (Aguilera-Méndez et al., 2024; Güder & Eker, 2023). Gut microbiota also contribute to biotin availability through endogenous synthesis. However, obesity-related microbial dysbiosis may reduce bacterial biotin production, potentially contributing to metabolic disturbances and systemic inflammation (Belda et al., 2022).

Despite widespread marketing of biotin supplements for hair and skin health, clinical evidence does not consistently demonstrate cosmetic benefits in individuals without deficiency. Studies have reported no significant improvement in hair density following high-dose supplementation (Khoso et al., 2025; Turkoglu et al., 2024). Conversely, observational research suggests that adequate dietary biotin intake may be associated with lower risks of depression and anxiety, potentially through reduced systemic inflammation (Kong et al., 2026).

Although biotin is water-soluble and has no established Tolerable Upper Intake Level (UL), excessive supplementation may cause adverse effects. High-dose biotin has been associated with proximal renal tubular acidosis, hypokalemia, and metabolic disturbances (Ahmad et al., 2026). Furthermore, excessive circulating biotin can interfere with streptavidin-biotin immunoassays, producing falsely low TSH and cardiac troponin results or falsely elevated thyroid hormone measurements. These errors may lead to inappropriate diagnoses and clinical decisions (Angelopoulos et al., 2023; Falotico & Lipner, 2022; Kahraman et al., 2025).

3.2 Discussion

The findings indicate that biotin (vitamin B7) plays an essential role in adolescent energy metabolism, insulin sensitivity, and lipid regulation. However, biotin deficiency is relatively rare and can generally be prevented through a balanced diet providing approximately 20–40 µg daily. Commercial high-dose supplements have no proven cosmetic benefits in healthy adolescents and may pose potential renal and laboratory diagnostic risks.

These findings are consistent with FDA safety warnings and nutritional guidelines emphasizing the risks of excessive and unsupervised supplementation (Falotico & Lipner, 2022; Jungert et al., 2022). Previous studies also suggest that obesity-related biotin depletion may involve alterations in gut microbiota and endogenous biotin synthesis rather than dietary insufficiency alone (Nugraha et al., 2023; Belda et al., 2022).

Biotin deficiency may impair carboxylase activity, fatty acid oxidation, and metabolic regulation, while excessive supplementation can interfere with renal function and laboratory immunoassays, potentially producing inaccurate thyroid and cardiac biomarker results (Ahmad et al., 2026; Kahraman et al., 2025). These mechanisms highlight the importance of maintaining appropriate biotin intake rather than assuming that higher doses provide greater benefits.

However, direct clinical evidence regarding biotin supplementation and metabolic outcomes specifically in adolescents remains limited, as most available evidence comes from animal models and adult populations (Aguilera-Méndez et al., 2024; Kong et al., 2026). Therefore, further adolescent-focused research is needed. Overall, this review supports

food-based nutritional strategies, appropriate supplementation when clinically indicated, and improved public health education to prevent unnecessary high-dose biotin consumption.

3.3 Implications

Public health policymakers and school health programs (UKS) must prioritize adolescent nutritional literacy, emphasizing that diverse, balanced diets adequately meet micronutrient demands without pharmaceutical pills. Clinical laboratories and primary care clinicians must implement mandatory screening questions regarding over-the-counter biotin supplement use before collecting blood for endocrine, metabolic, or cardiac panels, recommending a 48-to-72-hour washout period prior to testing.

3.4 Research contribution

This study bridges an important conceptual gap by consolidating scattered evidence across metabolic health, gut microbiology, dermatology, and laboratory medicine into a coherent adolescent-centered nutritional framework.

3.5 Limitations

Several limitations must be acknowledged: (1) The synthesis relies upon heterogeneous study designs (in vitro, animal, adult, and observational studies); (2) A lack of primary randomized controlled trials evaluating biotin's glycemic and lipid effects specifically in adolescent cohorts; and (3) Reliance on non-probability qualitative article extraction without formal meta-analytical pooling

4. CONCLUSION

Biotin (vitamin B7) is a vital cofactor required for optimal macronutrient metabolism, insulin regulation, and cellular homeostasis during adolescent physical growth and maturation. Daily adolescent physiological requirements (20–40 µg/day) are readily satisfied through balanced dietary consumption, and true deficiency is rare. High-dose commercial biotin supplementation lacks clinical evidence for cosmetic benefits in non-deficient individuals and introduces severe health risks, including nephrometabolic tubulopathy and hazardous laboratory immunoassay misdiagnoses. Consequently, adolescent nutritional management should strictly prioritize whole-food nutritional education over unsupervised supplementation.

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AUTHOR CONTRIBUTIONS STATEMENT

DCL, DRS: Conceptualization, Methodology, Writing original draft, Writing review and editing. NKFAN, MFA, DNHA, ANS, ASA, IW: Data curation, Formal analysis, Investigation, Validation, Project administration.

AUTHOR INFORMATION

Corresponding Author

Deviyah Chailatul Lutfiyani
Nutrition Study Program, Sunan Ampel State Islamic University Surabaya

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Email: deviyah.chailatul05@gmail.com
Phone : +62 888-1802-199

Authors
Naila Khurriyatul Friskya Afsokhah Nabilah
Nutrition Study Program, Sunan Ampel State Islamic University Surabaya

Muhamat Ferry Ardiansya
Nutrition Study Program, Sunan Ampel State Islamic University Surabaya

Dwi Nur Hikmatul Amaliyah
Nutrition Study Program, Sunan Ampel State Islamic University Surabaya

Azhwa Nayla Salsabilla
Nutrition Study Program, Sunan Ampel State Islamic University Surabaya

Auliya Savira Az Zahra
Nutrition Study Program, Sunan Ampel State Islamic University Surabaya

I'anatul Wiqoyah
Nutrition Study Program, Sunan Ampel State Islamic University Surabaya

Dwi Rukma Santi
Department of Public Health, Universitas Islam Negeri Sunan Ampel Surabaya
https://orcid.org/0000-0003-1000-899X

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