

Review

Micronutrient Deficiencies and Public Health Impact: An Epidemiological Narrative Review

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ABSTRACT

Background: Micronutrient deficiencies, often referred to as “hidden hunger,” remain a major global public health challenge despite significant advances in nutrition and health systems. Deficiencies in essential micronutrients such as iron, vitamin A, iodine, zinc, and vitamin D contribute substantially to morbidity, impaired cognitive development, poor pregnancy outcomes, and increased mortality, particularly among vulnerable populations. This narrative review aims to synthesize epidemiological evidence on the prevalence, determinants, and public health impact of major micronutrient deficiencies worldwide.

Methods: A narrative review approach was employed by searching PubMed, Scopus, and Google Scholar for relevant literature published between 2010 and 2024. Additional data were obtained from authoritative sources including the World Health Organization, UNICEF, and global nutrition reports. Studies addressing epidemiological patterns, risk factors, and health outcomes related to micronutrient deficiencies were included and narratively synthesized.

Results: The review identified iron deficiency anemia as the most prevalent micronutrient disorder globally, with persistently high rates among women of reproductive age and children. Vitamin A, iodine, zinc, and vitamin D deficiencies also remain widespread, particularly in low- and middle-income countries. Although some regions have shown modest improvements over time, global trends indicate fluctuating prevalence and continued public health burden driven by poor dietary diversity, socioeconomic inequalities, infectious diseases, and gaps in nutrition surveillance and intervention coverage.

Conclusion: Micronutrient deficiencies continue to pose a significant global health burden despite existing interventions. Strengthening integrated public health strategies—including food fortification, supplementation, dietary diversification, and routine screening within primary health care—is essential to reduce the long-term health and socioeconomic consequences of these deficiencies and to support progress toward global nutrition and health targets.

Keywords: micronutrient deficiencies, anemia, nutritional epidemiology, public health, hidden hunger

INTRODUCTION

Micronutrients are essential dietary elements required in trace amounts that play crucial roles in physiological processes and overall health. They include vitamins and trace elements such as iron, zinc, copper, and selenium, which are integral to enzymatic functions, immune responses, and metabolic regulation (1,2). Deficiencies in these micronutrients can lead to various health issues, including anemia, impaired immune function, chronic diseases, and complications during pregnancy (3). For instance, the impact of micronutrient deficiency is particularly pronounced in vulnerable populations, such as children and pregnant women, where it poses significant risks to development and well-being (4). Thus, ensuring adequate intake of micronutrients is vital not only for individual health but also for public health strategies aimed at addressing malnutrition and its associated consequences (5,6). Comprehensive interventions, including food fortification and supplementation programs, have been shown to be effective in mitigating micronutrient deficiencies, underscoring their importance in health promotion and disease prevention across populations (7).

The global burden of micronutrient deficiencies presents a severe public health challenge, with the World Health Organization (WHO) estimating that more than 2 billion individuals worldwide suffer from "hidden hunger," primarily due to deficiencies in essential nutrients like iron, vitamin A, and iodine (8). This phenomenon highlights significant nutritional disparities; despite improvements in food quantity, the quality and micronutrient content of diets remain insufficient for meeting the dietary needs of many populations. For instance, iron deficiency contributes to over 400 million cases of anemia globally, while vitamin A deficiency affects an estimated 250 million children under the age of five. These deficiencies are associated with increased morbidity and disability-adjusted life years (DALYs) lost, imposing a considerable burden on healthcare systems and economies worldwide, particularly in low- and middle-income countries where these deficiencies are most prevalent. The urgency to address micronutrient deficiencies is underscored by these striking statistics, emphasizing the need for effective public health interventions and policy changes to improve the nutritional quality of diets globally (8).

The relevance of micronutrient deficiencies to the Sustainable Development Goals (SDGs) 2 (Zero Hunger) and 3 (Good Health) is paramount, as addressing these deficiencies is essential for achieving food security and enhancing health outcomes globally. SDG 2 emphasizes the need to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture by 2030, directly linking the prevention of malnutrition—including micronutrient deficiencies—as a critical component of this goal (9). It is estimated that nearly 2 billion people are affected by "hidden hunger," highlighting the inadequacy of micronutrient intake despite the availability of sufficient caloric intake (8,10). This deficiency not only impairs the physical health and cognitive development of individuals, particularly vulnerable populations like children and pregnant women, but it also poses significant obstacles to SDG 3, which aims to ensure healthy lives and promote well-being for all at all ages (11). Investments in nutrition and systems designed to tackle these deficiencies are necessary to improve health outcomes and foster social and economic development, thus

achieving composite health and nutritional outcomes that align with the overarching objectives of both SDGs (11,12).

Populations most at risk for micronutrient deficiencies include pregnant women, infants, and adolescents, each of whom faces unique vulnerabilities during critical stages of growth and development. Pregnant women are particularly susceptible to deficiencies due to increased nutritional demands for both maternal health and fetal development. It has been reported that approximately 56% of pregnant women in low-income countries suffer from anemia, which is largely attributed to iron deficiency (13). This deficiency poses significant risks for maternal and infant health, manifesting in complications such as premature births and developmental delays. Infants also experience high rates of micronutrient deficiencies; for instance, it is estimated that over 250 million children under the age of five are affected by vitamin A deficiency globally, leading to health issues that include increased susceptibility to infections (14). Adolescents, particularly young girls, are at an elevated risk as they often encounter nutritional deficits during this key period of growth and hormonal change. The lack of adequate nutrients such as iron, calcium, and vitamins can negatively affect their health and development, contributing to long-term health consequences, including anemia and delayed cognitive development (15,16). Overall, addressing the micronutrient needs of these vulnerable groups is crucial for enhancing health outcomes and fostering resilience against malnutrition-related challenges.

Micronutrient deficiencies (MNDs) remain an under-recognized global health problem despite their substantial and far-reaching consequences for maternal, child, and population health. Although often termed “hidden hunger,” their impacts are anything but hidden—ranging from impaired cognitive development, weakened immunity, increased susceptibility to infections, pregnancy complications, to long-term productivity loss and elevated morbidity and mortality. The persistence of MNDs across low-, middle-, and even high-income countries highlights gaps in dietary diversity, health system capacity, fortification policies, and public awareness. Therefore, this narrative review aims to synthesize current epidemiological evidence on the prevalence, risk factors, and public health impact of key micronutrient deficiencies—such as iron, vitamin A, iodine, zinc, and vitamin D—to provide a comprehensive understanding that can inform targeted interventions and strengthen public health strategies.

Despite their profound health and developmental consequences, micronutrient deficiencies (MNDs) often remain under-recognized within public health agendas, overshadowed by more visible forms of malnutrition such as underweight and obesity. This under-recognition persists even though MNDs contribute significantly to global morbidity, impaired cognitive development, reduced immunity, poor pregnancy outcomes, and increased mortality, particularly in low- and middle-income countries. The “hidden” nature of these deficiencies—where individuals may appear adequately nourished yet lack essential micronutrients—compounds the difficulty in detection and intervention, leading to sustained population-level risks. Given these substantial but frequently overlooked impacts, it is critical to consolidate current knowledge on the epidemiological patterns of MNDs to better inform public health strategies. Therefore, the purpose of this narrative review is to synthesize existing epidemiological evidence on the prevalence, determinants, and health

consequences of major micronutrient deficiencies, with the aim of strengthening understanding and guiding effective interventions to reduce their global burden.

METHOD

This narrative review utilized a structured, integrative approach to gather and synthesize evidence on the epidemiology and public health impact of major micronutrient deficiencies. A comprehensive literature search was conducted across PubMed, Scopus, and Google Scholar using combinations of keywords such as *"micronutrient deficiency," "hidden hunger," "nutritional epidemiology," "vitamin A deficiency," "iron deficiency anemia," "iodine deficiency disorders," "zinc deficiency,"* and *"public health impact,"* covering publications from 2010 to 2024. Boolean operators (AND/OR) and MeSH terms were applied to enhance search precision. Additional grey literature, including global reports from the World Health Organization (WHO), UNICEF, FAO, and national nutrition surveys, was reviewed to complement peer-reviewed findings. Studies were included if they provided epidemiological data on prevalence, determinants, population risk, or health outcomes related to micronutrient deficiencies in children, adolescents, adults, or pregnant women. Articles focusing solely on molecular mechanisms, animal studies, or clinical trials unrelated to population health were excluded. All eligible sources were screened for relevance, and key data were extracted on geographic patterns, affected populations, associated morbidities, and policy implications. Findings were narratively synthesized and organized into thematic domains to enable a comprehensive, multidimensional interpretation of global micronutrient deficiency trends without applying formal systematic review procedures such as PRISMA, in accordance with narrative review methodology..

RESULT

The review identified five major micronutrient deficiencies of greatest global public health relevance—iron, vitamin A, iodine, zinc, and vitamin D—each demonstrating substantial prevalence across low-, middle-, and high-income countries. Iron deficiency remains the most widespread, affecting an estimated 30% of women and 40% of children globally, primarily driven by inadequate dietary intake, menstruation, pregnancy demands, and infections such as malaria and helminths. Vitamin A deficiency (VAD) continues to be highly prevalent in children under five, particularly in South Asia and sub-Saharan Africa, where inadequate consumption of vitamin A-rich foods and recurrent infections contribute significantly to the burden. Iodine deficiency persists despite global salt iodization efforts, with pockets of moderate-to-severe deficiency still reported in regions with poor iodization coverage, leading to cognitive impairment and thyroid-related disorders. Zinc deficiency is notable in populations consuming predominantly cereal-based diets high in phytates, which inhibit zinc absorption, contributing to impaired immunity, stunting, and increased susceptibility to infections. Meanwhile, vitamin D deficiency has emerged as a global issue—even in tropical regions—due to limited sun exposure, urban lifestyles, obesity, and cultural clothing practices. Collectively, these micronutrient deficiencies contribute to substantial morbidity, mortality, and developmental impairment

across vulnerable groups, especially children, pregnant women, and adolescents. A summary of key epidemiological patterns and impacts is presented in Table 1..

Table 1. Summary of Major Micronutrient Deficiencies, Epidemiological Patterns, and Public Health Impacts (17–20)

Micronutrient	Global Prevalence / Affected Groups	Key Determinants / Risk Factors	Public Health Impact
Iron	<ul style="list-style-type: none"> • ~400 million cases of anemia globally • High prevalence among women of reproductive age and young children 	Poor dietary intake; pregnancy; menstrual blood loss; infections (malaria, helminths); poverty	Maternal mortality risk; low birth weight; impaired cognition; fatigue; reduced productivity
Vitamin A	<ul style="list-style-type: none"> • ~250 million children <5 years affected • Most prevalent in LMICs (Africa, South Asia) 	Low intake of vitamin A-rich foods; measles; diarrhea; poor breastfeeding practices	Night blindness; impaired immunity; increased child mortality; growth retardation
Iodine	<ul style="list-style-type: none"> • Significant burden in areas with incomplete salt iodization • Affects pregnant women and school-aged children 	Lack of iodized salt; soil iodine deficiency; poor monitoring of iodization programs	Goiter; hypothyroidism; impaired fetal brain development; reduced IQ
Zinc	<ul style="list-style-type: none"> • Highly prevalent in regions with cereal-based diets • Affects children and pregnant women 	Low bioavailability from plant-based diets; infections; poor dietary diversity	Increased infection risk; stunting; impaired wound healing; diarrhea severity
Vitamin D	<ul style="list-style-type: none"> • Affects 30–60% of populations globally • Seen even in sunny regions 	Low sun exposure; obesity; indoor lifestyles; cultural clothing; poor dietary intake	Rickets; osteomalacia; weak immunity; metabolic dysfunction

The trend shown in the graph illustrates fluctuations in global anemia prevalence from 1990 to 2023, reflecting persistent challenges in addressing micronutrient deficiencies worldwide. In 1990, global anemia prevalence was estimated at approximately 28.2%, affecting a significant proportion of women and children (17). Prevalence increased to around 32.9% in 2010, a rise linked to poor dietary diversity, high infection burdens, and improved surveillance systems that enhanced detection rates (19). By 2019, global estimates indicated a decline to about 24.3%, likely due to expanded iron supplementation programs, improved antenatal care, and strengthened fortification policies (17). However, the most recent WHO Global Health Observatory data show that anemia prevalence among women aged 15–49 years increased again to approximately 30.7% in 2023, with pregnant women experiencing even higher rates at 35.5% (18). This resurgence is associated with ongoing nutritional deficiencies, rising food insecurity following the COVID-19 pandemic, and persistent inequities in reproductive health services. Overall, the trend highlights that anemia remains a major public health burden globally despite periods of improvement, underscoring the need for sustained and comprehensive nutrition strategies (17,18)

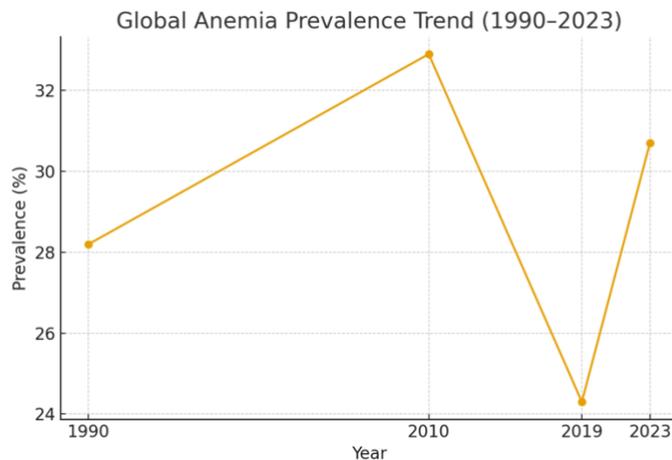


Figure 1. Global Anemia Prevalence Trends

These findings demonstrate that micronutrient deficiencies and their clinical manifestations—such as anemia—remain pervasive global health challenges, particularly in vulnerable groups such as children, pregnant women, and women of reproductive age. Despite progress in some regions, the persistence and, in some cases, resurgence of micronutrient-related conditions highlight substantial gaps in dietary quality, infection control, fortification coverage, and access to essential health services. The observed trends indicate that while targeted interventions have contributed to modest reductions in prevalence over time, the burden of micronutrient deficiencies continues to be reinforced by structural inequities, socioeconomic barriers, and evolving global food system pressures. These results underscore the urgent need for sustained, evidence-based public health strategies to address both the biological and social determinants of micronutrient deficiencies and to reduce their long-term health impacts at the population level.

DISCUSSION

Anemia, a significant global public health issue, is predominantly driven by micronutrient deficiencies, particularly iron deficiency, which affects substantial segments of the population. Reports indicate that despite various interventions aimed at reducing micronutrient deficiencies, the global burden of anemia remains persistently high, especially among vulnerable groups, including women of reproductive age and children. In many developing countries, prevalence rates of anemia can reach as high as 75%, with iron deficiency being the primary cause (21). A pooled analysis highlighted that women of reproductive age and preschool children constitute the most affected populations, reinforcing the widespread nature of micronutrient deficiencies globally (22). In a systematic review, iron deficiencies were documented as affecting up to 54% of the population in India (15). Furthermore, research indicates that iron deficiency anemia continues to account for approximately 50% of anemia cases worldwide (23,24)

In regions such as Sub-Saharan Africa and South Asia, children under five and women show particularly high prevalence rates, and interventions aimed at supplying micronutrients have shown only

marginal progress (25). Notably, although effective strategies like supplementation and food fortification have been implemented, the complex etiology of anemia, which includes nutritional and non-nutritional factors such as infections and genetic disorders, complicates the reduction of anemia prevalence (26,27). For example, in Namibia, the prevalence of anemia among women of reproductive age was reported as high as 25.2%, with children also significantly affected due to overlapping deficiencies (28). Consequently, it remains crucial to address not only the dietary intake of iron and other micronutrients but also the broader health determinants that contribute to the persistence of anemia in these vulnerable populations.

Determinants of Micronutrient Deficiencies

Micronutrient deficiencies are driven by a complex interplay of dietary, biological, socio-economic, and global crisis factors. Diet quality significantly impacts micronutrient intake, with a prevalent shift towards ultra-processed foods leading to lower nutritional quality and increased risks for deficiencies, particularly of iron and vitamins (29). Biologically, certain life stages such as pregnancy and menstruation heighten the demand for micronutrients, while chronic infections can exacerbate deficiencies by reducing nutrient absorption and utilization (30,31). Socio-economically, poverty and food insecurity remain critical determinants; low-income populations often face barriers to accessing diverse and nutritious food sources, thus perpetuating nutrient-poor diets (32). Furthermore, crises stemming from the COVID-19 pandemic, ongoing conflicts, and climate change have worsened global food security, affecting supply chains and increasing food costs, which ultimately impacts the nutritional status of vulnerable populations (33).

Public Health Impact

The public health impact of micronutrient deficiencies is profound, significantly contributing to morbidity, mortality, and Disability-Adjusted Life Years (DALYs). Anemia, a prevalent form of micronutrient deficiency, particularly affects women of reproductive age and children, leading to adverse health outcomes such as increased maternal mortality, complications during pregnancy, and hindered child growth and cognitive development (20,34). These health issues not only diminish individual productivity but also impose substantial economic burdens on healthcare systems and societies, primarily through direct healthcare costs and loss of workforce productivity due to illness (22,35). The interplay between micronutrient deficiencies and socio-economic factors such as poverty and food security has become increasingly pronounced amid global crises including the COVID-19 pandemic, which exacerbated food insecurity and hindered access to nutritional resources (36,37). Global estimates indicate that deficiencies, particularly among vulnerable populations, could lead to severe economic consequences, as countries grapple with heightened health service demands and the long-term effects of a nutritionally compromised population (18,38). Thus, addressing micronutrient deficiencies is vital for enhancing public health outcomes and sustaining economic stability, particularly in low- and middle-income countries.

The effectiveness of nutrition interventions such as food fortification, supplementation, and food-based approaches continues to be a focal point for addressing micronutrient deficiencies globally. Systematic

reviews indicate that large-scale food fortification (LSFF) and targeted supplementation programs can significantly improve the micronutrient status of populations, particularly in low- and middle-income countries (LMICs) (39). However, these interventions should not stand alone; a multi-sectoral approach incorporating health, agriculture, and education is essential to create sustainable and impactful changes. This includes integrating agriculture that promotes the production of nutrient-rich foods, delivering nutrition education to empower communities, and implementing robust health care policies to ensure accessibility and affordability of nutritious foods (40,41). Furthermore, community-based interventions, particularly through primary health care, play a crucial role in delivering these services effectively, enabling local populations to address their specific nutritional deficiencies while fostering sustainable consumption practices (42).

The relevance of addressing these micronutrient deficiencies aligns closely with the Sustainable Development Goals (SDGs), particularly Goal 2 (Zero Hunger) and Goal 3 (Good Health and Well-being). Achieving these targets requires a concerted global effort to ensure food security and improve nutrition, particularly for vulnerable populations such as women and children (43). The failure to meet these global targets by 2030 could result in severe implications, exacerbating health disparities and undermining economic productivity and human potential (44). Additionally, long-term investments in nutrition systems, including policies that support the fortification and biofortification of staple foods, must be prioritized to ensure that all populations have access to nutritious diets. Such investments are critical to combat malnutrition and enhance overall public health and economic resilience (45).

Research gaps in the field of micronutrient deficiencies, particularly regarding the availability of recent data and nutritional surveillance, remain significant obstacles to effectively addressing these public health issues. Many current studies fail to incorporate comprehensive longitudinal data, which is crucial for understanding the long-term effects and trends associated with micronutrient deficiencies across different populations (46). Additionally, there is an urgent need to conduct population-based interventions that evaluate the effectiveness of various strategies for preventing and addressing these deficiencies, particularly in low- and middle-income countries where the burden is greatest (19,47). Another major gap lies in the integration of micronutrient indicators into national monitoring systems, as many existing frameworks overlook essential biomarkers and dietary assessments that could provide a clearer picture of nutritional status and its associated health outcomes (48).

For future directions, expanding the scope of nutritional indicators and improving the methodologies for data collection and analysis are crucial for refining policy and program responses aimed at combatting micronutrient deficiencies. This includes enhancing the frequency and breadth of dietary surveys while ensuring that these surveys capture local dietary patterns and food availability (49). By integrating indicators of micronutrient intake into existing health monitoring systems and aligning these with global health initiatives, countries can better target interventions, assess their effectiveness, and ultimately contribute to achieving Sustainable Development Goals (SDGs) related to nutrition and health (21,50). Furthermore, fostering partnerships between public health, agriculture, and education sectors can facilitate synergistic

approaches that promote food sovereignty, enhance food security, and prioritize nutritional education within communities, thus addressing micronutrient deficiencies holistically (51,52).

This narrative review has several strengths, including its broad global scope, epidemiological perspective, and the integration of evidence from international sources such as WHO, UNICEF, and large-scale population studies, allowing for a comprehensive understanding of micronutrient deficiencies across diverse settings. However, certain limitations should be acknowledged, particularly the narrative nature of the review, which does not follow systematic review protocols and may be subject to selection bias, as well as the heterogeneity of data sources and methodological differences that limit direct comparability across regions and time periods. Despite these limitations, the findings carry important implications for both public health practice and clinical care. Strengthening routine screening for micronutrient deficiencies—especially anemia—within primary health care services is essential, alongside improved nutrition education targeting vulnerable populations such as pregnant women, children, and adolescents. Health professionals play a critical role in early detection, counseling, and referral, while population-level strategies focusing on primary prevention (food fortification, dietary diversification, and supplementation) and secondary prevention (early diagnosis and treatment) are necessary to reduce the long-term health and socioeconomic consequences of micronutrient deficiencies.

CONCLUSION

Micronutrient deficiencies remain a pervasive and under-recognized global public health problem with substantial implications for morbidity, mortality, and long-term human capital development. Epidemiological evidence demonstrates that deficiencies in key micronutrients—particularly iron, vitamin A, iodine, zinc, and vitamin D—continue to disproportionately affect vulnerable populations such as children, pregnant women, and women of reproductive age, despite decades of nutrition interventions. The persistent burden of conditions such as anemia reflects complex interactions between inadequate dietary quality, socioeconomic inequality, infectious diseases, and limitations in health system capacity. Addressing micronutrient deficiencies requires integrated, multisectoral strategies that combine strengthened nutrition surveillance, effective food fortification and supplementation programs, improved dietary diversity, and robust primary health care services. Sustained political commitment and evidence-based public health actions are essential to accelerate progress toward global nutrition targets and the Sustainable Development Goals related to food security and health.

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