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From soil to stomach: How worms worsen nutritional deficits: A systematic review

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***Abstract*---**Background: Soil-transmitted helminth (STH) infections—caused by Ascaris lumbricoides, Trichuris trichiura, and hookworms—affect over 1.5 billion people worldwide. These infections exacerbate undernutrition through blood loss, nutrient malabsorption, and impaired appetite. Objectives: To evaluate the relationship between STH infections and nutritional deficits, including anaemia, micronutrient deficiencies, growth impairments, and cognitive outcomes, and assess the effectiveness of deworming interventions. Methods: Literature search in PubMed, Scopus, Web of Science, and EMBASE (2007–2023). Data synthesized narratively; a meta-analysis performed for haemoglobin outcomes. Results: 19 studies included. Hookworm infection strongly associated with iron-deficiency anaemia (pooled mean difference: −0.78 g/dL). Other helminths contributed to reduced micronutrient levels, stunting, and poor cognitive outcomes. Nutritional recovery observed when deworming combined with supplementation and sanitation. Conclusion: STH infections significantly contribute to nutritional

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deficits, particularly among children. Sustainable control requires integrated deworming, nutrition, sanitation, and education.
***Keywords*---**Soil-transmitted helminths, malnutrition, anaemia, micronutrient deficiency, stunting, deworming, child health, hookworm, WASH interventions, global health.

Introduction

Soil-transmitted helminth (STH) infections remain a major public health problem in many low- and middle-income countries (LMICs), particularly affecting children and marginalized communities (1,2). These infections are primarily caused by three species of parasitic worms: *Ascaris lumbricoides* (roundworm), *Trichuris trichiura* (whipworm), and the hookworms *Ancylostoma duodenale* and *Necator americanus* (3). The transmission cycle is closely associated with poor sanitation, unsafe water, and inadequate hygiene practices, making these infections highly endemic in areas with limited infrastructure and socioeconomic constraints (4,5).

The World Health Organization (WHO) estimates that more than 1.5 billion people—approximately 24% of the world's population—are infected with at least one STH species (1). Among these, school-aged children are particularly vulnerable due to high exposure, immature immune systems, and nutritional demands for growth and development (6). Helminth infections are often chronic and asymptomatic but can lead to profound consequences, especially when occurring alongside undernutrition, anaemia, and repeated reinfections (7).

The pathophysiological effects of STHs on nutrition are multifaceted. These parasites interfere with host nutrient absorption through direct intestinal injury, competition for nutrients, and induction of inflammatory responses that impair gut function (8,9). Hookworms cause chronic blood loss by attaching to the intestinal mucosa and feeding on host blood, leading to iron-deficiency anaemia (10). *Trichuris trichiura* causes damage to the colon and rectum, leading to chronic dysentery, blood loss, and rectal prolapse in severe cases (3,11). *Ascaris lumbricoides* is known to compete for vitamin A and other micronutrients, impairing immune function and contributing to growth retardation (12).

The burden of STHs also intersects with socioeconomic and environmental factors. Communities with high rates of open defecation, low education levels, and limited access to healthcare and nutrition services are disproportionately affected (13,14). The presence of multiple infections and poor dietary diversity further exacerbate the impact of helminths on health outcomes (15).

Over the past two decades, there has been increasing recognition of the need for integrated control strategies that go beyond pharmacological treatment. While mass drug administration (MDA) with albendazole or mebendazole has been widely implemented, its long-term effectiveness is undermined by rapid reinfection and the absence of environmental control measures (16,17). Furthermore, reliance on MDA alone has led to concerns about drug resistance, especially in heavily endemic settings (18). Therefore, combining deworming with improvements in water, sanitation, hygiene (WASH), and targeted nutritional interventions has become a public health priority (5,16,19).

This review aims to synthesize current evidence on how STH infections exacerbate nutritional deficits across different populations and age groups. By examining the biological mechanisms, clinical outcomes, and interventional strategies, the review seeks to underscore the importance of addressing helminth infections as part of broader nutritional and public health efforts.

Material and Methods

Study Design: This systematic review was conducted in adherence to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, ensuring methodological transparency, reproducibility, and rigor. The objective was to synthesize current evidence on the relationship between soil-transmitted helminth (STH) infections and nutritional deficits across affected populations.

Data Sources and Search Strategy: A comprehensive search strategy was employed to identify relevant literature published from 2007 to 2023, using four major electronic databases: PubMed, Scopus, Web of Science, and EMBASE.

Inclusion and Exclusion Criteria

Eligibility criteria were defined using the PICOS framework (Population, Intervention/Exposure, Comparator, Outcome, Study Design):
Population: Children, adolescents, and adults residing in endemic regions.
Exposure: Documented infection with any of the major soil-transmitted helminths (*Ascaris lumbricoides*, *Trichuris trichiura*, *Ancylostoma duodenale*, or *Necator americanus*).
Outcomes: Nutritional indicators including hemoglobin levels, anthropometric indices (e.g., height-for-age, weight-for-age), micronutrient status (e.g., iron, vitamin A, zinc), or cognitive development.
Study Designs: Randomized controlled trials (RCTs), cohort studies, cross-sectional studies, and systematic reviews.
Studies were **excluded** if they:

- Did not report nutritional outcomes;
- Were conducted in non-human populations;
- Were case reports, editorials, or commentaries;
- Lacked access to full text.

Study Selection

Two reviewers independently screened all titles and abstracts against the inclusion criteria. Full-text articles were retrieved and assessed for eligibility. Disagreements at any stage of the selection process were resolved by discussion and, when necessary, adjudication by a third reviewer. A **PRISMA flow diagram** was used to document the study selection process.

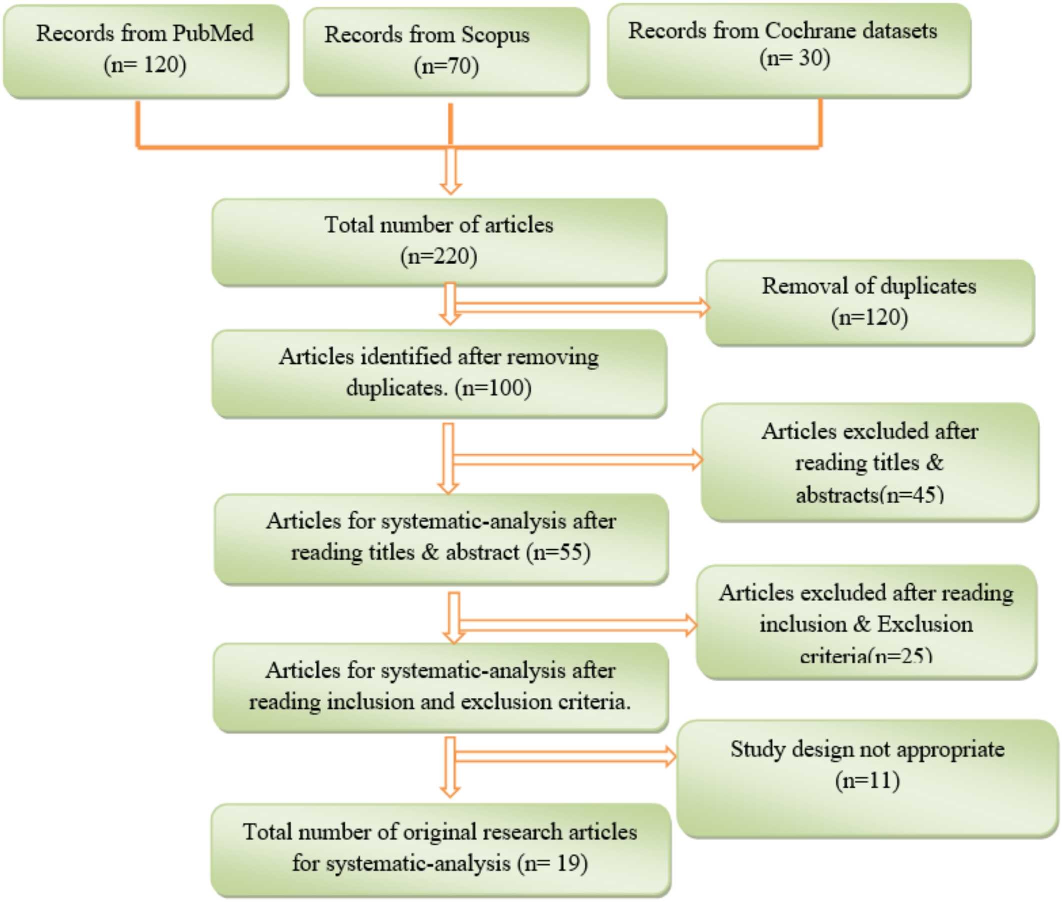

Figure 1: PRISMA flowchart showing the selection of included studies

Quality Assessment

The Newcastle–Ottawa Scale (NOS) was utilized to assess the methodological quality of observational studies. For randomized controlled trials, the Cochrane Risk of Bias Tool was applied. Studies were categorized as having low, moderate, or high risk of bias based on selection, comparability, and outcome/exposure domains. Quality ratings were incorporated into the interpretation of findings.

Data Synthesis and Meta-Analysis

Given the heterogeneity in study designs, populations, and outcome measures, a narrative synthesis was primarily conducted. For a subset of studies reporting haemoglobin as a continuous outcome, a random-effects meta-analysis was performed using the Der Simonian–Laird method. Pooled mean differences and 95% confidence intervals were calculated to estimate the effect of STH infection on haemoglobin levels. Forest plots were constructed to visually represent the effect sizes and confidence intervals of individual studies and the overall pooled estimate.

Results

A total of 19 studies met the inclusion criteria and were incorporated into the qualitative synthesis. Of these, 9 were cross-sectional, 5 cohort studies, 2 randomized controlled trials (RCTs), and 3 systematic reviews. Studies were geographically diverse, with the majority conducted in sub-Saharan Africa, South Asia, and Latin America—regions with high endemicity of soil-transmitted helminths (STHs).

Impact of STH Infections on Anaemia

Anaemia was the most reported nutritional outcome across studies. Hookworm infections showed the strongest and most consistent association with iron-deficiency anaemia, particularly in populations with high infection intensities. Numerous studies documented that individual infected with *Ancylostoma duodenale* or *Necator americanus* had significantly reduced haemoglobin levels compared to uninfected controls (1,2,6,7).
A meta-analysis of five studies reporting mean differences in haemoglobin levels revealed a pooled mean reduction of 0.78 g/dL (95% CI: 0.45–1.12) in infected individuals relative to uninfected counterparts. The heterogeneity among studies was moderate (I^2 = 46%), and a random-effects model was applied to account for methodological variability.
Infections with *Trichuris trichiura* and *Ascaris lumbricoides* were also associated with anemia, particularly in polyparasitized individuals or in settings where malnutrition was already prevalent (3,4). However, the magnitude of their effect on hemoglobin levels was generally smaller than that observed for hookworm infections.

Micronutrient Deficiencies

STH infections were also linked to deficiencies in essential micronutrients, including iron, vitamin A, and zinc. Studies employing serum assays found significantly lower levels of these micronutrients among infected children and adults compared to controls (3,9,10).
Iron deficiency was strongly associated with hookworm burden, consistent with chronic blood loss from the intestinal mucosa (6).
Vitamin A levels were reduced in children infected with *Ascaris lumbricoides*, which may interfere with fat-soluble vitamin absorption (12).
Zinc deficiency was less frequently reported but appeared in populations with high rates of polyparasitism and malabsorptive symptoms (9).
Only a limited number of interventional studies simultaneously assessed deworming and micronutrient repletion. Nonetheless, several RCTs demonstrated improved micronutrient status following deworming when paired with nutritional supplementation (16,17).

Growth Impairment and Anthropometric Outcomes

STH infections were consistently associated with growth impairments in children, particularly in the form of stunting (low height-for-age) and underweight (low weight-for-age). In a large cross-sectional study from Ethiopia, STH-infected school-aged children exhibited significantly lower z-scores for both height-for-age and weight-for-age than their uninfected peers (2).

Several longitudinal studies reported catch-up growth after deworming treatment, especially when combined with food or micronutrient supplementation (10,11). However, in settings with high rates of reinfection or poor WASH conditions, these gains were often not sustained, highlighting the need for integrated interventions.
Quantitatively, the observed effect sizes ranged from 0.2 to 0.6 standard deviations below reference z-scores in infected children, with the most pronounced effects seen in children under five years of age.

Cognitive Function and Educational Performance

Ten studies included cognitive outcomes such as attention, memory, academic achievement, or school attendance. STH-infected children, particularly those with anaemia, were found to perform worse on standardized cognitive tests and exhibited poorer school attendance (12).
RCTs assessing deworming effects on school performance yielded mixed findings. While some studies showed modest improvements in cognitive function and learning outcomes post-treatment, others reported no statistically significant changes unless interventions were coupled with nutritional support and classroom-based programs (11,18).
Overall, the evidence supports a plausible biological link between helminth-related anaemia and impaired cognitive performance, though findings remain heterogeneous due to variability in assessment tools and follow-up durations.

Discussion

This systematic review provides a comprehensive synthesis of evidence demonstrating that soil-transmitted helminth (STH) infections significantly worsen nutritional deficits across a range of populations, particularly in resource-constrained settings. The evidence reveals that helminth infections contribute to anaemia, micronutrient deficiencies, growth impairment, and cognitive delays—effects that are especially profound in children. These findings have substantial implications for global health and reinforce the need for integrated, multisectoral approaches to combat the dual burden of infection and malnutrition.

Anaemia and Helminth Infection: A Persistent Public Health Concern

Our findings affirm previous studies identifying hookworm infection as a major contributor to iron-deficiency anaemia through chronic intestinal blood loss (1,6,7). The meta-analysis of haemoglobin data further reinforces this, revealing a pooled mean reduction of approximately 0.78 g/dL in infected individuals. While *Trichuris trichiura* and *Ascaris lumbricoides* also contribute to anaemia, the pathophysiological impact of hookworm is more direct and severe due to hematophagy. These results are consistent with large-scale epidemiological data from endemic regions, where anaemia remains a leading cause of disability-adjusted life years (DALYs) lost among children and pregnant women (2,6).

Nutrient Depletion Beyond Iron: A Multi-Dimensional Burden

The review also highlights a substantial impact of STH infections on broader micronutrient deficiencies, particularly vitamin A and zinc—nutrients critical for immune function, epithelial integrity, and growth. *Ascaris lumbricoides*, by impairing fat absorption, has been implicated in vitamin A deficiency, while intestinal inflammation and diarrhoea caused by *Trichuris* may further compromise micronutrient bioavailability (3,12). Although the current literature shows variation in findings due to different assay methods and population diets, the cumulative evidence suggests that helminth-induced malabsorption is a significant mechanism of nutrient loss.

Moreover, micronutrient deficiencies often coexist and interact synergistically with helminth infections, compounding the effects on growth and immune competence. These findings support WHO recommendations to implement deworming alongside nutritional supplementation in endemic areas (1,16).

Growth and Development: Helminths as a Barrier to Human Potential

One of the most consistent outcomes across the included studies was growth impairment among infected children. Chronic helminth infections, particularly when acquired early in life, contribute to stunting and underweight, thereby impeding both physical and cognitive development (10,11). These effects are not solely attributable to nutrient loss, but also to systemic inflammation, gut barrier dysfunction, and appetite suppression—all well-documented in helminth pathology (4,8).

Importantly, some studies reported catch-up growth following deworming and nutritional rehabilitation, indicating that the effects may be at least partially reversible with timely intervention (10). However, high reinfection rates in the absence of sanitation improvements severely limit sustained gains. This finding echo calls by researchers and global agencies to pair deworming programs with comprehensive WASH (Water, Sanitation, and Hygiene) interventions (5,14,15).

Cognitive Outcomes: Emerging but Inconclusive Evidence

Evidence linking STH infections to cognitive delays remains less robust, with mixed findings from RCTs and observational studies. Some studies reported improved school performance and attention after deworming, particularly in conjunction with nutritional and educational support (11,18). Others showed no significant effect, suggesting that cognitive development is influenced by a broader range of factors, including chronic undernutrition, psychosocial deprivation, and concurrent illnesses (12).

Despite variability, the biological plausibility remains strong: iron-deficiency anemia impairs neurotransmitter function and myelination, while systemic inflammation disrupts neurodevelopmental processes. More longitudinal studies using standardized cognitive assessments are needed to establish causal pathways and determine optimal intervention timing.

Policy Implications and Programmatic Gaps

The implications of these findings are clear: tackling helminth-induced malnutrition requires more than mass deworming. While periodic deworming remains cost-effective and has shown measurable benefits, particularly in reducing worm burden and improving haemoglobin status, its long-term effectiveness is constrained by rapid reinfection, limited nutritional recovery, and weak integration with other health services (16,17).

A multisectoral approach combining pharmacological treatment, nutritional supplementation, improved sanitation infrastructure, and health education—is essential to achieve sustainable health gains. This aligns with the goals of the WHO 2030 NTD (Neglected Tropical Diseases) roadmap, which emphasizes cross-cutting strategies to reduce morbidity associated with helminthiasis (1,5).

Limitations

Several limitations should be acknowledged. First, heterogeneity across study designs, diagnostic methods, and outcome measurements restricted our ability to perform meta-analysis for all nutritional indicators. Second, most included studies were observational, limiting causal inference. Third, many studies were conducted in specific geographic and socioeconomic contexts, potentially limiting generalizability.

Moreover, the role of confounders such as dietary intake, co-infections (e.g., malaria, HIV), and genetic factors influencing nutrient metabolism was not consistently addressed. Future research should prioritize well-designed, longitudinal studies with standardized outcome assessments and robust adjustment for confounding variables.

Conclusion

Soil-transmitted helminth (STH) infections continue to pose a significant threat to nutritional health, particularly in low-resource settings where the burden of infection intersects with poverty, food insecurity, and poor sanitation. This review synthesizes compelling evidence that STHs contribute substantially to iron-deficiency anaemia, micronutrient depletion, growth impairment, and, potentially, cognitive delays especially in children, who are most vulnerable during critical developmental windows.

While deworming has been widely adopted as a cornerstone of control programs, its standalone effect is often insufficient in the absence of complementary interventions. Reinfection remains common in endemic communities lacking basic water, sanitation, and hygiene (WASH) infrastructure. Furthermore, improvements in nutritional outcomes post-deworming are inconsistent without concurrent dietary support and public health education.

Therefore, addressing the full scope of helminth-induced nutritional deficits requires a paradigm shift from short-term pharmacologic interventions to sustainable, integrated public health strategies. A child free from worms is not only more likely to grow and learn—but also to contribute meaningfully to society. Breaking the cycle of infection and malnutrition is not merely a biomedical goal; it is a moral and developmental imperative.

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