Perspective Piece

A One Health Approach to Child Stunting: Evidence and Research Agenda

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Abstract. Stunting (low height for age) affects approximately one-quarter of children aged < 5 years worldwide. Given the limited impact of current interventions for stunting, new multisectoral evidence-based approaches are needed to decrease the burden of stunting in low- and middle-income countries (LMICs). Recognizing that the health of people, animals, and the environment are connected, we present the rationale and research agenda for considering a One Health approach to child stunting. We contend that a One Health strategy may uncover new approaches to tackling child stunting by addressing several interdependent factors that prevent children from thriving in LMICs, and that coordinated interventions among human health, animal health, and environmental health sectors may have a synergistic effect in stunting reduction.

Stunting (low height for age) affects approximately one-quarter of children aged < 5 years1 and is associated with increased mortality, impaired neurodevelopment, elevated chronic disease risk, and reduced productivity.2 Despite gradual global declines in stunting prevalence, the absolute number of stunted children in Africa is increasing because of population growth.1 Nutrition interventions would reduce stunting prevalence by only 20% if implemented with 90% global coverage3; thus, additional approaches to complement nutrition interventions are needed.4 Preventing diarrhea through improved water, sanitation, and hygiene (WaSH) is central to stunting reduction efforts.5 However, recent studies using molecular methods to identify fecal pathogens have shown that enteropathogen colonization in low- and middle-income countries (LMICs) occurs much earlier in life than previously realized, and subclinical carriage is associated with larger and more sustained decrements in linear growth than diarrhea.6,7 It is hypothesized that infection by fecal microbes drives environmental enteric dysfunction (EED), a subclinical disorder of the small intestine characterized by inflammation, permeability, and malabsorption, and that EED contributes to stunting.8 However, randomized controlled trials of household-level WaSH interventions to interrupt fecal–oral transmission pathways in infants have failed to improve linear growth,9 and transformative approaches are therefore required.10

Recently, we argued that reducing microbial transmission from animals to children is an overlooked component of most WaSH programs because animal feces may be a major source of enteropathogens.11 However, strategies to separate animals and their feces from children must also consider the importance of animals for rural livelihoods, as well as the health of their shared environments. A holistic approach, considering human, animal, and environmental health as One Health, may be central to successfully reducing stunting.

EVIDENCE FOR A ONE HEALTH APPROACH

Animal–human links. Livestock contribute to the livelihoods of 70% of the world’s rural poor.12 An estimated 85% of rural households in sub-Saharan Africa keep poultry,13 with similar estimates for Asia14,15 and Latin America.16 Poultry and other peri-domestic livestock, including cattle, goats, sheep, and pigs, are economic assets; have sociocultural value; and provide labor, transportation, fertilizer, and fuel.17 Animal-source foods, such as milk, eggs, and meat, can prevent or ameliorate micronutrient deficiencies and provide high-quality protein.18 However, livestock and other peri-domestic animals (e.g., dogs and cats) are a source of fecal contamination of the domestic environment. Shared pathogenic and nonpathogenic microbes have been identified in humans and animals living in close proximity,19,20 and animal fecal pathogens can cause diarrhea21 and other adverse health outcomes22 in humans.

Animal–environmental links. With nearly 30 billion livestock animals on earth, recent estimates indicate 4-fold higher global production of animal feces compared with human feces.23 Management of animal feces is highly unregulated in LMICs and neglected in most WaSH programs.11 This particularly affects populations in rural LMICs who own peri-domestic animals, which typically forage freely within the household compound and are often kept indoors at night for

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security. Without adequate sanitation and hygiene, household environments and drinking water sources can become contaminated with animal feces, and multiple studies from Bangladesh and India have used microbial source-tracking to identify animal fecal-derived contamination in household environments and on human hands.

**Environmental-human links.** Exposure to human fecal pathogens due to unsafe or insufficient WaSH resources causes a significant burden of diarrheal disease in LMICs. Fecal contamination of the environment from human sanitation systems, including inadequate household sanitation systems and low community-level coverage, is well-documented and may be compounded by fecal contamination from animal sources. Conventional sanitation improvements focused on isolating human feces have failed to reduce fecal contamination in the environment; this may be in part because animal feces are not adequately managed.

On an individual scale, infants interact with their environments through hand- and object-mouthing, a common exploratory behavior during early development stages. Research from Bangladesh suggests that hand- and object-mouthing is more common in rural LMICs than in high-income countries. Geophagia, or ingestion of soil, is hypothesized to be an important route of fecal–oral transmission in infants, potentially contributing to enteropathogen carriage, diarrhea, EED, and, in turn, stunting. Studies from Bangladesh confirmed that children with reported geophagia have higher markers of EED and increased odds of stunting.

**Pulling it together: Human–animal–environmental links to stunting.** Several studies have highlighted that the interactions between humans, animals, and their shared environment may impact childhood growth. Environmental contamination with animal feces has been linked to child stunting in observational datasets: a study in Bangladesh and Ethiopia identified a negative association between the presence of animal feces in the compound and child height-for-age Z-scores. In Ethiopia, poultry ownership reduced the risk of stunting through increased consumption of eggs; however, corralling poultry in the household overnight increased the risk of stunting, suggesting that proximity of children and animals may be an important consideration.

Among Bangladeshi households owning poultry, an animal corral in a child’s sleeping room was associated with elevated EED biomarkers and increased odds of stunting; similarly, in Malawi, having an animal in a child’s sleeping environment was associated with EED. During an observational study in rural Zimbabwe to identify potential pathways of fecal–oral transmission that may contribute to stunting, 87% of household yards contained chicken feces, and infants actively ingested soil and dried chicken feces. Collectively, existing knowledge regarding human–animal–environmental linkages provides a strong rationale for a One Health approach to child stunting (Figure 1).

**UNKNOWNS AND RESEARCH AGENDA**

A multisectoral approach has the potential to improve human, animal, and environmental health in tandem and could inform the design of appropriate interventions to alleviate child undernutrition, reduce environmental fecal exposure, and maximize animal health, production, and welfare. To address current knowledge gaps, we propose a research agenda (Figure 2) with three goals outlined in the following paragraphs.

1. **Define the relationship between microbial carriage and child health.** Microbial carriage and shedding in animals may be influenced by age, health status, diet, management, and spatiotemporal dynamics; to our knowledge, these factors have not been well-evaluated in rural LMIC settings. Furthermore, characteristics of the environment itself (e.g., soil characteristics) may impact microbial diversity.

   ![Figure 1](https://example.com/figure1.png)

   **Figure 1.** Evidence to support the need for a One Health approach to stunting.

   1. Animals are commonly kept in household environments in rural LMIC with minimal housing/confine ment.
   2. Animal feces can contaminate household floors, soil, and water sources.
   3. Animals can acquire microorganisms from their environment.

   1. Environments can become contaminated with human feces in the absence of adequate WaSH infrastructure.
   2. Young children explore their environment through geophagia (ingestion of soil).
   3. Geophagia has been linked with environmental enteric dysfunction and stunting.

   ![Animals](https://example.com/animals.png)

   ![Humans](https://example.com/humans.png)

   ![Environment](https://example.com/environment.png)

   1. Animals provide nutritional, economic, and other benefits to rural households.
   2. Microbes can shared between humans and animals.
   3. Pathogens from animal sources can cause diarrhea and other adverse health outcomes in humans.
and spectrum of human carriage of animal-derived microbes is poorly characterized, and the risk to human health from animal feces has not been systematically quantified. It is unclear whether microbes from human and animal feces must be traditionally “pathogenic” to contribute to EED. Certain microbes can be conditionally pathogenic (so-called “pathobionts”) in both humans and animals depending on health status and other environmental factors. Evidence regarding whether some animals contribute more than others to child enteropathogen carriage (because of species compatibility, magnitude of shedding, or frequency of contact) remains limited, and it is uncertain how much reduction in fecal microbe ingestion is required for child health gains. Genotype-level microbiome evaluations of children, peri-domestic animals, and the environment, accounting for spatiotemporal variation, would improve our understanding of shared microbial communities. Next-generation sequencing and other stool-based molecular techniques may assist in characterizing shared species and strains.

**Document transmission pathways.** Proposed routes for transmission of fecal pathogens from animals to humans include the “modified F-diagram” factors: fluids (water sources), fields (or soil), food, flies, fingers, and fomites (objects and surfaces), which are routes of transmission shared with human feces. However, further research is needed to quantify the risk from each pathway, identify novel transmission routes (particularly in young, pre-mobile infants during breastfeeding), and ascertain key points for intervention in different contexts. A broader One Health approach should strive to characterize and quantify microbial transmission routes not just to humans but also among different animal species and the environment, as well as the consequences for animal health and production. Furthermore, environmental contamination from release of untreated human and animal fecal waste into the environment may perpetuate cycles of reinfection through repeated exposure and shedding and may contribute to emergence of antimicrobial resistance; transmission of resistant organisms and consequences for human, animal, and environmental health should be further characterized.

**Understand local contexts to inform interventions.** There is need to learn about the range of interactions between humans, animals, and the environment from communities to identify ways of promoting the benefits of livestock ownership while minimizing the risks of fecal microbe exposure. Intervention trials to reduce microbial transmission from peri-domestic animals are a critical proof-of-concept step. Among the few trials specifically aimed at reducing peri-domestic animal fecal contamination, interventions have included separating animals (specifically poultry) from human living spaces, creating safe play spaces for children, providing animal feces scoops, and improving veterinary care. The first three strategies have had limited effectiveness in reducing animal fecal contamination, and uptake of corralling interventions may be poor because of cost and community perception. Formative work regarding animal husbandry practices and perceptions of animal feces was included in the CAGED trial in Ethiopia and the SELEVER trial in Burkina Faso, and similar context-specific results may inform new interventions in additional settings. Agricultural extension interventions may be explored to improve delivery of animal health services and increase production of animal-source foods, although more research is needed to characterize the impact of these foods on child growth and to develop economically sustainable livestock production models. Consideration of animal feces in the design of WaSH interventions may also have potential to reduce pathogen burden and promote child health. Co-design of One Health strategies through community participation, considering the feasibility, acceptability, and trade-offs of different models, may be the most effective approach for each unique setting and context.
In summary, we believe our proposed research agenda could uncover new approaches to reducing child stunting by tackling several interdependent factors that prevent children from thriving in LMICs. A One Health approach could yield collective benefits by concurrently promoting the health of people, animals, and environments.

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REFERENCES


