Bayesian network analysis to elucidate potential causal associations between helminth infection, anthelmintic treatment and childhood stunting

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Background

Childhood stunting is defined by the World Health Organization (WHO) as falling more than -2 standard deviations below the height-for-age Child Growth Standards median and affects approximately 149.2 million children under five years globally[1]. Physical stunting may also be accompanied by cognitive stunting, characterised by delayed or reduced neurocognitive development, attention, and memory[2]. The prevention and/or treatment of stunted children is challenging since the aetiology and pathophysiological mechanisms underlying it remain largely undeciphered[3]. Although empirical data are often lacking, infection of pregnant mother and/or child with helminths has been associated with physical stunting, and further, anthelmintic treatment has been associated with improved stunting outcomes[4,5].

Eight-year-old children at primary school in Madagascar, underneath a chalk line that illustrates how tall children of that age should be. Photograph: Kate Holt/WaterAid.

Objectives

- Generate a directed acyclic graph (DAG) summarising potentially causal pathways potentially implicated in the relationship between helminth infection and childhood stunting.
- Parameterise a Bayesian Network (BN) based on the DAG using Demographic Health Survey (DHS) data.
- Use BN analysis (BNA) to evaluate drivers of stunting and examine evidence gaps.

Hypotheses

- There is a causal association between child helminth infection and/or anthelmintic treatment and childhood physical stunting.

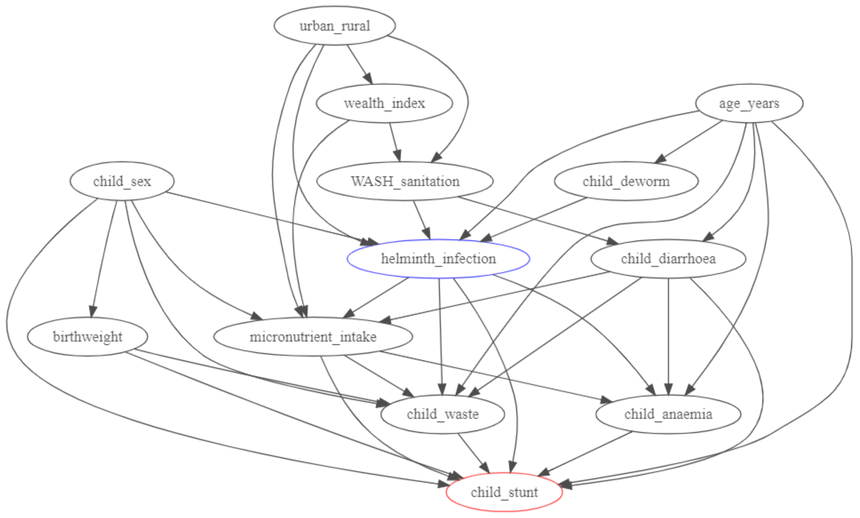
- **Bayesian networks (BN)** are probabilistic graphical models that represents a set of variables and their conditional dependencies via a directed acyclic graph.
- **Directed acyclic graphs (DAGs)** are visual representations of potential causal relationships between variables via a directed graph with no cycles.

Causation vs correlation

Observational studies may find correlations between observed variables and stunting. Alone, these studies cannot demonstrate causality. In the current study, BNA allows for causal modelling, thus predicting the likelihood of factors as causative in the pathway to stunting.

Evidence synthesis for constructing directed acyclic graphs (ESC-DAGs)

ESC-DAGs is a novel and systematic method for building DAGs[6]. To generate the DAG displayed in figure 1, controls and confounding variables were identified from studies included in a systematic review by Raj E. et al., (2022)[7] which looked at the association between anthelmintic treatment and childhood stunting. The potential relationship between the exposure of interest (helminth infection: helminth_infection), outcome of interest (childhood stunting: child_stunt), and each control and confounding variable found was assessed.



Edge assessment criteria:

- Temporality—does the posited cause precede effect?
- Face-validity—is the posited relationship plausible?
- Recourse to theory— is the posited relationship supported by theory?
- Counterfactual thought experiment

Edges were retained as posited, reversed, or noted as potentially bi-directional.

Figure 1 (left). Potential DAG displaying the causal assumptions between the exposure of interest (helminth_infection) and the outcome of interest (child_stunt). Causal relationships are conveyed via an arrow; absence of an arrow indicates a no causal relationship assumption.

The DAG in figure 2 is represented by the joint probability distribution of variables A, B, and C, where A is child_deworm, B is child_stunt, and C is wealth_index:

$$P(A,B,C) = P(C) \times P(A \mid C) \times P(B \mid A,C)$$

To determine the conditional probabilities of child_stunt given child_deworm, wealth_index was controlled for using bnlearn and gRain packages implemented in r. Wealth acts as a confounding factor, creating a false narrative where dewormed children are less likely to be stunted. When controlling for wealth index, the influence of deworming is still present, although less pronounced.

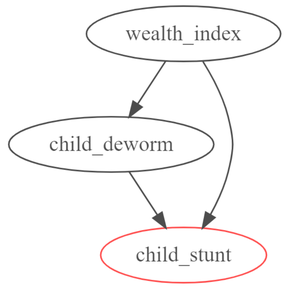


Figure 2. Simplified DAG showing the causal relationship of child_deworm on child_stunt, where wealth_index acts as a confounding factor.

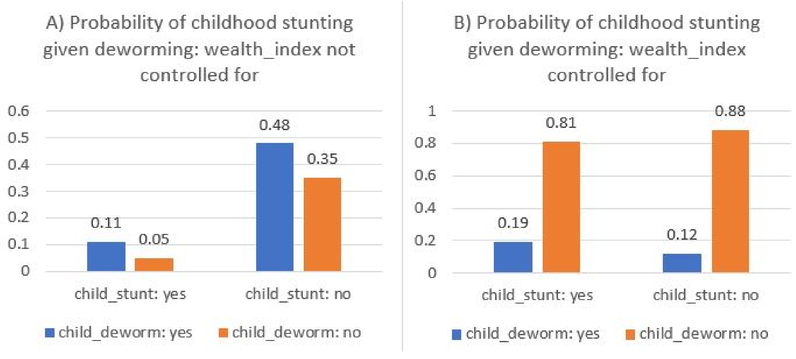


Figure 3. Using data from the DHS Senegal 2017 dataset, A) provides the conditional probabilities of childhood stunting given deworming B) included wealth index as a confounder.

Next steps

Next steps will involve including more variables from figure 1 in BNA to determine the relationship between helminth infection and anthelmintic treatment and childhood stunting, building a model that more closely mirrors reality.

Impact

To contribute towards policies around anthelmintic treatment of women during antenatal care and/or young children (under 5 years of age).

1) WHO (2014) Global Nutrition Targets 2025 Stunting Policy Brief, **2) de Onis M.et al.,** (2016) Matern Child Nutr, **3) Vonaesch P. et al.,** (2018)BMC Pediatr, **4) Gabain I.L. et al.,** (2023) Trends in Parasitology, **5) Lo N.C.** (2018)*PLoS Negl Trop Dis.* **6) Ferguson, et al.** (2020) *International journal of epidemiology, 7)* **Raj, E et al.** (2022) *Parasites & vectors.*