Rural Embodiment and Child Health (REACH) Study:
Effects of resource access and macroparasite exposure on intestinal inflammation among children from rural Mississippi

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Introduction

Embodiment theory describes how sociocultural circumstances become internalized and ultimately affect physiology and health.[1]

Importantly, in the United States:

- Life expectancy in the Mississippi Delta is lower than in other regions[2]
- Gastrointestinal cancer risk is higher among Black Americans[3]
- Black Americans show more robust inflammatory responses to intestinal infection that may contribute to cancer risk[4]
- These factors are not based on genetic predispositions to poor health, but rather embodied social and environmental experiences[1]

Little is known about the developmental trajectory of these health inequities. Here we provide a preliminary exploration of the potential roles that resource access and environmental exposure to macroparasites play in shaping intestinal health (**Figure 1**).

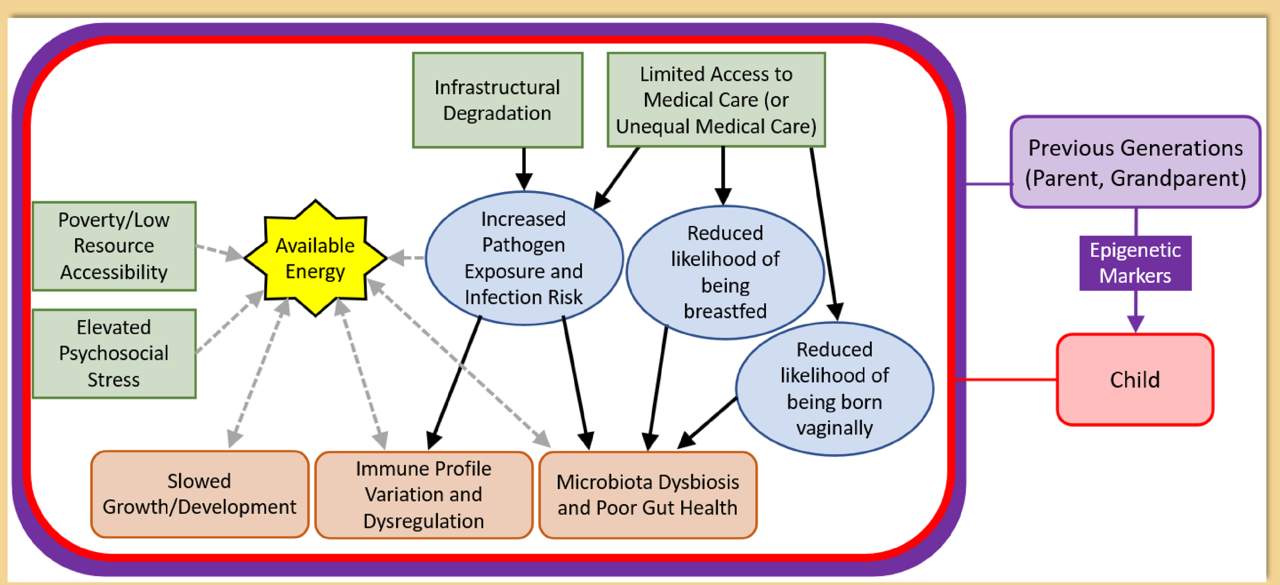

Figure 1. Pathways through which resource access, infrastructural degradation, and discrimination may alter child health and development

This preliminary data comes from the initial exploratory field season of the Rural Embodiment and Child Health (REACH) study, which aims to understand the prevalence and outcomes of parasitic infection in the U.S.

Data were collected among 20 children (ages 3 to 14 years) from 12 families living in a low-resource, predominantly Black community in the rural Mississippi Delta. We predict:

1. **Fecal calprotectin (a biomarker of intestinal inflammation) levels will be higher among sampled participants in association with anthropometric measures of under/overnutrition (e.g., BMI- and Height-for-age z-scores), lower parent-reported household income, larger household size, and living below the poverty threshold.**
2. **Fecal calprotectin will be higher in participants experiencing infections with macroparasitic worms (helminths).**

Methods

The following measures were collected:

- Stool Samples
  - **Fecal calprotectin** (**FC**; Extracted using Calex Cap devices and analyzed via ELISA [BUHLMANN Diagnostics]): clinically elevated at >50 ug/g
  - **Helminth infection status** (measured from 18s rRNA amplification/sequencing): **Platyhelminth** (flatworm) and/or **Nematode** (roundworm) presence
- Anthropometrics
  - Height (measured using a portable stadiometer): **Height-for-age z-scores** were calculated using WHO standards
  - Weight (measured using a TANITA children's scale)
  - **BMI-for-age z-scores** were calculated from height and weight following WHO standards
- Parent Interviews
  - **Household Income** (<$10,000; $10,000-$19,999; $20,000-$34,999; $35,000-$49,999; $50,000-$74,999; $75,000-$99.999; $100,000+)
  - **Household Size** (number of people living in the home)
- **Poverty Level** (calculated based on household income level and household size, following established methods)[5]

BCa bootstrap statistical analyses were conducted using SPSS 28. Results are considered significant if p < 0.05 and/or BCa 95% CI do not cross 0. ***Significant values are bolded and italicized in the tables.***

Results

Table 1 presents descriptive statistics. Values are presented as mean (SD) or % (n). FC is presented as median (IQR).

Table 1.		Participants (N = 20)
Age (years)		8.30 (3.18)
Intestinal Inflammation	FC level (ug/g)	129 (147)
	No Elevation (<50 ug/g)	20% (n = 4)
	Moderate Elevation (50-200 ug/g)	55% (n = 11)
	High Elevation (>200 ug/g)	25% (n = 5)
Anthropometrics	Height-for-age z-score	0.75 (1.30)
	BMI-for-age z-score	1.19 (0.79)
	Stunted (%)	5% (n = 1)
	Overweight (%)	50% (n = 10)
Household Information	Household Size	5.10 (1.41)
	Household Income Level	$20,000-$34,999
	Below poverty threshold (%)	65% (n = 13)
Infection Status	Helminth infection (any; %)	30% (n = 6)
	Nematode infection (%)	10% (n = 2)
	Platyhelminth infection (%)	25% (n = 5)
	Coinfection (%)	5% (n = 1)

Table 2 shows the results of BCa linear regression examining relationships between BMI-for-age and Height-for-age z-scores and FC levels.

Table 2.	Coefficient (SE)	BCa p	$CI_{95\%}$	Model r^2/p
Model				0.461/0.017
Household ID	13.76 (6.84)	0.081	-0.13, 23.92	
BMI Z-score	-80.30 (40.41)	0.081	***-154.63, -7.34***	
Height Z-score	39.24 (23.67)	0.143	-5.07, 89.21	

Table 3 contains the results of BCa linear regression for relationships between Household Size and Household Income and FC levels.

Table 3.	Coefficient (SE)	BCa p	$CI_{95\%}$	Model r^2/p
Model				0.38/0.017
Household Size	48.96 (24.58)	0.066	***4.65, 101.61***	
Household Income	-71.36 (29.00)	***0.023***	***-135.90, -16.44***	

Table 4 shows results from BCa ANCOVA test comparing FC levels based on infection status controlling for effects of body size and household income.

Table 4.	F	p	η_p^2	BCa p	BCa CI95%	Model r^2
Model	3.57	0.038	0.401			0.401
BMI Z-score	3.68	0.073	0.187			
Household Income	0.26	0.620	0.016			
Helminth infection	4.34	0.054	0.213	0.129	-54.87, 239.68	
Model	1.94	0.164	0.266			0.266
BMI Z-score	1.12	0.305	0.066			
Household Income	1.23	0.283	0.072			
Nematode infection	0.62	0.444	0.037	0.205	-167.90, 23.83	
Model	3.99	0.027	0.428			0.428
BMI Z-score	3.84	0.068	0.193			
Household Income	0.08	0.777	0.005			
Platyhelminth infection	5.30	***0.035***	0.249	0.128	-30.86, 301.42	

Figure 2 illustrates how platyhelminth infection, FC, and BMI z-scores are related. The relationship between platyhelminths and FC is likely driven by two infected children from different households with very high FC levels.

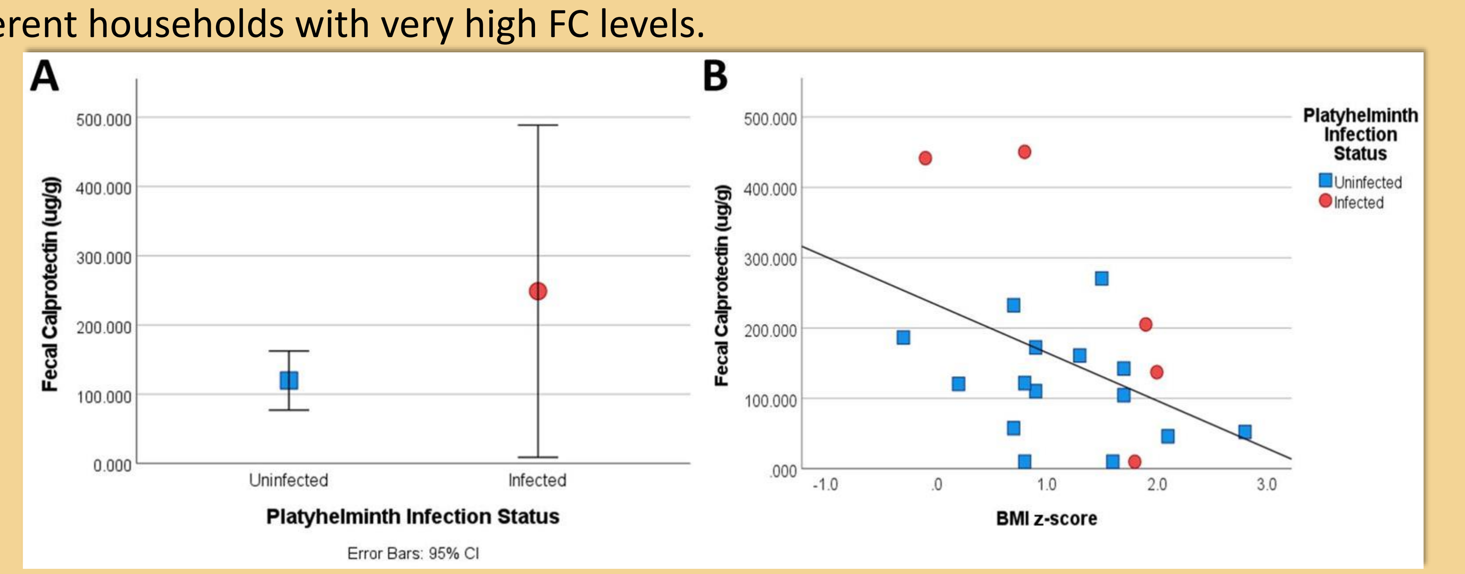

Figure 2. Relationships between platyhelminth infection, FC, and BMI Z-score

Key Findings

- Median FC (129 ug/g) in this sample was higher than clinical cutoffs (>50 ug/g).
- Most children (80%) had clinically elevated FC.
- FC was negatively associated with BMI z-score and Household Income. Poverty level had no effect.
- FC was positively associated with Household Size.
- 30% (n = 6) of children were experiencing helminth infections, including one double infection. The following types of helminths were found:
  - Nematodes (Roundworms): n = 2
  - Platyhelminths (Flatworms): n = 5
- Platyhelminth infection was positively associated with elevated FC, although this relationship appears to be driven by two infected participants with very high FC.

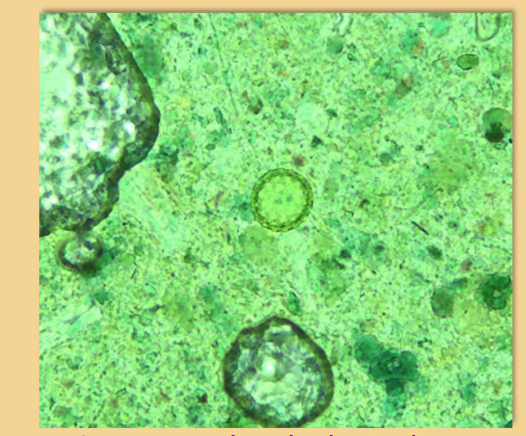

Figure 3. Platyhelminth egg detected microscopically from stool samples.

Discussion

This study found surprisingly high FC levels and high rates of clinically elevated intestinal inflammation. We also documented the presence of several helminth infections. Results provide tentative preliminary support for the predictions that intestinal inflammation is associated with resource access, nutritional status, and environmental exposures.

Resource Access: Children from households with lower household incomes had significantly higher FC levels, suggesting that socioeconomic status may play a role in intestinal inflammation. This may be occurring through embodied psychosocial stress, nutritional stress, suboptimal household infrastructure and sanitation, or other factors associated with socioeconomic status.

Nutritional Status: Smaller children had higher FC levels, suggesting that undernutrition or limited access to high quality, nutritionally dense food may be at play. This community is about 30 minutes from any grocery store selling fresh food and many community members do not have regular access to transportation. Most participants reported shopping at the local Dollar General or neighboring gas station for groceries.

Environmental Exposures: Children living in more crowded homes and those infected with helminths appear to have higher FC levels. It is important to consider that other disease agents and environmental toxins may also be at play. The community experiences frequent flooding and sewage back-ups both outside and in homes (**Figure 4**). The local nurse practitioner reported frequent pathogenic infections with *Helicobacter pylori*. The community also expressed concern about child exposure to pesticides and herbicides used on nearby farms. These environmental exposures will be explored in more detail in future field seasons.

Figure 4. A bayou runs through the study community, contributing to frequent flooding

Limitations and Future Directions

This research was conducted during the preliminary field season of the REACH study, which was mostly geared toward forging connections and learning about community concerns, resulting in a very small sample size and limited questionnaire. Future research will build on and broaden this sample size and will also incorporate community specific variables so we can more thoroughly speak to the roles of resource access, nutritional status, and environmental exposures on gastrointestinal health.

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Citations

[1]Gravlee. 2009. *Am J Phys Anthropol, 139*, 47-57. [2]Miller & Vasan. 2021. *Social Science & Medicine, 268*, 113443. [3]Ashktorab et al. 2017. *Gastroenterol, 153*, 910-923. [4]Butt et al. 2020. *Cancer Causes and Control, 31*, 601-606. [5]ASPE. 2021. Poverty Guidelines.