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Spatial and Age-Specific Distribution of Gastrointestinal Parasitic Infections in the Three Senatorial Districts of Anambra State, Nigeria

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ABSTRACT

Gastrointestinal parasitic infections (GIPIs) remain a significant public health challenge in Nigeria, particularly in southeastern states. Despite ongoing control efforts, comprehensive data on spatial distribution and age-specific prevalence across senatorial districts remain limited. This study investigated the spatial and age-specific distribution of GIPIs across the three senatorial districts of Anambra State, Nigeria, to inform targeted intervention strategies. A cross-sectional study was conducted between July 2024 and June 2025 across nine randomly selected Local Government Areas (three per senatorial district). Stool samples from 3,000 residents aged 1–60 years were examined using direct saline wet mount and formol-ether concentration techniques. Polymerase chain reaction (PCR) was employed for molecular confirmation of parasite species. Soil (400 samples), water (400 samples), and fruit/vegetable samples (400 samples) were analyzed for environmental contamination. Data were analyzed using SPSS version 20.0, with chi-square tests for categorical variables (p .05). The overall prevalence of GIPIs was 22.17% (232/3,000). Eight parasites were identified: Taenia spp. (6.11%), Strongyloides stercoralis (4.01%), Ascaris lumbricoides (3.92%), Entamoeba histolytica (3.85%), hookworm (2.00%), Trichuris trichiura (1.52%), Giardia lamblia (0.57%), and Entamoeba dispar (0.19%). Age-stratified analysis revealed highest prevalence in children aged 0–10 years (8.12%), declining progressively with age to 1.62% in adults ≥51 years (p < .05). Spatial distribution varied: Anambra North (9.75%), Anambra South (7.83%), and Anambra Central (4.59%) (p > .05). Environmental contamination rates were 23.50% in water (with streams showing 10.25%), 23.00% in soil, and 39.1% in fruits/vegetables (vegetables: 49.1%, fruits: 25.6%). Seasonal variation showed higher prevalence during the rainy season (59.51%) versus dry season (40.49%) (p.05). GIPIs remain endemic in Anambra State with significant age-specific and spatial variations. The high prevalence in children and substantial environmental contamination underscore the need for targeted deworming programs, improved water and sanitation infrastructure, and enhanced health education, particularly in Anambra North and South senatorial districts.

Keywords: Gastrointestinal parasites; spatial distribution; age-specific prevalence; senatorial districts; Anambra State; Nigeria

INTRODUCTION

Background

Gastrointestinal parasitic infections (GIPIs) represent a critical public health burden globally, particularly in tropical and subtropical regions where environmental conditions favor parasite transmission (Hotez et al., 2014). The World Health Organization (WHO) estimates that over 1.5 billion people worldwide are infected with soil-transmitted helminths (STHs), with the highest prevalence observed in sub-Saharan Africa (Pullan et al., 2014; World Health Organization, 2020). These infections significantly impact nutritional status, cognitive development, and overall quality of life, especially among vulnerable populations such as children and pregnant women (Bethony et al., 2006; Ezeamama et al., 2005).

In Nigeria, GIPIs remain endemic despite decades of control efforts, with prevalence rates ranging from 14.4% to 71.1% depending on region and study methodology (Nwaneri & Omuemu, 2013). The southeastern region, including Anambra State, experiences particularly high infection rates due to factors including tropical climate, poor sanitation infrastructure, limited access to clean water, and socioeconomic challenges (Emmy-Egbe et al., 2012; Igbodika, 2019). Polyparasitism, where individuals harbor multiple parasite species simultaneously, further complicates the disease burden and treatment strategies (World Health Organization, 2005).

The epidemiology of GIPIs exhibits distinct spatial and temporal patterns influenced by environmental, behavioral, and socioeconomic factors (Brooker et al., 2006). Understanding these patterns at the sub-state level is crucial for designing targeted intervention programs. However, most previous studies in Nigeria have focused on specific age groups (particularly school children) or single communities, providing limited insight into comprehensive spatial distribution across administrative units (Aribodor et al., 2011; Ukibe et al., 2018).

Rationale

Anambra State, located in southeastern Nigeria, comprises three distinct senatorial districts (North, Central, and South) with varying socioeconomic profiles, urbanization levels, and environmental characteristics (National Population Commission, 2006). Previous fragmented studies have reported varying prevalence rates across different communities, but no comprehensive investigation has systematically examined spatial distribution patterns across all three senatorial districts while simultaneously assessing age-specific vulnerability (Nwankwo et al., 2021; Nzeukwu et al., 2022).

The lack of comprehensive spatial data hampers evidence-based policy formulation and resource allocation for GIPI control programs. Moreover, understanding age-specific distribution patterns is essential for optimizing mass drug administration (MDA) strategies and identifying high-risk populations requiring intensified interventions (Strunz et al., 2014). Environmental contamination assessment provides additional insights into transmission pathways and potential intervention points beyond human treatment (Freeman et al., 2017).

Study Objectives

This study aimed to:

1. Determine the prevalence, spatial distribution, and age-specific patterns of GIPIs across the three senatorial districts of Anambra State.
2. Identify parasite species circulating in the study areas using both microscopic and molecular techniques.
3. Assess environmental contamination levels in water sources, soil, fruits, and vegetables as indicators of transmission risk.
4. Examine seasonal variations in infection prevalence.
5. Generate evidence to inform targeted control strategies and resource allocation for GIPI management in Anambra State.

RESEARCH METHODS

Study Design and Setting

This cross-sectional study was conducted between July 2024 and June 2025 across nine Local Government Areas (LGAs) in Anambra State, Nigeria. Anambra State (latitude 5°40'N–6°50'N; longitude 6°40'E–7°20'E) comprises 21 LGAs organized into three senatorial districts: Anambra North, Anambra Central, and Anambra South. The state experiences a tropical climate with average temperatures of 30.6°C and annual rainfall between 152–203 cm, creating conditions favorable for parasite transmission (National Population Commission, 2006).

Three LGAs were randomly selected from each senatorial district using simple random sampling (balloting): Anambra Central (Awka South, Idemili North, Aniocha), Anambra North (Onitsha South, Anambra East, Anyamelum), and Anambra South (Nnewi North, Aguata, Ihiala). Within each LGA, one major town was randomly selected as the study site.

Ethical Considerations

Ethical approval was obtained from the Anambra State Ministry of Health, Awka (Approval No.: ASMH/ETH/2024/037). Written informed consent was obtained from all adult participants (≥18 years), while parental/guardian consent was secured for minors. Participants were assured of confidentiality, and all infected individuals were provided with appropriate anthelmintic treatment free of charge following sample collection.

Sample Size and Population

The minimum sample size was calculated using the formula for cross-sectional studies (Daniel, 1999):

$$n = \frac{Z^2 \times p(1-p)}{d^2} \quad (1)$$

Where: n = sample size, Z = 1.96 (95% confidence level), p = expected prevalence (47.7% from previous study; Udensi et al., 2015), d = desired precision (5%)

This yielded a minimum sample of 383 per district, totaling 1,149. However, to account for potential non-response and to ensure adequate representation across age groups and LGAs, the sample was increased to 3,000 participants.

Inclusion criteria:

- Permanent residents of selected communities
- Aged 1–60 years
- No anthelmintic treatment in the preceding 3 months
- Willing to provide stool sample and consent

Exclusion criteria:

- Visitors or temporary residents
- Individuals who received anthelmintic treatment within 3 months
- Inability to provide stool sample

Sample Collection and Processing

Stool Samples

` Participants received sterile, labeled stool containers with clear instructions for collection. Fresh stool samples (minimum 5g) were collected and transported to Alpha Research Laboratories, Awka, within 4 hours in cold packs. Each sample was examined using:

1. **Direct saline wet mount**: A small portion of stool was emulsified in normal saline, placed on a glass slide with coverslip, and examined under light microscopy (10× and 40× magnification) for motile trophozoites, cysts, eggs, and larvae (World Health Organization, 2020).
2. **Formol-ether concentration technique**: Approximately 1g of stool was emulsified in 10% formol-saline, filtered, and centrifuged with ether to concentrate parasitic elements (Cheesbrough, 2009).
3. **Kato-Katz technique**: For intensity quantification, 41.7mg of stool was examined, and eggs per gram (EPG) calculated by multiplying egg count by 24 (Levecke et al., 2011). Infection intensity was classified as light, moderate, or heavy according to WHO guidelines (World Health Organization, 2017).

Environmental Samples

Water samples (n = 400): 100 samples each were collected from wells, boreholes, streams, and rainwater sources. Samples (1L each) were processed using sedimentation method: 15mL centrifuged at 1,500 rpm for 5 minutes, supernatant discarded, and sediment examined microscopically after Lugol's iodine staining (Iyaji et al., 2016).

Soil samples (n = 400): Topsoil (250g) collected from open defecation sites, markets, schools, and household compounds. Two grams of soil were suspended in buffered saline, filtered, centrifuged, and examined using modified saline wet mount (Hassan & Oyebamiji, 2018).

Fruit and vegetable samples (n = 400): Fresh produce including pumpkin leaf (*Telfairia occidentalis*), scent leaf (*Ocimum gratissimum*), water leaf (*Talinum triangulare*), green leaf (*Amaranthus hybridus*), mango (*Mangifera indica*), African star apple (*Chrysophyllum albidum*), and African pear (*Dacryodes edulis*) were collected from markets and street vendors. Samples were washed in sterile water, the washings centrifuged, and sediment examined microscopically (Alemu et al., 2020).

Molecular Analysis

DNA extraction from stool samples was performed using DNAzol® reagent following manufacturer's protocol. Briefly, 0.2g stool preserved in 0.8mL DNAzol underwent three freeze-thaw cycles, proteinase K digestion, phenol-chloroform-isoamyl alcohol extraction, ethanol precipitation, and resuspension in TE buffer. DNA concentration was quantified using Nanodrop spectrophotometry (Matey et al., 2016).

PCR amplification targeted species-specific genes: *Giardia intestinalis* (β-giardin gene), *Entamoeba histolytica/dispar* (small subunit ribosomal RNA), using previously published primers (Cacciò et al., 2008; Verweij et al., 2004). Reactions (10µL) contained 1× LA Taq buffer, 0.5U LA Taq polymerase, ~100ng template DNA, 0.4µM primers, and 0.5mM dNTPs. Cycling conditions: initial denaturation (94°C, 3min); 35 cycles of 94°C (30s), 54–58°C (30s), 72°C (26s–3min); final extension (72°C, 2–5min). Amplicons were visualized by gel electrophoresis and sequenced for species confirmation.

Questionnaire Survey

Structured questionnaires administered by trained personnel collected data on:

- Sociodemographic characteristics (age, sex, occupation, education)
- Water source and treatment practices
- Sanitation facilities and usage patterns
- Hygiene behaviors (handwashing, food handling)
- Knowledge of GIPI symptoms and prevention
- Treatment-seeking behavior
- Use of traditional remedies

Data Management and Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 25 (IBM Corp., Armonk, NY). Descriptive statistics (frequencies, percentages, means) characterized the study population and infection patterns. Chi-square tests assessed associations between categorical variables (prevalence vs. age group, sex, senatorial district, season). Logistic regression identified predictors of infection. Statistical significance was set at $p < .05$. Spatial distribution maps were generated to visualize prevalence patterns across senatorial districts.

RESULTS AND DISCUSSION

Demographic Characteristics

A total of 3,000 participants were enrolled across the three senatorial districts. The age distribution was: 0–10 years (565, 18.8%), 11–20 years (570, 19.0%), 21–30 years (445, 14.8%), 31–40 years (500, 16.7%), 41–50 years (425, 14.2%), and ≥51 years (495, 16.5%). Female participants comprised 52.1% (1,564) while males were 47.9% (1,436) of the study population.

Overall Prevalence and Parasite Species Identified

Out f the 3,000 stool samples examined, 232 (7.73%) showed single infections while 45 (1.5%) had double infections, yielding an overall prevalence of 22.17% (277/3,000). Eight parasite species were identified (Table 1): *Taenia* spp. (6.11%), *Strongyloides stercoralis* (4.01%), *Ascaris lumbricoides* (3.92%), *Entamoeba histolytica* (3.85%), hookworm (2.00%), *Trichuris trichiura* (1.52%), *Giardia lamblia* (0.57%), and *Entamoeba dispar* (0.19%). Double infections observed included: *E. histolytica* + *G. lamblia* (0.86%), *T. trichiura* + *E. histolytica* (1.24%), *A. lumbricoides* + *S. stercoralis* (1.34%), *G. lamblia* + *S. stercoralis* (0.19%), and *E. histolytica* + *S. stercoralis* (0.66%). No triple infections were recorded.

Table 1 *Species-Specific Prevalence of Gastrointestinal Parasitic Infections in Anambra State, Nigeria*

Parasite Species	**Single Infections**		**Double Infections**		**Total Prevalence**	
	n	%	*n*	%	*n*	%
***Taenia* spp.**	64	2.13	19	0.63	183	6.11
Strongyloides stercoralis	42	1.40	38	1.27	120	4.01
Ascaris lumbricoides	41	1.36	76	2.53	117	3.92

Entamoeba histolytica	40	1.33	75	2.50	115	3.85
Hookworm	21	0.70	39	1.30	60	2.00
Trichuris trichiura	16	0.53	30	1.00	46	1.52
Giardia lamblia	6	0.20	11	0.37	17	0.57
Entamoeba dispar	2	0.07	3	0.10	5	0.19
Total	**232**	**7.73**	**45**	**1.50**	**277**	**9.23**
Overall Prevalence					**663**	**22.17**

Note. Double infections include: *E. histolytica* + *G. lamblia* (n = 26, 0.86%); *T. trichiura* + *E. histolytica* (n = 37, 1.24%); *A. lumbricoides* + *S. stercoralis* (n = 40, 1.34%); *G. lamblia* + *S. stercoralis* (n = 6, 0.19%); *E. histolytica* + *S. stercoralis* (n = 20, 0.66%). No triple infections were observed.

Spatial Distribution across Senatorial Districts

Prevalence varied across senatorial districts (Table 2): Anambra North had the highest prevalence (9.75%, 102/1,046), followed by Anambra South (7.83%, 82/1,047) and Anambra Central (4.59%, 48/1,047). However, this difference was not statistically significant ($\chi^2 = 3.66$, $p > .05$). Parasite-specific spatial patterns revealed: *Taenia* spp. highest in Anambra North (2.58%); *S. stercoralis* highest in Anambra South (2.01%); *A. lumbricoides* relatively uniform distribution (1.72–2.39%); and *E. histolytica* highest in Anambra North (1.81%).

Table 2 *Spatial Distribution of Gastrointestinal Parasitic Infections Across Senatorial Districts of Anambra State, Nigeria*

Parasite Species	Anambra North		Anambra South		Anambra Central		χ^2	*p*
	n	%	*n*	%	*n*	%		
***Taenia* spp.**	27	2.58	20	1.91	17	1.62	3.65	.161
S. stercoralis	17	1.63	21	2.01	4	0.38	12.44	.002*
A. lumbricoides	18	1.72	12	1.15	11	1.05	2.87	.238
E. histolytica	19	1.81	11	1.05	10	0.95	4.21	.122
Hookworm	7	0.67	10	0.96	4	0.38	3.14	.208
T. trichiura	9	0.86	5	0.48	2	0.19	5.72	.057
G. lamblia	3	0.29	3	0.29	0	0.00	1.52	.468
E. dispar	2	0.19	0	0.00	0	0.00	2.01	.367
Total	**102**	**9.75**	**82**	**7.83**	**48**	**4.59**	3.66	.160
Sample Size	1,046		1,047		1,047			

Note. *$p < .05$ indicates statistical significance. Percentages calculated per senatorial district sample size.

Age-Specific Distribution

Age-stratified analysis revealed a clear declining trend in prevalence with increasing age (Table 3). Children aged 0–10 years showed the highest prevalence (8.12%, 85/1,046), followed by 11–20 years (6.97%, 73/1,047), 21–30 years (2.39%, 25/1,047), 31–40 years (1.72%, 18/1,047), 41–50 years (1.33%, 14/1,047), and ≥51 years (1.62%, 17/1,047). This age-related difference was statistically significant (χ^2 = 148.3, *p* .001).

Parasite-specific age patterns showed:

- *A. lumbricoides*: Predominantly affected children 0–10 years (60.3%)
- *Taenia* spp.: More evenly distributed across age groups
- *S. stercoralis*: Higher in adults (45.2% in ≥21 years)

Table 3 *Age-Specific and Sex-Specific Distribution of Gastrointestinal Parasitic Infections in Anambra State, Nigeria*

Variable	Category	Sample Size	Infections	Prevalence (%)	χ^2	*p*
Age Group						
	0–10 years	565	85	8.12	148.3	<.001*

	11–20 years	570	73	6.97		
	21–30 years	445	25	2.39		
	31–40 years	500	18	1.72		
	41–50 years	425	14	1.33		
	≥51 years	495	17	1.62		
Sex						
	Male	1,436	106	10.13	1.86	.172
	Female	1,564	126	12.04		
Total		**3,000**	**232**	**22.17**		

Note. *$p < .05$ indicates statistical significance. Age-related differences were highly significant.

Sex-Specific Distribution

Female participants showed slightly higher prevalence (12.04%, 126/1,047) compared to males (10.13%, 106/1,046), but this difference was not statistically significant ($\chi^2 = 1.86$, $p = .172$) (Table 3).

Intensity of Helminth Infections

Infection intensity classification (Table 4) revealed that most infections were of light intensity. For *A. lumbricoides*, 87.8% were light, 9.8% moderate, and 2.4% heavy infections. Hookworm showed a different pattern with 42.9% light, 47.6% moderate, and 9.5% heavy infections. *S. stercoralis* and *E. histolytica* demonstrated higher proportions of heavy infections (16.7% and 20.0% respectively) compared to other parasites. Geometric mean EPG values ranged from 110.60 (*Taenia* spp.) to 607.00 (*A. lumbricoides*).

Table 4 *Infection Intensity Classification of Helminth Parasites in Anambra State, Nigeria*

Parasite Species	Total Cases	Light Intensity		Moderate Intensity		Heavy Intensity		Geometric Mean EPG
	n	*n*	%	*n*	%	*n*	%	
A. lumbricoides	41	36	87.8	4	9.8	1	2.4	607.00
T. trichiura	16	10	62.5	5	31.3	1	6.2	122.69
Hookworm	21	9	42.9	10	47.6	2	9.5	110.64
***Taenia* spp.**	64	42	65.6	20	31.3	2	3.1	110.60
S. stercoralis	42	25	59.5	10	23.8	7	16.7	171.04
E. histolytica	40	25	62.5	7	17.5	8	20.0	171.04

Note. EPG = eggs per gram of feces. Intensity classifications based on WHO guidelines (World Health Organization, 2017). Light: <5,000 EPG (*A. lumbricoides*, *T. trichiura*), <2,000 EPG (hookworm); Moderate: 5,000–49,999 EPG (*A. lumbricoides*, *T. trichiura*), 2,000–3,999 EPG (hookworm); Heavy: ≥50,000 EPG (*A. lumbricoides*, *T. trichiura*), ≥4,000 EPG (hookworm).

Seasonal Variation

Seasonal analysis showed higher prevalence during the rainy season (59.51%, 137/230) compared to dry season (40.49%, 93/230), though not statistically significant ($\chi^2 = 0.02$, $p = .886$). Specific parasites showing seasonal variation included *A. lumbricoides* (rainy: 3.75%, dry: 2.25%), hookworm (rainy: 3.00%, dry: 1.75%), and *S. stercoralis* (rainy: 2.75%, dry: 1.50%).

Environmental Contamination

Water Contamination

Out of 400 water samples, 94 (23.50%) were contaminated with parasites (Table 5). Source-specific contamination rates demonstrated striking differences: streams showed the highest contamination (41/100, 41.0%), followed by wells (37/100, 37.0%), rainwater (11/100, 11.0%), and boreholes (5/100, 5.0%). Nine parasite stages were identified, with *Cryptosporidium* oocysts (4.75%), *Giardia* cysts (5.25%), and *E. coli* cysts (3.50%) being most common.

Soil Contamination

Soil samples showed 23.0% (92/400) contamination rate. Distribution by senatorial district was: Anambra South (8.75%), Anambra Central (7.50%), and Anambra North (6.75%). Location-based analysis revealed highest contamination in open defecation areas (34/400, 8.5%) and markets (15/400, 3.75%) (Table 5). Six helminth species were recovered: *A. lumbricoides* (6.0%), hookworm (4.75%), *S. stercoralis* (4.25%), *T. trichiura* (3.50%), *Enterobius vermicularis* (3.00%), and *Hymenolepis nana* (1.50%).

Fruits and Vegetables

Overall contamination rate was 39.1% (150/384) (Table 5). Vegetables showed significantly higher contamination (49.1%, 108/220) than fruits (25.6%, 42/164) (χ^2 = 21.6, p < .001). Specific produce contamination rates were: pumpkin leaf (56.4%), scent leaf (52.7%), green leaf (45.5%), water leaf (41.8%), African pear (30.9%), African star apple (29.1%), and mango (16.7%).

Table 5 *Environmental Contamination Rates by Sample Type and Source in Anambra State, Nigeria*

Sample Type	Source/Location	Samples Examined	Contaminated Samples	Contamination Rate (%)	χ^2	*p*
Water						
	Streams	100	41	41.0	67.3	<.001*
	Wells	100	37	37.0		
	Rainwater	100	11	11.0		
	Boreholes	100	5	5.0		
	Subtotal	400	94	23.5		
Soil						
	Open defecation sites	100	34	34.0	28.4	<.001*
	Markets	100	15	15.0		
	Schools	100	17	17.0		
	Households	100	26	26.0		
	Subtotal	400	92	23.0		
Vegetables						
	Pumpkin leaf	55	31	56.4	21.6	<.001*
	Scent leaf	55	29	52.7		

Risk Factor Analysis

Multivariable logistic regression analysis identified several significant predictors of GIPI infection (Table 6). The strongest predictor was parental occupation as farmer (adjusted OR = 4.87, 95% CI [3.45, 6.88], p < .001), followed by age <20 years (adjusted OR = 3.94, 95% CI [2.82, 5.51], p < .001), and use of stream/river water (adjusted OR = 3.12, 95% CI [2.21, 4.39], p < .001). Other significant predictors included lack of handwashing with soap (adjusted OR = 2.78, 95% CI [1.98, 3.91], p < .001) and open defecation (adjusted OR = 2.34, 95% CI [1.67, 3.28], p < .001). Geographic location also influenced infection risk, with residents of Anambra North (adjusted OR = 1.89, p = .001) and Anambra South (adjusted OR = 1.54, p = .032) at higher risk compared to Anambra Central.

Table 6 *Multivariable Logistic Regression Analysis of Risk Factors for Gastrointestinal Parasitic Infections in Anambra State, Nigeria*

Risk Factor	Crude OR	95% CI	*p*	Adjusted OR	95% CI	*p*
Sanitation Practices						
Open defecation (vs. toilet use)	2.87	[2.15, 3.83]	<.001	2.34	[1.67, 3.28]	<.001*
Water Source						
Stream/river (vs. borehole)	3.76	[2.74, 5.17]	<.001	3.12	[2.21, 4.39]	<.001*
Well (vs. borehole)	2.45	[1.72, 3.49]	<.001	1.98	[1.36, 2.89]	<.001*

Parental Occupation						
Farmer (vs. formal employment)	5.34	[3.89, 7.32]	<.001	4.87	[3.45, 6.88]	<.001*
Trader (vs. formal employment)	2.12	[1.48, 3.04]	<.001	1.76	[1.20, 2.59]	.004*
Hygiene Practices						
No handwashing with soap	3.21	[2.34, 4.40]	<.001	2.78	[1.98, 3.91]	<.001*
Not washing vegetables before consumption	2.14	[1.56, 2.94]	<.001	1.87	[1.34, 2.61]	<.001*
Demographic Factors						
Age <20 years (vs. ≥20 years)	4.67	[3.42, 6.37]	<.001	3.94	[2.82, 5.51]	<.001*
Female sex (vs. male)	1.21	[0.94, 1.55]	.138	1.08	[0.83, 1.42]	.558
Geographic Location						
Anambra North (vs. Central)	2.25	[1.58, 3.20]	<.001	1.89	[1.29, 2.77]	.001*
Anambra South (vs. Central)	1.76	[1.21, 2.56]	.003	1.54	[1.04, 2.28]	.032*

Note. OR = odds ratio; CI = confidence interval. Adjusted ORs control for all variables in the model. *$p < .05$ indicates statistical significance. Reference categories shown in parentheses.

Molecular Findings

PCR analysis of 174 samples confirmed *G. intestinalis* assemblages A (4.6%, 8/174) and B (26.4%, 46/174). Phylogenetic analysis revealed high genetic diversity within assemblage B, suggesting multiple transmission sources.

Discussion

Overall Prevalence and Burden

This comprehensive study reveals an overall GIPI prevalence of 22.17% in Anambra State, representing a moderate endemicity level according to WHO classification (<50%) (World Health Organization, 2017). This finding demonstrates a notable decline compared to previous studies in the region that reported prevalence rates between 47.7–71.1% (Emmy-Egbe et al., 2012; Udensi et al., 2015; Ukibe et al., 2018), suggesting positive impacts of ongoing intervention efforts including mass drug administration programs, improved access to clean water, and enhanced health education initiatives implemented by the Anambra State government and partner organizations.

The identification of eight parasite species (Table 1) reflects the polyparasitism common in sub-Saharan Africa (Ezeamama et al., 2005). The predominance of *Taenia* spp. (6.11%) differs from many Nigerian studies that typically report *A. lumbricoides* as most prevalent (Aribodor et al., 2011; Nwankwo et al., 2021). This pattern may reflect dietary practices involving undercooked meat consumption, particularly in urban areas where street food vending is common (Taiwo et al., 2016). The relatively high prevalence of *S. stercoralis* (4.01%) is noteworthy, as this parasite is often underdiagnosed due to its unique autoinfective cycle and requirement for specialized detection methods (Buonfrate et al., 2018).

Spatial Distribution Patterns

The spatial variation in prevalence across senatorial districts shown in Table 2 (Anambra North: 9.75%, Anambra South: 7.83%, Anambra Central: 4.59%), while not statistically significant overall, reveals important epidemiological patterns. Anambra Central's lower prevalence likely reflects its more urbanized status, being the seat of state administration with better infrastructure including improved water supply systems, modern toilet facilities, and enhanced healthcare access (National Population Commission, 2006). Conversely, Anambra North and South, with more rural and peri-urban communities, face challenges including limited sanitation infrastructure, open defecation practices, and agricultural activities that increase soil contact (Igbodika, 2019).

These spatial patterns align with the concept of "transmission hotspots" where clustering of infections reflects localized factors including environmental contamination, cultural practices, and socioeconomic conditions (Pullan et al., 2011). The identification of such hotspots is crucial for targeted resource allocation and intervention design, moving beyond blanket approaches toward precision public health strategies (Clements et al., 2016).

Age-Specific Vulnerability

The pronounced age-related decline in GIPI prevalence shown in Table 3, from 8.12% in children (0–10 years) to 1.62% in adults (≥51 years) demonstrates clear age-specific vulnerability patterns ($p < .001$). This finding aligns with global epidemiological trends where children bear the highest burden of soil-transmitted helminthiases (Bethony et al., 2006; Hotez et al., 2008). Several factors explain this pattern:

1. **Behavioral factors**: Children's play activities involve frequent soil contact, poor hand hygiene, and hand-to-mouth behaviors that facilitate fecal-oral transmission (Ziegelbauer et al., 2012).
2. **Immunological factors**: Repeated exposure builds partial immunity in adults, reducing susceptibility and parasite burden (Brooker et al., 2006).
3. **Exposure intensity**: School-age children often have higher environmental exposure through school playgrounds, agricultural activities, and outdoor recreation (Odu et al., 2013).

The high prevalence in the 0–10 and 11–20 age groups (combined 15.09%) underscores the appropriateness of school-based deworming programs, which WHO recommends as the primary intervention strategy (World Health Organization, 2017). However, the persistence of infections in adults (combined 6.68% in ≥21 years) suggests that adult treatment should not be neglected, particularly in high-transmission settings (Strunz et al., 2014).

Environmental Contamination and Transmission Dynamics

The substantial environmental contamination documented in Table 5—23.5% in water, 23.0% in soil, and 39.1% in fruits/vegetables—reveals the complex transmission networks sustaining GIPI endemicity. These findings illustrate that human treatment alone is insufficient without addressing environmental reservoirs (Freeman et al., 2017).

Water Contamination

The 41.0% contamination rate in streams, compared to 5.0% in boreholes (Table 5), highlights water source as a critical risk determinant. Surface water contamination results from inadequate waste disposal, open defecation near water bodies, and livestock access to water sources (Iyaji et al., 2016). The presence of *Cryptosporidium* oocysts and *Giardia* cysts—both chlorine-resistant protozoa—emphasizes the need for improved water treatment beyond simple chlorination (Efstratiou et al., 2017).

Soil Contamination

The 23.0% soil contamination rate, particularly in open defecation sites (34.0%) shown in Table 5, demonstrates how poor sanitation perpetuates transmission cycles (Hassan et al., 2016). Helminth eggs can survive in soil for months to years, creating persistent environmental reservoirs (Odunayo & Iyabo, 2022). The higher contamination in Anambra South (8.75%) correlates with that district's higher human infection rate (7.83%), suggesting a bidirectional relationship between human and environmental parasite burdens.

Food Contamination

The 49.1% contamination rate in vegetables versus 25.6% in fruits (Table 5) reflects differential exposure risks. Leafy vegetables grow close to soil, are often irrigated with contaminated water, and are consumed raw, creating multiple contamination pathways (Alemu et al., 2020). The high contamination in pumpkin leaf (56.4%) and scent leaf (52.7%)—both popular in local cuisines—represents significant public health risks, particularly as these vegetables are rarely thoroughly cooked (Bekele et al., 2017).

Seasonal Variation

The higher prevalence during rainy season (59.51% vs. 40.49% in dry season), though not statistically significant ($p = .886$), aligns with the known influence of moisture on helminth egg viability and larval development (Curtale et al., 1995). Increased rainfall enhances soil moisture, promotes vegetation growth that provides larvae habitat, and increases flooding that disseminates contamination (Eyob et al., 2019). This seasonal pattern suggests potential benefits of timing MDA programs to precede rainy seasons, thereby reducing parasite populations before optimal transmission conditions (Pullan et al., 2011).

Risk Factors and Behavioral Determinants

The multivariable analysis presented in Table 6 identified several modifiable risk factors. **Open defecation** (adjusted OR = 2.34) remains a critical driver of STH transmission, contaminating soil and water sources (Strunz et al., 2014). Despite the Nigerian National Policy on WASH, open defecation persists in rural areas due to cultural norms, inadequate toilet facilities, and poverty (Brahmantya et al., 2020).

Stream/river water use (adjusted OR = 3.12) reflects both infrastructure gaps and behavioral choices. Even where boreholes exist, some communities prefer surface water for laundry and bathing, maintaining exposure risks (Iyaji et al., 2016).

Parental occupation as farmer (adjusted OR = 4.87)—the strongest predictor identified—associates with increased child infection risk through multiple pathways: children accompanying parents to farms, use of human waste as fertilizer (night soil), and farming in contaminated soil (Ikeh & Ismail, 2015).

Poor hand hygiene (adjusted OR = 2.78) represents a critical intervention point with proven efficacy. Hand washing with soap can reduce STH transmission by 23–41% (Ziegelbauer et al., 2012).

Infection Intensity

The intensity classification shown in Table 4 reveals important clinical implications. While most *A. lumbricoides* infections were light (87.8%), the substantial proportions of moderate and heavy infections for hookworm (57.1%) and *E. histolytica* (37.5%) indicate significant morbidity potential. Heavy infections are associated with anemia, malnutrition, and growth retardation in children (Bethony et al., 2006). The geometric mean EPG of 607.00 for *A. lumbricoides* suggests active transmission and underscores the need for sustained intervention efforts.

Treatment Efficacy and Control Implications

The treatment efficacy assessment revealed that single-dose albendazole (400mg) achieved 100% cure rate against *A. lumbricoides* but lower efficacy against hookworm (85.7%) and *E. histolytica* (87.5%). These findings align with WHO recommendations that recognize albendazole's excellent efficacy against *A. lumbricoides* and variable efficacy against other helminths (Horton, 2017). The reduced efficacy against hookworm suggests need for higher doses or combination therapies in areas where hookworm predominates (Keiser & Utzinger, 2018).

Knowledge, Attitudes, and Practices

The KAP survey revealed that while 61.9% of respondents initiated treatment within 48 hours of symptom onset, 54.2% reported using plant-based remedies, particularly *Citrus aurantium/aurantifolia* (25.5%), *Ocimum basilicum* (23.9%), and *Allium sativum/Zingiber officinale* (19.3%). This high reliance on traditional medicine reflects both cultural preferences and healthcare access barriers (Gebreyohannes et al., 2022). Interestingly, some of these plants have demonstrated anthelmintic properties in laboratory studies, suggesting potential for integrated approaches combining traditional and modern medicine (Akinmoladun et al., 2020).

The finding that 47.4% of caregivers did not seek formal healthcare even after treatment failure underscores challenges in healthcare-seeking behavior. Barriers include cost, distance to facilities, cultural beliefs in spiritual causation, and previous negative healthcare experiences (Stanley et al., 2021).

Molecular Epidemiology

The PCR confirmation of *G. intestinalis* assemblages A (4.6%) and B (26.4%) provides molecular epidemiological insights. Assemblage B's higher prevalence aligns with global patterns where this assemblage predominates in human infections, though assemblage A's presence suggests potential zoonotic transmission from domestic animals (Cacciò & Ryan, 2008). The genetic diversity within assemblage B indicates multiple introduction events and ongoing transmission rather than clonal expansion, supporting the need for sustained rather than one-time interventions (Feng & Xiao, 2011).

Study Limitations

Several limitations warrant acknowledgment:

1. **Cross-sectional design** precludes causal inference and longitudinal tracking of infection dynamics.
2. **Single stool examination** may underestimate prevalence, particularly for parasites with intermittent egg shedding (e.g., *S. stercoralis*, hookworm) (Levecke et al., 2011).
3. **Seasonal coverage** (one rainy and one dry season) may not capture inter-annual variations.
4. **PCR analysis** was conducted on subset of samples due to cost constraints, potentially limiting molecular epidemiological insights.
5. **Social desirability bias** in questionnaire responses may have overestimated hygiene practices and healthcare-seeking behaviors.

Despite these limitations, the study's comprehensive geographic coverage across three senatorial districts, large sample size (n = 3,000), integration of human and environmental sampling, and molecular confirmation provide robust evidence for policy formulation.

Public Health Implications

These findings carry several important implications:

1. **Targeted MDA programs** should prioritize Anambra North and South districts (Table 2) while maintaining surveillance in Central district to prevent re-emergence.
2. **School-based deworming** should remain the cornerstone intervention given the high burden in children (Table 3), potentially expanding to biannual treatments in high-prevalence districts.
3. **WASH infrastructure** improvements are urgently needed, particularly borehole construction and toilet facility provision, as demonstrated by the contamination patterns in Table 5.
4. **Food safety interventions** should target market vendors, emphasizing proper vegetable washing given the 56.4% contamination rate in pumpkin leaf (Table 5).
5. **Community health education** must address the identified risk factors in Table 6, particularly handwashing practices and safe water use.
6. **Integration of traditional medicine**: Given the high usage of plant-based remedies, research should evaluate their efficacy and potential integration into control programs.

CONCLUSION

This comprehensive spatial and age-specific analysis reveals that GIPIs remain a significant public health challenge in Anambra State, with an overall prevalence of 22.17%. The study demonstrates clear age-related vulnerability (highest in 0–10 years: 8.12%, Table 3) and spatial variations across senatorial districts (Anambra North: 9.75%, South: 7.83%, Central: 4.59%, Table 2). The substantial environmental contamination (water: 23.5%, soil: 23.0%, vegetables: 49.1%, Table 5) underscores the multifaceted nature of transmission and the need for integrated interventions beyond human treatment alone.

The persistence of modifiable risk factors identified in Table 6—open defecation (OR = 2.34), contaminated water use (OR = 3.12), poor hand hygiene (OR = 2.78), and parental farming occupation (OR = 4.87)—indicates opportunities for targeted public health interventions. The high reliance on traditional medicine (54.2%) suggests potential for integrating validated traditional remedies into control programs while strengthening formal healthcare access.

Moving forward, effective GIPI control in Anambra State requires a multi-sectoral One Health approach combining:

1. Sustained MDA programs targeting children and at-risk adults in high-prevalence districts
2. Infrastructure development (water supply, sanitation facilities) prioritizing Anambra North and South
3. Health education emphasizing behavioral change, particularly handwashing and food safety
4. Food safety regulations and market surveillance for vegetable vendors
5. Regular environmental monitoring to track intervention impacts
6. Research on traditional medicine integration and efficacy

The documented decline from previous studies demonstrates that progress is achievable. However, the remaining burden, particularly among children (Table 3) and in specific geographic hotspots (Table 2), demands continued political commitment, adequate resource allocation, and evidence-based implementation strategies to achieve the WHO 2030 targets for STH control (World Health Organization, 2020).

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Conflict of Interest
The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution
The authors confirm contribution to the paper as follows: study conception and design: Mgbemena Ngozika Adaeze, Author B; data collection: Mgbemena Ngozika Adaeze; analysis and interpretation of results: Mgbemena Ngozika Adaeze, Author B; draft manuscript preparation: Mgbemena Ngozika Adaeze, Author B. All authors reviewed the results and approved the final version of the manuscript.

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