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Prevalence, Intensity and Factors Associated with Soil Transmitted Helminths among School Aged Children in Mudende Sector, Rubavu District, 2023

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Abstract: **Background: Soil-transmitted helminths (STHs) remain a leading cause of morbidity among school-aged children in sub-Saharan Africa. Rwanda has implemented national mass drug administration (MDA) programmes, yet persistent hotspots remain. Mudende Sector, Rubavu District a high-altitude, predominantly rural area bordering the Democratic Republic of the Congo with documented WASH infrastructure deficits has never been characterised by sector-specific STH data. This study aimed to determine the prevalence, infection intensity, and independent risk factors for STH infection among school-aged children in this setting.**

Methods: A retrospective cross-sectional analysis was conducted using secondary data from a community survey carried out by the Rwanda Biomedical Center (RBC) in 2023. All 1,093 school-aged children (aged 5–14 years) with complete stool examination results and household WASH data were included. Infection was diagnosed using the duplicate Kato-Katz technique; intensity was classified per WHO criteria. Bivariate chi-square analysis and multivariate logistic regression identified independent predictors of STH infection (significance threshold $p < 0.05$).

Results: Overall STH prevalence was 95.3% (n = 1,042). Ascaris lumbricoides (86.0%) and Trichuris trichiura (85.9%) were the predominant species; hookworm was rare (0.5%). Dual Ascaris–Trichuris co-infections affected 76.7% of children. Moderate-intensity infections predominated for both Ascaris (85.1%) and Trichuris (83.4%). In multivariate analysis, only two variables independently predicted infection: absence of a household handwashing facility (adjusted odds ratio [aOR] = 6.57; 95% confidence interval [CI]: 1.77–19.8; p = 0.002) and reliance on unimproved water sources (aOR = 3.20; 95% CI: 1.23–7.32; p = 0.009). Gender, age, parental education and literacy, religion, latrine cleanliness, and knowledge-attitude-practice scores were not independently significant.

Conclusions: STH infections are hyper-endemic in Mudende Sector a prevalence that has not declined despite years of national MDA and are driven entirely by structural deficits in WASH infrastructure rather than individual behavioral or demographic factors. High STH knowledge coexisting with near-universal infection demonstrates that awareness cannot substitute for physical infrastructure in hyper-endemic settings. Mudende Sector should be formally designated a priority hotspot within Rwanda's national NTD control programme, with deworming frequency increased to at least three rounds per year and investment in household handwashing facilities and safe water access accelerated through multi-sectoral collaboration.

Keywords: **soil-transmitted helminths; Ascaris lumbricoides; Trichuris trichiura; Rwanda; school-aged children; WASH; handwashing; hyper-endemic; Kato-Katz; neglected tropical diseases.**

1. INTRODUCTION

Soil-transmitted helminths (STHs) principally Ascaris lumbricoides, Trichuris trichiura, and hookworm species are among the most prevalent parasitic infections globally, collectively affecting an estimated 1.5 billion people and ranking among the world's neglected tropical diseases (NTDs) [1]. School-aged children bear a disproportionate burden: chronic infection causes malnutrition, stunted growth, anemia, and cognitive impairment that limits educational attainment and perpetuates cycles of poverty [2,3]. The World Health Organization (WHO) recommends preventive chemotherapy through periodic mass drug administration (MDA) to high-risk populations in endemic settings, combined with improvements in water, sanitation, and hygiene (WASH) infrastructure [4].

Despite MDA scale-up over two decades, sub-Saharan Africa retains high-transmission foci particularly in rural, high-altitude communities where environmental conditions favor STH egg viability and WASH infrastructure remains severely deficient. In East Africa, studies consistently document marked geographic heterogeneity in STH burden, with district and sector-level variation that national programmes cannot adequately target without granular, subnational epidemiological data [5,6].

In Rwanda, national MDA programmes have achieved documented reductions in STH prevalence across many districts. However, significant hotspots persist: a national survey involving 8,313 children across 136 primary schools reported an overall STH prevalence of 65.8%, with Rubavu District in the Western Province recording 92% the highest of all districts surveyed [7]. A subsequent multi-district study in the Western Province confirmed Rubavu District's position as a persistent high-transmission area, while demonstrating intra-provincial heterogeneity with rates ranging from 54% to 92% across the four districts studied [8]. National geospatial mapping based on 2014 data identified several sectors within Rubavu District Nyakiriba, Nyamyumba, and Gisenyi as high-risk zones for Ascaris lumbricoides [9], but Mudende Sector was not captured in that analysis.

Mudende Sector occupies a specific ecological niche within Rubavu District: high altitude, high rainfall, fertile volcanic soils, and a predominantly subsistence-agricultural population with very limited access to improved water and sanitation. These environmental conditions volcanic alkaline soils, consistent moisture, and cool temperatures are selectively favorable for the survival of Ascaris and Trichuris eggs but less hospitable for hookworm larvae, suggesting that sector-level species distribution may differ substantially from broader district estimates. Critically, no published study has provided a sector-specific STH epidemiological profile for Mudende, leaving local health managers without the evidence needed to evaluate programme coverage, assess reinfection dynamics, or design targeted WASH interventions.

This study was conducted to address that gap. Our objectives were: (1) to determine the overall prevalence and species-specific distribution of STH infections among school-aged children in Mudende Sector; (2) to describe infection intensity by species according to WHO classification; and (3) to identify independent predictors of STH infection through multivariate analysis of WASH, sociodemographic, and knowledge-attitude-practice variables.

2. METHODS

Study design and setting

We conducted a retrospective cross-sectional study based on secondary analysis of a community survey implemented by the Rwanda Biomedical Center (RBC) in 2023. The study was conducted in Mudende Sector, an administrative unit within Rubavu District, Western Province, Rwanda. Mudende Sector is a predominantly rural area situated at high altitude near Rwanda's border with the Democratic Republic of Congo. The local population is engaged primarily in subsistence agriculture on volcanic soils. The sector has limited WASH infrastructure: piped water access is negligible and household sanitation facilities are widely absent.

Study population and sampling

The study population comprised all school-aged children aged 5–14 years residing in Mudende Sector who participated in the original RBC community survey. All 1,093 children with complete stool examination results and household WASH and sociodemographic data were included. As the study employed a total census of eligible records rather than sampling, a formal a priori sample size calculation was not required. The use of all available records maximised the precision of prevalence estimates and avoided selection bias. Children under 5 years, those above 14 years, and those with incomplete records (missing stool examination results or key sociodemographic/WASH variables) were excluded.

Data collection

Data were extracted from the de-identified RBC survey dataset, accessed via REDCap. The original survey comprised five sections: (1) sociodemographic and socioeconomic characteristics of children; (2) demographic and socioeconomic details of parents or caregivers; (3) individual Kato-Katz laboratory results; (4) parental knowledge and practices regarding STH prevention; and (5) environmental and hygiene conditions assessed by survey teams at the household level. A secondary data extraction checklist was used to compile variables relevant to the three study objectives while excluding records not meeting inclusion criteria.

Diagnostic method and quality assurance

STH infection was diagnosed using the duplicate Kato-Katz technique the WHO-recommended standard for field-based STH prevalence and intensity surveys [10]. Duplicate smears were prepared from fresh stool samples and examined under light microscopy for the presence and enumeration of helminth eggs per gram of stool (epg). Quality control was performed by a senior parasitologist from the National Reference Laboratory, who re-examined 10% of slides daily. This quality assurance procedure ensured the accuracy and reproducibility of infection status and intensity classifications.

Infection intensity classification

Infection intensity was classified according to WHO criteria (Table 1) [10]: for *Ascaris lumbricoides* light (1–4,999 epg), moderate (5,000–49,999 epg), heavy (≥50,000 epg); for *Trichuris trichiura* light (1–999 epg), moderate (1,000–9,999 epg), heavy (≥10,000 epg); for hookworm light (1–1,999 epg), moderate (2,000–3,999 epg), heavy (≥4,000 epg).

Variables

Independent variables included: sociodemographic characteristics (child gender, age group, religion, parental education, parental occupation); WASH characteristics (main water source [tap vs. unimproved], reported ease of access to water, latrine cleanliness, presence of household handwashing facility, use of human fertilizer in agriculture); and composite knowledge, attitude, and practice (KAP) scores derived from the original survey questionnaire. KAP scores were categorised as poor, moderate, or good based on pre-defined cut-off points used in the original RBC survey. The dependent variable was binary STH infection status: infected (positive for at least one species by Kato-Katz) versus uninfected.

Statistical analysis

Data were analysed using SPSS Version 29. Descriptive statistics (frequencies and percentages) characterised participant demographics and WASH conditions. STH prevalence was estimated as the proportion of children with at least one positive Kato-Katz result; species-specific prevalences and co-infection rates were calculated from the total sample (N = 1,093). Infection intensity distributions were summarised by species as proportions of infected children in each intensity category. Bivariate analysis used chi-square (χ^2) tests to assess associations between independent variables and infection status; crude odds ratios (cOR) with 95% confidence intervals (CIs) were reported. All variables with $p \leq 0.05$ in bivariate analysis were entered into a multivariate binary logistic regression model to identify factors independently associated with STH infection while controlling for potential confounders. Adjusted odds ratios (aOR) with 95% CIs were reported. Statistical significance was set at $p < 0.05$ throughout.

3. RESULTS

Participant characteristics

A total of 1,093 school-aged children aged 5–14 years were included. Gender distribution was near-equal: 561 (51.3%) female and 532 (48.7%) males. The largest age group was 5–9 years (50.9%), followed by 10–14 years (36.5%) and 15+ years (12.6%). Most children identified as Christian (76.9%). Most caregivers (63.9%) had no formal education; 24.1% had completed primary school or higher; and 12.0% had attended nursery school only. The WASH environment was severely deficient: 94.6% of households relied on unimproved water sources; 98.4% lacked a household handwashing facility; and 34.7% had dirty latrines. Despite these infrastructure deficits, 62.3% of caregivers demonstrated good STH knowledge and 61.9% held positive attitudes toward STH prevention; however, only 9.3% reported consistently good preventive practice (Table 1).

Table 1. Sociodemographic, WASH, and KAP characteristics of study participants (N = 1,093).

Variable	Category	n (%)
Sociodemographic characteristics		
Gender	Female	561 (51.3)
	Male	532 (48.7)
Age group (years)	5–9	556 (50.9)
	10–14	537 (49.1))
Religion	Christian	840 (76.9)
	Other	253 (23.1)
Parental education	None	699 (63.9)
	Nursery	131 (12.0)
	Primary or higher	263 (24.1)

Parental occupation	Student	553 (50.6)
	Employed/other	540 (49.4)
Water, sanitation and hygiene (WASH) characteristics		
Main water source	Tap water (improved)	59 (5.4)
	Unimproved (river, spring, well, rainwater)	1,034 (94.6)
Easy access to water	Yes	611 (55.9)
	No	482 (44.1)
Latrine cleanliness	Clean	714 (65.3)
	Dirty	379 (34.7)
Handwashing facility	Present	17 (1.6)
	Absent	1,076 (98.4)
Use of human fertilizer	No	1,013 (92.7)
	Yes	80 (7.3)
Knowledge, attitude, and practice (KAP) characteristics		
STH knowledge	Good	681 (62.3)
	Moderate	380 (34.8)
	Poor	32 (2.9)
STH attitude	Good	677 (61.9)
	Moderate	416 (38.1)
Preventive practice	Good	102 (9.3)
	Moderate	722 (66.1)
	Poor	269 (24.6)

Abbreviations: WASH = water, sanitation, and hygiene; KAP = knowledge, attitude, practice; STH = soil-transmitted helminths.

STH prevalence and species distribution

The overall prevalence of STH infection was 95.3% (1,042/1,093 children infected with at least one species). *Ascaris lumbricoides* was the most prevalent species (86.0%; n = 940), followed very closely by *Trichuris trichiura* (85.9%; n = 939). Hookworm infection was strikingly rare at 0.5% (n = 5). Dual co-infection with *Ascaris* and *Trichuris* simultaneously was the dominant infection pattern, affecting 76.7% of all children. Other co-infection combinations were uncommon: *Ascaris* + hookworm (0.4%), *Trichuris* + hookworm (0.3%), and triple infections involving all three species (0.3%) (Table 2; Fig 1).

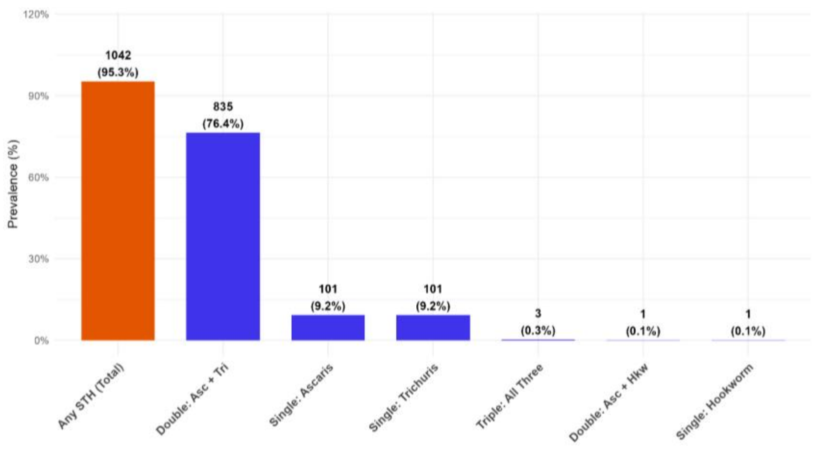

Figure 1: Prevalence of Soil transmitted Helminths infections among School Aged Children in Mudende sector, ubavu district

Infection intensity

Infection intensity varied markedly by species (Table 1; Fig 2). For *Ascaris lumbricoides*, moderate-intensity infections predominated (85.1%), with light infections comprising 14.0% and heavy infections 0.9%. For *Trichuris trichiura*, moderate intensity was also dominant (83.4%), with light infections at 14.1% and heavy infections at 2.6%. Combined moderate-to-heavy intensity infections thus affected 86.0% of *Ascaris*-infected children and 86.0% of *Trichuris*-infected children, indicating a high burden of clinically relevant infection. In sharp contrast, hookworm infections already rare in absolute terms were almost entirely of light intensity (99.5%), with negligible proportions of moderate (0.3%) or heavy (0.2%) intensity cases.

Table 2. STH prevalence, species distribution, and infection intensity among school-aged children in Mudende Sector (N = 1,093).

Species	Overall prevalence n (%)	Light intensity n (%)	Moderate intensity n (%)	Heavy intensity n (%)
Any STH	1,042 (95.3)	—	—	—
Ascaris lumbricoides	940 (86.0)	132 (14.0)	799 (85.1)	9 (0.9)
Trichuris trichiura	939 (85.9)	132 (14.1)	783 (83.4)	24 (2.6)
Hookworm spp.	5 (0.5)	5 (99.5 of hookworm)	<1 (0.3)	<1 (0.2)
Co-infection patterns (among N = 1,093)				
Ascaris + Trichuris (dual)	838 (76.7)	—	—	—
Ascaris + Hookworm	4 (0.4)	—	—	—
Trichuris + Hookworm	3 (0.3)	—	—	—
Triple (all three species)	3 (0.3)	—	—	—

Intensity proportions for each species are calculated among infected children only. Co-infection proportions are calculated from the total sample (N = 1,093). = not applicable. epg = eggs per gram of stool.

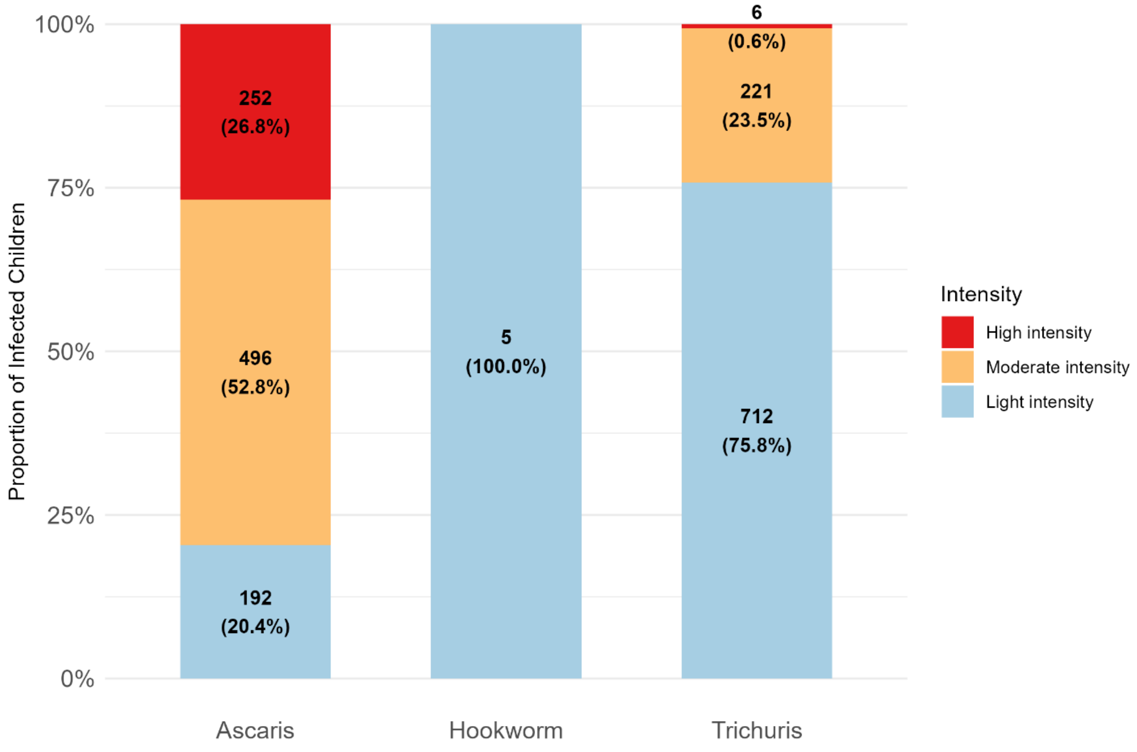

Figure 2: Level of infection intensity among school aged children in Mudende sector, Rubavu district Factors associated with STH infection

Bivariate analysis

Of all variables tested, two demonstrated statistically significant associations with STH infection status (Table 3). Reliance on unimproved water sources was significantly associated with infection ($\chi^2 = 5.65$, $p = 0.017$), with 95.0% of infected children using unimproved sources compared to 86.3% of uninfected children (cOR = 3.03; 95% CI: 1.20–6.66). Absence of a household handwashing facility showed a highly significant association ($\chi^2 = 9.84$, $p = 0.006$): 98.8% of infected children lacked handwashing facilities versus 92.2% of uninfected children (cOR = 6.74; 95% CI: 1.84–19.9). No other variable including gender, age group, parental education, religion, latrine cleanliness, use of human fertilizer, reported ease of water access, or any KAP composite score was statistically associated with infection status in bivariate analysis.

Table 3. Bivariate analysis of factors associated with STH infection among school-aged children in Mudende Sector, Rubavu District (N = 1,093).

Characteristic	Overall N (%)	STH negative n (%)	STH positive n (%)	χ^2	p-value	cOR (95% CI)
Gender						
Female	561 (51.3)	31 (60.8)	530 (50.9)	—	—	—
Male	532 (48.7)	20 (39.2)	512 (49.1)	1.54	0.209	Ref
Age group (years)						
5–9	556 (50.9)	30 (58.8)	526 (50.5)	—	—	—
10–14	537 (49.1)	21 (41.2)	516 (49.5)	1.39	0.514	Ref
Religion						
Christian	840 (76.9)	38 (74.5)	802 (77.0)	—	—	—
Other	253 (23.1)	13 (25.5)	240 (23.0)	0.06	0.702	0.87 (0.47–1.73)
Parental education						
None	699 (63.9)	35 (68.6)	664 (63.7)	—	—	—
Nursery	131 (12.0)	4 (7.8)	127 (12.2)	—	—	—
Primary or higher	263 (24.1)	12 (23.5)	251 (24.1)	0.95	0.632	Ref
Water source						
Tap water (Ref)	59 (5.4)	7 (13.7)	52 (5.0)	—	—	Ref
Other (unimproved)	1,034 (94.6)	44 (86.3)	990 (95.0)	5.65	0.017*	3.03 (1.20–6.66)
Easy access to water						
Yes (Ref)	611 (55.9)	34 (66.7)	577 (55.4)	—	—	Ref
No	482 (44.1)	17 (33.3)	465 (44.6)	2.08	0.109	1.61 (0.90–2.99)
Latrine cleanliness						
Clean (Ref)	714 (65.3)	35 (68.6)	679 (65.2)	—	—	Ref
Dirty	379 (34.7)	16 (31.4)	363 (34.8)	0.13	0.625	—
Handwashing facility						
Present (Ref)	17 (1.6)	4 (7.8)	13 (1.2)	—	—	Ref
Absent	1,076 (98.4)	47 (92.2)	1,029 (98.8)	9.84	0.006**	6.74 (1.84–19.9)
Use of human fertilizer						
No (Ref)	1,013 (92.7)	49 (96.1)	964 (92.5)	—	—	Ref
Yes	80 (7.3)	2 (3.9)	78 (7.5)	0.46	0.634	—
STH knowledge						
Good (Ref)	681 (62.3)	35 (68.6)	646 (62.0)	—	—	Ref
Moderate	380 (34.8)	16 (31.4)	364 (34.9)	—	—	—
Poor	32 (2.9)	0 (0)	32 (3.1)	2.09	0.512	—

STH attitude						
Good (Ref)	677 (61.9)	31 (60.8)	646 (62.0)	—	—	Ref
Moderate	416 (38.1)	20 (39.2)	396 (38.0)	0.00	0.901	—
Preventive practice						
Good (Ref)	102 (9.3)	6 (11.8)	96 (9.2)	—	—	Ref
Moderate	722 (66.1)	36 (70.6)	686 (65.8)	—	—	—
Poor	269 (24.6)	9 (17.6)	260 (25.0)	1.56	0.413	—

*cOR = crude odds ratio; CI = confidence interval; χ^2 = chi-square statistic. * $p < 0.05$; ** $p < 0.01$. Only variables yielding complete data for both infected and uninfected groups are included in the cOR column; = odds ratio not calculated due to sparse data in one or more cells. Reference categories are indicated as (Ref).*

Multivariate analysis

Both variables significant in bivariate analysis retained independent significance after multivariate adjustment (Table 4). Absence of a household handwashing facility was the strongest predictor: children from households without handwashing facilities had 6.57 times higher odds of infection compared to children from households with such facilities (aOR = 6.57; 95% CI: 1.77–19.8; p = 0.002). Reliance on unimproved water sources independently tripled infection odds (aOR = 3.20; 95% CI: 1.23–7.32; p = 0.009). Religion, included as a comparator variable, was not independently significant after adjustment (aOR = 0.97; 95% CI: 0.51–1.96; p = 0.871).

Table 4. Multivariate logistic regression: independent predictors of STH infection in Mudende Sector (N = 1,093).

Characteristic	cOR	95% CI (crude)	p	aOR	95% CI (adjusted)
Handwashing facility					
Present (reference)	Ref	—	—	Ref	—
Absent	**6.74**	1.84–19.9	**0.001****	**6.57**	**1.77–19.8**
Main water source					
Tap water (reference)	Ref	—	—	Ref	—
Unimproved source	**3.03**	1.20–6.66	**0.010***	**3.20**	**1.23–7.32**
Religion (non-significant comparator)					
Christian (reference)	Ref	—	—	Ref	—
Other	0.87	0.47–1.73	0.701	0.97	0.51–1.96

*cOR = crude odds ratio; aOR = adjusted odds ratio; CI = confidence interval. Both predictor variables were entered simultaneously in the multivariate model. * $p < 0.05$; ** $p < 0.01$. Reference categories are indicated.*

4. DISCUSSION

This study provides the first sector-specific STH epidemiological profile for Mudende Sector, Rubavu District, Rwanda, documenting a hyper-endemic burden of 95.3% overall prevalence among school-aged children. This figure exceeds the previous district-wide estimate for Rubavu (92.0%) reported by Kabatende et al. [8] and is substantially higher than the national average of 65.8% [7], confirming Mudende as one of the highest-transmission STH settings ever documented within Rwanda and among the highest reported in any single community in sub-Saharan Africa.

A hotspot that Rwanda's national programme has not reached

The persistence of 95.3% prevalence in 2023, following years of Rwanda's national MDA programme, is a signal that intervention coverage or effectiveness in Mudende Sector is critically inadequate. National MDA programmes operate on WHO threshold-based treatment frequency recommendations: annual treatment for communities where prevalence is ≥20% and biannual treatment where ≥50% [4]. A 95.3% prevalence suggests that even the most intensive recommended schedule of two MDA rounds per year is failing to reduce the infection burden, likely because treatment eliminates existing worm burdens but does not prevent near-immediate reinfection in the absence of WASH infrastructure. This pattern has been described in other hyper-endemic sub-Saharan African settings: Goshu et al. [11] in Ethiopia and Samuel et al. [12] found that communities with inadequate WASH show minimal MDA impact between treatment rounds. For Mudende, a threeround annual schedule should be considered while structural WASH improvements are implemented consistent with WHO guidance on high-burden settings and with the recommendations of Rujeni et al. [7], who specifically argued that MDA alone is insufficient for sustainable control in Rwanda's endemic districts.

The comparison with neighbouring countries contextualises the severity of this finding: Tanzania's comparable setting documented 56.2% overall STH prevalence [13]; Ethiopia's national survey reported 33.4% [14]; Indonesia's rural school-based study found 57.2% [15]. Mudende's 95.3% is not simply at the high end of a regional distribution it is categorically outlying and demands a response commensurate with its scale.

Species distribution and the hookworm anomaly

The near-exclusive dominance of *Ascaris lumbricoides* (86.0%) and *Trichuris trichiura* (85.9%), combined with the strikingly low hookworm prevalence (0.5%), reflects the ecological specificity of Mudende's transmission environment. Hookworm larvae require warm, moist, sandy, or loamy soils and are susceptible to the alkaline pH of volcanic substrates and the cooler temperatures associated with high altitude [16]. The fertile volcanic soils and elevated altitude of Mudende Sector create conditions selectively unfavorable for hookworm but well-suited to the survival of *Ascaris* and *Trichuris* eggs, which are notably resistant to desiccation and temperature variation [16,17]. Kabatende et al. [8] documented a similar pattern across western Rwanda, with hookworm substantially less prevalent than *Ascaris* and *Trichuris* in the Rubavu and Nyamasheke districts. This species-specific profile has direct programmatic implications: species-targeted drug selection with albendazole preferred for its superior efficacy against *Ascaris* and mebendazole considered for *Trichuris* [4] may be more appropriate than standardised blanket tri-species MDA for Mudende.

The 76.7% dual *Ascaris–Trichuris* co-infection rate substantially higher than the 23.1% documented in Tanzania [13] underscores that in this setting, co-occurrence rather than single-species infection is the norm. Children with polyparasitism carry heavier overall worm burdens and face compounded morbidity risks, including synergistic contributions to malnutrition and growth impairment that have been documented in similar co-infected populations across East Africa [3,18].

Intensity distribution and morbidity implications

The dominance of moderate-intensity infections for both *Ascaris* (85.1%) and *Trichuris* (83.4%) carries clinically significant morbidity implications. Moderate-intensity *Ascaris* infection is associated with vitamin A and protein deficiency, impaired intestinal absorption, and at the upper end of the moderate range risk of intestinal obstruction in children [19]. Moderate-to-heavy *Trichuris* infection causes trichuris dysentery syndrome, finger-clubbing, and growth faltering [19]. Given that 86.0% of *Ascaris*-infected and 86.0% of *Trichuris*-infected children in Mudende carry moderate-to-heavy burdens, the nutritional and developmental impact on this child population is likely substantial and extends well beyond the individual infections visible in any single point-prevalence survey.

These intensity findings reinforce the case for clinical screening alongside population-level MDA. Children with heavy Ascaris burdens require individual clinical evaluation for intestinal obstruction risk before treatment a recommendation embedded in WHO guidance [4] but rarely operationalised in resource-limited programmatic settings.

WASH infrastructure as the structural driver of transmission

The multivariate analysis reveals that STH infection risk in Mudende Sector is fundamentally a WASH infrastructure problem. Two variables independently predict infection: absence of household handwashing facilities (aOR = 6.57) and reliance on unimproved water sources (aOR = 3.20). No behavioural or sociodemographic variable including parental education, caregiver STH knowledge, attitude scores, preventive practice scores, or child age was independently associated with infection status after adjustment.

This finding is analytically important because it documents a structural determinism of STH transmission: in settings where virtually no household has a handwashing facility (98.4%) and almost all households rely on unimproved water (94.6%), the physical availability of infrastructure determines infection risk, not individual awareness or intent. 62.3% of caregivers with good STH knowledge and 61.9% with positive attitudes were no less likely to have infected children confirming that knowledge without infrastructure cannot interrupt transmission. This pattern is consistent with Goshu et al. [11] in Ethiopia, who reported a comparable handwashing-facility odds ratio (aOR = 3.84), and with the broader literature documenting the limited impact of hygiene education in the absence of the facilities needed to act on it [20].

The policy implication is direct: health education initiatives, while valuable for community engagement, will not reduce STH infection rates in Mudende until handwashing stations are physically installed at household or school level and safe water access is extended. The infrastructure gap must be closed before behavioral interventions can have measurable epidemiological impact. This challenges a common programmatic framing that treats health education and structural investment as equivalent and interchangeable programme components.

Limitations

Several limitations warrant consideration. First, the retrospective cross-sectional design precludes causal inference regarding identified risk factors; households with tap water may differ from those without it in unmeasured ways. Second, this is a single-sector study; findings may not generalize to other sectors within Rubavu District or to Rwanda more broadly. Third, the very small number of uninfected children (n = 51; 4.7%) limits the statistical precision of multivariate estimates, as reflected in the wide confidence intervals for both significant predictors. The small uninfected group also constrains the power to detect associations for less prevalent risk factors. Fourth, the near-zero hookworm prevalence prevents species-specific risk factor analysis for hookworm. Fifth, KAP composite scores were based on cut-off points defined in the original RBC survey; their psychometric properties in this specific population have not been independently validated.

5. CONCLUSIONS

STH infections are hyper-endemic in Mudende Sector, Rubavu District, Rwanda, with a 95.3% prevalence that is among the highest documented in sub-Saharan Africa and that has not declined despite national MDA implementation. Near-universal *Ascaris–Trichuris* co-infection, a high burden of moderate-intensity infections, and the virtual absence of hookworm collectively define a distinctive transmission profile driven by volcanic soil ecology and severe WASH infrastructure deficits.

The exclusive role of physical WASH infrastructure handwashing facility absence and unimproved water sources as the independent determinants of infection, with no contribution from individual knowledge, attitudes, or practices, establishes that sustainable transmission reduction in this setting is contingent on structural investment. Mudende Sector should be formally classified as a priority hotspot within Rwanda's national NTD control programme. Specific actions indicated by this evidence are: (1) increase deworming frequency to a minimum of three rounds annually pending WASH improvements; (2) prioritize the installation of low-cost handwashing facilities at household and school level; (3) accelerate extension of piped or treated water access through multisectoral collaboration between the Ministry of Health, the Ministry of Infrastructure, and development partners; and (4) establish a routine annual STH monitoring system at the sector level to assess programme impact and detect reinfection trends. Multi-center longitudinal studies across the Northern and Western Provinces are needed to validate these risk factor profiles and assess the impact of integrated WASH–MDA interventions on transmission dynamics over time.

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AUTHOR CONTRIBUTIONS

Conceptualization: UL. Data curation: UL. Formal analysis: UL. Methodology: UL. Supervision: AKA. Writing – original draft: UL. Writing, review and editing: UL, AKA.

AKA = Dr. Amanuel Kidane Andegiorgish (supervisor, Mount Kenya University).

DATA AVAILABILITY

The dataset analyzed in this study was generated by and remains the property of the Rwanda Biomedical Center (RBC). The de-identified dataset was accessed by the authors under formal permission from the RBC. Researchers wishing to access the data should contact the Rwanda Biomedical Center directly (www.rbc.gov.rw). The authors do not have independent authority to share the dataset.

Ethics Consideration

Ethical clearance for this secondary data analysis was obtained from the Institutional Review Board of Mount Kenya University (reference: MKU04/ERC/0615). Written authorization to access the de-identified Rwanda Biomedical Center

(RBC) dataset was granted by the RBC. No new data collection, participant contact, or biological sampling was undertaken. All data were de-identified prior to analysis; no personal identifiers appeared in any analytical output. Data were stored on a password-protected device in compliance with Rwanda's Data Protection Law No. 058/2021. The original RBC survey obtained written informed consent from household heads prior to data collection and biological sample collection.

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COMPETING INTERESTS

The authors declare no competing interests.

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