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Livestock cattle as a predictor of schistosomiasis transmission in Nigeria

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ABSTRACT

Livestock cattle have been widely linked to schistosomiasis epidemiology, but little is known about its contribution to schistosomiasis transmission in Nigeria. The aim of this study is to examine the association between prevalence of schistosomiasis and livestock cattle index in Nigeria. The study's data came from three sources: the demographic and health survey (DHS), the malaria indicators survey (MIS), and the expanded special project for the eradication of neglected tropical diseases (ESPEN). Analysis of variance, correlation, and logistic regression were used to evaluate the mean difference in schistosomiasis prevalence across geopolitical zones, the relationship between schistosomiasis prevalence and livestock cattle, and the risk of schistosomiasis in each geopolitical zone when the cattle index was known, respectively. The overall relationship of the pooled data showed that schistosomiasis endemicity increased significantly with livestock cattle index ($r = 0.052$, $P = 0.0001$). Reduction in livestock cattle significantly reduced schistosomiasis transmission in the Northeast and South south in 2021 ($P < 0.05$). Livestock cattle was consistently a significant negative predictor of schistosomiasis in the Northeast and South-South but a consistent significant risk factor of schistosomiasis transmission in the Northwest, Southeast, Southwest in 2018 and 2021 ($P < 0.05$). The possibility that livestock cattle are a predictor of transmission of schistosomiasis cannot be disparaged; hence, policies that will curtail the zoonotic mode of transmission should be developed for possible future implementation.

1. Introduction

Schistosomiasis continues to be a major global health challenge. The disease poses significant health and economic impacts in endemic areas with 251.4 million people estimated in 2021 to require preventive chemotherapy with praziquantel (World Health Organization (WHO). Schistosomiasis Fact Sheet 2021. ⟨https://www.who.int/news-room/fact-sheets/detail/schistosomiasis⟩. Retrieved 22 April 2023.). Sub-Saharan African countries bear the largest burden of schistosomiasis and account for approximately 90% of the world's schistosomiasis cases (World Health Organization (WHO). Schistosomiasis. Geneva 2018. ⟨https://www.who.int/schistosomiasis/en/⟩. Retrieved 22 April 2023.). Schistosomiasis is associated with poverty and it affects resource-constrained individuals with limited access to clean water, and poor sanitation and hygiene services (Hotez et al., 2009).

Currently, schistosomiasis control strategies in Africa largely rely on mass treatment with preventive chemotherapy. Significant reduction in infection and morbidity has been generally recorded in endemic areas because of this effort (Tchuem Tchuenté et al., 2017). In other regions of the world where zoonotic schistosomiasis infections are rampant, mass treatment of humans and bovines, vaccination, and replacement of the latter with tractors in farming are parts of the comprehensive integrated schistosomiasis control approaches (Cao et al., 2016; Ross et al., 2023). While *Schistosoma mansoni* and *S. haematobium* transmission dynamics were initially thought to be exclusively human-specific and not

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associated with zoonoses, recent evidence suggests that the disease has a zoonotic component in their epidemiology. For example, the morphological and molecular analyses of parasites isolated from children in Senegal and Benin identified viable hybrids of human *S. haematobium* with livestock *S. bovis* and/or *S. curassoni* (Webster et al., 2013; Savassi et al., 2021) as well as *S. bovis* with *S. curassoni* in a Nigerien child (Léger et al., 2016). A recent study in Nigeria reported *S. magrebowiei* in the human population, which was traditionally only parasitic in lechwe, suggesting possible interspecific interactions with other human schistosome species that may be present in the area (Bayegun et al., 2022).

Nigeria with 20.7 million herds of cattle is one of the countries with the largest cattle population in Africa (Benson and These, 2023). Although open grazing of cattle has been criminalized in the country, the majority of the herders still adopt this method of grazing. This is particularly utilized during the non-automotive transportation of cattle from producing areas in the north to the consuming areas in the south. In the south, many of the cattle are maintained through open grazing thus increasing the interaction of the livestock with the natural population of humans. Considering the recent concerns on animal schistosomiasis as a risk factor for transmission and recrudescence of schistosomiasis infection in the human population, this study was conducted to evaluate the association between cattle livestock index and the prevalence of schistosomiasis in Nigeria. To the best of our knowledge, this has not been examined in Nigeria despite the massive cattle livestock market and persistent transmission of schistosomiasis in the country. The findings of this study have potential implications for schistosomiasis control, particularly in terms of managing the environmental burden of human schistosomes in cattle and addressing the challenge of drug resistance in the event of a hybridization between a cattle-specific *Schistosoma* parasite and the human species.

2. Materials and methods

2.1. Study design

Administrative and site level data on neglected tropical diseases (NTDs) in African countries are very scarce before the introduction of Expanded Special Project for Elimination of Neglected Tropical Diseases (ESPEN). This project sponsored by the WHO commenced in 2003 and focuses on the five most prevalent NTDs at administrative and site level in African countries. This study leveraged this data source as well as the Nigerian Demographic and Health Surveys (NDHS) of 2018 and the Malaria Indicator Survey (MIS) of 2021. The number of persons examined for schistosomiasis as well as those confirmed positive to the disease through clinical, parasitological, and other diagnostic procedures were extracted from ESPEN dataset at the site level for the year 2018 and 2021. Equally, livestock cattle index data for the same years were also collected from the NDHS and MIS, respectively. The dataset from these sources were merged together in SPSS statistical package using the administrative level 1 variable as the unique identifier. After merging and data cleaning, the number of human schistosomiasis cases in the dataset was found to be 13,659 disaggregating into 6893 and 6766 for 2018 and 2021, respectively.

2.2. Ethics

Ethical approval is unnecessary for this study as it relied solely on secondary data without any identifiable information.

2.3. Statistical analysis

In line with the goal of the study, three hypotheses were put forward and investigated using Kruskal Wallis Test and Spearman's rank correlation and logistic regression, respectively. Firstly, the claim that there is no significant mean difference in the prevalence of schistosomiasis and livestock cattle index in the six geopolitical zones of Nigeria was tested. Secondly, the statement that there is no significant relationship between livestock cattle index and prevalence of schistosomiasis was verified. Thirdly, to ascertain the effect of livestock cattle on the prevalence of schistosomiasis, it was hypothesized that there is no significant impact of livestock cattle index on prevalence of schistosomiasis. Contrary to the binary nature of dependent variable in a logistic regression, the study relied on count of target class out of several trials. That is, the number of persons tested positive to schistosomiasis out of total number of persons examined at specific site. This resulted in a binomial outcome and the logistic regression formulation is given as;

$$\log\left(\frac{\pi_i}{1-\pi_i}\right) = \sum_{k=0}^{K} x_{ik}\beta_k \quad i = 1, 2, \ldots, N \tag{1}$$

The unknown parameter β_k in the Eq. (1) is estimated by the maximum likelihood which can be derived from the probability distribution of the dependent variable. Since the number of positive instances of schistosomiasis y_i out of n_i persons examined at each site represents a binomial experiment, the joint probability density function of Y is given as;

$$f\left(y \middle/ \beta\right) = \prod_{i=1}^{N} \binom{n_i}{y_i} \quad \pi_i^{y_i}(1-\pi_i)^{n_i - y_i} \tag{2}$$

The likelihood function is similar in form with the probability density function, albeit the parameters of the function are reversed such that the likelihood function expresses the values of β in terms of unknown, fixed value of y. Thus, the likelihood function is expressed as.

$$L\left(\beta \middle/ y\right) = \prod_{i=1}^{N} \binom{n_i}{y_i} \quad \pi_i^{y_i}(1-\pi_i)^{n_i - y_i} \tag{3}$$

The value that maximizes the likelihood function in Eq. (3) is called the maximum likelihood estimate. The logistic regression was computed at a disaggregated level by splitting the dataset into the six geopolitical zones in both 2018 and 2021, and the odd ratio was computed as the exponential of β. The statistical significance of all hypotheses was established at a 5% level of significance. This implies that a probability value of less than 0.05 on any estimate adjudges it to be statistically significant.

3. Results

The Kolmogorov-Smirnov test of normality for livestock cattle index and prevalence schistosomiasis in Nigeria is presented in Table 1. From 2018–2021, the livestock cattle index exhibited an upward trend in the Northwest, Southeast, and Southwest regions, with percentages increasing from 19.3% to 76.0%, 2.2–2.7%, and 0.1–2.0%, respectively. The relationship between schistosomiasis prevalence and the livestock cattle index revealed four distinct patterns. The first pattern involved a decline in the livestock cattle index in the South South and Northeast regions, accompanied by a corresponding decrease in schistosomiasis endemicity in these areas. The second pattern entailed an increase in the livestock cattle index without any change in schistosomiasis endemicity observed in the Northwest and Southwest regions. The third scenario

Table 1
Kolmogorov-Smirnov test of normality for livestock cattle index and prevalence schistosomiasis in Nigeria.

		Kolmogorov-Smirnov[a]	
Year	Variable	Statistic	P-value
2018	Prevalence of schistosomiasis	0.188	0.000
	Livestock cattle	0.253	0.000
2021	Prevalence of schistosomiasis	0.190	0.000
	Livestock cattle	0.306	0.000
Combined	Prevalence of schistosomiasis	0.189	0.000
	Livestock cattle	0.277	0.000

showcased an increase in the livestock cattle index coupled with a decrease in schistosomiasis endemicity in the Southeast, and finally, a stable livestock cattle index accompanied by a decline in schistosomiasis endemicity (Table 2).

Between 2018 and 2021, there was a decrease in schistosomiasis endemicity in several regions of Nigeria. Specifically, the North central, Northeast, Southeast, and South South regions experienced reductions in schistosomiasis endemicity, with percentages decreasing from 9.7% to 9.1%, 8.7–8.0%, 10.7–8.0%, and 29.1–14.0%, respectively (Table 2). Notably, there was no change in the prevalence of schistosomiasis in the Northwest and Southwest regions between 2018 and 2021 (Table 2).

There were positive correlations between the endemicity of schistosomiasis and livestock cattle index in the years 2018 and 2021. The relationships were significant both in 2018 ($r = 0.045$, $P = 0.009$) and 2021 ($r = 0.058$, $P = 0.001$). The overall relationship of the pooled data showed that schistosomiasis endemicity increased significantly with livestock cattle index ($r = 0.052$, $P = 0.0001$) (Table 3).

In 2018, livestock cattle did not demonstrate a significant positive impact on schistosomiasis in the North central region. However, in 2021, there was a significant effect observed, indicating that livestock cattle contributed to reducing schistosomiasis in that region ($P < 0.05$). The role of livestock cattle as a negative predictor of schistosomiasis transmission also underwent changes in the Northeast geopolitical zone of Nigeria. In 2018, the effect was not significant ($P > 0.05$), but in 2021, it became significant, indicating a potential reduction in schistosomiasis transmission ($P < 0.05$). Conversely, in both the Northwest and Southeast regions, livestock cattle consistently acted as a risk factor, contributing to increased schistosomiasis transmission in 2018 and 2021 ($P < 0.05$). While livestock cattle served as a negative predictor of schistosomiasis in the South-south region ($P < 0.05$), they acted as a positive predictor of disease transmission in the Southwest during both 2018 and 2021 ($P < 0.05$) (Table 4). The logistic regression model demonstrated good performance, correctly identifying positive or negative classes with an accuracy of approximately 72.0%.

4. Discussion

Schistosomiasis continues to be a public health issue in Nigeria. Efforts to control the disease are directed toward mass drug administration. In recent times, there has been wide advocacy to integrate WASH and snail control into the currently employed control strategy (Oyeyemi, 2020) but little is known about the role of livestock in the transmission of the disease in Nigeria. Given the increasing reports of the occurrence of hybrid schistosomes in several countries in sub-Saharan Africa and a recent report of animal *Schistosoma* in the human population in Nigeria (Bayegun et al., 2022), it is possible there is an ongoing yet to be reported hybridization between bovine and human *Schistosoma* spp. in the country. While the focus of this study is not on *Schistosoma* hybridization, the role of livestock cattle in promoting schistosomiasis transmission through the development of hybrid schistosomes cannot be trivialized. Hybrid schistosomes could develop resistance to praziquantel, thus, compromising control efforts.

Table 2
Livestock cattle index and schistosomiasis endemicity in Nigeria.

	Livestock cattle index (IQR)			Prevalence of schistosomiasis (IQR)		
Regions	2018	2021	Combined	2018	2021	Combined
North Central	2.7	2.7	2.7	9.7	9.1	9.1
North East	26.6	17.3	17.3	8.7	8.0	8.0
North West	19.3	76.0	32.8	12.0	12.0	12.0
South East	2.2	2.7	2.7	10.7	8.0	10.0
South South	2.9	2.7	2.9	21.9	14.0	17.7
South West	0.1	2.0	1.2	7.9	7.9	7.9

IQR; interquartile range

Table 3
Non-parametric Correlation between livestock cattle index and endemicity of schistosomiasis.

Year			Prevalence	Livestock Cattle
2018	Prevalence	Rank Correlation	1	0.045**
		Sig. (2-tailed)	.	0.009
	Livestock Cattle	Rank Correlation	0.045**	1
		Sig. (2-tailed)	0.009	.
2021	Prevalence	Rank Correlation	1	0.058**
		Sig. (2-tailed)	.	0.001
	Livestock Cattle	Rank Correlation	0.058**	1
		Sig. (2-tailed)	0.001	.
Combined	Prevalence	Rank Correlation	1	0.052**
		Sig. (2-tailed)	.	0.0001
	Livestock Cattle	Rank Correlation	0.052**	1
		Sig. (2-tailed)	0.0001	.

**. Correlation is significant at the 0.01 level (2-tailed).

Our findings indicate a notable increase in livestock cattle, highlighting the growing significance of livestock farming as a vital source of income for Nigeria's economy. The rise in the livestock cattle index can be attributed to the country's expanding population. Projections suggest that to accommodate the population growth rate, the demand for livestock products is expected to increase by more than 3% annually (Sasu, 2023). Our results concerning the variation in the livestock cattle index relative to schistosomiasis transmission demonstrate regional differences, strongly suggesting that livestock may indeed play a role as a predictor of schistosomiasis transmission in Nigeria. The results obtained from the correlation and logistic regression analysis conducted for both 2018 and 2021 support the hypothesis that cattle serve as a significant risk factor for the transmission of schistosomiasis in the country. The Northeast and South south regions experienced a decrease in cattle index from 2018 to 2021, suggesting that a reduction in cattle population could serve as a negative predictor for schistosomiasis transmission. Conversely, in the Northwest, Southeast, and Southwest regions, the increase in livestock cattle index did not appear to reduce the risk of schistosomiasis transmission. These observations align with the hypothesis that cattle contribute to the increased risk of human schistosomiasis in Nigeria. However, the situation in Northcentral region differed from the other zones. While the exact reasons for this deviation are difficult to ascertain at present, it is possible that other factors exerted a more significant impact on schistosomiasis transmission than livestock cattle. One contributing factor could be the presence of non-governmental organizations (NGOs) such as the Carter Center, focusing on neglected tropical diseases (NTDs) control, which may have strengthened government efforts in the Northcentral region (Oyeyemi, 2020). Consequently, there was a significant reduction in schistosomiasis transmission even though livestock cattle index remained stable. In light of these findings, it becomes increasingly evident that tailored schistosomiasis control strategies specific to each endemic region of Nigeria and possibly sub-Saharan Africa should be a top priority, particularly in relation to the livestock index. This emphasizes the importance of implementing localized initiatives for schistosomiasis management.

Although there have been no specific studies investigating the correlation between human-specific *Schistosoma* transmission and livestock cattle in Nigeria, research conducted in Asia has indicated a potential association between bovine schistosomes and transmission in humans (Olveda et al., 2016; Jiz et al., 2021; Grover et al., 2022). A recent report highlighting a suspected case of *S. japonicum* in Nigeria (Bayegun et al., 2022) suggests the possibility of ongoing, undetected transmission of the

Table 4
Logistic regression to evaluate livestock as a predictor of prevalence of schistosomiasis transmission by geopolitical zone relative to years.

	Livestock cattle (LSC) estimate		Odd ratio (LSC)		95% (LSC)	
Regions	2018	2021	2018	2021	2018	2021
North Central	0.00056	-0.0179***	1.0006	0.9823	(1.000,1.001)	(0.980,0.984)
North East	-0.00041	-0.0020*	0.9996	0.9980	(0.998,1.001)	(0.996,1.000)
North West	0.0013**	0.0027***	1.0013	1.0027	(1.001,1.002)	(1.002,1.003)
South East	0.0584***	0.0682***	1.0601	1.0706	(0.057,1.063)	(1.0668,1.074)
South South	-0.2090***	-0.160***	0.8113	0.8525	(0.804,0.819)	(0.845,0.861)
South West	0.0149***	0.0448***	1.0151	1.0458	(1.013,1.017)	(1.034,1.052)

Asian type schistosome in the country, potentially facilitated by the presence of a high population of free-range grazing cattle. However, further investigation is required to validate this hypothesis in multiple schistosomiasis endemic regions within Nigeria.

In conclusion, this study has examined the potential involvement of cattle in the transmission of schistosomiasis in Nigeria. The role of cattle in schistosomiasis transmission has been primarily speculative, and this study represents the first attempt to evaluate such an association. It is important to note that this study relied on secondary data collected under different circumstances. Therefore, a comprehensive and systematic assessment of this association should be conducted in endemic areas, considering both human and cattle populations. It may be necessary to reconsider the current recommendations for schistosomiasis control in Nigeria and other sub-Saharan African countries by incorporating bovine treatment into ongoing efforts, thereby mitigating the interface between animal-human transmission. Others should include the establishment of robust surveillance systems to monitor the prevalence and distribution of schistosomiasis in both human and potential animal reservoirs, the implementation of regular screening and diagnostic testing for schistosomiasis in at-risk human populations and animals, and the development of legislative measures to regulate activities that contribute to the spread of zoonotic schistosomiasis, such as managing livestock access to water bodies, improving sanitation, and controlling snail populations. These recommendations if implemented will improve livestock health and interrupt possible zoonotic transmission of the disease.

Conflicts of interest

None.

Informed consent statement

Not applicable.

CRediT authorship contribution statement

Conceptualization OTO; methodology, OTO and OAO; data analysis; OAO; validation, OTO, YH, and LMS; Writing – original draft preparation, OTO and OAO; Writing – review and editing, YH, ZF, JHC, and LMS. All authors read and approved the final manuscript version. The requirements for authorship have been met as each author believes that the manuscript represents honest work.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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