Impact of Chikungunya Epidemic on Household Out-of-Pocket Health Expenditures in Kassala State, Sudan

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Abstract

This study examines the health and economic repercussions of the 2018 Chikungunya epidemic on households in Kassala State, Sudan. The study draws on primary survey data from 407 households sampled proportionally across the localities of Kassala, Rural Kassala, and Rural West Kassala. The epidemic displayed widespread prevalence, with infection rates highest in urban areas due to greater population density and vector exposure. The study finds that existing socioeconomic vulnerabilities, particularly high illiteracy rates, female-headed households, and low-income prevalence in rural localities, substantially exacerbated financial pressures on affected households. The results from ordered logistic regression reveal that Chikungunya infection significantly increases out-of-pocket health expenditures (OOPHE), while health insurance offers notable financial protection. Furthermore, probit regression analysis confirms that catastrophic health expenditure (CHE), defined as OOPHE exceeding 20% of household income, is common across all income groups and strongly correlated with infection status. Elevated OOPHE is further shown to depress household consumption levels, deepening poverty risks, especially among economically disadvantaged groups. In coping with these health shocks, the majority of households turned to borrowing and informal support networks, highlighting the limited reach of formal safety nets. Taken together, these findings point to the urgent need for robust public health interventions, expanded insurance coverage, and strengthened financial protection systems. Enhancing epidemic preparedness through improved vector control, health education, and equitable access to healthcare is essential to safeguarding vulnerable populations and promoting resilience in Kassala State and similar contexts in Sudan.

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Keywords: Sudan, Kassala, Chikungunya Epidemic, Ordered Logistic Regression

JEL: I15, I18, O12, C25, D12, R23

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1. Introduction

Infectious disease outbreaks pose profound and multidimensional threats to public health systems and household welfare, especially in low-resource settings where capacities to respond are often weakest (Moon et al., 2015; Rohwerder, 2020; Omosigho et al., 2023). The 2018 Chikungunya epidemic in Kassala State,[4] Sudan, serves as a stark example of how acute health shocks can undermine socioeconomic resilience through both direct morbidity impacts and rising OOPHE. The outbreak began abruptly in August 2018, initially detected in the Garab Elgash area on the west bank of the Gash River, before rapidly spreading to the east bank and encompassing the localities of Rural West Kassala and Rural Kassala (UNICEF Sudan, 2018; Siam et al., 2022). This unprecedented epidemic constituted a critical shock for both households and public health authorities. The state's already fragile health system, marked by limited infrastructure, persistent shortages of medical supplies, underdeveloped laboratory capacity, and insufficient numbers of trained personnel, proved ill-equipped to manage the sudden spike in healthcare demand. Lacking adequate preparedness and resources, the system was swiftly overwhelmed, leaving many infected individuals without timely diagnosis or supportive care. As a result, much of the population, facing confusion and insufficient institutional support, was unprepared to cope with the crisis independently.

Public confusion was significantly exacerbated by widespread fear and uncertainty, primarily due to the absence of accurate, timely information regarding the nature of the disease. During the early phase of the outbreak, misinformation and circulating rumors intensified anxiety among local communities. Clarity began to emerge when a faculty member from the Faculty of Medicine and Health Sciences at the University of Kassala clinically identified the illness as chikungunya, relying on direct observation and field-based evidence.[5] This early local diagnosis represented the first credible recognition of the outbreak's origin, offering an initial sense of explanation to a distressed population. Nevertheless, definitive confirmation of the outbreak's etiology was delayed, prolonging public uncertainty and amplifying psychological distress. While early clinical assessments had pointed toward chikungunya, it was not until 10 August 2018, that laboratory validation was obtained. Of the 24 blood samples collected and tested by the Sudanese National Public Health Laboratory (STACK Laboratory) in Khartoum, 22 returned positive results for chikungunya via both polymerase chain reaction (PCR) and enzyme-linked immunosorbent assay (WHO, 2018). This formal diagnosis not only corroborated prior field-based clinical observations but also marked a turning point in the public health response by substantiating the presence of the virus through standardized virological techniques. Primary estimates indicated that at the peak of the epidemic, more than 487,600 confirmed cases were reported across the three affected localities (Bower et al., 2021).

[4] The Chikungunya fever outbreak in Kassala State lasted from August 2018 to March 2019, affecting thousands of individuals across both urban and rural localities. It was commonly known among locals as Kankasha, a term reflecting the incapacitating nature of the disease, which often left individuals struggling to stand or move.

[5] Professor Tajeldin Mohammedein Abdallah, a faculty member at the Faculty of Medicine and Health Sciences, University of Kassala, was the first to clinically diagnose Chikungunya during the 2018 outbreak, marking the initial identification of the disease in Sudan. Notably, in the epidemic's early stages, the disease was frequently misdiagnosed as malaria, with impaired mobility often mistaken as a primary symptom.

Given that the total population of Kassala State was approximately 2.2 million at that time, this figure implies that nearly 22% of the state's population was directly infected with chikungunya during the peak phase of the outbreak. This proportion is likely even greater within the three localities most impacted by the epidemic, Kassala, Rural West Kassala, and Rural Kassala, where concentrated transmission resulted in heightened infection rates relative to the broader state population. Furthermore, over one hundred deaths were attributed to the outbreak, though precise figures remain limited due to incomplete reporting. While the overall mortality rate appeared relatively low, at approximately 0.01%, the sheer scale of infection and rapid case surge imposed extraordinary burdens on both households and the already fragile health system. Officials and clinicians clarified that most fatalities resulted from complications associated with underlying co-morbidities such as diabetes, cardiovascular diseases, and hypertension, rather than chikungunya infection alone. Nevertheless, the cumulative impact in terms of morbidity, mortality, and healthcare system strain was substantial, exacerbating pre-existing vulnerabilities within Kassala's socio-economic context.

Beyond the immediate health impacts, the epidemic imposed a substantial financial burden on affected households. The sharp rise in morbidity rates led to significant increases in OOPHE, placing severe strain on household incomes. Although chikungunya has no specific treatment, medical protocols required patients to undergo numerous diagnostic tests and consultations to rule out other infections, further escalating healthcare costs. This financial pressure was exacerbated by the limited health insurance coverage in the state; only 40.1% of the population was insured, according to the National Health Insurance Fund (2018). In addition, the epidemic contributed to reduced household incomes by increasing work absenteeism, particularly among informally employed individuals.

The elevated levels of OOPHE associated with chikungunya infection are expected to reduce the share of household income available for essential expenditures such as food and basic necessities. Reductions in these life-sustaining purchases may push households into food insecurity, thereby triggering a range of adverse consequences for their health and livelihoods. In this regard, a substantial body of literature has shown that OOPHE represents a heavy burden on household incomes, particularly among those living under poverty conditions (Xu et al., 2007; Bredenkamp et al., 2010; Berman et al., 2010; Reddy et al., 2011; Shahrawat and Rao, 2011; Van Minh et al., 2013; Arsenijevic, 2013; Ebaidalla and Mustafa, 2019; Ali et al., 2022). More specifically, several studies have demonstrated that the incidence of epidemic diseases leads to unanticipated and unbudgeted health spending among affected communities. For instance, existing evidence highlights that chikungunya epidemics significantly heighten OOPHE among infected individuals, thereby exacerbating their vulnerability and deteriorating overall livelihood conditions (Kumar et al., 2007; Vijayakumar et al., 2013).

Given that over 37% of the population in Kassala State lives below the poverty line and lacks health insurance coverage, the increase in OOPHE triggered by the chikungunya epidemic is expected to entail a wide array of negative consequences on household livelihoods. The situation is further complicated by Kassala's epidemiological landscape, which is marked by a high prevalence of communicable diseases such as malaria, typhoid, and tuberculosis (CBS, 2018). This broader disease burden is likely to amplify the poverty-deepening effects of the chikungunya outbreak among affected communities. Additionally, a substantial portion of Kassala's population is illiterate, which impedes timely and appropriate health-seeking behavior, thereby exacerbating disease outcomes and financial strain. The limited penetration of health insurance in the region is expected to intensify household vulnerability by increasing reliance on out-of-pocket payments, particularly among socially and economically disadvantaged groups.

These contextual realities give rise to several critical research questions concerning the impact of the 2018 chikungunya epidemic in Kassala State: (1) What role did chikungunya play in raising OOPHE among households in the affected localities during the outbreak? (2) Did the epidemic drive OOPHE to a level that consumed a substantial portion of household income, thereby reaching catastrophic expenditure thresholds? (3) To what extent did health insurance coverage mitigate the patterns of OOPHE among chikungunya-infected households? And (4) Did the financial pressures associated with OOPHE ultimately worsen household consumption and overall welfare in the affected areas?

To address these questions, the study will draw on primary survey data to be collected from households in the chikungunya-affected localities of Kassala, Rural Kassala, and Rural West Kassala. The sample will be proportionally allocated across these localities based on their population size to ensure representativeness and account for demographic heterogeneity. The analysis will combine descriptive statistics with econometric techniques, including probit and logistic regression models, to examine the effect of chikungunya infection on OOPHE, with particular attention to instances where OOPHE exceeds critical thresholds and becomes catastrophic for household welfare.

After this introductory section, the study proceeds to outline the Contribution of the Study, emphasizing its relevance in understanding the socioeconomic impacts of health crises in fragile contexts like Sudan. It then presents the Objectives of the Study, clearly stating the research aims. The Literature Review follows, providing an overview of existing studies on epidemics, health expenditures, and socioeconomic vulnerability. The study then offers a detailed Background on the Chikungunya Epidemic, highlighting its spread and implications in Kassala State. The Research Methodology section describes the data sources, estimation techniques, and analytical framework employed. This is followed by a presentation of the Empirical Results, offering insights into the epidemic's impact on household health expenditures. The study concludes with a Conclusion that summarizes the main findings and suggests policy recommendations.

2. Contribution of the Study

This study offers significant contributions to the literature on the economic impact of epidemic diseases, with a specific focus on the Chikungunya outbreak. First, it represents the inaugural empirical analysis of Chikungunya in Sudan, marking the first documented outbreak in 2018, thereby filling a critical research gap. Second, it provides policymakers and stakeholders with actionable, evidence-based insights into the escalation of OOPHE triggered by the Chikungunya epidemic, enabling the development of targeted policy interventions to mitigate its adverse effects on household livelihoods. Third, it evaluates the effectiveness of health insurance in shielding households from excessive OOPHE during sudden health shocks like the Chikungunya outbreak, offering practical implications for enhancing financial protection mechanisms. Finally, the study assesses the downstream welfare implications of OOPHE by analyzing its negative impact on household consumption, thereby offering empirical evidence on how health shocks translate into broader economic vulnerabilities and reduced living standards.

3. Objectives of the study

This study aims to investigate the role of the Chikungunya epidemic outbreak in elevating OOPHE among households in infected localities of Kassala State, utilizing data collected from Kassala, Rural Kassala, and Rural West Kassala. Specifically, it seeks to:

1. Quantify the contribution of the Chikungunya epidemic to increased OOPHE among infected households.
2. Assess the mitigating effect of health insurance coverage on OOPHE among Chikungunya-affected households.
3. Examine whether the epidemic drives OOPHE to catastrophic levels for infected households.
4. Evaluate the impact of Chikungunya-related OOPHE on reducing household consumption among affected households.
5. Analyze the influence of geographic and socioeconomic factors, such as locality and education, on the prevalence and severity of Chikungunya infections.
6. Investigate the role of treatment-seeking behavior and healthcare access in shaping OOPHE and household resilience during the epidemic.

4. Literature Review

A substantial body of literature has examined the determinants and consequences of OOPHE across various socioeconomic and geographical contexts. However, the findings exhibit significant variation, largely shaped by the structural characteristics of health systems and the broader macroeconomic conditions in which these studies are conducted. While some scholars have focused on the general drivers of OOPHE, others have explored its catastrophic implications, namely, CHE, and the poverty-inducing consequences for households. To provide a comprehensive understanding of this evolving body of research, the following review is structured around three key themes: the determinants of OOPHE, with attention to household, health system, and contextual factors; the determinants of CHE, which highlight thresholds beyond which OOPHE becomes unsustainable; and the interconnections between OOPHE, CHE, and household impoverishment, particularly the ways in which high health spending affects consumption and deepens vulnerability. This structure enables a nuanced synthesis of how health shocks translate into financial hardship and diminished household welfare.

4.1 Determinants of OOPHE

In the context of developing countries, household-level socio-economic characteristics are commonly identified as strong predictors of OOPHE. For instance, Malik and Syed (2012), using Ordinary Least Squares (OLS) estimation on data from the Household Integrated Economic Survey (HIES) and Pakistan Standard of Living Measurement (PSLM), found that non-food expenditure, literacy of the household head and spouse, poor sanitation, recent childbirth, unsafe drinking water, and regional location were significant determinants of OOPHE in Pakistan. Similarly, Pal (2012) emphasized the critical role of education in determining the incidence of OOPHE among Indian households. In Vietnam, Chaudhuri and Roy (2008) identified the ability to pay as a primary determinant of whether an individual incurs out-of-pocket expenses.

Several studies have focused specifically on the role of health insurance coverage in mitigating OOPHE. Johnson & Krish (2012), using data from India's National Sample Survey Organization (2009), applied a difference-in-differences approach to evaluate the impact of the Rashtriya Swasthya Bima Yojana (RSBY), a national health insurance scheme. They found only modest reductions in OOPHE for outpatient care. However, Azam (2018), using longitudinal household survey data, reported no significant reduction in per capita OOPHE attributable to RSBY, challenging the effectiveness of such schemes.

A relevant study by Ali & Abdullah (2021) investigates the determinants of OOPHE and CHE incurred by urban households in five Sudanese states: Red Sea, Kassala, Gadarif, Sinnar, and South Darfur. The study also examines the impact of CHE on household livelihoods in these states. Using OLS and probit regression on data from the Sudanese National Baseline Household Surveys (NBHS) conducted in 2009 and 2014, the authors found that household size, education level, and the presence of elderly members significantly influence OOPHE. Disaggregated state-level analysis revealed that income, health insurance coverage, the presence of children and elderly members, education, gender of the household head, and household wealth were key drivers of OOPHE. For the 2014 data, additional factors such as the age of the household head, wage employment, marital status, and proximity to healthcare facilities played major roles in determining OOPHE. These findings underscore the multifaceted nature of healthcare expenditure burdens in Sudan.

Other studies suggest that health system inefficiencies and uneven insurance coverage exacerbate OOPHE. For instance, Ladusingh and Pandey (2013) demonstrated that 10.1% of rural and 6.2% of urban households in India fell below the poverty line due to OOPHE, with inadequate insurance coverage and poor health infrastructure contributing significantly to the burden. This emphasizes the role of structural and institutional factors in mediating household vulnerability to health shocks. Ali et al. (2020) further support this perspective in their analysis of 45 Sub-Saharan African countries, where they found that foreign aid did not significantly reduce OOPHE, nor did its effect depend on the quality of institutions**.** This challenges the widely held assumption that institutional quality amplifies the effectiveness of aid in improving health financing outcomes.

Adding to this literature, Kusi et al. (2015) evaluated the impact of Ghana's National Health Insurance Scheme (NHIS) and found that full enrollment significantly reduced OOPHE. However, even insured households still made some out-of-pocket payments due to limited benefit coverage and provider shortages, indicating that insurance alone does not eliminate financial risk entirely.

4.2 Determinants of CHE

A parallel strand of literature has examined when and how OOPHE becomes catastrophic—defined typically as exceeding a specified share of household income or capacity to pay. Misra et al. (2015), for example, identified hospitalization and prolonged illness as major drivers of CHE in urban Lucknow, India. Yazdi-Feyzabadi et al. (2018), using Iranian household expenditure data, reported higher CHE prevalence in rural areas despite lower average OOPHE. Factors such as rural residence, inpatient service use, and presence of elderly members were strongly correlated with CHE.

In Colombia, Amaya-Lara (2016) used a probit model and found that approximately 9.6% of households incurred CHE, defined as OOPHE exceeding 20% of capacity to pay. Rural residence, larger household sizes, and lack of insurance were significant correlates. Similarly, Koch et al. (2017) conducted a systematic review of financial protection in Chile and found that about 4% of households experienced CHE (threshold: 30% of capacity to pay), though less than 1% were pushed into poverty as a result. In Ghana, Kusi et al. (2015) found that households fully enrolled in the NHIS had a 4.2 times lower likelihood of experiencing CHE compared to uninsured households, providing strong evidence of the protective role of comprehensive insurance coverage. Ebaidalla and Mustafa (2019) analyzed the 2009 NBHS for Sudan and found that disease incidence, income, household size, and demographic composition (particularly elderly and young children) were the primary factors influencing both OOPHE and CHE. They also found that CHE was significantly associated with impoverishment, especially among low-income households.

The findings of Ali and Abdullah (2021) corroborate prior evidence, emphasizing that household wealth, insurance coverage, and proximity to healthcare facilities play a critical role in determining the risk of catastrophic health expenditure (CHE).

4.3 OOPHE, CHE, and Household Impoverishment

A number of studies have delved into the impoverishing effects of high health expenditures. Kumar et al. (2015), using WHO-SAGE data, found that OOPHE pushed approximately 7% and 8% of the population in China and India, respectively, into poverty. Their multivariate results emphasized that lack of wealth and hospitalization increase the likelihood of impoverishment. Rahman et al. (2013), studying urban Bangladesh, observed a fourfold increased risk of CHE among the poorest households, especially those using formal healthcare services. Garg and Karan (2008), using Indian Consumer Expenditure Survey data, estimated that OOPHE increased poverty by 1%, with the burden disproportionately affecting lower-income households. In Africa, Onwujekwe et al. (2012) found that poorer and rural Nigerian households faced higher CHE incidence despite urban populations reporting higher absolute

OOPHE. Van Doorslaer et al. (2006) delivered a landmark contribution by reassessing poverty estimates in 11 low- and middle-income Asian countries after adjusting for OOPHE. Their findings showed that conventional poverty statistics underestimated poverty by as much as 14% once OOPHE was accounted for. Further, Thuan et al. (2006) illustrated in Vietnam's Bavi district that health conditions, including communicable diseases, were a dominant cause of elevated OOPHE among poor households, reinforcing the disease-poverty nexus.

In conclusion, the literature consistently highlights the role of socioeconomic factors, such as income, education, household composition, and insurance coverage, as key determinants of OOPHE and CHE in developing countries. These financial burdens are further intensified by structural weaknesses in health systems and unequal access to care. Evidence from Sudan, particularly the work of Ali and Abdullah (2021), affirms these patterns while also revealing important regional and demographic disparities in the incidence of OOPHE and CHE.

Evidence also shows that high health expenditures contribute significantly to household impoverishment, especially among low-income and rural populations. These findings underscore the need for comprehensive policies that enhance financial protection through effective health insurance schemes and improve healthcare accessibility in vulnerable communities.

5. Chikungunya Epidemic

5.1 Background

Chikungunya is a mosquito-borne viral illness that affects humans through the bite of infected *Aedes* mosquitoes, most commonly *Aedes aegypti* and *Aedes albopictus* (Weaver & Lecuit, 2015; CDC, 2023). First identified in Tanzania in 1952, the disease is now widespread in Africa, Asia, the Indian subcontinent, and parts of the Americas (Staples & Fischer, 2014; WHO, 2023). Chikungunya is caused by the chikungunya virus (CHIKV), an RNA virus belonging to the alphavirus genus of the Togaviridae family (Weaver & Lecuit, 2015; Aubry et al., 2015). The disease is characterized by the sudden onset of symptoms, typically appearing 3 to 7 days after a mosquito bite (Staples & Fischer, 2014; CDC, 2023). The most prominent symptom is severe joint pain, often in the hands, feet, knees, or wrists, which may persist for weeks or months and can resemble arthritis (Simon et al., 2011; WHO, 2023). Other common symptoms include high fever, muscle pain, headache, fatigue, nausea, rash, and swelling of the joints (Weaver & Lecuit, 2015; CDC, 2023). While most individuals recover fully, some, especially the elderly or those with underlying health conditions, may suffer from prolonged or recurrent joint pain and fatigue (Aubry et al., 2015; Simon et al., 2011).

Beyond its direct health effects, Chikungunya imposes considerable socio-economic burdens on affected populations. The hallmark symptoms, particularly severe joint pain and debilitating fatigue, often result in prolonged absenteeism from work, disproportionately impacting individuals in their prime productive years. This loss of labor capacity translates into reduced economic productivity at both the household and community levels, with especially pronounced effects in labor-intensive sectors such as agriculture, construction, and informal services. For many, the inability to engage in regular employment during and after infection leads to substantial income loss. This impact is particularly acute for low-income or self-employed individuals who lack access to paid sick leave or social protection mechanisms. The financial strain resulting from such income disruptions can undermine a household's ability to meet essential needs, including adequate nutrition, housing, education, and healthcare.

In contexts where livelihoods depend heavily on physical labor, the persistent effects of Chikungunya can further deepen economic vulnerability. As affected individuals struggle to resume work or fulfill physically demanding tasks, household incomes may decline, exacerbating poverty cycles and deepening socio-economic disparities. For already at-risk populations, the long-term economic consequences of the disease can be as damaging as the health impacts themselves.

Moreover, the economic burden of Chikungunya extends to out-of-pocket health expenditures, which can further strain households' financial stability. Individuals affected by the disease often incur significant out-of-pocket costs for medical care, including doctor's visits, diagnostic tests, medications for pain and inflammation, and other treatments to manage symptoms. In areas with limited access to public healthcare or where health insurance is scarce, these out-of-pocket expenses can be a substantial burden, particularly for families already struggling with lost income due to illness. The combination of lost wages and rising medical costs can lead to catastrophic financial consequences, pushing many households further into poverty. For those with chronic or recurrent symptoms, the cost of managing the disease over an extended period can become unsustainable, further exacerbating the economic hardships faced by individuals and families. As a result, Chikungunya not only undermines the health of individuals but also has long-lasting economic impacts, affecting household livelihoods, increasing financial vulnerability, and burdening already overstretched healthcare systems.

5.2 Outbreak of Chikungunya in Kassala State

Chikungunya has emerged as a significant public health challenge in Sudan, with the first and only documented outbreak occurring in Kassala State in 2018. Prior to this, the disease had not been reported in the country, underscoring Sudan's vulnerability to mosquito-borne illnesses, particularly in eastern states like Kassala. The state's warm climate, seasonal rainfall, and inadequate infrastructure created ideal conditions for the proliferation of *Aedes* mosquitoes—the primary vectors of the CHIKV. The outbreak affected a substantial portion of the local population and exposed critical weaknesses in the region's healthcare system and epidemic preparedness. The outbreak began in August 2018 in Garab Elgash, situated on the west bank of the Gash River. The virus quickly spread to the east bank, reaching both urban and rural areas of Kassala and Rural Kassala localities. In the early stages, many residents misidentified Chikungunya as malaria due to overlapping clinical symptoms such as high fever, fatigue, and joint pain. This confusion delayed appropriate public health responses. The first accurate clinical diagnosis was made by a professor at the University of Kassala's Faculty of Medicine and Health Sciences, based on field observations and symptom patterns. This academic identification preceded official confirmation by the Sudanese National Public Health Laboratory (STACK Laboratory) in Khartoum. The delay in official recognition fueled public anxiety, as communities lacked clear information about the disease and its transmission.

The outbreak overwhelmed an already fragile healthcare system, marked by limited diagnostic capacity, shortages of supplies, and insufficient trained personnel. Health facilities were quickly overrun, leaving many without timely care. Kassala's inadequate infrastructure—especially poor sanitation and the absence of modern sewage systems—further amplified the crisis. Both urban and rural areas rely on traditional pit latrines and lack effective waste management, creating ideal mosquito breeding grounds in stagnant water near human settlements.

Environmental and occupational factors added to the vulnerability. Stagnant water used for domestic and agricultural purposes facilitated mosquito proliferation, while agricultural livelihoods—central to the local economy—exposed farmers and laborers to infection risks. Many work outdoors for long periods, often near water sources and domestic animals, which provide additional breeding sites. Combined with poor drainage and frequent flooding, these conditions accelerated the spread of Chikungunya.

Overcrowding in both urban and rural settlements also contributed to the swift transmission of Chikungunya. High population density, particularly in informal and underdeveloped areas with limited ventilation, facilitated disease spread. A lack of public health education and limited access to preventive tools, such as mosquito nets and insect repellents, further increased vulnerability, particularly among low-income households. At the height of the epidemic, widespread misinformation and public confusion complicated containment. Uncertainty surrounding the nature and transmission of the disease fueled fear and hindered timely healthcare-seeking behavior.

The epidemiological burden was substantial. Approximately more than 400,000 confirmed cases were recorded, implying that nearly 22% of Kassala's estimated 2.2 million residents were infected over the course of a few weeks. Although the case fatality rate was relatively low at 0.06%, the outbreak resulted in over 100 deaths, primarily due to complications in individuals with pre-existing conditions such as diabetes and hypertension. These figures underscore the scale of the epidemic and the pressure it exerted on healthcare and community resilience. Beyond health, the outbreak imposed considerable economic hardship. Households incurred substantial OOPHE for diagnostics, consultations, and medications. As there is no specific antiviral treatment for Chikungunya, patients required extensive symptomatic care. With only 40.1% of the population covered by health insurance at the time (National Health Insurance Fund, 2018), most households faced significant financial strain.

The economic impact extended to lost income, particularly among informal workers lacking paid sick leave. The severe joint pain and fatigue associated with Chikungunya forced many individuals, especially those engaged in manual labor and agriculture, to miss work for prolonged periods. For daily wage earners and low-income households, the epidemic deepened existing financial problems, compounding both short- and long-term economic vulnerabilities.

The 2018 Chikungunya outbreak in Kassala highlights the deep interconnection between health and socio-economic well-being. The epidemic not only revealed weaknesses in healthcare infrastructure and disease surveillance systems but also highlighted the absence of effective social protection mechanisms. Poor sanitation, overcrowding, and high-risk occupational practices contributed to the outbreak's rapid spread and amplified its socio-economic consequences.

Conducting a detailed subnational analysis will provide valuable insights into the specific vulnerabilities of Kassala's population and healthcare system. These findings are essential for strengthening epidemic preparedness at the state level and informing national policies that address the systemic health challenges faced across Sudan. A focused study on the socio-economic impacts of Chikungunya will help identify effective interventions to reduce out-of-pocket health expenditures, mitigate financial strain on households, and guide the development of social support systems tailored to regions most at risk. Such an analysis will also inform national strategies to improve healthcare infrastructure, sanitation, and disease prevention measures, thereby reducing the likelihood of future epidemics.

6. Research Methodology

6.1 Models Specification

Building on the reviewed literature and empirical framework, this study develops three econometric models to examine the determinants and consequences of OOPHE and the incidence of CHE among households affected by the Chikungunya epidemic in Kassala State, Sudan. The models are grounded in the health demand theory articulated by Grossman (1972) and extended by Parker and Wang (1997) and Su et al. (2006), while also incorporating methodologies used in the health financing literature (e.g., Berki, 1986; O'Donnell & van Doorslaer, 2005).

6.1.1 Determinants of OOPHE

The first model assesses the factors influencing the total OOPHE incurred by households over the previous six months, which serves as a proxy for health-seeking behavior and financial burden due to illness. The specification is as follows:

$$OOPHE_i = \alpha + \beta HH_i + \gamma SE_i + \lambda DEM_i + \delta LOC_i + \mu_i \qquad (1)$$

Where OOPHE is total amount that household spends on health care services during the last six months; HH_i is a vector of health-related variables (e.g., presence of chronic diseases, recent morbidity, and Chikungunya infection); SE_i captures socioeconomic characteristics (e.g., monthly income, employment status, household assets, literacy); DEM_i includes demographic factors (e.g., household size, number of dependents, gender and age of household head); LOC_i reflects locational attributes (e.g., rural vs. urban location, proximity to healthcare facilities), and μ_i is the error term.

6.1.2 Determinants of CHE

To explore whether the Chikungunya epidemic triggered catastrophic health spending, a second model is specified. CHE is defined using the threshold approach established by Berki (1986) and further operationalized by Wagstaff and van Doorslaer (2003), where a household is said to incur catastrophic expenditure if its health spending exceeds 20% of his monthly income. The CHE ratio is calculated as:

$$\text{CHE}_i = \frac{OOPHE_i}{Income_i} \quad (2)$$

Where CHE is a binary variable taking the value of 1 if the household's OOPHE exceeds 20% of its monthly income, and 0 otherwise. CHE is a share of OOPHE in households' monthly income, OOPHE is the total health spending undertaken by household during last six months; $income$ is the household's monthly income. To identify the determinants of CHE, a probit model is used, specified as:

$$\text{CHE}_i = \alpha + \beta HH_i + \gamma SE_i + \lambda DEM_i + \delta LOC_i + \mu_i \quad (3)$$

The explanatory variables are consistent with those in Equation (1), allowing a coherent comparison of what drives both OOPHE and the risk of catastrophic financial burden.

6.1.3 Income-Based Analysis of CHE

To contextualize catastrophic health expenditure within different income strata, an additional stepwise analysis is conducted. This involves assigning a representative midpoint income value for each household income category. These midpoints serve as proxies for actual household income, enabling evaluation of financial burden by income level. The midpoint income values are defined as:

$$Y_i = \begin{cases} 250 & \text{if } Q31_i = 1 \text{ (Less than SDG 500)} \\ 1000 & \text{if } Q31_i = 2 \text{ (SDG 500– 1500)} \\ 2000 & \text{if } Q31_i = 3 \text{ (SDG 1500– 2500)} \\ 3000 & \text{if } Q31_i = 4 \text{ (SDG 2500 – 3500)} \\ 4250 & \text{if } Q31_i = 5 \text{ (SDG 3500 – 5000)} \\ 6000 & \text{if } Q31_i = 6 \text{ (Greater than SDG 5000)} \end{cases}$$

Where Y_i is the assigned income value for household i and $Q31_i$ denotes the reported income category of household i. Using this income-based classification, a household is considered to have experienced CHE if**:**

$$CHE_i = \begin{cases} 1 \; if \; OOPHE_i > 0.2 * Y_i \\ 0, \quad \text{otherwise} \end{cases}$$

This binary variable captures income-adjusted vulnerability to catastrophic health costs[6]. Next, the percentage of households experiencing CHE within each income category is calculated using:

$$\text{Percentage}_\text{i} = \frac{nCHE_i}{ni} \times 100$$

[6] This extended approach allows for a more nuanced understanding of financial vulnerability by income level. A higher proportion of households in lower income brackets incurring CHE indicates an inequitable burden of health costs. For instance, a household within the SDG 500–1500 range that spends more than SDG 200 (i.e., 20% of SDG 1000) on health care would be classified as experiencing CHE. The method enables comparative insights into the distribution of health shocks across socioeconomic tiers, enhancing the policy relevance of the findings.

Where $nCHE_i$ is the number of households experiencing CHE in income group i, ni is the total number of households in income group i.

6.1.4 Impact of OOPHE on Household Consumption

The third model evaluates the economic consequences of high OOPHE on household welfare, specifically its effect on essential consumption expenditures. This reflects growing concern in the literature that rising health costs crowd out spending on basic needs, thereby exacerbating poverty and vulnerability. The model is specified as:

$$Consumption_i = \alpha + \beta HH_i + \gamma EC_i + \lambda DEM_i + \varphi OOPHE_i + \mu_i \qquad (4)$$

Where $Consumption_i$ represents consumption expenditure undertaken by underlying household during the period under consideration (i.e. food and other expenditures incurred by the household); EC_i captures broader economic variables (including income and expenditure patterns); $OOPHE_i$ is the variable of interest, representing the direct cost burden from health-related expenses.

6.2 Data Source

A cross-sectional household survey was conducted in Kassala State, Sudan, encompassing three localities: Kassala, Rural Kassala, and Rural West Kassala. The study employed a structured questionnaire to collect primary data from 407 households, capturing comprehensive information on socioeconomic status, health conditions, Chikungunya infection history, healthcare-seeking behavior, and financial coping mechanisms. The questionnaire was meticulously designed to collect data on demographic attributes (e.g., household size, gender of household head, and education level), health status (e.g., presence of chronic illnesses and recent morbidity), exposure to the Chikungunya epidemic, treatment patterns, and key economic indicators such as OOPHE, household income, and consumption levels. Data collection was conducted after the epidemic subsided to facilitate accurate recall of illness episodes and associated costs. Enumerators received intensive training to ensure consistency in data recording and to minimize response and recall bias. Ethical clearance was obtained from the relevant institutional bodies, and informed consent was obtained from all respondents prior to participation.

6.3 Determining Sample Size

To determine the appropriate sample size, this study adopted a cluster sampling technique, guided by the methodology proposed by Krejcie and Morgan (1970) and Cohen (1992). The sample size was calculated using the following formula:

$$n = \frac{Z^2 pq}{d^2} \times deff$$

Where n represents the sample size; Z is the confidence level (Z = 95% confidence level which corresponds to 1.96 z-score); p is the proportion of the community (i.e. the ratio of chikungunya infected households to total number of households in the two localities under consideration); $q = 1 - p$; d is the error term, assumed to be 5 percent and $deff$ is the effect of the sample design which usually takes the value of 2.

This formula yielded a total sample size of 407 households. Following sample size determination, the study employed a stratified random sampling approach to ensure proportional representation from the three localities under investigation: Kassala, Rural Kassala, and Rural West Kassala. The distribution of the sample was aligned with the official population estimates for each locality, resulting in 229 households from Kassala (56.27%), 117 from Rural Kassala (28.75%), and 61 from Rural West Kassala (14.98%). This proportional allocation ensured robust urban–rural comparisons and enhanced the representativeness of the sample. Within each stratum, households were randomly selected using an updated population census as the sampling frame. This ensured adequate coverage across a spectrum of socioeconomic and geographic profiles, thereby increasing the generalizability of the findings and improving the study's ability to detect locality-specific variations in epidemic exposure, healthcare utilization, and economic coping strategies.

6.4 Analytical Approach

To rigorously examine the health and economic impacts of the Chikungunya epidemic on households in Kassala State, the study employed a combination of descriptive and econometric techniques. This mixed-method approach allowed for both an overview of general patterns and a deeper investigation of causal relationships and statistical associations.

6.4.1 Descriptive Analysis

The initial stage of analysis involved summarizing key household characteristics, demographic, socioeconomic, and health-related, using descriptive statistics. Frequencies, percentages, means, and standard deviations were computed to illustrate the distribution of variables such as household size, income levels, morbidity, insurance coverage, and Chikungunya infection status. Cross-tabulations were conducted to explore relationships between infection and key household attributes, disaggregated by locality and income quintiles. Chi-square tests were used to test the significance of associations between categorical variables (e.g., locality, gender of household head, education) and Chikungunya infection, thereby revealing structural and spatial disparities in disease burden and health expenditure patterns.

6.4.2 Ordered Logistic Regression

To assess the determinants of OOPHE and household consumption levels, the study applied ordered logistic regression models. This modeling technique is appropriate due to the ordinal nature of both dependent variables, OOPHE and household consumption, which were categorized into ascending levels of financial burden or consumption**.** Let Y_i^* denote the latent (unobserved) continuous measure of financial burden or consumption level for household i. The observed ordinal outcome Y_i is determined by threshold crossing as follows:

$$Y_i = \begin{cases} 1 \ \text{if } Y_i^* \leq \mu_1 \\ 2 \ \text{if } \mu_1 < Y_i^* \leq \mu_2 \\ \vdots \\ \text{J} \ \text{if } \mu_{J-1} < Y_i^* \end{cases}$$

The latent variable is modeled as:

$$Y_i^* = X_i\beta + \varepsilon_{i,} \ \ \varepsilon_i \sim \text{Logistic } (0,1)$$

Where X_i is the vector of independent variables (e.g., Chikungunya infection status, chronic illness, health insurance, income, education, household size, etc.); β is the vector of coefficients to be estimated; μ_1,μ_2 ,…,μ_{J-1} are the cut points (threshold parameters) to be estimated, and ε_i is the error term following a logistic distribution.
The probability that household i falls into category J is given by:

$$P(Y_i = j) = \Lambda(\mu_j \ - X_i\beta) - \Lambda(\mu_{j-1} \ - X_i\beta), \qquad j = 1, \dots, J$$

Where Λ(·) is the cumulative logistic distribution function:

$$\Lambda(\text{z}) = \frac{1}{1 + e^{-z}}$$

The OOPHE model incorporated Chikungunya infection status, presence of chronic illness, health insurance coverage, and various socioeconomic controls (e.g., education, income, household size). The household consumption model examined the extent to which increased health expenditures translated into lower consumption categories, thereby indicating potential welfare loss.

6.4.3 Probit Regression

Given that CHE was defined as a binary outcome, whether a household spent more than 20% of its income on health, the study utilized a probit regression model. This approach enabled the estimation of the probability of incurring CHE as a function of Chikungunya infection and other covariates. Key explanatory variables included health insurance status, urban versus rural residence, education level, and household income. The model facilitated a nuanced understanding of which groups were most vulnerable to financial distress due to health shocks, and whether risk mitigation mechanisms (e.g., insurance, access to electricity) effectively buffered against CHE. To formally model this relationship, let the binary outcome variable CHE_i be defined as:

$$CHE_i = \begin{cases} 1 & \text{\textit{if household i experienced CHE}} \\ 0 & \text{otherwise} \end{cases}$$

This binary outcome is assumed to arise from an underlying latent variable CHE_i^*, which represents the unobserved propensity for household i to incur catastrophic health expenditure. The latent variable is specified as:

$$CHE_i^* = X_i\beta + \varepsilon_i$$

Where X_i is a vector of explanatory variables (e.g., Chikungunya infection, health insurance, urban versus rural residence, education, income, etc.); β is a vector of coefficients to be estimated, and $\varepsilon_i \sim N(0,1)$ is a normally distributed error term. The observed binary outcome CHE_i takes the value of 1 if the latent variable CHE_i^* exceeds zero, and 0 otherwise:

$$CHE_i = \begin{cases} 1 & if\ CHE_i^* > 0, \\ 0 & \text{otherwise.} \end{cases}$$

Thus, the probability that a household experiences catastrophic health expenditure is given by:

$$P(CHE_i = 1|X_i) = \Phi(X_i\beta)$$

Where $\Phi(\cdot)$ is the cumulative distribution function of the standard normal distribution. This probit specification is used to estimate the model sketched in Equation 3**.**

7. Empirical Results

This analysis examines the impact of the Chikungunya epidemic on households in Kassala State, drawing on survey data from Kassala, Rural Kassala, and Rural West Kassala. It explores household socioeconomic characteristics, health status, and exposure to the epidemic, including chronic illnesses, morbidity patterns, and healthcare-seeking behavior. The analysis also investigates Chikungunya prevalence, geographic and socioeconomic disparities, hospitalization and mortality outcomes, as well as household coping strategies. Further attention is given to the role of the epidemic in driving OOPHE and the determinants of CHE, using ordered logistic and probit models, respectively. Finally, the relationship between epidemic-related OOPHE and household consumption is assessed through ordered logit analysis.

7.1 Socioeconomic Profile and Household Vulnerabilities

A detailed understanding of the surveyed households' socioeconomic profile is crucial for evaluating the differential financial burden of the Chikungunya epidemic in Kassala State. This analysis, supported by six figures and one summary table, highlights key demographic and economic characteristics, locality, household head's gender, household size, marital status, education, and income, that influence healthcare-seeking behavior and OOPHE.

Figure 1 illustrates the spatial distribution of the 407 respondents across Kassala (56.27%), Rural Kassala (28.75%), and Rural West Kassala (14.98%). The larger share of respondents from urban Kassala reflects its comparatively larger population size, with the sample proportionally distributed according to the demographic composition of the three localities. This distribution is analytically relevant, as urban residents, benefiting from relatively better healthcare infrastructure, transportation networks, and public health outreach, may be less exposed to prohibitive OOPHE. Conversely, residents in rural Kassala and Rural West Kassala likely encounter more limited healthcare access, resulting in delayed care-seeking, reliance on costlier informal providers, and ultimately greater financial strain during the epidemic. In rural areas, barriers such as transportation cost, fewer health facilities, and limited disease awareness further exacerbate these vulnerabilities. Moreover, the high population density in urban Kassala may have facilitated the wider transmission of the Chikungunya virus, given the increased human-vector contact and the concentration of breeding grounds in densely populated environments.

Figure 1: Distribution of Respondents by Locality

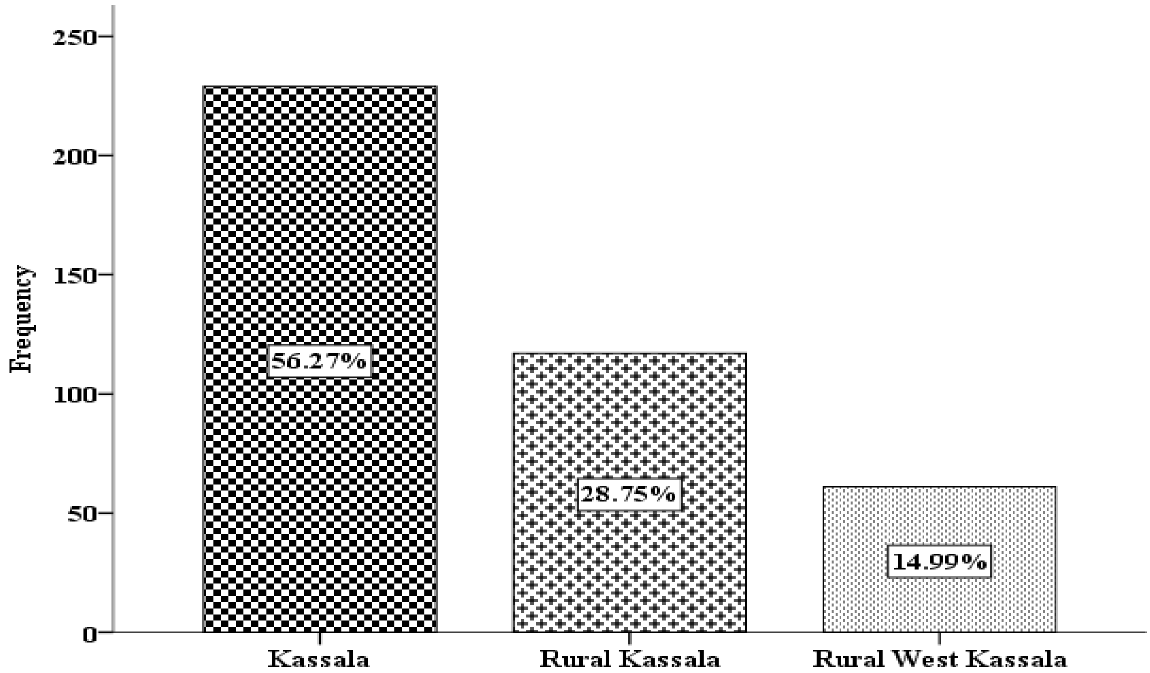


Figure 2 reveals a skewed gender distribution among household heads, with 90.42% male and only 9.58% female. This gender imbalance reflects entrenched social norms governing household leadership and financial autonomy. Male-headed households may be more financially empowered to respond promptly to health emergencies, while female-headed households, particularly in conservative or rural settings, may be constrained by lower labor force participation, restricted access to credit, and sociocultural barriers in navigating healthcare systems. Such asymmetries may delay timely treatment and exacerbate cost burdens, particularly if health crises coincide with the absence of spousal or extended family support. In addition, female-headed households may lack the financial resources to afford preventive tools such as mosquito nets or insecticide spraying, increasing their exposure to the vector and deepening their vulnerability to infection and subsequent medical expenses.

Figure 2: Gender Distribution of Household Heads

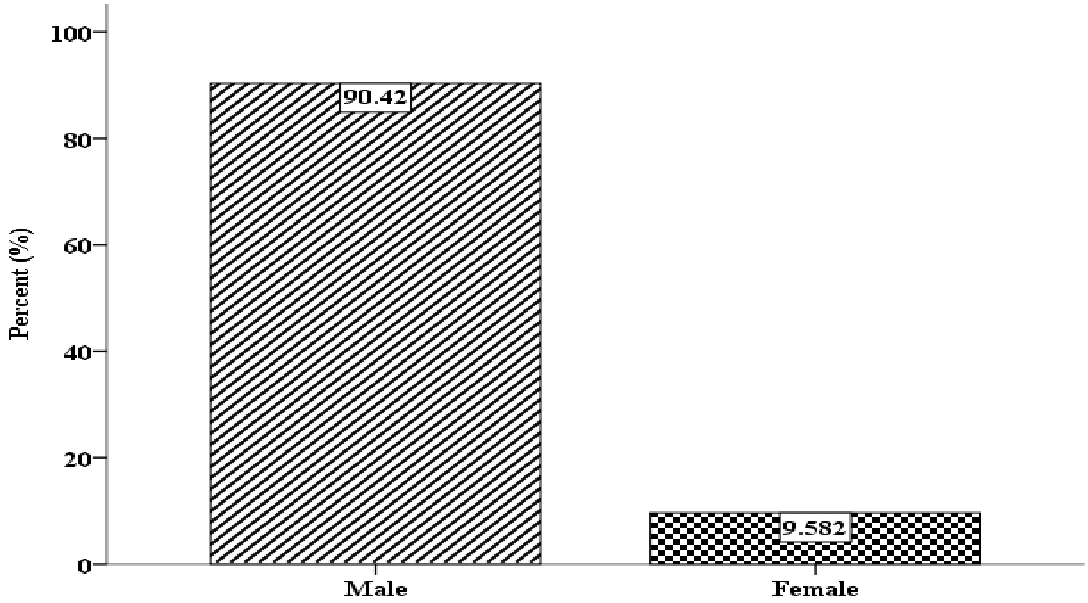


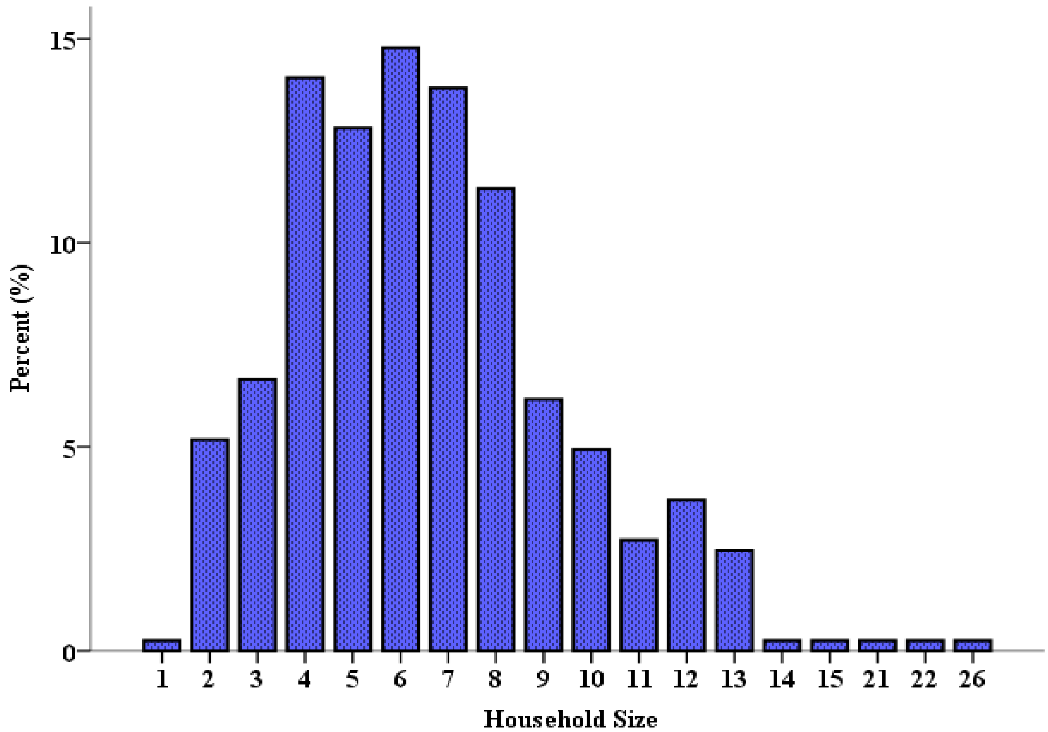
Figure 3 presents the distribution of household sizes in the sample, ranging from one to 26 members. The most common household size falls between four and six members, accounting for over 40% of respondents. While larger households may benefit from pooled income and shared caregiving responsibilities under normal conditions, they are particularly vulnerable during public health emergencies such as the Chikungunya outbreak. The likelihood that multiple household members will be simultaneously exposed to infection increases with household size, creating a multiplicative burden in terms of both disease transmission and the cost of medical care. Each additional infected member compounds the need for consultations, diagnostic tests, medications, and supportive care, quickly exhausting household financial resources.

The financial strain is not limited to direct medical expenses. Larger households are also more likely to suffer indirect costs, including lost productivity when working-age members are incapacitated and the diversion of time and labor toward caregiving duties. These disruptions can reduce household income and compromise other essential expenditures such as food, education, or agricultural inputs, thereby generating broader and more lasting welfare impacts. The burden is especially pronounced in rural areas of Kassala State, where households often operate on thin financial margins, have higher dependency ratios, and lack access to formal employment and savings mechanisms. Moreover, larger household sizes present significant challenges for risk pooling. In theory, having more members could spread out the financial burden of illness. However, in practice, the limited per capita resources in large, low-income households render such internal insurance mechanisms ineffective. The absence of public or private health insurance schemes exacerbates this vulnerability, forcing families to rely on out-of-pocket expenditures that are often financed through distress mechanisms such as borrowing, asset sales, or foregoing treatment altogether. These coping strategies may provide short-term relief but frequently lead to deeper cycles of debt and deprivation.

The geographic context further intensifies these pressures. In rural settings with limited healthcare infrastructure, physical access to medical facilities is a major barrier. Larger households may face elevated transportation costs and logistical difficulties in seeking care for multiple members, especially when health centers are distant or poorly staffed. These challenges are compounded by seasonal factors, such as flooding, which can isolate communities and further delay treatment. As a result, illness episodes tend to be more prolonged and severe, raising both human and economic costs.

Together, these factors highlight the disproportionate financial and health risks borne by large rural households during epidemic outbreaks. The case of Chikungunya in Kassala State illustrates how household size interacts with poverty, infrastructure gaps, and inadequate health financing to produce layered vulnerabilities. These findings underscore the need for targeted public health interventions and social protection measures that account for household demographics, particularly in rural areas. Expanding insurance coverage, strengthening primary healthcare delivery, and improving transport infrastructure could mitigate the economic burden of future outbreaks and build household resilience to health shocks.

Figure 3 : Household Size Distribution



The marital profile depicted in Figure 4 shows that 88.37% of respondents are married, suggesting potential for shared economic responsibility within households. Marriage often facilitates financial cooperation and pooling of resources, which could ease the economic burden of unexpected events like the Chikungunya epidemic. However, the financial coping capacity of single, divorced, or widowed individuals, especially female-headed households, may be considerably more fragile. The interplay between marital status and gender is critical; for instance, widowed or divorced female heads may lack formal income sources or social capital, which increases their vulnerability to financial distress. These women may face particular barriers in accessing resources or support networks, further exacerbating their exposure to CHE during the epidemic. In the context of Kassala State, where social norms and gender roles are more pronounced, female-headed households, especially in rural areas, may also struggle with additional cultural and logistical barriers. These might include limited mobility, restricted access to healthcare facilities, and insufficient household income, which can delay health-seeking behavior or lead to reliance on informal and costlier healthcare providers. As a result, the financial impact of Chikungunya may be disproportionately high for female-headed households, particularly those already dealing with the absence of a male income earner or familial support.

Figure 4: Distribution of Respondents' Marital Status

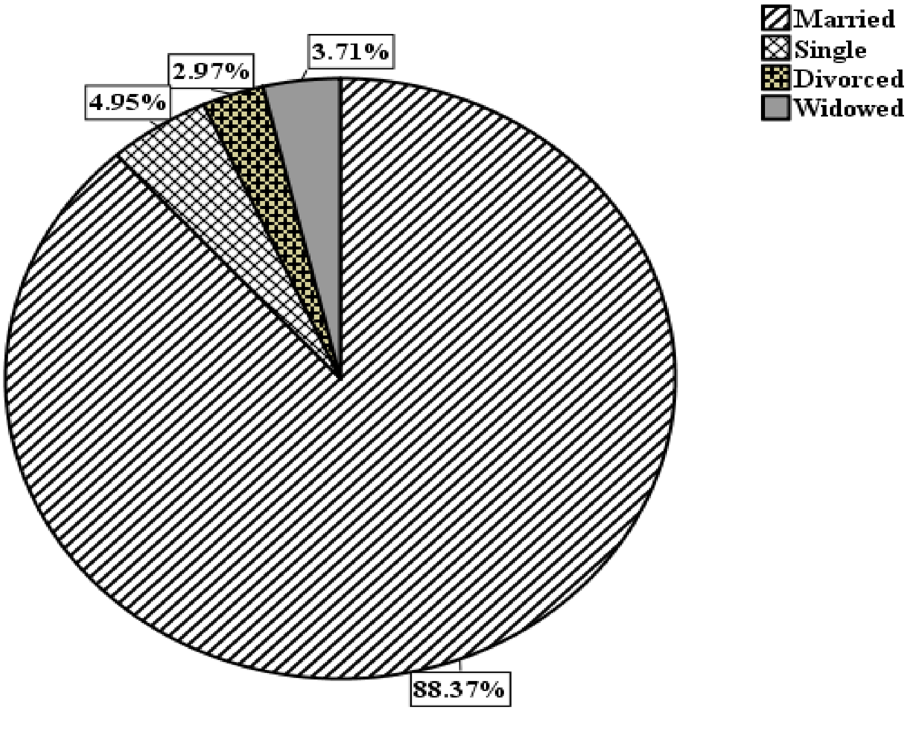
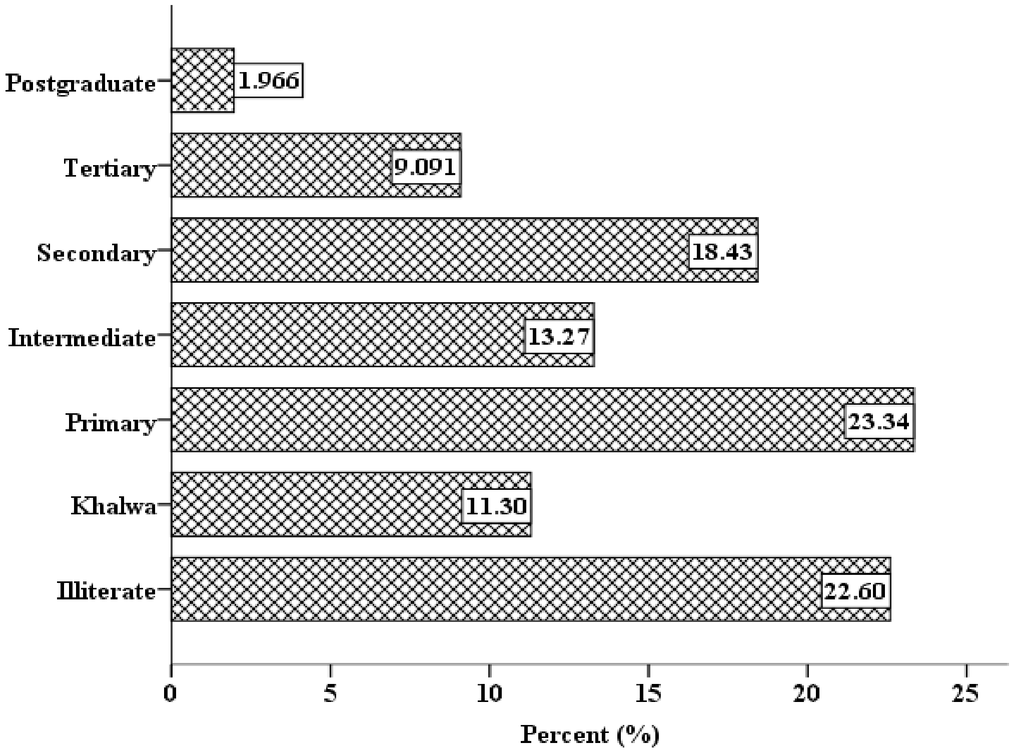


Figure 5 and Table 1 provide a detailed disaggregation of educational attainment across localities under consideration, further reinforcing the link between educational disparities and household health vulnerability during the Chikungunya epidemic. While the overall educational profile shows that only 11.1% of respondents have attained tertiary or postgraduate education, a much larger share, 22.6%, are illiterate, pointing to a substantial portion of the population lacking the foundational literacy skills essential for interpreting health information and navigating the healthcare system during health crises.

A closer look at the locality-specific data in Table 1 reveals sharp contrasts between urban and rural areas. Kassala locality, the urban center and state capital, emerges with the highest educational attainment: only 5.4% of residents are illiterate, while 17.0% have completed secondary education, and 9.1% and 2.0% have reached tertiary and postgraduate levels, respectively. This urban concentration of educational resources has profound implications for health outcomes. Urban residents are not only more likely to comprehend the symptoms and transmission dynamics of Chikungunya but also to act on public health advice, utilize preventive tools such as mosquito nets, and seek timely and appropriate care. Consequently, these households are more capable of avoiding unnecessary expenditures and minimizing the financial impact of the epidemic. In stark contrast, Rural West Kassala, a predominantly agrarian and less developed area, shows the highest illiteracy rate (9.3%) and the lowest levels of higher educational attainment, with only 0.7% attaining tertiary education and no recorded postgraduate qualifications. This educational deprivation is compounded by the area's lower access to healthcare infrastructure and public health outreach. For these residents, poor literacy limits not only the recognition of Chikungunya symptoms but also the ability to interpret treatment instructions, evaluate health risks, or challenge misinformation. As a result, households are more likely to delay care, misdiagnose symptoms, or rely on ineffective traditional remedies, behaviors that escalate health complications and financial costs.

Figure 5: Distribution of Highest Educational Level Attained by Respondents



These disparities in educational capital are not merely academic concerns; they translate directly into differences in health literacy, treatment-seeking behavior, and ultimately OOPHE. As previously discussed, households with lower education are more susceptible to misinformation, fatalism, and ineffective treatment choices. This contributes to delayed care and greater reliance on curative rather than preventive services, which are often costlier. The higher proportion of rural and less-educated households reporting substantial OOPHE, including expenditures above SDG 1000 as shown in earlier figures, can thus be partially attributed to this educational gap.

Moreover, lower educational attainment also influences coping mechanisms for health costs. Households with limited education are less likely to navigate complex health insurance schemes and therefore rely more heavily on direct cash payments, further depleting their already scarce resources. In rural areas, where health insurance uptake is minimal and awareness is limited, the intersection of low education and limited financial protection leaves these households particularly exposed during epidemics.

Table 1: Distribution of Highest Educational Attainment Across Localities

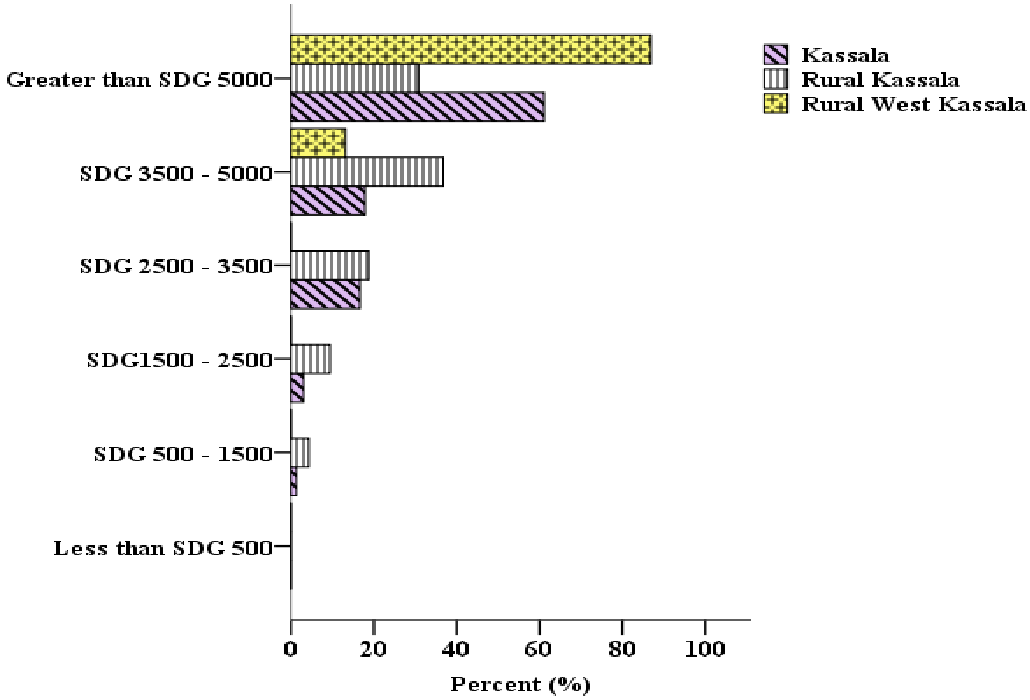
Educational Level	Kassala	Kassala (%)	Rural Kassala	Rural Kassala (%)	Rural West Kassala	Rural West Kassala (%)	Total	%	Cumulative Frequency
Illiterate	22	5.4%	32	7.9%	38	9.3%	92	22.6%	92
Khalwa	20	4.9%	22	5.4%	4	1.0%	46	11.3%	138
Primary	39	9.6%	42	10.3%	14	3.4%	95	23.3%	233
Intermediate	42	10.3%	11	2.7%	1	0.2%	54	13.3%	287
Secondary	69	17.0%	5	1.2%	1	0.2%	75	18.4%	362
Tertiary	29	7.1%	5	1.2%	3	0.7%	37	9.1%	399
Postgraduate	8	2.0%	0	0.0%	0	0.0%	8	2.0%	407

In sum, educational disparities across Kassala State, clearly visualized in Figure 5 and Table 1, serve as both a cause and a catalyst for health and financial vulnerability. While urban households are more equipped to manage health shocks due to better educational capital and health system access, rural and less-educated households face systemic disadvantages. These disadvantages are magnified during crises like the Chikungunya epidemic, where timely action, accurate information, and financial resilience are critical. Bridging these educational gaps is therefore not only a long-term development priority but also a short-term imperative for improving epidemic preparedness and reducing the inequitable burden of OOPHE in the State.

Figure 6 highlights notable income disparities across Kassala, Rural Kassala, and Rural West Kassala localities, revealing important insights into household vulnerability to health-related financial shocks. In Rural West Kassala, the income distribution is heavily skewed toward the upper end, with 86.9% of households earning above SDG 5,000 per month. This suggests that despite its rural status, the area may benefit from unique economic dynamics, such as remittances, cross-borders trading, or concentrated wealth, granting households a relatively stronger financial buffer against unexpected health expenditures. In contrast, Rural Kassala exhibits a more constrained and uneven income structure, with only 30.8% of households earning above SDG 5,000, and a significant concentration (36.8%) falling within the SDG 3,500–5,000 range. Notably, a substantial portion of households (14%) earn below SDG 2,500, indicating limited financial flexibility. This group is expected to be more vulnerable to epidemic-induced financial stress, especially in the absence of comprehensive health insurance or subsidized healthcare services.

Kassala locality stands out with the most favorable income distribution, where 61.1% of households earn above SDG 5,000 per month. The higher concentration of better-paying formal employment and urban infrastructure likely contributes to this relative financial advantage. However, a non-negligible proportion (21%) still earn less than SDG 3,500, highlighting pockets of economic vulnerability even within urban settings. These patterns reveal that Rural Kassala, rather than being the poorest, may face the most precarious situation due to its moderate income levels combined with limited access to services and weaker economic diversification. Unlike Rural West Kassala, where high incomes dominate, or Kassala, where urban advantages mitigate health shocks, Rural Kassala's middle-income majority may lack the capacity to manage OOPHE while also missing targeted assistance typically directed toward the poorest.

Figure 6: Monthly Income Stratification of Households by Locality

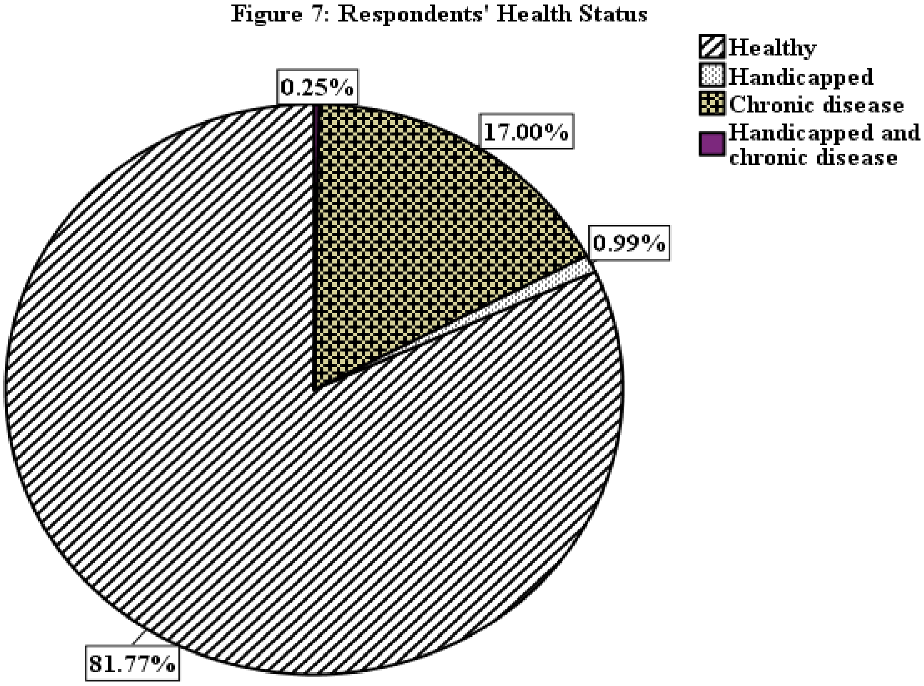


Collectively, these socioeconomic indicators present a compelling framework for understanding the differentiated impact of the Chikungunya epidemic on household expenditures. Urban households, characterized by higher income, better education, and improved healthcare access, are comparatively insulated from the economic shock of disease outbreaks. In contrast, rural households, especially those that are female-headed, large in size, or led by individuals with low education, face a confluence of vulnerabilities that magnify OOPHE and undermine economic resilience.

7.2 Health Profile and Epidemic Vulnerability

The health characteristics of respondents offer critical insights into how underlying vulnerabilities may interact with epidemic shocks to intensify OOPHE in Kassala State. As Figure 7 illustrates, a substantial majority (81.77%) of the sampled population self-identify as healthy. However, this self-reported measure warrants closer scrutiny. In a low-literacy, resource-constrained setting like Kassala, individuals' perceptions of health may not align with clinical realities. Limited awareness of non-communicable diseases or asymptomatic conditions, especially among populations with lower educational attainment, may lead to underreporting of health issues. Consequently, the seemingly high proportion of "healthy" individuals might mask latent vulnerabilities that remain undiagnosed or poorly understood.

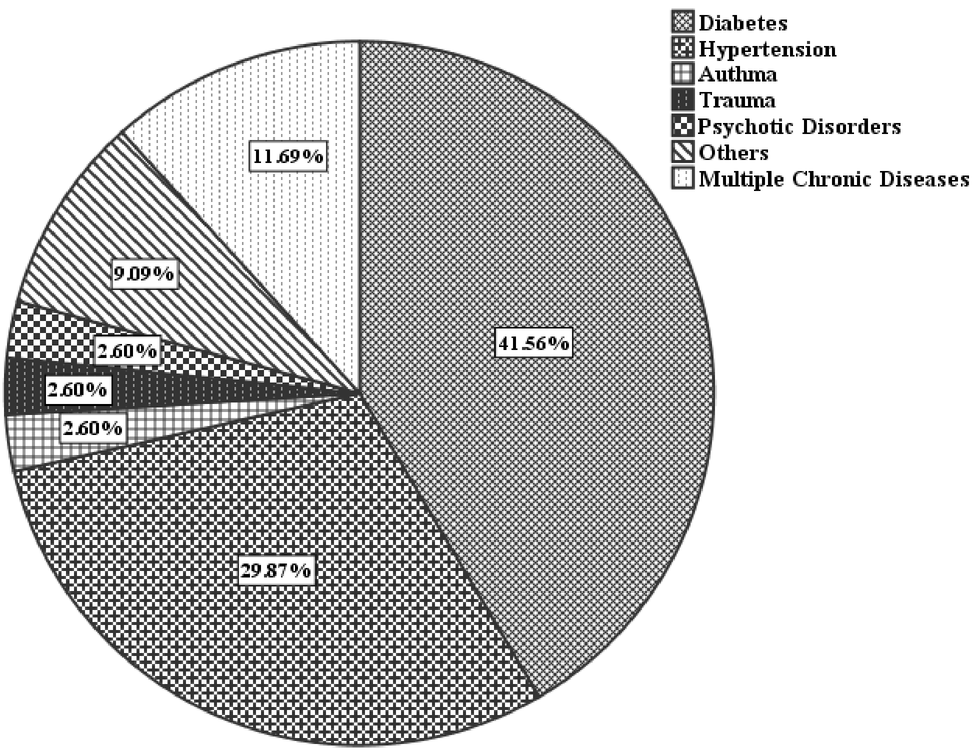
Figure 7: Respondents' Health Status



This misalignment has serious implications during epidemic outbreaks, as individuals who perceive themselves as healthy may delay seeking treatment or ignore preventive behaviors. At the same time, a non-trivial share of the population faces persistent health challenges:0.99% are handicapped, 17.00% suffer from chronic diseases, and an additional 0.25% are burdened by both conditions. While these figures suggest a predominantly healthy population on the surface, they obscure the heightened susceptibility of medically vulnerable subgroups, particularly those residing in rural areas or lacking formal education, who are more likely to experience adverse health and financial outcomes during epidemic episodes such as Chikungunya.

Figure 8 illustrates the distribution of chronic illnesses among respondents who reported at least one chronic condition (n = 77). Within this subgroup, diabetes emerges as the most prevalent condition (41.6%), followed by hypertension (29.9%), while 11.7% reported suffering from multiple chronic illnesses. Less common conditions include asthma, trauma-related disorders, and psychotic illnesses, each comprising 2.6% of cases. An additional 9.1% of respondents reported other unspecified chronic conditions. Although only 18.9% of the total surveyed sample reported a chronic condition, the health and financial implications of these illnesses are considerable. Chronic diseases tend to elevate baseline out-of-pocket health expenditures (OOPHE) even in non-crisis periods due to the sustained need for medications, clinical check-ups, and health monitoring. During public health emergencies such as the Chikungunya outbreak, the burden of chronic illness intensifies. These pre-existing conditions not only increase individuals' susceptibility to complications but also prolong the duration and severity of illness episodes. For instance, individuals with diabetes or hypertension who contract Chikungunya often require more intensive medical management, greater use of healthcare resources, and extended recovery periods. This translates into substantially higher direct medical expenses and greater indirect economic costs, including missed workdays, reduced earning capacity, and increased caregiving demands within the household. The compounding effects of chronic illness and acute infection thus deepen household vulnerability and place added strain on both families and the healthcare system during epidemics.

Figure 8: Distribution of Chronic Diseases among Respondents

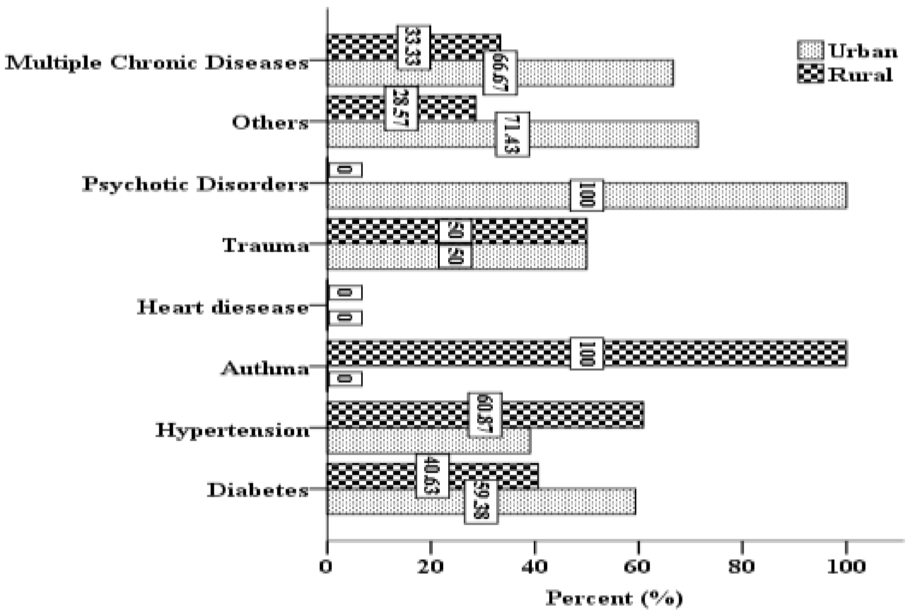


This vulnerability is further compounded in Kassala, where many households operate under thin financial margins and lack access to health insurance or adequate social safety nets. The triple burden of chronic disease, epidemic exposure, and limited institutional capacity critically undermines household resilience. In particular, rural areas outside Kassala city face heightened challenges. These include low educational attainment and limited health literacy, which constrain individuals' ability to recognize symptoms, adhere to treatment regimens, or seek timely medical care. In such contexts, reliance on traditional or informal remedies is common, often delaying effective intervention and increasing the risk of complications. Moreover, the scarcity of specialized services and chronic disease management programs in rural localities means that even when illnesses are identified, access to sustained, quality care remains limited.

In sum, chronic illnesses among the surveyed population are not isolated health events but reflect systemic vulnerabilities. The Chikungunya epidemic serves as a stress test, exposing and intensifying existing inequalities in access, health outcomes, and financial protection. Effective policy responses must therefore address not only the immediate epidemic threats but also the underlying structural conditions that perpetuate health and economic insecurity across Kassala State.

Figure 9 illustrates the spatial distribution of chronic illnesses across Kassala State, highlighting significant urban-rural disparities. Diabetes is more prevalent among urban respondents (59.4%), while hypertension (60.9%) and asthma (100%) are concentrated in rural areas. Trauma-related conditions are evenly distributed (50% each), whereas psychotic disorders are reported only in urban settings (100%), likely due to greater diagnostic capacity. Other chronic conditions and multiple morbidities are also more common in urban areas, indicating higher health service access and comorbidity detection.

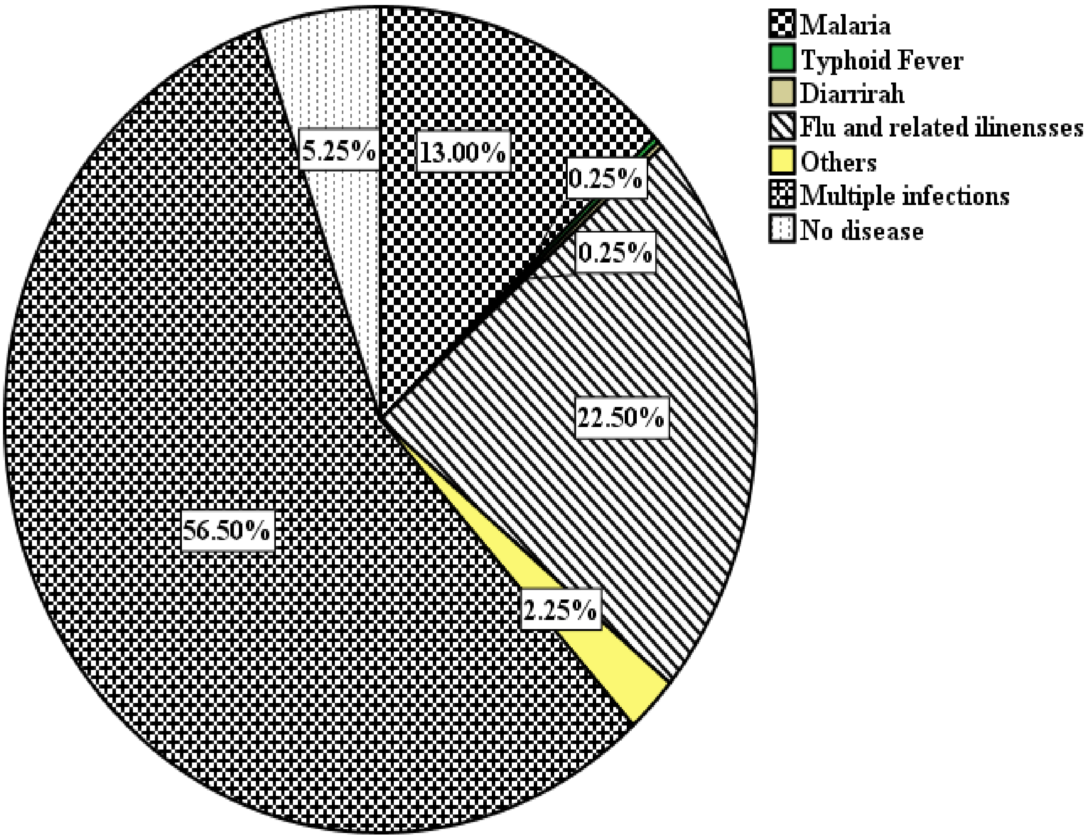
Figure 9: Distribution of Chronic Diseases By Residence Area



These patterns underscore structural inequities in chronic disease burden and management. Rural populations face limited access to specialized care, low health literacy, and weak disease surveillance, which delay diagnosis and treatment. As a result, chronic conditions often remain unmanaged, compounding during health shocks. The financial implications are profound. Pre-existing chronic conditions elevate baseline health expenditures, and during epidemics such as Chikungunya, they intensify illness severity and prolong recovery, increasing both direct and indirect costs. This dynamic is especially critical in resource-constrained rural households, where even modest medical expenses can induce financial distress. Moreover, low educational attainment and poor health literacy in rural localities compromise disease management, leading to poor adherence and delayed care-seeking. The intersection of chronic illness, spatial disadvantage, and epidemic exposure creates a triple burden, medical, economic, and institutional, that disproportionately affects rural households and exposes systemic health inequities.

Figure 10 presents household morbidity over the preceding six months, revealing a complex pattern of disease incidence. Notably, 56.5% of households reported multiple concurrent infections, while only 5.3% experienced no illness, indicating a high underlying disease burden. Among specific conditions, flu and respiratory inflammations were the most common (22.5%), followed by malaria (13.0%), with typhoid and diarrhea each accounting for just 0.3% of cases. The category "other diseases" (2.3%) likely includes cases of Chikungunya, given its symptom overlap and absence of explicit classification in the dataset.

Figure 10: Common Diseases Experienced by Respondents' and his/her Family Member(s) in the Last Six Months

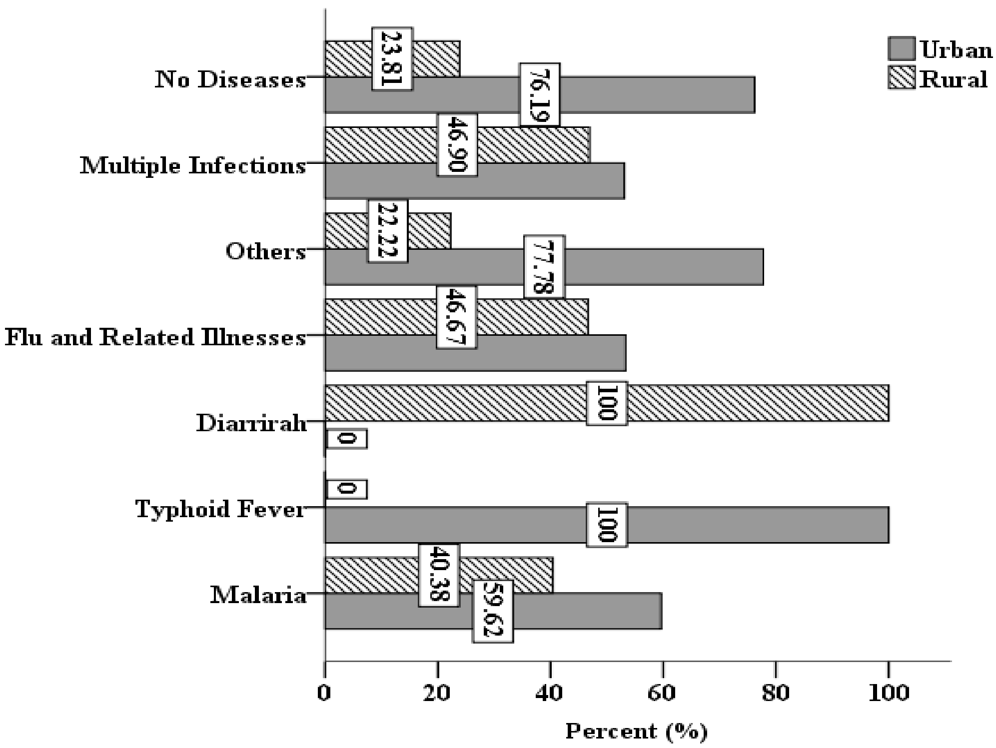


The dominance of the "multiple infections" category suggests not only diagnostic ambiguity but also the potential co-circulation of Chikungunya with other febrile illnesses, which may have compounded both clinical severity and treatment costs. These mixed presentations often necessitate repeated visits to health providers, overlapping treatments, and uncertain diagnoses, particularly in contexts with limited laboratory confirmation capacity. Moreover, epidemics such as Chikungunya impose disproportionate financial strain on households, not only through direct out-of-pocket expenditures, but also via productivity losses, care delays, and dependence on informal care. This dynamic is especially pronounced in Kassala State, where structural healthcare limitations and low insurance coverage magnify the economic impact of morbidity, even when not explicitly attributed to a named epidemic.

In sum, the data illustrate how high morbidity rates, overlapping infections, and health system gaps converge to exacerbate household vulnerability, with Chikungunya acting as both a direct and indirect driver of increased disease burden and financial hardship.

Figure 11 illustrates the spatial stratification of morbidity, revealing a clear urban, rural divide in disease burden across Kassala State. Among reported cases, urban households accounted for the majority of typhoid (100%) and flu (53.3%), while malaria and diarrheal illnesses were more prevalent in rural areas (40.4% and 100%, respectively). Additionally, urban respondents made up 76.2% of those reporting no recent illness, compared to just 23.8% in rural areas. These disparities are shaped by more than just environmental exposure. They reflect entrenched structural inequalities in public health infrastructure, access to clean water, waste management, and housing quality.

Figure 11: Common Diseases Experienced by Respondents' and his/her Family Member (s) in the Last Six Months by Residence Area



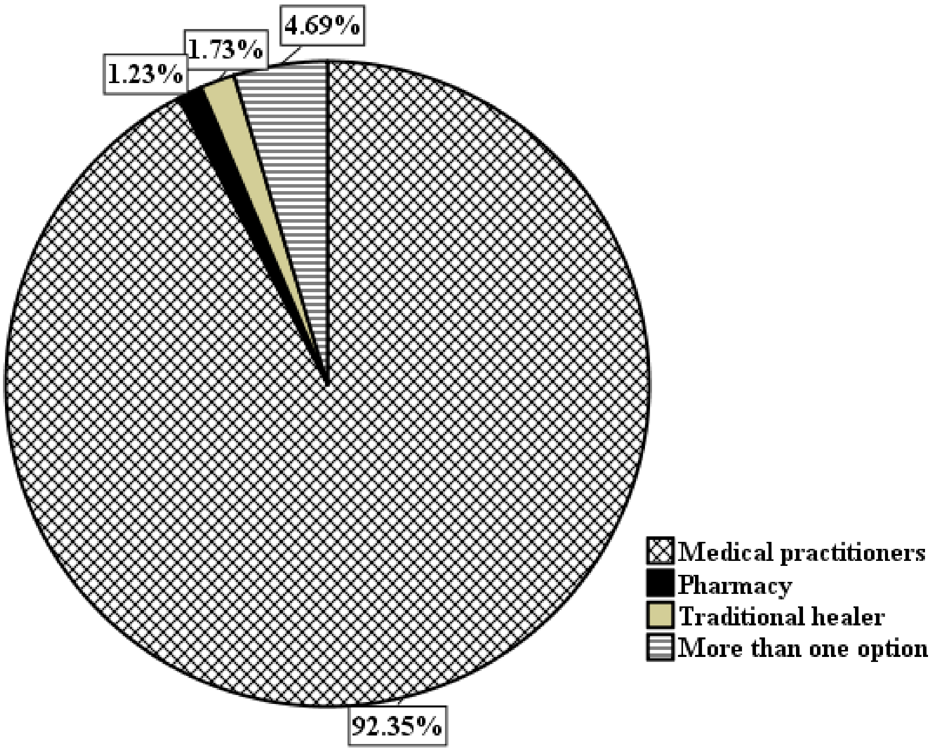
Rural communities, particularly in peripheral Kassala, remain under-resourced, with limited healthcare access, long distances to facilities, and chronic shortages of trained personnel and essential drugs. These deficits delay diagnosis and treatment, allowing otherwise manageable diseases to escalate. Compounding the epidemiological divide is a parallel gap in educational attainment and health literacy, which constrains rural households' ability to recognize symptoms, seek timely care, and navigate treatment regimens. The inability to distinguish between febrile conditions such as malaria and typhoid, particularly in low-literacy contexts, leads to delayed referrals, reliance on informal remedies, and costly care-seeking cycles. Moreover, low literacy impedes engagement with public health messaging during epidemics, weakening compliance with preventive practices such as vector control, hygiene, and community surveillance. As a result, rural households bear a dual burden: they are more likely to fall ill and less equipped to mitigate the health and financial consequences.

In sum, the urban, rural divergence in morbidity patterns represents not just a difference in disease incidence but a manifestation of systemic inequities. Epidemics such as Chikungunya exacerbate these vulnerabilities, turning existing gaps in infrastructure, education, and access into compounding risks for rural communities across Kassala State.

Figure 12 illustrates treatment-seeking behavior among respondents, with an overwhelming 92.35% initially consulting medical practitioners. This dominant preference for formal healthcare indicates a general trust in biomedical systems and suggests a baseline level of health awareness. Urban residents constituted 52.9% of those seeking care from medical practitioners, compared to 47.1% from rural areas—highlighting a relatively balanced reliance across spatial divides. A smaller proportion sought help from pharmacies (4.69%), traditional healers (1.73%), or multiple sources (1.23%), with all such cases reported in urban areas, reflecting their greater access to diversified care options. However, during the Chikungunya outbreak, this dependence on formal systems became a double-edged sword. Kassala's under-resourced health infrastructure was ill-equipped to absorb the surge in demand, resulting in diagnostic delays, service congestion, and provider fatigue. In such strained conditions, even households inclined toward institutional care experienced barriers to timely and effective treatment.

Moreover, educational attainment significantly mediates how households respond to illness and navigate care systems during health crises. In rural Kassala, where education levels are lower and public health information dissemination is weaker, treatment decisions are often shaped by misinformation, fatalism, or adherence to cultural norms. This dynamic proved particularly consequential during the Chikungunya epidemic. Households unfamiliar with the disease's symptoms or unaware of its viral nature frequently delayed seeking formal care, initially resorting to home remedies or traditional healers. Formal medical attention was often sought only after symptoms worsened, escalating both health risks and the eventual cost and complexity of treatment. While the low usage of informal providers in survey data may suggest limited reliance, it likely underrepresents their role during the epidemic peak, especially in contexts marked by low literacy and weak health infrastructure. These actors, often lacking diagnostic tools and standardized treatment protocols, contributed to fragmented care pathways and higher cumulative OOPHE.

Figure 12:Distribution of the First Place Respondents Usually Visit for Treatment

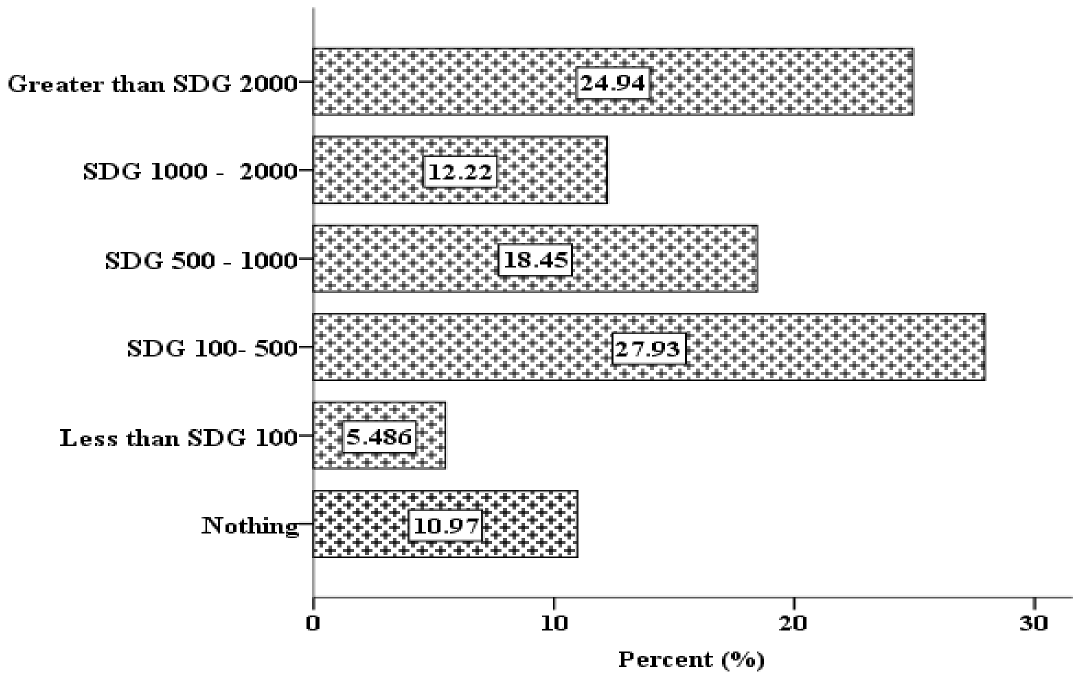


In sum, while the data show a commendable orientation toward formal care, the Chikungunya epidemic revealed the limits of system capacity, the role of social and informational asymmetries, and the hidden costs of delayed or ineffective treatment, especially among rural, less-educated, and economically vulnerable households.

Figure 13 illustrates the distribution of OOPHE, underscoring the significant financial burden borne by households during illness episodes, particularly acute during the Chikungunya epidemic. A substantial share of households reported spending between SDG 500–1000 (18.5%) and SDG 1000–2000 (12.2%), while nearly one-quarter (24.9%) incurred costs exceeding SDG 2000. These figures highlight the prevalence of moderate to high health-related expenses, suggesting that a significant portion of households are vulnerable to financial stress when faced with health shocks.

At the other end of the spectrum, 11% reported no health expenditure, a statistic that warrants cautious interpretation. This may reflect treatment avoidance due to financial constraints, especially among rural and less-educated households, rather than an absence of need. As discussed previously, barriers such as high user fees, distance to facilities, and lack of health literacy may discourage timely healthcare utilization, particularly during epidemics when demand surges and services are strained. These financial pressures are compounded in households managing chronic conditions, including hypertension, diabetes, asthma, and psychotic disorders, where baseline medical expenses are already high. The Chikungunya epidemic layered additional costs such as consultation fees, diagnostic tests, medications for fever and joint pain, and repeat visits, further straining already fragile household budgets. Rural populations, where access to subsidized care is limited and informal providers are more common, face heightened risk of falling into catastrophic health expenditure. This is exacerbated by the near absence of effective public health insurance schemes. As noted by Mustafa and Ebaidalla (2019), low insurance coverage, especially in regions like Kassala, forces households to rely heavily on personal savings, borrowing, or asset liquidation to finance care. The epidemic thus revealed not only epidemiological gaps but also systemic weaknesses in health financing and social protection, disproportionately affecting those with chronic conditions and lower socioeconomic status.

Figure 13: Distribution of Out-of-Pocket Health Expenditures Undertaken by Respondents



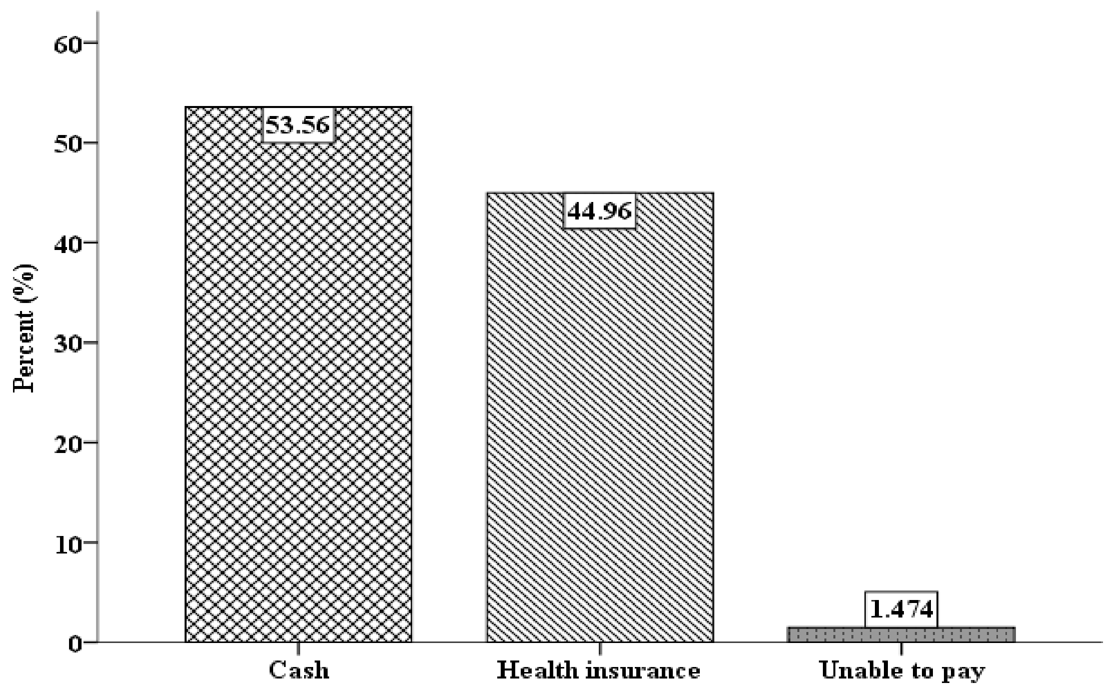
Taken together, the treatment-seeking patterns in Figure 12 and the OOPHE distribution in Figure 13 reveal a reinforcing cycle: delayed or fragmented care, often due to financial or informational barriers, leads to worsened health outcomes and escalated treatment costs, which in turn intensify economic vulnerability, particularly in rural, low-literacy households facing simultaneous burdens from chronic disease and epidemic shocks.

Figure 14 presents the methods that households employed to finance medical expenses during the Chikungunya epidemic, revealing critical insights into the limitations of current health financing systems in Kassala State. Over half of the respondents (53.6%) reported relying on direct cash payments, underscoring a prevailing dependence on immediate OOPHE spending to access care. This pattern, when compared to the earlier findings on the magnitude of OOPHE

(Figure 13), paints a stark picture of financial precarity, particularly among rural and chronically ill households who face compounded health and economic shocks. The cash-based payment model places a disproportionate burden on households already struggling with limited income, lack of savings, or seasonal livelihoods, conditions common in rural Kassala.

The need to mobilize cash quickly during acute health crises often results in distress financing strategies, such as borrowing, selling assets, or forgoing other essential expenditures, which may deepen cycles of poverty and limit long-term resilience. As earlier figures demonstrated, many households already incur high health costs, and in the absence of accessible and effective social protection mechanisms, cash payments become both a necessity and a liability. While 45.0% of respondents reported using health insurance, this figure masks significant geographic and socioeconomic disparities. Health insurance coverage is typically more accessible to urban, formally employed, and better-educated individuals, and far less so for rural populations, informal sector workers, or those with limited health literacy. As discussed in previous sections, low education levels in rural Kassala correlate with poorer understanding of health entitlements and limited engagement with insurance mechanisms. In many cases, insurance schemes may be underutilized due to administrative complexity, poor outreach, or a mismatch between covered services and actual care needs, particularly during fast-moving epidemics like Chikungunya.

Figure 14: Respondents' Methods to Pay Medication Bill



Most troubling is the 1.5% of households who reported being unable to pay for treatment. While numerically small, this group represents a critical failure of the health system, as these households likely forgo essential care altogether or turn to informal and potentially unsafe alternatives. This aligns with earlier observations regarding delays in treatment-seeking and increased reliance on traditional healers or self-medication in low-resource settings. Left unaddressed, such exclusion not only worsens health outcomes but also reinforces the inequality in access to care based on geography, income, and education. These findings echo the concerns raised by Ali and Abdalla (2021) and Mustafa and Ebaidalla (2019), who document how limited health insurance penetration and weak public safety nets in Sudan, especially in peripheral states like Kassala, perpetuate systemic vulnerability during health shocks. In the face of an epidemic, where healthcare needs surge rapidly and unpredictably, the absence of universal and equitable health financing mechanisms magnifies household-level risks, transforming health crises into financial catastrophes.

In sum, Figure 14 reinforces the structural inequities highlighted in Figures 10 to 13: from unequal disease exposure and treatment-seeking behavior to escalating OOPHE and fragile coping mechanisms. Together, these dynamics reveal how the Chikungunya epidemic exploited and deepened existing health, financial, and informational asymmetries, underscoring the urgent need for integrated reforms in public health financing, rural healthcare delivery, and community-level health education in Kassala State.

7.3 Chikungunya Epidemic: Prevalence and Household Resilience

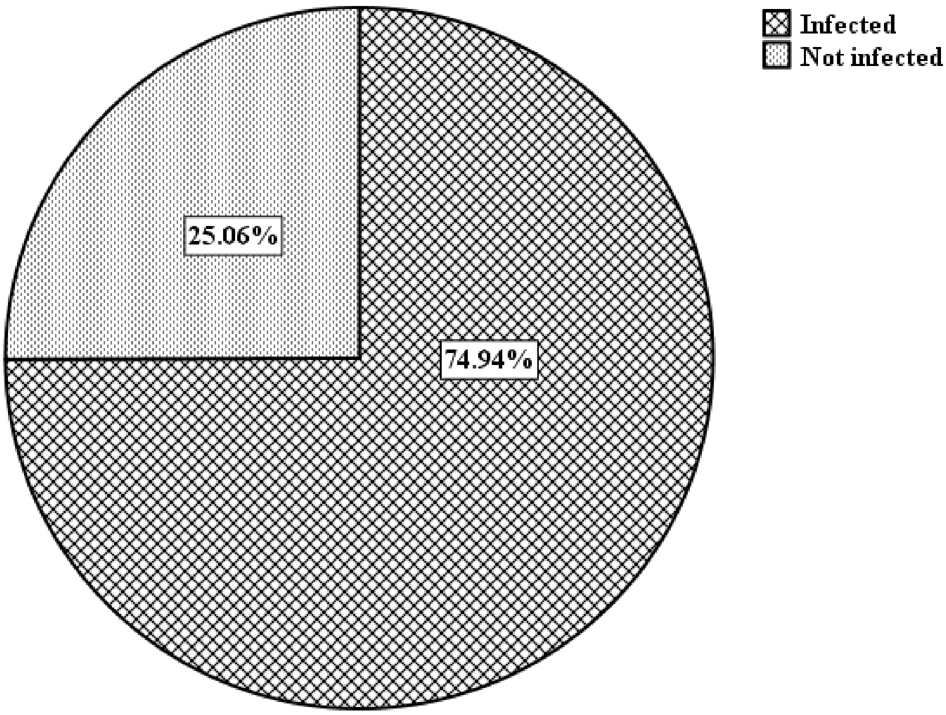
This section provides a rigorous and concise analysis of the Chikungunya epidemic's prevalence, epidemiological dynamics, and socioeconomic impacts on households in Kassala State. It explores the epidemic's scope, severity, spatial patterns, healthcare utilization, mortality trends, and the interplay of environmental and socioeconomic factors influencing infection rates, while assessing household economic resilience strategies to address financial burdens.

7.3.1 Prevalence of Chikungunya Infections

Figure 15 illustrates the prevalence of Chikungunya infection in Kassala State, revealing that 74.94% of respondents were infected, while 25.06% remained uninfected. This high infection rate reflects the widespread nature of the epidemic, likely influenced by a combination of environmental, social, and biological factors. The state's tropical climate fosters the proliferation of mosquitoes, particularly the Aedes aegypti and Aedes albopictus vectors, which are responsible for transmitting Chikungunya (Siam et al., 2022). Additionally, the limited immunity within the population, potentially due to prior lack of exposure to the virus, may further explain the rapid spread of the infection.

The socio-economic and environmental context in the State offers probable explanations for the widespread transmission of the epidemic. Water storage practices, particularly in rural and agricultural areas, represent a significant risk factor. Households engaged in horticulture and animal husbandry often rely on storing water in open barrels and containers, which serve as ideal breeding grounds for mosquitoes. These practices, combined with stagnant water and favorable environmental conditions, contribute to high mosquito density and increased transmission risk. In addition, overcrowded living conditions, common in both urban and rural settings due to limited housing and infrastructure, further heighten household exposure to mosquito bites. Poor sanitation and inadequate waste management exacerbate the problem by creating additional breeding sites and intensifying the risk of infection.

Figure 15: Prevalence of Chikungunya Infection among Respondents



The infection rate, as depicted in Figure 15, sets the stage for understanding the broader economic impact on households. Limited access to preventive measures, such as mosquito nets or mosquito sprays, and the challenging living conditions in the state, particularly in rural areas, compound the public health threat. As a result, households experience significant health-related and economic burdens, with decreased productivity in agricultural and livestock sectors and increased healthcare costs.

7.3.2 Geographical Distribution of Infections

Building upon the previously reported overall infection rate of 74.94% (Figure 15), Table 2 presents a disaggregated view of Chikungunya prevalence by locality among 407 respondents in Kassala State. This cross-tabulation offers a deeper understanding of how infection patterns vary geographically, highlighting localized vulnerabilities that contributed to the epidemic's widespread reach. The table reports both observed and expected frequencies for each locality, Kassala, Rural Kassala, and Rural West Kassala, alongside column percentages indicating the proportion of infected and uninfected individuals in each locality.

Table 2: Distribution of Chikungunya Infection Status by Locality

Locality	Infected (n)	Not Infected (n)	Expected Infected (n)	Expected Not Infected (n)	% of Infected	% of Not Infected
Kassala	180	49	171.6	57.4	59.02%	48.04%
Rural Kassala	92	25	87.7	29.3	30.16%	24.51%
Rural West Kassala	33	28	45.7	15.3	10.82%	27.45%
Total	**305**	**102**			**100.00%**	**100.00%**

Note: Pearson Chi-square = 16.59, df *= 2,* p *< .001.*

The data reveal substantial variation across localities. Kassala locality accounted for the highest proportion of infected individuals (59.02%), exceeding its expected count of 171.6, which aligns with the higher infection concentration in urban areas suggested earlier. Conversely, Rural West Kassala reported the lowest infection rate (10.82%), far below its expected value (45.7), while simultaneously registering the highest proportion of uninfected individuals (27.45%), an outcome that exceeded expectations (15.3) and suggests a relative protective factor. Rural Kassala's figures approximated the expected counts, indicating a more neutral role in driving the overall infection distribution. A Pearson Chi-square test confirmed a statistically significant relationship between locality and infection status, $\chi^2(2, N = 407) = 16.59$, $p < .001$, reinforcing the notion that geographic location was a key determinant of exposure to risk during the outbreak.

Further insights are drawn from Table 3, which collapses the localities into a binary urban–rural classification. Urban residents (mainly from Kassala locality) accounted for 59.02% of infections, while rural residents constituted 40.98%. Although this pattern is consistent with the locality-specific data, the Pearson Chi-square statistic was marginally significant: $\chi^2(1, N = 407) = 3.74$, $p = 0.053$. This finding suggests a potential association between residence area and infection status, albeit at the threshold of conventional significance levels. It indicates that while a simple urban–rural divide may partially explain infection disparities, more nuanced locality-level differences likely play a more substantial role in shaping exposure and vulnerability patterns.

Table 3: Association Between Residence area and Chikungunya Infection Status

Residence	Infected (Yes)	Not Infected (No)	Total	Expected Frequency (Infected)	Expected Frequency (Not Infected)	Percentage (Infected)	Percentage (Not Infected)
Urban	180	49	229	171.6	57.4	59.02%	48.04%
Rural	125	53	178	133.4	44.6	40.98%	51.96%
Total	305	102	407	305.0	102.0	100%	100%

Note: Pearson Chi-Square = 3.7430, p = 0.053.

Together, these results substantiate earlier findings on the epidemic's widespread prevalence while revealing that spatial factors, especially at the locality level, played a critical role in shaping patterns of exposure and vulnerability. The marginally significant association between residence type and infection status underscores the need to consider both macro and micro-spatial dynamics in understanding the epidemic's impact across Kassala State.

7.3.4 Socioeconomic and Environmental Correlates of Chikungunya Infection

- ***Educational Attainment***

Table 4 displays the distribution of chikungunya infection status across different levels of educational attainment among 406 respondents. The observed and expected frequencies are shown, along with the percentage distribution within each infection category. The results indicate that the proportions of infected and non-infected individuals are relatively similar across educational groups. A chi-square test of independence showed no statistically significant association between educational attainment and infection status, $\chi^2(6, N = 406) = 2.11$, $p = 0.909$, suggesting that education level was not a significant factor in determining the likelihood of infection in this sample.

Table 4: Association between Educational Attainment and Chikungunya Infection

Educational Level	Infected (n)	Not Infected (n)	Expected Infected (n)	Expected Not Infected (n)	% Infected	% Not Infected
Illiterate	66	25	68.1	22.9	21.71%	24.51%
Khalwa	35	13	35.9	12.1	11.51%	12.75%
Primary	70	23	69.6	23.4	23.03%	22.55%
Intermediate	43	11	40.4	13.6	14.14%	10.78%
Secondary	54	21	56.2	18.8	17.76%	20.59%
Tertiary	30	7	27.7	9.3	9.87%	6.86%
Postgraduate	6	2	6.0	2.0	1.97%	1.96%
Total	**304**	**102**			**100.00%**	**100.00%**

Note: Pearson Chi-square = 2.11, df = *6,* p = *.909.*

- ***Indoor Spraying Practices Prior to the Outbreak***

Table 5 presents the association between household indoor spraying before the Chikungunya outbreak and subsequent infection status. Among the 405 respondents, 40.46% of infected individuals reported spraying their homes beforehand, compared to 30.69% of those who remained uninfected. Conversely, 59.54% of infected individuals had not sprayed, compared to 69.31% of the non-infected group. While these figures suggest a difference in infection rates based on pre-outbreak spraying behavior, the Pearson Chi-square test result, $\chi^2(1, N = 405) = 3.07$, $p = 0.080$, indicates a marginally significant association, falling just outside the conventional 5% threshold. This marginal significance points to a potential protective effect of indoor spraying, though the evidence is not robust enough to draw definitive conclusions. Nonetheless, the observed pattern implies that households practicing spraying may have experienced slightly lower infection rates, warranting further investigation in future studies with larger samples or more precise exposure measures.

Table 5: Association Between Indoor Spraying and Chikungunya Infection Status

Sprayed Before Outbreak	Infected (n)	Not Infected (n)	Expected Infected (n)	Expected Not Infected (n)	% Infected	% Not Infected
Yes	123	31	115.6	38.4	40.46%	30.69%
No	181	70	188.4	62.6	59.54%	69.31%
Total	**304**	**101**	304.0	101.0	**100.00%**	**100.00%**

Note: Pearson Chi-square = 3.07, df = 1, p = .080.

It is worth noting that indoor spraying is not a widespread cultural or behavioral practice in Kassala State. Several factors may contribute to this limited uptake, including insufficient public health outreach, a lack of awareness regarding the effectiveness of insecticide use, and financial constraints that restrict household-level adoption of preventive measures. These structural and behavioral barriers suggest that promoting indoor spraying as a vector control strategy may require targeted health education campaigns and subsidized access to spraying materials to mitigate both informational and economic obstacles.

- ***Mosquito Net Usage***

Table 6 explores the relationship between mosquito net usage and infection status. The majority of both infected (84.26%) and non-infected (79.21%) individuals reported using mosquito nets. The slight variation between groups was not statistically significant ($\chi^2(1, N = 406) = 1.37$, $p = .241$), suggesting that while mosquito net usage was widespread, it did not significantly differentiate infection outcomes during the chikungunya outbreak. These findings highlight a limitation in relying solely on net usage as a preventive indicator, as proper timing, condition, and effectiveness of net usage were not assessed.

Table 6: Association Between Mosquito Net Usage and Chikungunya Infection Status

Mosquito Net Ownership	Infected (n)	Not Infected (n)	Expected Infected (n)	Expected Not Infected (n)	% Infected	% Not Infected
Yes	257	80	253.2	83.8	84.26%	79.21%
No	48	21	51.8	17.2	15.74%	20.79%
Total	**305**	**101**	305.0	101.0	**100.00%**	**100.00%**

Note: Pearson Chi-square = 1.37, df = 1, p = .241.

Moreover, mosquito net usage may not offer meaningful protection against chikungunya transmission because *Aedes* mosquitoes, the primary vector, are known to bite during the day, whereas mosquito nets are typically used at night. This mismatch between the vector's biting behavior and the timing of net use further limits the effectiveness of this preventive measure in this context.

- *Living Conditions*

As shown in Table 7, a chi-square test revealed a statistically significant association between the number of rooms in a household and the likelihood of chikungunya infection ($\chi^2(7) = 17.80$, $p = .013$). Households with only one or two rooms accounted for a disproportionately high share of infections (9.5% and 35.7%, respectively), whereas households with more rooms had relatively lower infection rates. In particular, individuals living in single-room households had a much higher proportion of infection compared to their representation among the uninfected group (20.6%).

These findings suggest that crowding or limited living space may increase exposure to the virus, possibly due to shared airspace or vector density. Overcrowding can facilitate closer and prolonged contact with infected individuals or infected mosquitoes, thereby increasing the risk of transmission. Limited space may also reduce opportunities for spatial separation and hinder preventive measures such as the use of mosquito nets or indoor repellents.

Table 7: Association Between Number of Rooms and Chikungunya Infection Status

Number of Rooms	Infected (n)	Not Infected (n)	Expected Infected (n)	Expected Not Infected (n)	% Infected	% Not Infected
1	29	21	37.5	12.5	9.51%	20.59%
2	109	31	104.9	35.1	35.74%	30.39%
3	94	29	92.2	30.8	30.82%	28.43%
4	43	9	39.0	13.0	14.10%	8.82%
5	10	9	14.2	4.8	3.28%	8.82%
6	13	3	12.0	4.0	4.26%	2.94%
7	4	0	3.0	1.0	1.31%	0.00%
8	3	0	2.2	0.8	0.98%	0.00%
Total	**305**	**102**	**305.0**	**102.0**	**100%**	**100%**

Note: *Pearson Chi-square = 17.80,* df *= 7,* p *= .013.*

- *Household Size*

Table 8 examines the relationship between household size and Chikungunya infection in Kassala State, using a four-category classification: small (1–3 members), medium (4–6), large (7–9), and very large (10+). Infection prevalence was consistently high across all groups but was particularly elevated among individuals in very large households, where 85.48% reported being infected, compared to 77.08% in small households. The Pearson Chi-square test yields a marginally significant result (χ^2(3, N = 407) = 6.90, p = 0.075), suggesting a possible association between household size and infection status. In the context of Kassala State, characterized by high household density, limited housing space, and suboptimal vector control infrastructure, larger households may inadvertently facilitate more mosquito bites per night. With more individuals residing in confined spaces, the probability of contact with infected *Aedes* mosquito increases, thereby amplifying the risk of intra-household transmission. This pattern highlights the importance of considering household composition in vector-borne disease control strategies, particularly in resource-limited settings where overcrowding and inadequate indoor protection measures are common.

Table 8: Association Between Household Size[7] and Chikungunya Infection Status

Household Size	Infected (n)	Not Infected (n)	Expected Infected	Expected Not Infected	% Infected	% Not Infected
1–3 members	37	11	36.0	12.0	77.08%	22.92%
4–6 members	117	52	126.6	42.4	69.23%	30.77%
7–9 members	98	30	95.9	32.1	76.56%	23.44%
10+ members	53	9	46.5	15.5	85.48%	14.52%
Total	**305**	**102**	305.0	102.0	74.94%	25.06%

Note: Pearson Chi-square = 6.9001, df = 3, p = 0.075

- ***Sources of Power and Infection Status***

A chi-square test showed a statistically significant association between the source of power in the household and the likelihood of Chikungunya infection ($\chi^2(3) = 9.98$, $p = .019$) (Table 9). Public electricity was the most common source of power, used by 81.91% of infected and 67.65% of non-infected individuals. While public electricity accounted for the majority in both groups, the observed and expected values suggest that individuals with access to this power source were slightly less likely to be infected than expected under the assumption of no association. Households relying on lamb lighting represented a smaller portion of the sample, but exhibited a distinct pattern: only 16.12% of infected individuals used lamb power, compared to 28.43% of non-infected individuals. The observed counts indicate fewer infections and more non-infections than expected in this category, suggesting a potentially protective association or a reflection of differing environmental or housing characteristics.

Table 9: Association Between Sources of Power and Chikungunya Infection Status

Sources for Light in the Home	Infected (n)	Not Infected (n)	Expected Infected (n)	Expected Not Infected (n)	% Infected	% Not Infected
Public Electricity	249	69	238.1	79.9	81.91%	67.65%
Generator	3	1	3.0	1.0	0.99%	0.98%
Lamb	49	29	58.4	19.6	16.12%	28.43%
Others	3	3	4.5	1.5	0.99%	2.94%
Total	**304**	**102**	**304.0**	**102.0**	**100%**	**100%**

Note: Pearson Chi-square = 9.98, df = 3, p = .019.

These findings suggest that the type of power source may reflect broader socioeconomic or environmental factors influencing chikungunya exposure. Households using lamb lighting,

[7] In the original questionnaire, household size was recorded as a continuous variable. For analytical clarity, we categorized it into four groups based on distributional and contextual considerations.

which is less common and associated with higher infection rates, may face conditions that increase vector exposure, such as poorer housing quality or limited access to electricity-dependent appliances like fans or air conditioning. These appliances can reduce indoor vector density by improving ventilation or creating less favourable conditions for mosquitoes. Conversely, the widespread use of public electricity, while associated with lower infection rates relative to lamb lighting, does not eliminate risk, as it was still the dominant light source among infected households. The small sizes for generator and other lighting sources limit conclusions about their impact, but their minimal representation suggests they are less relevant to the overall epidemic dynamics in this context.

- ***Sources of Water***

A chi-square test revealed a statistically significant association between the source of water and Chikungunya infection status ($\chi^2(3) = 12.25$, $p = .007$), as shown in Table 10. The most common source of water among both groups was public piped water, used by 65.25% of the infected and 53.92% of the non-infected individuals. The observed count of infected individuals in this category slightly exceeded the expected value (199 observed vs. 190.3 expected), while the non-infected count was lower than expected (55 observed vs. 63.7 expected). This suggests that reliance on public piped water was associated with a higher-than-expected proportion of infections, though it remains the dominant water source overall. The second most reported category, "using donkey to supply water," was nearly equally represented among the infected (26.56%) and non-infected (26.47%) individuals. The observed values closely matched the expected counts (81 vs. 80.9 for infected; 27 vs. 27.1 for non-infected), indicating no meaningful deviation from what would be expected under independence, and suggesting a neutral association with infection risk.

Table 10: Association Between Sources of Water and Chikungunya Infection Status

Sources of Water	Infected (n)	Not Infected (n)	Expected Infected (n)	Expected Not Infected (n)	% Infected	% Not Infected
Public Piped Water	199	55	190.3	63.7	65.25%	53.92%
Using Donkey to Supply Water	81	27	80.9	27.1	26.56%	26.47%
Water from Dug Wells	0	1	0.7	0.3	0.00%	0.98%
Others	25	19	33.0	11.0	8.20%	18.63%
Total	**305**	**102**	**305**	**102**	**100%**	**100%**

Note: Pearson Chi-square = 12.25, df = *3,* p = *.007.*

Water sourced from dug wells was extremely rare, with only one non-infected individual reporting its use and none among the infected. This minimal frequency (0.98% in the non-infected group) does not allow for meaningful inference about its association with infection risk but contributes to the overall significance of the chi-square test due to the discrepancy between expected and observed values. Notably, the "other" water sources category, which likely includes a heterogeneous mix of non-piped, potentially untreated sources, was used by

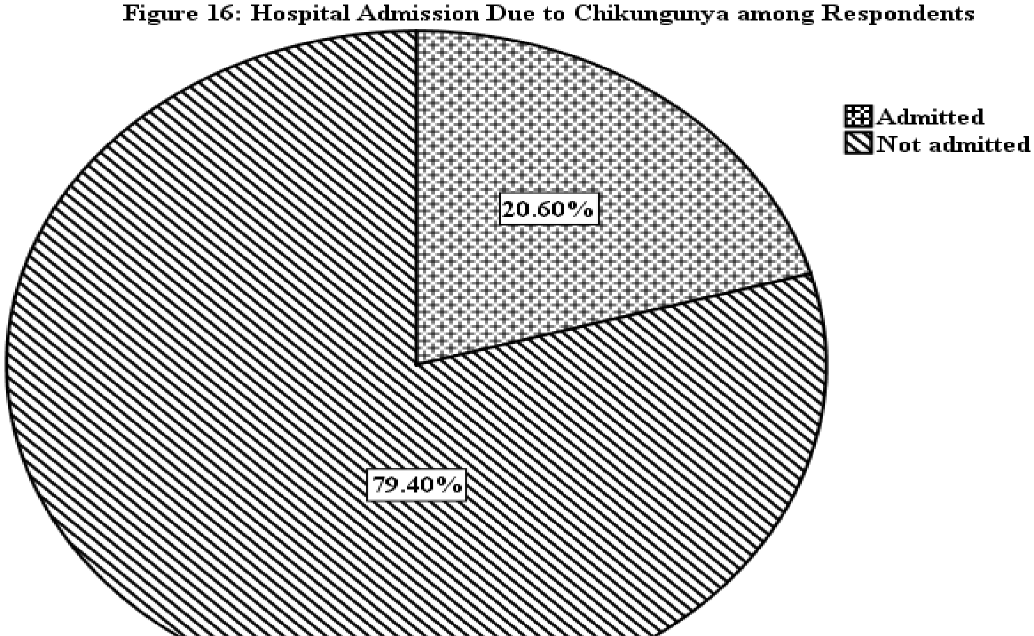
8.20% of infected and 18.63% of non-infected individuals. Here, the proportion of non-infected individuals was markedly higher than expected (19 observed vs. 11.0 expected), whereas the infected group showed fewer cases than expected (25 observed vs. 33.0 expected). This finding is counterintuitive, as one might expect less reliable water sources to correlate with higher infection risk. This deviation suggests that households relying on “other” sources may differ systematically, in terms of location, preventive behavior, or vector exposure, in ways not captured solely by water source categorization.

Overall, these results indicate that while public piped water is the predominant source across both groups, it may not offer full protection from exposure. In contrast, the unexpectedly higher proportion of non-infected individuals among users of “other” water sources invite further investigation into environmental, behavioral, or geographic factors that mediate Chikungunya exposure.

7.3.5 Hospital Admission Rates Due to Chikungunya

Figure 16 presents the hospital admission rates due to Chikungunya, showing that 20.60% of respondents required inpatient care, while 79.40% did not. Although the infection was widespread, only a minority of cases progressed to the severity requiring hospitalization. The clinical manifestation of Chikungunya varies, with many cases presenting as mild fever and joint pain that can be managed at home, while a smaller subset develops severe arthralgia or complications that necessitate hospitalization. The relatively low hospitalization rate may reflect several factors, including systemic barriers to healthcare access in Kassala State, such as limited hospital capacity, geographic distance to healthcare facilities, especially in rural areas, and financial constraints, which align with the high OOPHE observed in Figure 13.

Figure 16: Hospital Admission Due to Chikungunya among Respondents

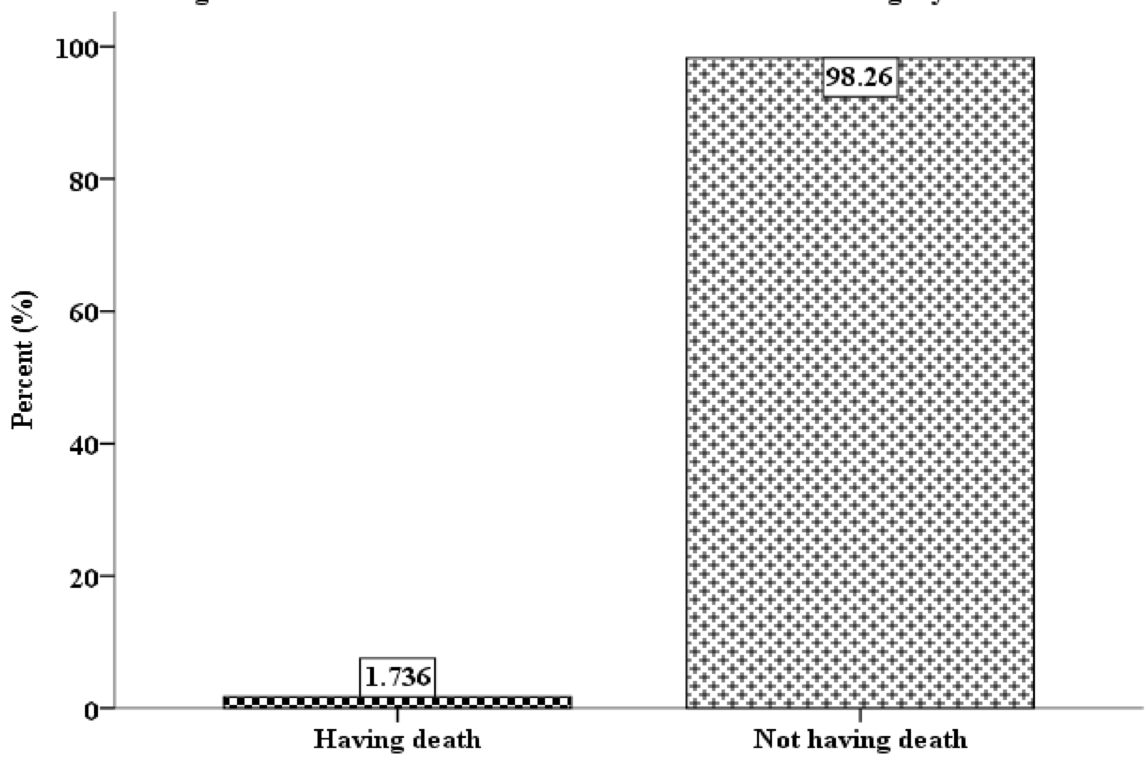


Another possible explanation for the relatively high initial hospitalization rate is the misidentification of the disease early in the outbreak. In the early stages, many individuals may have been admitted to the hospital before the true nature of the disease was recognized. Once the disease was identified and its characteristics understood by local health authorities, the hospitalization rate dropped. For the 79.40% of the respondents who were not admitted, alternatives such as outpatient care, self-medication, or traditional remedies (as seen in the 1.73% consulting traditional healers in Figure 12) may have been more common. These alternatives likely increased the financial burden on households, not only through direct medical costs but also due to indirect costs, such as transportation to healthcare facilities or lost income from time off work. This pattern highlights the uneven distribution of healthcare utilization, emphasizing the significant economic strain on households, especially for those unable to access formal inpatient care.

7.3.6 Chikungunya-Related Mortality

Figure 17 reports a notably low mortality rate of 1.736%, with 98.26% of respondents not experiencing a death due to Chikungunya. This low fatality rate aligns with the global understanding that Chikungunya is typically a non-lethal disease, with mortality generally occurring in vulnerable populations, such as the elderly or those with pre-existing health conditions.

Fgure 17: Distribution of Death Incidence Due to Chikungunya

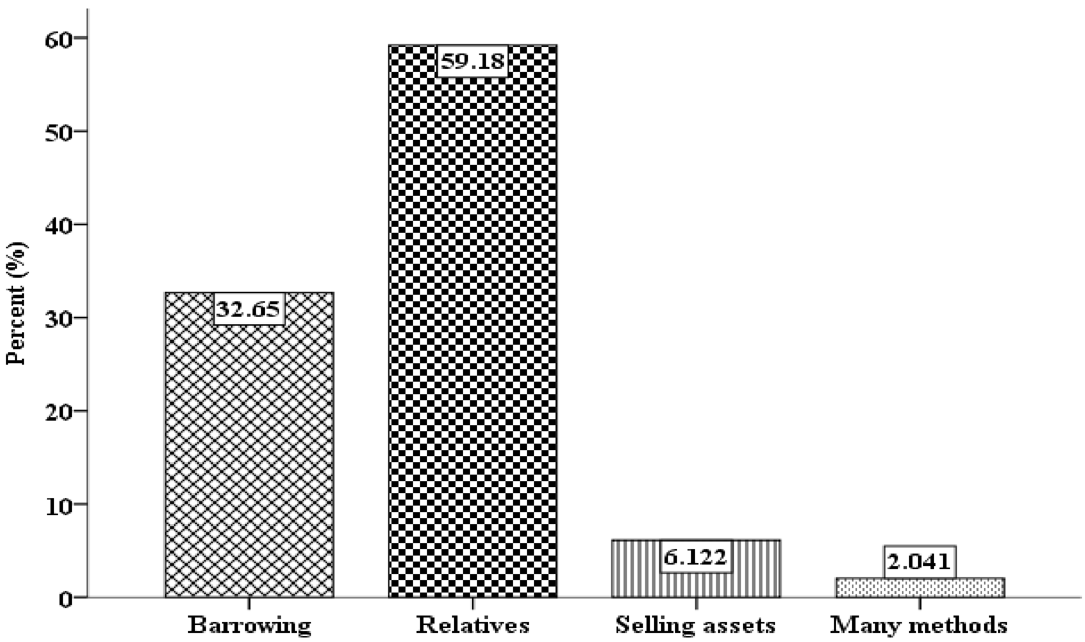


In the context of Kassala State, where 81.77% of respondents are reported as healthy (Figure 7), the low mortality rate is not surprising but remains significant. However, it is important to consider that the reported mortality rate may be somewhat inflated due to the extended family relationships typical in the region. When respondents were asked about deaths in their families, they may have included deaths within the wider extended family network, rather than just immediate household members. This broader interpretation could result in an inflated mortality figure, as extended families often play a central role in individuals' lives and the communal nature of family structures leads to a more inclusive definition of "family" when reporting deaths. Even with this potential inflation, the low mortality rate still suggests that while Chikungunya posed a widespread health threat, its primary impact was morbidity, rather than mortality.

7.3.7 Household Coping Mechanisms and Economic Resilience

Figure 18 provides insight into the economic coping mechanisms employed by households to manage Chikungunya-related expenditures. Of the 49 respondents who reported specific coping strategies, 32.7% resorted to borrowing, 59.2% relied on relatives, 6.1% sold assets, and 2.0% adopted multiple methods. These proportions closely reflect those described earlier and are derived from the subsample of households who answered this specific question (approximately 12% of the total sample, n = 49).

Figure 18: Strategies Adopted by Respondents to Cope with Chikungunya-Related Expenditures



The predominant reliance on familial support (59.2%) underscores the strength of informal safety nets within Kassala State, where extended family and kinship ties often substitute for the absent formal social protection systems. Nevertheless, over one-third (32.7%) reported borrowing, which signals significant financial vulnerability, particularly when viewed in the context of the high infection rate (74.94%) and hospitalization rate (20.60%). The fact that only 6.1% resorted to asset sales, and an even smaller proportion (2.0%) used mixed coping strategies, suggests both limited liquid assets and a cultural or strategic hesitation to compromise long-term household stability.

Importantly, the limited number of responses to this item (49 out of 407) may reflect a reluctance to disclose sensitive financial coping behaviors or a lack of recognition of informal strategies as "reportable" coping mechanisms, which is not uncommon in socioeconomically strained contexts. Still, the distribution of responses provides a telling snapshot of the economic pressures faced by affected households, where support from relatives and recourse to debt appear as the primary, if not only, viable options in the absence of state-sponsored relief. These findings reinforce earlier evidence of Chikungunya's broad socio-economic impact and further highlight the need for more resilient and inclusive public health and social safety infrastructure in Kassala State.

7.4 The Role of Chikungunya in Spurring Households' OOPHE

This section presents the empirical estimates derived from the econometric model developed in Section 6 and represented by Equation (1). The model is designed to identify and quantify the key determinants of OOPHE among households in Kassala State, with particular attention to the role of the Chikungunya epidemic. The ordered logistic regression results reported below offer insights into how individual, household, and systemic factors shape the financial burden of healthcare during an infectious disease outbreak.

Table 11 presents the results of an ordered logistic regression model estimating the determinants of OOPHE among households in Kassala State, with a particular focus on the role of Chikungunya infection as the variable of interest. The coefficient for Chikungunya is 0.4250 and is statistically significant at the 10% level ($p = 0.098$), indicating that households affected by the Chikungunya epidemic are more likely to fall into higher categories of OOPHE. This result is consistent with prior descriptive statistics that showed elevated spending among infected households. The positive sign of the coefficient suggests that the financial burden associated with Chikungunya, potentially due to medication, diagnostic tests, or supportive care, plays a substantial role in driving OOPHE during epidemic conditions.

Health insurance coverage exhibits a strong and statistically significant negative association with OOPHE, with a coefficient of –2.0537 ($p < 0.01$). This result confirms the protective effect of health insurance, whereby insured households are significantly less likely to incur high levels of OOPHE. The magnitude of this coefficient is among the largest in the model, suggesting a powerful mitigating effect of insurance on health-related financial strain. This aligns with earlier descriptive insights that emphasized the importance of financial risk protection in mitigating health expenditure shocks during health crises. Moreover, in the specific context of Kassala State, this finding gains further relevance: the available health insurance scheme offers full coverage for diagnostic tests, including those necessary for confirming Chikungunya infection.

Given the clinical ambiguity during the early days of illness, many individuals, especially those uninsured, rushed to diagnostic centers to determine the cause of their symptoms. This immediate response behavior, driven by uncertainty and fear of epidemic-related complications, likely elevated OOPHE among uninsured households in the initial phase of illness. In contrast, insured households were largely shielded from such early expenditures due to their entitlement to free diagnostic services. This dynamic highlights not only the direct financial protection provided by insurance, but also its critical role in buffering households against the cost shocks associated with epidemic outbreaks and diagnostic uncertainty.

Table 11: Determinants of OOPHE – Ordered Logistic Regression

Variable	Coefficient	Std. Err.	z	P > z	[95% Conf. Interval]
Head health status	0.6642	0.9086	0.73	0.465	[-1.1166, 2.4450]
Chikungunya	0.4250*	0.2570	1.65	0.098	[-0.0788, 0.9288]
Insurance	-2.0537***	0.2667	7.70	0.000	[1.5310, 2.5765]
Marital status	0.3352	0.4700	0.71	0.476	[-0.5860, 1.2565]
Household size	0.0432	0.0421	1.03	0.305	[-0.0394, 0.1258]
No. of toilets	-0.5084**	0.2476	2.05	0.040	[-0.9938, -0.0231]
Years of schooling	0.0278	0.0261	1.06	0.287	[-0.0234, 0.0789]
Gender of head	-0.0429	0.4863	0.09	0.930	[-0.9961, 0.9103]
Urban	-0.0033	0.5068	0.01	0.995	[-0.9967, 0.9900]
Age of household head	-0.0416***	0.0126	3.31	0.001	[0.0169, 0.0663]
Over 60 age members	0.6301***	0.2262	2.79	0.005	[0.1867, 1.0735]
Electricity access	-0.7033*	0.4186	1.68	0.093	[-1.5237, 0.1170]
Number of rooms	0.2069*	0.1155	1.79	0.073	[-0.0195, 0.4334]
Cost of transportation	-0.0005	0.0018	0.28	0.777	[-0.0041, 0.0031]
Income_1500_2500	1.0762	0.9510	1.13	0.258	[-0.7877, 2.9400]
Income_2500_3500	1.1920	0.8666	1.38	0.169	[-0.5066, 2.8905]
Income_3500_5000	1.6024**	0.8367	1.92	0.055	[-0.0375, 3.2422]
Income_above_5000	1.6940**	0.8383	2.02	0.043	[0.0509, 3.3371]
Morbidity	6.6156***	0.6704	9.87	0.000	[5.3016, 7.9295]
Water access	0.4797	0.5543	0.87	0.387	[-0.6068, 1.5661]
Proximity	0.4901*	0.2522	1.94	0.052	[-0.0042, 0.9843]
Assets	-0.1361	0.2976	0.46	0.647	[-0.7195, 0.4472]
Cut Point					
cut1	2.629	1.473			[–0.257 to 5.515]
cut2	3.913	1.512			[0.950 to 6.876]
cut3	6.380	1.548			[3.347 to 9.413]
cut4	7.549	1.556			[4.499 to 10.598]
cut5	8.539	1.559			[5.483 to 11.595]

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Number of observations: 321, LR $chi^2(22)$: 253.63, Prob > chi^2: 0.000, Log likelihood: –413.710, Pseudo R^2: 0.2346.

Morbidity status, which captures the presence of illness in the household, displays a very large positive and highly statistically significant coefficient of 6.6156 ($p < 0.01$). This finding strongly reinforces the expectation that sickness significantly increases the likelihood of higher OOPHE, irrespective of whether it is due to Chikungunya or other health conditions. Importantly, this effect is much larger than that of Chikungunya alone, suggesting that while Chikungunya contributes to OOPHE, broader morbidity burdens remain a more dominant factor.

Among demographic variables, the presence of household members aged over 60 years has a positive and significant association with OOPHE, with a coefficient of 0.6301 ($p = 0.005$). This is likely reflective of higher care needs and susceptibility to complications among the elderly during epidemics. Conversely, the age of the household head is negatively and significantly associated with OOPHE (coefficient = –0.0416, $p = 0.001$), indicating that households led by younger individuals tend to spend more on healthcare, potentially due to greater health-seeking behavior or risk tolerance. Several household characteristics also show statistically significant associations with OOPHE. The number of toilets in the household has a negative coefficient of –0.5084 ($p = 0.040$), suggesting that better sanitation conditions are linked with lower OOPHE. This supports the inference that improved hygiene infrastructure reduces the incidence or severity of illness, thereby diminishing health costs.

The number of rooms in a household, often used as a proxy for wealth or living space, has a positive coefficient of 0.2069 ($p = 0.073$), significant at the 10% level, indicating that better-off households may spend more on health either due to greater ability to pay or higher expectations of care quality. Access to electricity, with a coefficient of –0.7033 ($p = 0.093$), also appears to reduce the likelihood of high OOPHE, potentially by contributing to better living conditions and overall household well-being.

Income group variables reveal interesting gradients. Compared to the reference category (lowest income group), households earning 3,500–5,000 SDG and above 5,000 SDG have positive and statistically significant coefficients of 1.6024 ($p = 0.055$) and 1.6940 ($p = 0.043$), respectively. This suggests that households with higher income levels are more likely to fall into higher OOPHE categories. While this might appear counterintuitive, it likely reflects greater capacity and willingness to spend on health services among better-off households, particularly in a context where public provision is weak and out-of-pocket payments dominate health financing. The lower-income groups (1,500–2,500 SDG and 2,500–3,500 SDG) do not show statistically significant effects, pointing to a potential threshold effect where only upper-income groups demonstrate increased spending. This finding aligns with numerous previous studies that have shown wealthier households tend to seek more comprehensive and often higher-cost healthcare, especially in low-resource settings where private provision plays a major role (Ebaidalla & Ali, 2019 and Ebaidalla & Ali, 2021).

The variable proximity to health facility is marginally significant (coefficient = 0.4901, $p = 0.052$), suggesting that closer proximity may lead to more frequent health facility use and therefore higher expenditures. However, this effect is modest in size and significance. In contrast, variables such as household size, years of schooling, gender of the household head, urban/rural residence, marital status, transportation cost, water access, and asset ownership are not statistically significant, indicating limited explanatory power in this model for predicting variations in OOPHE during the Chikungunya epidemic.

The model's overall performance is robust, with a likelihood ratio chi-square of 253.63 ($p < 0.001$), indicating that the set of predictors collectively explains a significant portion of the variation in OOPHE. The pseudo R^2 value of 0.2346 further suggests moderate explanatory power, which is acceptable in models of this kind.

In sum, the analysis confirms that Chikungunya infection contributes meaningfully to increased OOPHE in Kassala State, although broader morbidity, income, and health system variables like insurance status and proximity remain central drivers. These findings call for urgent policy attention to epidemic preparedness, financial protection mechanisms, and basic public health infrastructure to shield households from excessive health-related financial burdens during disease outbreaks.

7.5 The CHE Induced by Chikungunya Epidemic

This section examines the financial impact of the Chikungunya epidemic on households in Kassala State, with a particular focus on the incidence and determinants of CHE. The analysis is structured around three key results: (1) the association between Chikungunya infection and CHE incidence, (2) the distribution of CHE across income groups, and (3) the determinants of CHE based on a probit regression analysis. Each of these results is presented and discussed in its own subsection below.

7.5.1 Association Between Chikungunya Infection and CHE Incidence

The association between Chikungunya infection and the incidence of CHE is explored in Table 12, using household-level data from Kassala State. The results reveal a statistically significant relationship between the two variables, as indicated by the Pearson Chi-square test ($\chi^2 = 46.42$, $p < 0.001$). This suggests that the financial burden experienced by households is not randomly distributed but is strongly linked to whether a household member was infected with Chikungunya.

Table 12: Association between CHE and Chikungunya Infection

Chikungunya Infection	Frequency (CHE = 0)	% of (CHE = 0)	Frequency (CHE = 1)	% of (CHE = 1)	Total Frequency	Total Percentage
No	5	4.90%	97	95.10%	102	25.06%
Yes	126	41.31%	179	58.69%	305	74.94%
Total	131	32.19%	276	67.81%	407	100%

Note: Pearson Chi-square (χ^2) = 46.42, $p < 0.001$

Among the 131 households that did not experience CHE (i.e., CHE = 0), only 4.90% reported no incidence of Chikungunya, while a much larger share, 41.31%, had at least one member infected. Conversely, in the group that did incur CHE (n = 276), an overwhelming 95.10% of households had experienced a Chikungunya infection, compared to just 58.69% of those who did not. These figures demonstrate a clear trend: households affected by the epidemic were significantly more likely to experience health-related financial distress.

This pattern has important implications for public health policy in Kassala. The high prevalence of CHE among Chikungunya-affected households indicates that the epidemic was not only a health crisis but also a major economic shock, particularly for households with limited financial buffers. The data suggest that infection with Chikungunya substantially increases the risk of incurring OOPHE that surpass 20% of household income—a threshold commonly used to define catastrophic spending. In Kassala's context, where many families, particularly in rural areas, lack access to health insurance or savings, the impact of a vector-borne epidemic such as Chikungunya can be devastating. Medical expenses for diagnosis, treatment, medications, and transportation, coupled with potential income loss due to illness or caregiving responsibilities, can quickly accumulate. These pressures can push households deeper into poverty, forcing them to adopt harmful coping strategies such as borrowing, asset liquidation, or pulling children out of school.

7.5.2 CHE Across Income Groups During the Chikungunya Epidemic

Table 13 presents the distribution of households in Kassala State by income group and the incidence of CHE, defined as OOPHE that exceeds 20% of estimated household income. This metric provides a clear picture of the financial strain induced by the Chikungunya epidemic, which placed a sudden and substantial burden on already vulnerable households. The findings show that CHE is alarmingly prevalent across all income groups. Among the poorest households (SDG 500–1500), 6 out of 8 households incurred CHE (75%). Likewise, 13 out of 18 households in the SDG 1500–2500 group also faced catastrophic costs (72.22%). This underscores how the epidemic disproportionately affected the economically disadvantaged, leaving them highly exposed to health-related financial shocks. However, the burden is not confined to low-income groups. Even in the upper-middle-income range (SDG 3500–5000), 54 out of 93 households experienced CHE (58.06%). Surprisingly, the highest incidence, 178 out of 229 households (77.73%), was observed among those earning more than SDG 5000. This trend suggests that Chikungunya's impact overwhelmed household coping capacities across the economic spectrum, likely due to increased healthcare demand, prolonged illness, and loss of income during recovery periods.

Cumulative figures reinforce this concern: by the highest income category, the total share of households incurring CHE reached 276, reflecting the epidemic's far-reaching financial consequences. In contrast, only 131 households across all income groups did not incur CHE, pointing to the widespread economic vulnerability during the outbreak. This pattern suggests that CHE can have especially harsh consequences for poorer households in Kassala, particularly those in rural areas where income-generating opportunities are already limited and health infrastructure is often inadequate. When a household in these settings incurs catastrophic health expenses, it may be forced to reduce spending on essential needs such as food, education, or shelter. In many cases, families resort to selling productive assets, borrowing at high interest, or pulling children out of school to cope, which can deepen the cycle of poverty and reduce long-term resilience.

Table 13: Distribution of Households by Income Group and Incidence of CHE

Income Group (SDG)	Not Incur CHE	Incur CHE	% Not Incurred (within group)	% Incurred (within group)	Cumulative % (Not Incurred)	Cumulative % (Incurred)
500 – 1500	2	6	25.00%	75.00%	2.2%	1.9%
1500 – 2500	5	13	27.78%	72.22%	6.9%	6.1%
2500 – 3500	34	25	57.63%	42.37%	16.0%	14.1%
3500 – 5000	39	54	41.94%	58.06%	35.7%	31.4%
> 5000	51	178	22.27%	77.73%	100.0%	100.0%
Total	**131**	**276**	–	–	–	–

Note:

- *CHE = 1 if OOPHE ≥ 20% of household income; 0 otherwise;*
- % within group columns show how many households in each income band incurred or did not incur CHE
- Cumulative % columns are based on the total of each CHE status across all income groups.

Rural households are also less likely to have savings or access to formal credit and are typically excluded from insurance schemes. Therefore, a single health shock like the Chikungunya outbreak can rapidly push them into economic hardship. Additionally, travel costs to reach health facilities, often located far from rural communities, add another layer of financial strain that is not always captured in the reported health expenditure figures. In this context, CHE is more than just a statistic, it is a marker of severe household vulnerability. For rural poor families in Kassala, it reflects both a symptom and a driver of deprivation, emphasizing the urgent need for targeted policy interventions that improve health access and offer financial protection to the most at-risk populations.

In the context of Kassala State, these findings highlight the fragile financial resilience of households when confronted with health emergencies. The Chikungunya epidemic not only strained the health system but also exacerbated poverty risks, particularly in the absence of robust health financing mechanisms.

7.5.3 Determinants of CHE

The probit regression results presented in Table 14 examine the determinants of CHE, defined as a binary variable where households incur CHE if OOPHE due to the Chikungunya epidemic exceeds 20% of their income. The focus of this analysis is on the role of Chikungunya infection as a primary determinant of CHE, alongside other socio-economic and demographic factors. The coefficient for the Chikungunya variable is 1.840 (p-value = 0.000), indicating a strong and statistically significant positive relationship between Chikungunya infection and the likelihood of a household experiencing catastrophic health expenditure. This result suggests that households affected by the Chikungunya epidemic are significantly more likely to face catastrophic health costs, likely due to the high direct costs of medical treatment, medications, and potentially the need for additional care associated with the illness. The large coefficient underscores the substantial economic burden that the epidemic imposes on households, pushing many to the brink of financial distress. These findings are consistent with the broader literature on health shocks, which shows that epidemics can strain household budgets, leading to catastrophic expenditures when insurance coverage is inadequate or unavailable.

Table 14: Determinants of CHE - Probit Regression Estimates (Dependent variable = CHE)

Variable	Coefficient	Std. Err.	z	P-value	95% Confidence Interval
Head health status	-0.534	0.861	-0.62	0.535	[-2.221, 1.154]
Chikungunya	1.840 ***	0.324	5.69	0.000	[1.206, 2.474]
Insurance	-1.639 ***	0.224	-7.31	0.000	[-2.078, -1.200]
Marital status	-0.332	0.390	-0.85	0.394	[-1.096, 0.432]
Household size	0.062	0.041	1.52	0.128	[-0.018, 0.142]
No. of toilets	0.332	0.224	1.49	0.137	[-0.106, 0.770]
Years of schooling	0.029	0.024	1.19	0.236	[-0.019, 0.076]
Gender of head	0.319	0.433	0.74	0.460	[-0.528, 1.167]
Urban	0.811 **	0.404	2.01	0.045	[0.018, 1.604]
Age of household head	-0.004	0.011	-0.36	0.718	[-0.026, 0.018]
Over 60 age members	0.307	0.209	1.47	0.142	[-0.102, 0.716]
Electricity access	-0.823 **	0.382	-2.15	0.031	[-1.572, -0.073]
Number of rooms	-0.183 *	0.098	-1.87	0.062	[-0.374, 0.009]
Cost of transportation	0.005 *	0.003	1.85	0.064	[-0.0003, 0.010]
Income_1500_2500	-0.002	0.979	-0.00	0.998	[-1.921, 1.917]
Income_2500_3500	-1.348	0.919	-1.47	0.142	[-3.148, 0.452]
Income_3500_5000	-0.771	0.900	-0.86	0.391	[-2.535, 0.992]
Income_above_5000	-0.767	0.913	-0.84	0.401	[-2.557, 1.024]
Morbidity	0.060	0.359	0.17	0.867	[-0.643, 0.763]
Water access	-0.317	0.446	-0.71	0.478	[-1.191, 0.557]
Proximity	0.327	0.227	1.44	0.151	[-0.119, 0.773]
Assets	-0.308	0.272	-1.13	0.258	[-0.841, 0.225]
Cut Point					
Cut	-.4341877	1.441759			[-3.260, 2.392]

*Note : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Number of Observations: 324; Log Likelihood: -116.557; LR Chi²(22): 170.53 and Pseudo R^2: 0.4225*

In contrast, other variables, such as health status of the household head, marital status, household size, and years of schooling, do not show statistically significant associations with CHE. Specifically, the health status of the household head has a negative coefficient (-0.534), but the result is not statistically significant (p = 0.535), suggesting that the household head's health status does not have a significant impact on the likelihood of incurring catastrophic health expenditure in this context. Similarly, marital status, household size, and education level do not exhibit strong associations with catastrophic expenditures, as their p-values exceed the typical significance threshold. Several other variables show significant effects. Insurance coverage is strongly negatively associated with CHE (coefficient = -1.639, p-value = 0.000), indicating that households with insurance are less likely to experience CHE.

This result underscores the critical role of health insurance in shielding households from severe financial shocks during health crises such as the Chikungunya outbreak. By absorbing a significant portion of medical costs, insurance effectively breaks the link between illness and impoverishment. This finding fully aligns with previous studies that have consistently demonstrated the protective effect of insurance in reducing vulnerability to CHE in both epidemic and non-epidemic settings. Urban households also exhibit a higher likelihood of experiencing catastrophic health expenditure, as evidenced by a significant positive coefficient of 0.811 (p = 0.045). This could be due to higher medical costs or greater exposure to the epidemic in urban areas compared to rural settings, where access to health services and treatment options might be more limited or less costly. Additionally, access to electricity negatively impacts the likelihood of catastrophic health expenditure (coefficient = -0.823, p = 0.031), which may reflect better infrastructure and access to healthcare services in areas with electricity, potentially reducing the financial burden of health expenses. The cost of transportation also shows a marginally significant positive effect (coefficient = 0.005, p = 0.064), suggesting that higher transportation costs may contribute to the overall burden of healthcare spending, especially in areas where healthcare facilities are geographically distant.

Income variables do not significantly affect the likelihood of catastrophic health expenditure. Households with incomes ranging from 1,500 to 5,000 SDG or above do not show significant differences in the likelihood of incurring catastrophic health expenses, indicating that the severity of the health shock may override the protective effect of income in this context. This lack of significance may be attributed to the fact that even middle- or higher-income households are vulnerable to financial strain when faced with sudden and intense health shocks, especially in the absence of insurance or social safety nets. The unpredictability and severity of epidemic-related costs may render income an insufficient buffer. Furthermore, other factors, such as morbidity, water access, proximity to healthcare services, and asset ownership, do not demonstrate statistically significant relationships with catastrophic health expenditure. The insignificance of asset ownership may reflect the limited liquidity of household assets during emergencies. Households may own durable goods or land, but such assets are not readily convertible to cash to cover urgent medical costs, rendering them ineffective in preventing financial catastrophe during an epidemic.

The overall model fit is assessed by the LR $Chi^2(22)$ statistic, which is 170.53 (p-value = 0.000), suggesting that the model is statistically significant and provides a good fit to the data. The pseudo R^2 of 0.4225 indicates that the model explains a substantial portion of the variation in catastrophic health expenditure.

In summary, the results of this probit regression underline the significant impact of Chikungunya infection on CHE in households. The findings also highlight the importance of insurance coverage and urban residency as key determinants of financial vulnerability in the face of health shocks. While several other factors, such as income and household characteristics, do not show significant associations, the role of Chikungunya infection in driving catastrophic expenditures remains prominent, pointing to the need for targeted policy interventions to protect vulnerable households from the financial repercussions of such health crises.

7.5.4 Impact of Chikungunya-led OOPHE on Household Consumption

The results of the ordered logit regression presented in Table 15 provide robust empirical evidence on the determinants of household consumption categories in Kassala State, with a particular focus on the role of OOPHE arising from the Chikungunya epidemic. The dependent variable, household consumption category, is ordinally scaled, reflecting ascending levels of welfare. Among the covariates, the variable of interest, OOPHE, is statistically significant at the 10% level, exhibiting a negative coefficient of –0.153 ($p = 0.077$). This negative association indicates that increased out-of-pocket health expenditures, stemming from treatment, medications, and transportation costs, diminish the likelihood of households advancing to higher consumption categories. This finding aligns with previous research, including Ebaidalla and Ali (2019) and Mustafa and Ebaidalla (2019), which explored the broader context of Sudan, and Ali and Abdalla (2021), which focused on specific Sudanese states, including Kassala. Both studies substantiate the detrimental impact of out-of-pocket expenditures on household food consumption and overall welfare.

This finding is consistent with the descriptive analysis conducted earlier, which revealed that households incurring higher health-related expenditures during the Chikungunya outbreak experienced greater financial strain. The descriptive statistics also showed that such households disproportionately occupied the lower rungs of the consumption distribution, which reinforces the regression-based inference that health shocks can erode welfare through reduced disposable income. High OOPHE may also coincide with a temporary or prolonged inability to work resulting from the debilitating effects of the disease, thereby compounding the economic vulnerability of affected households, especially those already living near or below the poverty line. Given that the poverty incidence in Kassala State already exceeds the national average, the surge in OOPHE driven by the epidemic is likely to push a sizable segment of the population into a poverty trap, where health-related financial burdens compound existing economic vulnerabilities. The negative relationship between OOPHE and consumption category underscores the vulnerability of affected households, particularly in contexts where health shocks are uninsured and public health systems are weak.

Additional control variables yield intuitive and policy-relevant insights. Income levels are positively and strongly associated with higher consumption categories, as expected. Compared to the reference group, households earning more than 2,500 SDG monthly are significantly more likely to belong to better-off consumption categories, with the marginal effect intensifying as income increases. For instance, households earning above 5,000 SDG exhibit the highest coefficient (5.541, $p < 0.01$), suggesting a substantial positive shift in consumption status.

Table 15: Impact of OOPHE on Household Consumption- Ordered Logit Regression (Dependent variable: Household Consumption Category)

Variable	Coefficient	S.E.	z	p-value	95% Confidence Interval
Gender of head	1.034 **	0.395	2.62	0.009	[0.260, 1.807]
Marital status	–0.725 **	0.345	–2.10	0.035	[–1.401, –0.049]
Income_1500_2500	1.142	0.759	1.50	0.133	[–0.346, 2.630]
Income_2500_3500	2.299 ***	0.688	3.34	0.001	[0.950, 3.647]
Income_3500_5000	3.226 ***	0.692	4.66	0.000	[1.870, 4.582]
Income_above_5000	5.541 ***	0.727	7.62	0.000	[4.117, 6.966]
OOPHE	–0.153 *	0.087	–1.77	0.077	[–0.323, 0.017]
Household size	0.167 ***	0.044	3.83	0.000	[0.082, 0.253]
Cost of transportation	0.004 **	0.002	2.41	0.016	[0.001, 0.008]
Years of schooling	0.036	0.024	1.46	0.145	[–0.012, 0.083]
Urban	0.536	0.554	0.97	0.334	[–0.551, 1.622]
Insurance	–0.631 ***	0.236	–2.68	0.007	[–1.093, –0.169]
Age of household head	–0.028 ***	0.010	–2.73	0.006	[–0.048, –0.008]
Water access	1.014 *	0.571	1.78	0.076	[–0.104, 2.133]
Electricity access	–0.104	0.329	–0.32	0.753	[–0.748, 0.541]
Head health status	1.020	0.797	1.28	0.201	[–0.543, 2.583]
Financial Support	0.503 *	0.277	1.82	0.069	[–0.039, 1.045]
Cut Point					
Cut1	1.100	1.250			[-1.351, 3.551]
Cut2	2.536	1.265			[0.057, 5.015]
Cut3	4.234	1.286			[1.713, 6.755]
Cut4	5.713	1.306			[3.155, 8.272]

*Note : *p < 0.10, **p < 0.05, ***p < 0.01. Number of observations: 244; Log likelihood: –146.229; LR* $\chi^2(18)$*: 293.99; Prob >* χ^2*: 0.000, and Pseudo* R^2*: 0.5013*

Demographic factors also play a meaningful role. Being male-headed increases the likelihood of being in a higher consumption category (coef. = 1.034, p = 0.009), whereas marital status appears to have a dampening effect (coef. = –0.725, p = 0.035). Household size has a positive and highly significant association with consumption category, potentially reflecting economies of scale or labor supply advantages in larger households. Meanwhile, increased transportation costs, a proxy for access burdens, are positively associated with higher consumption categories (coef. = 0.004, p = 0.016), possibly indicating that better-off households can afford longer commutes to access services.

Interestingly, insurance coverage is associated with a statistically significant reduction in the probability of being in higher consumption categories (coef. = –0.631, p = 0.007). This counterintuitive result may reflect adverse selection or the limited coverage scope of insurance schemes in the study area. Age of the household head also has a negative association with consumption status, indicating that older heads may face productivity declines or income insecurity. The Urban variable, although positive, is statistically insignificant (p = 0.334), suggesting that residing in an urban area does not meaningfully affect the likelihood of being in a higher consumption category. This lack of significance may stem from the blurred socio-economic distinctions between rural and urban settings in Kassala State, where income sources, consumption patterns, and access to services often overlap. Additionally, shared vulnerabilities—such as exposure to epidemics and inadequate infrastructure—may neutralize the expected urban advantage. As such, the presumed welfare gains associated with urban residence may be less pronounced in contexts marked by weak spatial development and pervasive poverty. Water Access and receiving Financial Support were also positively associated with higher consumption categories, albeit with marginal levels of significance.

In sum, the regression results support the conclusion that OOPHE related to the Chikungunya outbreak significantly undermine household welfare in Kassala State by reducing the likelihood of being in higher consumption categories. This finding, corroborated by descriptive trends, highlights the need for effective financial protection mechanisms in health policy, such as risk pooling, subsidized care, or targeted support during epidemics. The broader set of covariates reinforces the multidimensional nature of consumption welfare, shaped by income, demographic structure, and access to essential services.

The overall model fit statistics suggest that the ordered logit specification performs well in explaining variations in household consumption categories in Kassala State. The log-likelihood value of –146.229 indicates the model's fit to the observed data, while the likelihood ratio (LR) chi-square statistic of 293.99 with a p-value of 0.000 confirms that the model is statistically significant as a whole, rejecting the null hypothesis that all coefficients are jointly zero. Moreover, the Pseudo R^2 value of 0.5013 reflects a relatively high explanatory power for an ordinal model, suggesting that over 50% of the variation in the dependent variable is accounted for by the included covariates.

8. Conclusion

This study presents a comprehensive empirical assessment of the Chikungunya epidemic in Kassala State, Sudan, revealing a multidimensional crisis that imposed substantial health and economic burdens on households. Drawing on primary survey data from Kassala, Rural Kassala, and Rural West Kassala, the analysis highlights how the epidemic exacerbated existing vulnerabilities and exposed systemic shortcomings in both public health infrastructure and financial protection mechanisms. This multidimensional crisis was first evident in the widespread prevalence of infection, with 74.94% of households affected, underscoring the epidemic's extensive reach. The outbreak was fueled by environmental factors conducive to Aedes mosquito proliferation, particularly tropical climates and open water storage practices. Geographic disparities in infection rates, with urban Kassala (59.02%) more affected than Rural West Kassala (10.82%), reflect variations in population density, healthcare accessibility, and capacity for vector control. These patterns intersect with structural inequities, such as inadequate sanitation, poor housing, and limited rural health services, which amplify disease transmission risks.

Building on these structural vulnerabilities, the epidemic's financial impact was deeply shaped by socioeconomic characteristics. Households with limited education, especially in rural areas (e.g., 9.3% illiteracy in Rural West Kassala), exhibited greater vulnerability due to low health literacy, delayed care-seeking, and dependence on informal providers. Female-headed households (9.58%) and larger families (4–6 members) experienced disproportionate financial strain, compounded by income constraints, restricted credit access, and higher aggregate health risks. The incidence of low income (e.g., 45% of Rural West Kassala households earning below SDG 1500/month) further heightened susceptibility to OOPHE. These patterns are empirically confirmed by econometric analysis, which provides robust evidence of the epidemic's financial toll. Ordered logistic regression shows that Chikungunya infection significantly increased OOPHE (coefficient = 0.4250, $p = 0.098$), largely due to diagnostic, treatment, and supportive care costs. Chronic conditions, such as hypertension (41.56% prevalence), amplified this burden (coefficient = 6.6156, $p < 0.01$), indicating a compounding effect of pre-existing health needs. Health insurance proved protective (coefficient = –2.0537, $p < 0.01$), though coverage remains limited, particularly in rural areas (only 44.96% insured). Beyond routine expenditures, households faced even more severe financial hardship in the form of CHE. CHE, defined as OOPHE exceeding 20% of household income, affected 67.81% of households, with a strong association with Chikungunya infection ($\chi^2 = 46.42$, $p < 0.001$). Probit regression corroborates this link (coefficient = 1.840, $p < 0.001$). Notably, CHE incidence remained high even among higher-income groups (77.73% for incomes > SDG 5000), indicating that the epidemic's financial shock transcended income categories. Protective factors such as insurance (coefficient = –1.639, $p < 0.001$) and electricity access (coefficient = –0.823, $p = 0.031$) reduced CHE risk, while urban residence (coefficient = 0.811, $p = 0.045$) heightened it, likely due to higher treatment costs and greater disease exposure.

The financial strain imposed by OOPHE and CHE also translated into broader reductions in household welfare, most notably in consumption levels. Ordered logit regression reveals that rising OOPHE significantly decreased the probability of belonging to higher consumption categories (coefficient = –0.153, $p = 0.077$), reflecting income losses from illness-related work disruptions and reduced disposable income. This effect is particularly acute in a context where poverty rates already exceed the national average, pushing vulnerable households further into deprivation. Although higher income levels increased consumption (e.g., coefficient = 5.541 for incomes > SDG 5000, $p < 0.01$), these gains were insufficient to counterbalance the economic strain imposed by the epidemic.

In response to these financial shocks, households adopted various coping mechanisms. Interventions should aim at improving epidemic preparedness and financial risk protection in Kassala State. Strengthening rural health infrastructure, through investments in sanitation, vector control, and health education, is critical for reducing disease transmission and improving health outcomes. Expanding insurance coverage, particularly for low-income and rural populations, is essential to mitigate OOPHE and reduce the incidence of CHE. Additional interventions, such as mobile clinics, subsidized healthcare, and income-support or microcredit programs, are also necessary to enhance access and build resilience. Future research should explore long-term welfare impacts through longitudinal studies and simulation models to inform evidence-based strategies.

In conclusion, the Chikungunya epidemic in Kassala State constituted a major health and economic shock, with disproportionately severe consequences for rural, low-income, and less-educated households. The epidemic exposed the intersection of environmental risks, socioeconomic vulnerabilities, and health system inadequacies. Addressing these structural deficiencies is vital to bolstering household resilience and mitigating the impact of future public health crises, thereby fostering a more inclusive and sustainable health system.

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Appendix

Appendix A: Definition of Variables Used in the Analysis

Variable	Definition and Coding
OOPHE	Ordered categorical variable of out-of-pocket health expenditure: 1 = no expenditure, 2 = < SDG 100, 3 = SDG 100–500, 4 = SDG 500–1000, 5 = SDG 1000–2000, 6 = > SDG 2000.
CHE	Binary variable indicating catastrophic health expenditure (out-of-pocket payments > 20% of household income): 1 = yes, 0 = no.
Chikungunya	Household member infected with Chikungunya: 1 = yes, 0 = no.
Health status	Self-reported health condition of household head: 1 = good/very good, 0 = poor/fair.
Insurance	Health insurance coverage: 1 = insured, 0 = uninsured.
Marital status	Marital status of household head: 1 = married, 0 = otherwise.
Household size	Total number of household members.
Number of toilets	Number of functioning toilets in the household.
Years of schooling	Years of formal education completed by the household head.
Gender of head	Gender of household head: 1 = male, 0 = female.
Urban	Residence location: 1 = urban, 0 = rural.
Age of head	Age of household head in years.
Over 60 age members	Presence of household members aged over 60: 1 = yes, 0 = no.
Electricity access	Access to public electricity: 1 = yes, 0 = no.
Number of rooms	Number of rooms in the dwelling.
Cost of transportation	Monthly transportation costs for accessing health services (in SDG).
Household monthly income	Ordered categorical income classification: 1 = < SDG 500, 2 = SDG 500–1500, 3 = SDG 1500–2500, 4 = SDG 2500–3500, 5 = SDG 3500–5000, 6 = > SDG 5000.
Morbidity	Whether household members sought any medical care (hospital/clinic/traditional healer) in the past month: 1 = yes, 0 = no.
Water access	Access to improved water source: 1 = yes, 0 = no.
Proximity	Household located within Less than 15 minutes of health facility: 1 = yes, 0 = no.
Asset	Dwelling ownership status: 1 = owned or inherited by the household head, 0 = otherwise.
Financial Support	Whether household sought financial help from others to cover health expenses: 1 = yes, 0 = no.
Consumption	Ordered categorical household consumption: 1 = < SDG 500, 2 = SDG 500–1500, 3 = SDG 1500–2500, 4 = SDG 2500–3500, 5 = SDG 3500–5000, 6 = > SDG 5000.
Income_1500_2500	Monthly household income between 1500 and 2500 SDG (1 = yes, 0 = no)
Income_2500_3500	Monthly household income between 2500 and 3500 SDG (1 = yes, 0 = no)
Income_3500_5000	Monthly household income between 3500 and 5000 SDG (1 = yes, 0 = no)
Income_above_5000	Monthly household income above 5000 SDG (1 = yes, 0 = no)