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SPATIAL EPIDEMIOLOGY OF CHOLERA IN KENYA: AN EIGHT-YEAR ANALYSIS OF OUTBREAK DISTRIBUTION FROM 2015 TO 2023

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SPATIAL EPIDEMIOLOGY AND DISTRIBUTION OF CHOLERA OUTBREAKS IN KENYA, 2015–2023

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ABSTRACT

Background: **Cholera hotspot mapping is critical in the prioritization of interventions to cholera outbreaks in various settings. This study aimed to map cholera hotspots in Kenya between 2015 and 2023.**
Methods: **The study used a descriptive cross-sectional design using the National Cholera case linelist and bacterial culture and serology of *Vibrio cholerae* obtained from the National Public Health Laboratory. Cholera cases were mapped using ArcGIS pro to generate cholera hotspots on the basis of Mean Annual Incidence (MAI) and persistence.**
Results: **A total of 42,850 cholera cases were line listed with Nairobi County bearing the highest burden (24.8%) while Garissa county showed the highest Mean Annual Incidence (MAI) (163.8/100,000). The five high burden counties, are; Nairobi, Garissa, Wajir, Mandera and Tana River, accounting for 63.4% (27,169) of all the cases. Spatial and temporal analysis of the cholera outbreak, further identified Dadaab, Embakasi East, Embakasi West and Kibra as high priority sub-counties. Significant temporal variation in incidence was observed with 2015 and 2022 having the highest MAI while no cases were reported in 2019 and 2021. Majority of cholera patients who succumbed to cholera were male (67.6%) ($\chi2$ = 19.734, df=1, p< 0.001). Furthermore, age was significantly associated with vital status with the mean age of cholera patients who died being higher than that of the survivors (p<0.05).**
C*onclusion*: **This study highlights the importance of spatial analysis in identifying cholera hotspots to guiding targeted interventions. The study recommends periodic cholera hotspot mapping and enhanced cholera surveillance to guide prioritization of key preventive strategies or interventions.**
Keywords; **Cholera, GIS, Cholera Hotspots, Kenya, Disease Surveillance. (Word count:254)**

INTRODUCTION

Globally, cholera has been a public health concern for centuries with six pandemics causing millions of deaths since the 19th century. The disease has been estimated to account for approximately 1.3 to 4 million cases and 21,000 to 143,000 deaths annually (1). Evidence suggests that the disease disproportionately affects vulnerable communities exposed to insecurity, conflict, poverty and climate change (2). Cholera cases have been rising worldwide since 2021 with Africa particularly being significantly affected accounting for 90% of all the reported cases in 2023 and experiencing a significant outbreak in 2024 with nearly 400,000 cases and over 7,000 fatalities (3,4). A significant challenge in controlling these outbreaks especially in low and middle income countries such as Kenya is the persistent lack of comprehensive hotspot mapping which hinders targeted interventions and resource allocation (5).

Climate change further compounds the challenges associated with disease control through events such as drought and floods which triggers cholera outbreaks by destroying WASH infrastructure and contaminating water sources (6). This results to widespread displacement and increased risk of cholera as seen in the Horn of Africa and Malawi whereby over 36 million people were affected by drought hence increasing the number of climate refugees (3,7). Additionally, violence and political instability worsen these outbreaks by limiting access to clean water and impeding disease control and management efforts by government and NGOs (2,7).

In Kenya, Cholera is a significant public health problem and is one of the diseases prioritized under the Kenya Integrated Disease Surveillance and Response (IDSR) strategy. Since the first case was detected in 1971 in the Turkana district, Kenya has continuously experienced cyclic and periodic cholera epidemics, which have occurred every five to seven years (8). For instance, surveillance data from the Kenya Ministry of Health have indicated that Kenya has experienced annual outbreaks, with the highest number of cases reported in 2015, which declined in 2016, followed by an increase from 2017 to 2019 (5). Cholera incidence and burden vary over time, and surveillance data capture these variances. Surveillance and reporting of cholera cases have been identified by the Global Task Force on Cholera Control (GTFCC) as one of the pillars that form the basis for effective control of cholera (9). Surveillance data are usually utilized for decision-making and inform the prioritization of cholera control interventions in the country. Thus, the present study aimed to map cholera hotspots in selected counties in Kenya by using epidemiological data from 2015 to 2023.

METHODS

Study design

This study adopted a descriptive cross-sectional design. It assessed cholera surveillance data from 2015 to 2023 and the sociodemographic factors associated with cholera cases.

Study area

This research was conducted in Kenya.

Sample size determination and Sampling technique

Census sampling was employed in this study, including all reported cholera cases from all counties in Kenya from 2015 to 2023, allowing for a comprehensive and accurate assessment of the spatial and temporal distributions of cholera outbreaks. This approach ensures that no relevant data is excluded, which is crucial for mapping trends and identifying persistent or emerging hotspots.

Inclusion and exclusion criteria

The study included confirmed cholera cases reported in Kenya between 2015 and 2023 with complete geographic identifiers. Cases with missing location data, duplicate entries, or reported outside the study period were excluded.

Quality control

To ensure quality of data used comprehensive data quality measures were implemented. This involved systematic validation checks and data cleaning protocols during the merging of cholera line list data. Additionally to ensure accuracy and completeness of geographical identifiers cross referencing of counties and sub counties with geocodes generated using Google Maps.

Data collection tools and procedures

Epidemiological data were obtained using a data abstraction form. Cholera case data was extracted from the National cholera case linelist in the Division of Disease Surveillance and Response (DDSR) at the Ministry of Health, Kenya. The National Cholera Line list covering the entire country during the study period was consolidated. The cholera line list was collected and collated from all counties. The consolidated or compiled line list of cholera cases was cleaned and georeferenced based on their geographical location. The population of each county and sub-county was obtained from the Kenyan National Bureau of Statistics (KNBS).

Data analysis

The cholera case data from various sources was cleaned and checked for duplicates. Cases were entered into SPSS version 25 for descriptive analysis. Trends from 2015 to 2023 were analyzed to assess seasonality and geographic distribution on the basis of Mean Annual Incidence (MAI) and persistence. GIS coordinates of the patients' residential locations were used to construct a graphical map of the distribution of V. cholerae isolates using ArcGIS pro. One way ANOVA was used to examine temporal differences.

Ethical consideration

Ethical approval and authorization to conduct the study were sought from the Mount Kenya University Ethical Review Committee (Ref: MKU/ISERC/4306) and the National Commission for Science, Technology, and Innovation (NACOSTI) (License no: NACOSTI/P/24/39710), respectively. Approval to access the cholera line list data was obtained from the Kenya Ministry of Health Division of Disease Surveillance and Response. Additionally to ensure data privacy and protection no personal identifiers including names, addresses and contact information or any other directly identifying information were collected or extracted from the secondary data sources.

RESULTS

Distribution of Cholera Outbreak in Kenya by County, 2015 to 2023

From 2015 to 2023 there was a total of 42,850 cholera suspected cases countrywide. Nairobi County had the highest cholera burden (24.8%) followed by Garissa (15.7%) and Wajir (10.2%), while Kitui (0.1%) and Narok Counties (0.1%) had the least burden. This data highlights temporal differences in cholera cases in Kenya. Nairobi County documented the highest burden potentially because of the dense urban population, informal settlements whith poor sanitation and high mobility which facilitates disease spread. In contrast the low cholera burden in Kitui and Narok counties could potentially be due to lower population densities and under reporting of cholera cases.

In regards to MAI analysis Garissa County (163.8/100,000) had the highest values, followed by Wajir (104.7/100,000), Mandera (58.6/100,000), Tana River (48.4/100,000) and Nairobi County (23.4/100,000) (Figure 1). On the other hand, the five counties with the least cholera MAI included Nyeri, Kwale, Nandi, Kitui, and Narok.

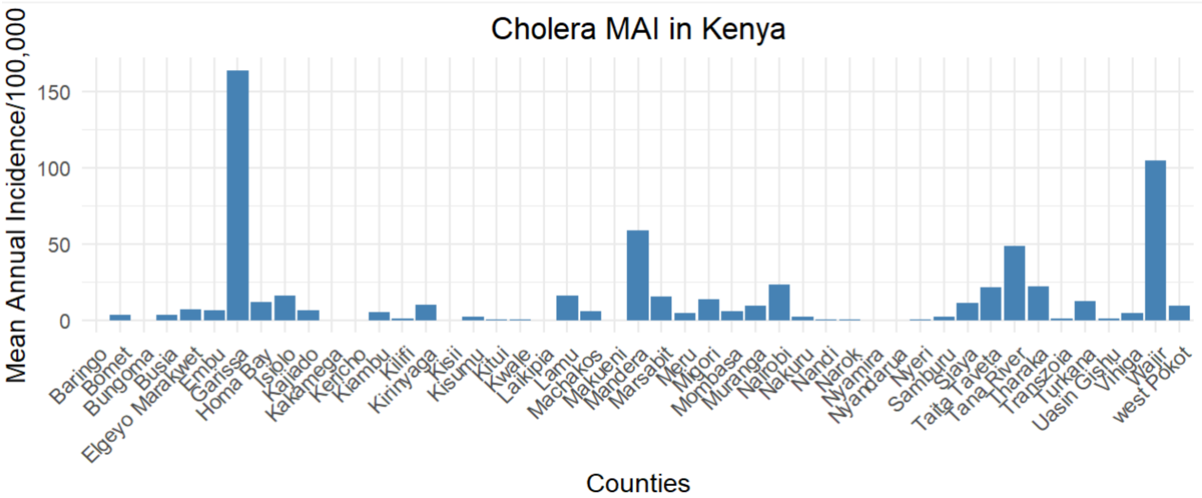

Figure 1: Cholera Mean Annual Incidence (MAI) in Kenya by County, 2015 to 2023

Cholera Annual Incidence Rate in Kenya from 2015 to 2023

As shown in Table 2, there was a significant temporal difference in cholera MAI between 2015 and 2023 (p= 0.047). The highest annual cholera incidence was in 2015, followed by 2023, whereas no cases were documented in 2019 and 2021.

Table 2: Cholera Mean Annual Incidence in Kenya by Year (2015 and 2023)

Year	Annual incidence/ 100,000	SD
2015	135.79	469.38
2016	81.77	183.98
2017	39.35	104.29
2018	54.00	230.64
2019	0	0
2020	40.19	79.37
2021	0	0
2022	67.41	192.46
2023	82.78	150.82
P value	0.047	

[SD] standard deviation

Cholera Annual Incidences by Sub-County

Out of the 42,850 cholera suspected cases countrywide cases the five high burden counties i.e. Garissa, Wajir, Mandera, Tana River and Nairobi Counties accounted for 63.4% of all the cases (27,169). Furthermore there was spatial and temporal differences in cholera incidences as shown in figure 2. In 2015, Wajir East sub-county had the highest annual cholera incidence (2663.25/100,000). In 2016, 2017, 2018, 2022, and 2023, Dadaab Sub County had the highest annual cholera incidence of 640.85/100,000, 577.11/100,000, 1287.27/100,000, 783.65/100,000, and 611.50/100,000, respectively while in 2020 Embakasi East sub-county had the highest annual cholera incidence (365.29/100,000). The consistently high incidences in Dadaab sub county is alarming. The sub-county hosts large refugee camps and thus the data suggests that humanitarian crises and conditions in refugee or IDP settlements are key drivers of cholera outbreaks. The shift of high incidence to Embakasi East sub county in 2020 implies that cholera hotspots can change over time thus public health responses need to be flexible and adaptive. In Ijara, North Horr, Saku, and Laisamis there were no reported cholera cases between 2015 and 2023. The absence of documented cholera cases could potentially be due to effective ongoing control measures or under reporting due to limitations in surveillance.

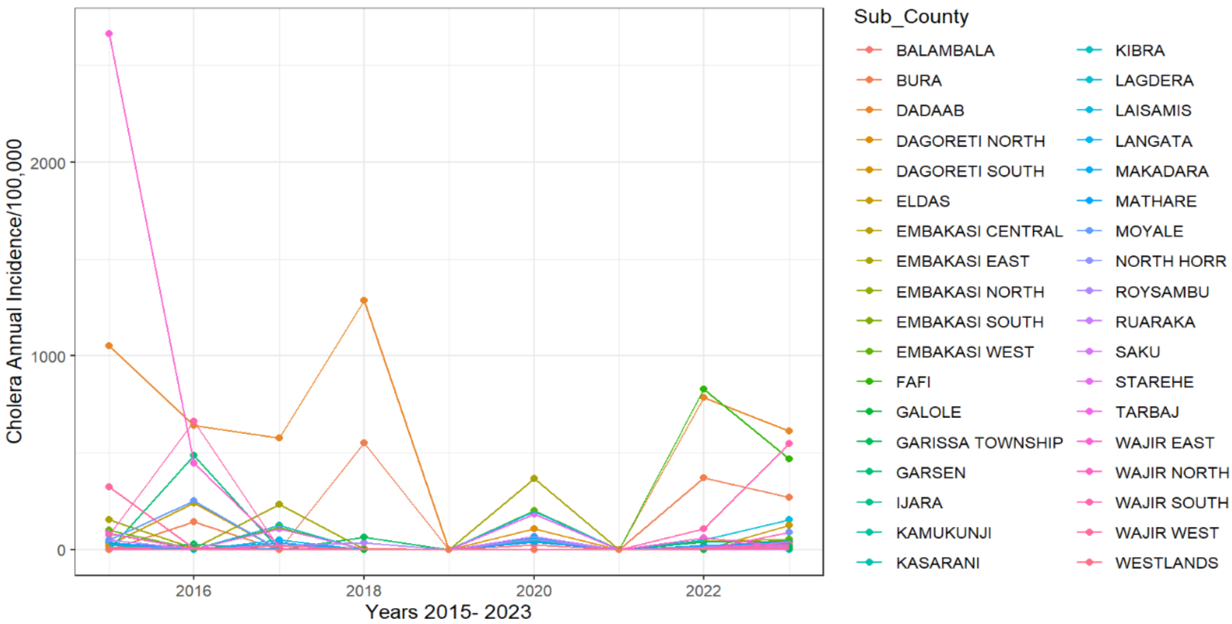

Figure 2: Cholera Annual Incidence in Kenya by Sub-County between 2015 to 2023

Mean Annual Incidence (MAI) for Cholera Outbreak in sub counties in Nairobi, Garissa, Wajir, Mandera and Tana River counties

Using MAI and persistence, four sub-counties, Dadaab, Embakis East, Embakasi West, and Kibra, were classified as high priority, as shown in Table 3 and Figure 3. Using the same criteria, five sub-counties–Bura, Wajir East, Wajir South, Fafi, and Garsen–were classified as medium to low priority. Additionally, 8 and 17 sub-counties were classified as medium and low priority, respectively.

Table 3: Classification of cholera cases by sub-county using MAI and cholera persistence in in Nairobi, Garissa, Wajir, Mandera and Tana River counties

Type of hotspot	Sub County	Mean annual incidence /100, 000 (MAI)	Proportion of years reporting cholera (persistence)	Interpretation	Priority level
T1	Dadaab	550.28	66.67	High incidence and high persistent	High
	Embakasi East	94.79	77.78		
	Embakasi West	53.54	66.67		
	Kibra	51.01	77.78		
T2	Bura	148.10	44.44	High incidence and low persistence	Medium
	Wajir East	356.00	55.56		
	Wajir South	155.57	55.56		
	Fafi	144.12	22.22		
	Garsen	55.82	22.22		
T3	Starehe	47.59	77.78	Low incidence and high persistence	Medium to low
	Dagoretti North	29.68	66.67		
	Makadara	19.01	77.78		
	Ruaraka	18.57	66.67		
	Kamukunji	16.52	66.67		
	Mathare	16.00	66.67		
	Kasarani	13.97	66.67		
	Roysambu	13.13	66.67		
T4	Moyale	43.77	33.33	Low incidence and low persistence	Low
	Eldas	43.14	33.33		
	Wajir West	40.05	44.44		
	Lagdera	22.63	22.22		
	Garissa Township	18.46	44.44		
	Langata	15.01	55.56		
	Wajir North	9.92	11.11		
	Embakasi central	6.63	22.22		
	Westlands	6.34	55.56		
	Embakasi South	4.02	22.22		
	Embakasi North	3.61	22.22		
	Tarbaj	3.22	44.44		
	Dagoretti South	2.62	22.22		
	Galole	1.18	22.22		
	Balambala	0.82	22.22		
	Ijara	0	0		

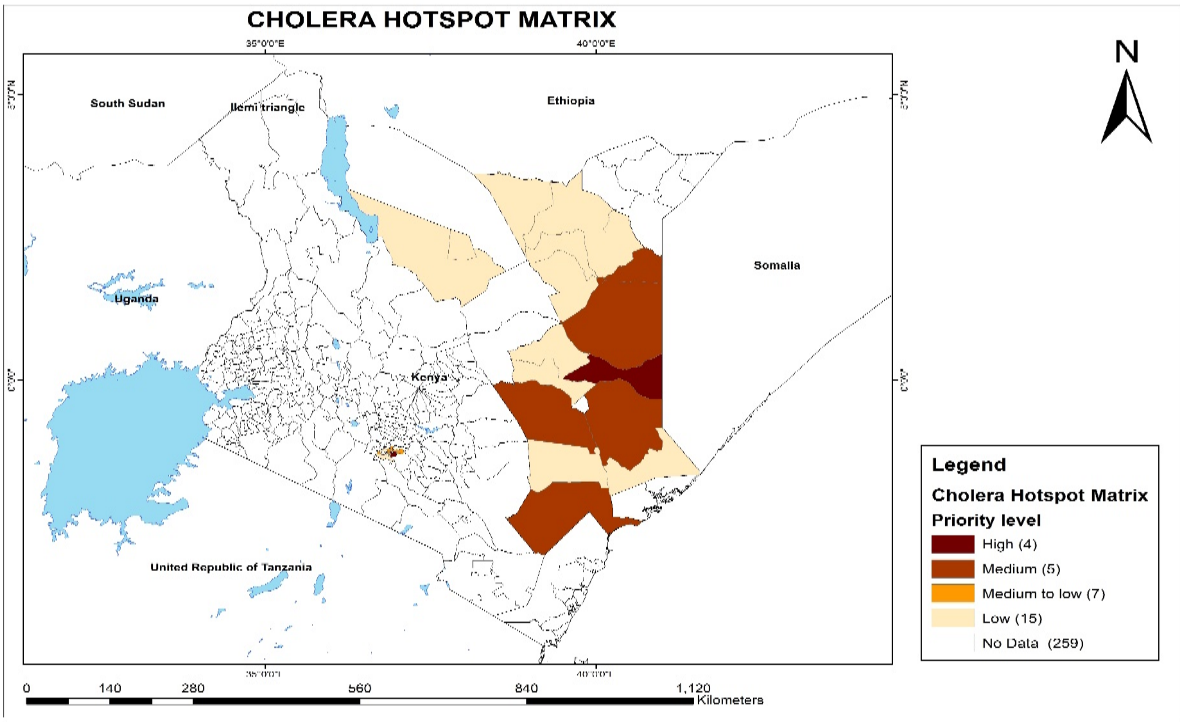

Figure 3: Cholera hotspot map for Nairobi, Garissa, Wajir, Mandera and Tana River counties in Kenya based on MAI and persistence data between 2015 and 2023.

Association between socio-demographic characteristics and vital status

Table 4 shows a significant association between gender and vital status ($\chi2$ = 19.734, df=1, p< 0.001). The majority of cholera cases (67.6%) who succumbed to cholera were male, while a third (32.4%) were female. The findings suggests that men are disproportionately affected by cholera potentially due to factors such as poor health seeking behavior and low levels of hygiene as compared to females. Additionally, age had a significant association with vital status (t=-3.968, df=12658, p<0.001). The mean age of cholera patients who died was higher (29.52 ± 22.34 years) as compared to that of those who were alive (23.88 ± 19.92 years).

Table 4: Association between socio-demographic factors and vital status among cholera cases documented in Nairobi, Garissa, Wajir, Mandera and Tana River counties in Kenya between 2015 and 2023.

	Vital status			
	Dead f(%)	Alive (f)	$\chi2$	P value
Gender				
Male	140(67.6)	6485(52.1)	19.734	<0.001
Female	67(32.4)	5966(47.9)		
Age				
Mean	29.52	23.88		
std	22.34	19.93		

T static	-3.968			
P value	<0.001			

DISCUSSION

Kenya recorded 42,850 suspected cholera cases between 2015 and 2023 with temporal disparities across counties with Nairobi County having the highest burden followed by Garissa County while Kitui and Narok had the least burden. The high burden in Nairobi County could potentially be associated with poor sanitiation, open sewage systems and overcrowding in urban settlements such as Kibera and Mathare slums (10). Furthermore, Nairobi is a major transport hub being the capital city of the Kenya, characterized with high population movement in and out, which potentially facilitates rapid spread of cholera (11). High burden in ASAL counties and humanitarian zones may majorly be due to climate change parameters such as drought and floods which affects water quality and consequently results in huge reliance on contaminated water sources (12). The MAI data revealed disparities in cholera burden across the county with Garissa having the highest MAI (163.8/100,00) followed by Wajir County while Kitui and Narok had the least MAI. Poor WASH infrastructure, influx of refugees and climate shocks could explain the high MAI in Garissa county (13). Additionally cross border transmission and nomadic way of life could be associated with the high MAI in Wajir and Mandera counties (14).

Five high burden counties i.e. Nairobi, Garissa, Wajir, Mandera and Tana River accounted for a substantial 63.4% (27,169) of all nationwide cholera cases between 2015 and 2023 indicating a persistent spatial and temporal cholera burden in Kenya. This disproportionate distribution shows that cholera transmission is not uniform in the country but is majorly present in hotspot areas mainly in arid and semi arid lands (ASALs) and highly populated urban settings such as Nairobi. Further, the lower MAI in Kitui and Narok counties indicates the spatial differences in cholera transmission. The study findings aligns with a Kenyan study which documented that cholera is mainly present in areas with poor water sanitation and hygiene (WASH) infrastructure, huge population and in refugee settlements (5). The spatial understanding is important for enhancing public health interventions and focusing resources such as Oral Cholera Vaccination (OCV) and improvements of WASH infrastructure in high burden counties for purposes of cholera control and consequent elimitation.

The classification of sub-counties into high, medium and low priority level using MAI and levels of persistence is critical in guiding implementation of targeted cholera control interventions in hotspot regions. The present study identified Dadaab, Embakasi East, Kibra, and Embakasi West sub-counties as high priority areas. Dadaad is a well known refugee settlement and is regularly affected by high cholera burden due to poor humanitarian conditions such as overcrowding, poor WASH infrastructure and regional instability characterized by cross border movement and influx of refugees (15). For instance conflict and drought in Somalia and flooding in South Sudan resulted to a significantly high number of refugees trooping to the Dadaab refugee camp in 2022 with considerable cholera cases being reported among new arrivals (16). Further evidence suggests that climate change, which is characterized by severe droughts and flooding propagate the spread of cholera (17).

Embakasi East, Embakasi West and Kibra which were also identified as high priotity sub-counties are densely populated urban informal settlements in Nairobi County. These informal settlements are persistently affected by cholera outbreaks majorly caused by poor urban planning, poor sanitation and inadequate access to safe drinking water (18). Evidence suggests that crowded living areas, such as slum dwellings, contribute to cholera outbreaks (19). Further a World Bank report indicated that, as the population grows, poor urban dwellers are pushed into informal and low-income settlements with little or no sanitation and water (20). For instance, informal urban settlements such as Kibra are faced with poor sanitation, congestion, poverty among inhabitants, and unreliable sewerage systems, which increase the risk of the spread of cholera (21). The findings underscores the need for context specific interventions which may include; targeted OCV, improvement of WASH infrastructure in refugee settings and enhanced waste control and management in urban slums.

A considerable number of medium-priority sub-counties, that is, two in Wajir Sub County, two in Tana River County, and one in Garissa County were also identified. While these sub-counties experience low MAI and persistence there is still need for preparedness and disease surveillance. The occurrence of cholera in medium priority areas could be linked to environmental triggers such as floods, drought or movement of people from a highly endemic neighbouring sub-counties. For instance the influx of refugees into Wajir County from Somalia and Ethiopia could explain the identification of the county as a cholera hotspot (5). Furthermore the lack of portable drinking water due to drought and flooding in Tana River could potentially explain the high incidence and persistence of cholera in this county (22).The mapping of cholera hotspots is critical in enabling pulic health initiatives to optimize resource distribution hence ensuring that high priority areas receive intensive and sustained multi sectoral interventions. Additionally medium and low priority areas may benefit from increased surveillance, rapid response and targeted preventive measures to prevent future occurrence of cholera outbreaks (5).

Interestingly, Ijara sub-county in Garissa County did not report any cases between 2015 and 2023. This observation could be potentially due to government Oral Cholera Vaccination interventions in Garissa County among other counties (23). Furthermore, the lack of cholera cases could also be due to underreporting, health promotion education, and the distribution of water treatment solutions by non-governmental organizations (NGOs) operating in the County (24). Evidence suggests that cholera is a neglected and under-reported disease, potentially due to limitations in surveillance systems, stigma, and fear of the effect on trade and tourism (2).

Age was significantly associated with vital status, whereby the mean age of cholera patients who died was higher than the mean age of those who were alive. This observation could be majorly be associated with differences in exposure patterns, immune responses, and health-seeking behaviors across age groups. For instance, immunosenescence, a phenomenon characterized by a decrease in immune response with an increase in age, has been reported in humans starting in middle age (25). This phenomenon has been associated with the increased severity of infectious diseases, such as cholera and influenza, and the increased prevalence of cancer (26,27). For instance, a Nigerian study reported high cholera case fatality rates in older adults (28). Additionally, evidence suggests that delayed healthcare seeking behavior among elderly individuals due to dismissal of cholera symptoms as common diarrhea, poor economic status and physical immobility may explain the study findings (29).

Gender had a significant influence on vital status among the cholera cases, whereby the majority of cholera patients (67.6%) who had succumbed to cholera were male, while close to a third (32.4%) were female. The findings indicate a notable gender disparity in cholera mortality, with males being disproportionately affected compared to females. Similarly, according to a study assessing global trends of cholera between 1990 and 2019, the rate of cholera mortality in the African region was higher in males (12.29/ 100,000) than in females (10.53/100,000) (30). A Zimbabwean study also reported that men had higher odds of dying from cholera than did women (31). During the 2018 cholera pandemic in Nigeria, sex was significantly associated with clinical outcomes, whereby the number of males who succumbed to cholera (54.72%) was higher than that of females (45.28%) (32).

Limitations of the study

One expected limitation of this study was the potential for underreporting or inconsistencies in cholera surveillance data across different counties and years, which may have affected the accuracy of trend and hotspot analyses. To overcome this limitation the study included both suspected and laboratory confirmed cholera cases. Furthermore to account for potential gaps in the data, cross verification was done with official reports by Kenya MOH. Furthermore, analysis was done at sub-county level which is a lower administrative unit where epidemiological and demographic data are consistently available. Additionally thorough data cleaning was done to clear the inconsistencies and gaps in the dataset.

Conclusion

The cholera burden in Kenya between 2015 and 2023 shows geographical disparities with Nairobi county reporting the highest burden (24.8%). Garissa County reported the highest MAI (163.8/100,000) highlighting the vulnerabilities in ASAL and humanitarian regions. The five high burden counties accounted for close to two thirds (63.4%) of all cholera cases reported nationwide. Dadaab sub-county consistently experiencing alarming high MAI while other high priority sub-counties were in informal urban settlements. The findings further highlights an association between cholera with humanitarian settings as well as a disproportionate effect on males and older individuals. These findings are vital in informing a proactive and targeted approach rather than a nationwide approach. Further stakeholders in health should ensure surveillance, enhancement of WASH infrastructure and health education in the identified high priority sub-counties especially in refugee camps and informal urban areas. This targeted approach is in line with the GTFCC global roadmap to 2030 which emphasis on data driven strategies to allocate resources in hotspots with the aim of significantly reducing the cholera cases and deaths.

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Conflict of interest: The authors declare no conflict of interest.

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