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Artificial Intelligence in Predicting Diarrhea Outbreaks in African Cities

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ABSTRACT

Diarrheal diseases remain a leading cause of morbidity and mortality in African urban centers, particularly affecting children in informal settlements where inadequate sanitation, unsafe water, and overcrowding prevail. Traditional surveillance systems often rely on retrospective health data, limiting timely outbreak detection and response. This review explores the potential of artificial intelligence (AI) in predicting diarrheal outbreaks in African cities, highlighting machine learning, deep learning, and data fusion techniques that integrate diverse data streams, including environmental, climatic, demographic, and health facility records. Case studies from Nigeria, Kenya, and South Africa illustrate how AI-driven models can improve early warning systems, optimize resource allocation, and reduce disease burden. The review also examines challenges such as data limitations, infrastructural constraints, ethical concerns, and capacity gaps, while identifying opportunities for hybrid modeling, community engagement, policy integration, and regional collaboration. Strategic application of AI promises proactive, data-driven public health interventions, contributing to resilient urban health systems and improved outcomes for vulnerable populations.

Keywords: Artificial intelligence; Machine learning; Diarrheal diseases; Outbreak prediction; African cities; Urban health.

INTRODUCTION

Diarrheal diseases remain among the most pressing public health challenges worldwide, particularly in low- and middle-income countries where infrastructure limitations intersect with rapid urbanization, poverty, and climate variability [1]. Despite being largely preventable through improved sanitation, access to clean water, and health education, diarrhea continues to cause significant morbidity and mortality across sub-Saharan Africa [2]. According to the World Health Organization (WHO) [3], diarrheal illnesses are the second leading cause of death among children under five, killing an estimated 480,000 children annually. This burden is disproportionately felt in Africa, where poor sanitation and contaminated water sources create fertile grounds for recurrent outbreaks.

In Africa's urban settings, the problem is particularly acute. Cities such as Kampala, Lagos, and Nairobi face rapid and largely unplanned population growth, which exerts immense pressure on existing sanitation and water supply systems [4]. Informal settlements which are home to millions of urban poor, are often excluded from formal waste management and piped water services, leading to reliance on unsafe water sources and unhygienic waste disposal practices. Coupled with limited healthcare access, these conditions create a cycle of vulnerability where diarrheal outbreaks occur frequently and spread rapidly. The urban poor, especially children, remain the most affected group.

Traditional epidemiological approaches to diarrhea surveillance and outbreak detection are heavily reliant on retrospective data collected from health facilities [5]. This includes hospital records, clinical reports, and laboratory confirmation of cases. While useful, such data are inherently reactive; by the time outbreaks are detected and interventions deployed, significant transmission has often already occurred. In addition, underreporting and data

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delays further weaken the effectiveness of conventional surveillance systems. This reality underscores the urgent need for innovative, proactive, and data-driven approaches that can anticipate outbreaks and trigger timely public health responses [6].

Artificial intelligence (AI), through techniques such as machine learning (ML), deep learning (DL), and data fusion, offers promising pathways for strengthening diarrheal disease surveillance. Predictive analytics can process diverse and real-time data streams including weather patterns, environmental sanitation indicators, water quality measures, mobility data, and health facility reports to generate early warning signals of potential outbreaks [7]. Unlike traditional statistical models, AI approaches can capture complex, nonlinear relationships among multiple factors that influence disease transmission. For example, a deep learning model could integrate rainfall data with geospatial information on sewage overflow to predict diarrhea hotspots in a city. Similarly, machine learning algorithms could leverage satellite imagery, demographic patterns, and mobile health data to anticipate risks at the community level [8].

Globally, AI-driven outbreak prediction has demonstrated considerable potential in detecting infectious diseases such as cholera, influenza, and COVID-19. However, its application to diarrheal diseases in African urban contexts remains relatively limited and underexplored. Existing studies often focus on specific pathogens, such as Vibrio cholerae, or rely on datasets from high-income countries with advanced surveillance infrastructure [9]. There is, therefore, a critical knowledge gap in understanding how AI tools can be tailored to African realities, particularly in urban environments where infrastructural deficits, informal settlements, and climate variability intersect to drive disease risk. This review situates itself at the intersection of public health, technology, and urban development. It seeks to synthesize current evidence on the use of AI for predicting diarrheal outbreaks, with a focus on African cities where vulnerability is highest. By examining existing models, their predictive accuracy, data requirements, and contextual applicability, the review highlights both opportunities and challenges in leveraging AI to address one of Africa's most persistent health burdens [10]. Diarrhea persists as a leading cause of morbidity and mortality in Africa despite decades of interventions aimed at improving sanitation, water access, and health education. The burden is particularly concentrated in urban settings where infrastructure cannot keep pace with rapid population growth. Informal settlements often lack sewerage systems, safe water, and regulated waste disposal, creating persistent risks for diarrheal disease transmission [11]. Conventional surveillance approaches are inadequate for timely outbreak detection and response. Reliance on retrospective health data means outbreaks are often identified only after they are widespread, reducing the effectiveness of interventions. Moreover, challenges such as underreporting, limited laboratory capacity, and bureaucratic delays hinder data accuracy and timeliness [12].

At the same time, the increasing availability of diverse data streams ranging from satellite imagery and mobile health records to climate and demographic data remains underutilized in Africa's public health systems. Artificial intelligence offers an opportunity to harness these data for predictive modeling, yet its application to diarrheal disease remains poorly developed [13]. Without exploring and contextualizing AI-driven prediction tools, African cities will continue to face preventable diarrheal outbreaks, with devastating consequences for child health, economic productivity, and overall urban well-being. This review is guided by a set of specific objectives aimed at enhancing the understanding and application of artificial intelligence (AI) in managing diarrheal diseases within African urban environments. First, it seeks to examine the current burden of diarrheal disease, with attention to critical underlying drivers such as inadequate sanitation, poor water quality, and rapid population growth that exacerbate disease prevalence in densely populated cities. Second, the review explores existing AI-based approaches, including machine learning, deep learning, and data fusion, used globally for predicting outbreaks of diarrhea and other infectious diseases. In doing so, it critically analyzes the applicability, strengths, and limitations of these models when deployed in the unique socio-environmental contexts of African urban areas. Furthermore, the study identifies gaps in current research, proposing directions for future studies that could strengthen the integration of AI into disease surveillance and early warning systems. Finally, it evaluates the potential for embedding AI-driven predictions within African public health frameworks to enable timely and targeted interventions. To address these objectives, the study is framed around research questions that probe the epidemiological and environmental determinants of diarrheal disease, the global application of AI in outbreak prediction, and the challenges and opportunities of translating these approaches into African contexts. It also examines the literature for knowledge gaps in AI-based diarrhea prediction and explores how predictive tools can be adapted and scaled for effective surveillance and response in urban African settings. The significance of this study spans multiple levels. For policymakers, it underscores how AI can complement traditional surveillance systems to improve early detection, resource allocation, and outbreak prevention. For researchers, it highlights opportunities for interdisciplinary collaboration and the need for context-specific AI models. At the community level, AI-enabled early warning systems could protect vulnerable populations, particularly children, reduce healthcare costs, and minimize productivity losses. Overall, the study contributes to

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digital health advancement, sustainable urban development, and the achievement of Sustainable Development Goals related to health, water, sanitation, and resilient cities.

Burden of Diarrheal Diseases in African Cities

Diarrheal diseases remain a major public health challenge in African urban centers, disproportionately affecting residents of informal settlements where access to clean water, adequate sanitation, and proper hygiene facilities is limited. In cities such as Lagos, Kampala, and Nairobi, epidemiological studies have documented recurring seasonal spikes in diarrhea cases, often associated with heavy rainfall, flooding, and subsequent contamination of water sources with pathogens. Poor drainage systems and overcrowded living conditions exacerbate the risk of outbreaks, creating environments where infectious agents spread rapidly. Beyond the direct health impacts, diarrheal diseases impose substantial socioeconomic burdens on affected communities. Families face high healthcare costs, which can be catastrophic for low-income households, while productivity losses occur as caregivers spend time attending to sick children and adults [14]. In addition, repeated diarrheal episodes contribute to malnutrition, stunted growth, and increased child mortality, compounding the long-term vulnerability of urban populations. Addressing these challenges requires integrated interventions targeting water, sanitation, and hygiene (WASH) infrastructure, alongside community education, to reduce disease incidence and improve overall urban health resilience..

Role of Artificial Intelligence in Outbreak Prediction

Artificial Intelligence (AI) has the potential to transform outbreak prediction by leveraging complex, multidimensional datasets to provide timely and accurate insights into disease dynamics [15]. Machine learning algorithms, including logistic regression, random forests, support vector machines, and gradient boosting models, have been successfully employed to forecast the incidence of diseases such as diarrhea by analyzing environmental factors, health surveillance records, and demographic information. Deep learning approaches, particularly Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks, further enhance predictive capacity by capturing temporal patterns and trends in outbreak data, enabling public health authorities to anticipate disease spikes weeks in advance. Geospatial AI techniques integrate satellite imagery and remote sensing data to identify environmental hotspots prone to outbreaks, such as regions with poor sanitation, water stagnation, or climate-related vulnerabilities. Additionally, the integration of diverse big data sources, including hospital records, meteorological measurements, water quality indicators, and real-time mobile health reports improves the accuracy and robustness of predictive models [16]. By synthesizing these advanced AI methodologies, public health systems can move from reactive responses to proactive interventions, optimizing resource allocation, guiding vaccination campaigns, and mitigating the impact of infectious disease outbreaks in at-risk communities.

Case Studies and Applications

Several African countries have implemented innovative approaches to understanding and managing diarrhea incidence through predictive modeling and artificial intelligence (AI) applications. In Nigeria, predictive models that integrate rainfall and flooding data have been successfully employed to estimate the likelihood and incidence of diarrhea in informal settlements in Lagos [17]. These models allow public health authorities to anticipate outbreaks following periods of heavy rainfall or flooding, enabling targeted interventions such as sanitation campaigns, distribution of clean water, and emergency medical support. In Kenya, mobile health platforms combined with machine learning algorithms have significantly improved the early reporting and tracking of diarrheal cases within Nairobi's slum areas. This integration allows for real-time surveillance, enabling healthcare providers to respond quickly to emerging hotspots and optimize resource allocation. Meanwhile, in South Africa, AI-driven climate-health models have demonstrated substantial potential in forecasting diarrhea peaks linked to extreme weather events, including heatwaves and the rainy season [18]. These models facilitate proactive public health planning, ensuring that communities at risk receive timely preventive measures. Collectively, these case studies illustrate how the integration of climate data, machine learning, and digital health platforms can enhance predictive accuracy, strengthen early warning systems, and ultimately reduce the burden of diarrheal diseases across urban informal settlements in Africa.

Challenges in AI Implementation

Implementing artificial intelligence (AI) in urban and public health contexts in African cities faces multiple interrelated challenges. First, data limitations pose a significant barrier, as inconsistent reporting practices, missing datasets, and low levels of digitization prevent the development of robust AI models. Without comprehensive and high-quality data, predictive algorithms may produce biased or unreliable results. Second, infrastructure constraints, including poor internet connectivity, limited server capacity, and inadequate computational resources, restrict the deployment of large-scale AI solutions, especially in resource-limited settings. Third, ethical and privacy concerns arise when AI applications require access to sensitive health, mobility, or personal data, necessitating clear consent procedures, secure data storage, and robust governance frameworks to prevent misuse [19]. Fourth, contextual adaptation is challenging because models trained in one urban environment may not perform well in another, due to variations in population demographics, disease prevalence, and local risk factors. Finally, capacity gaps remain critical; many public health practitioners and municipal staff lack sufficient training in AI and data science, slowing adoption and limiting the integration of AI into routine decision-making processes. Addressing these challenges requires coordinated investment in data infrastructure, capacity building, and context-sensitive model development.

Opportunities and Future Directions

The integration of advanced technologies, particularly artificial intelligence (AI), into public health systems presents numerous opportunities to enhance disease prevention, monitoring, and management. One critical area for development is strengthening data systems; substantial investments in real-time disease surveillance, continuous water quality monitoring, and comprehensive digitized health records are essential to improve the timeliness and accuracy of public health responses [20]. Additionally, hybrid models that combine AI algorithms with traditional epidemiological methods offer the potential to significantly enhance predictive capabilities, allowing for earlier identification of disease outbreaks and more informed decision-making [21]. Community engagement is another promising avenue; by leveraging widely available mobile phones and crowdsourced health data, public health authorities can improve early detection and response at the grassroots level. For sustainable impact, policy integration is crucial, with governments incorporating AI-based predictive models into national disease surveillance frameworks to ensure consistency, scalability, and long-term adoption. Finally, regional collaboration across African cities through the sharing of AI tools, datasets, and technical expertise can foster innovative, context-specific solutions that address common public health challenges, paving the way for resilient, data-driven health systems across the continent.

CONCLUSION

Artificial intelligence offers transformative potential in predicting and mitigating diarrheal disease outbreaks in African urban settings, particularly within informal settlements where traditional surveillance systems are insufficient. By integrating diverse data sources ranging from environmental and climatic indicators to health facility records and mobile health reports AI-driven models can generate timely, accurate early warnings, enabling proactive public health interventions. Case studies from Nigeria, Kenya, and South Africa demonstrate that machine learning and deep learning approaches can enhance outbreak prediction, optimize resource allocation, and reduce morbidity and mortality. However, significant challenges remain, including limited data quality, infrastructural constraints, ethical considerations, and capacity gaps among public health practitioners. Addressing these barriers requires investment in digitized health systems, policy integration, and regional collaboration to share tools and expertise. Overall, the strategic application of AI within African cities promises more resilient, data-driven public health systems capable of protecting vulnerable populations and improving urban health outcomes.

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