American Journal of Biology and Natural Sciences
https://biojournals.us/index.php/AJBNS
ISSN: 2997-7185

Evaluating the Effectiveness of Health Information Systems in Enhancing Disease Surveillance and Reporting in Selected Nigerian States

Owoeye James Olasunkanmi, Egbinade Joshua Oluwafemi
Department of Health Information Management, Faculty of Basic Medical Sciences, Adeleke University, Ede

Amin Muyiwa Adeleke
Adeleke University, Ede

Ayinde Abayomi O
Public Health Epidemiology, University of Ibadan

Received: 2025, 15, Jul
Accepted: 2025, 21, Aug
Published: 2025, 10, Sep

Annotation: Introduction: Health Information Systems (HIS) play a critical role in enhancing disease surveillance and reporting, yet their effectiveness in Nigerian states remains underexplored. Strengthening HIS is essential to detect outbreaks early, guide public health interventions, and improve overall health system performance.

Objective: This study evaluated the effectiveness of HIS in strengthening disease surveillance and reporting in Ogun, Osun, and Oyo States, while examining sociodemographic influences and barriers to optimal system use.

Method of Analysis: A cross-sectional survey was conducted among 200 health professionals, including Medical Officers and Disease Surveillance and Notification Officers. Data were analyzed using descriptive statistics and chi-square tests to assess relationships between

sociodemographic characteristics and perceived HIS effectiveness.

Results: The majority of respondents (64.0%) considered HIS tools adequate, 55.0% rated data quality as high, and 60.0% confirmed frequent use of HIS data for decision-making. Significant associations were observed between HIS effectiveness and education level ($p = 0.032$), designation ($p = 0.001$), and years of experience ($p = 0.017$). Major barriers identified were limited funding (69.0%), poor infrastructure (62.0%), and inadequate training (56.0%). Key recommendations included improved funding (78.0%), strengthened ICT infrastructure (74.0%), and regular capacity building (71.0%).

Conclusion: HIS are vital for accurate and timely disease surveillance in Nigeria. Addressing barriers through resource investment, workforce training, and policy support will enhance system effectiveness and improve health security.

Keywords: Health Information Systems, Disease Surveillance, Data Reporting, Nigeria, Public Health, Capacity Building, Health Workforce, Health Infrastructure.

Background to the Study

Infectious and communicable diseases remain a persistent threat to global health and socio-economic development. Outbreaks such as HIV/AIDS, tuberculosis, cholera, influenza, Ebola virus disease, and Lassa fever continue to cause significant morbidity and mortality, particularly in sub-Saharan Africa (WHO, 2018; NCDC, 2021). Beyond their health burden, disease outbreaks exert severe economic and political consequences. For example, the annual economic impact of tuberculosis in India is estimated at over 3 billion US dollars (Rajeswari et al., 1999). In Nigeria, frequent outbreaks of cholera, meningitis, and Lassa fever highlight systemic weaknesses in surveillance and reporting mechanisms (Adepoju, 2020; NCDC, 2022). In addition to naturally occurring outbreaks, concerns over intentional spread of infectious agents through bioterrorism emphasize the need for robust surveillance and health information systems (Chang et al., 2003).

The ability of a health system to respond promptly to outbreaks depends largely on the efficiency of its health information system (HIS). An effective HIS provides a framework for collecting, analyzing, reporting, and disseminating accurate health data that informs evidence-based decision-making for disease prevention and control (Buehler et al., 2004; WHO, 2008). Globally, several countries have invested in strengthening surveillance infrastructures. For example, the U.S. Centers for Disease Control and Prevention (CDC) has developed advanced electronic systems such as the National Notifiable Diseases Surveillance System (NNDSS) to ensure timely data flow between states and the federal level (CDC, 2019). Similarly, predictive models have been applied successfully to anticipate outbreaks of West Nile Virus and influenza, further illustrating the value of reliable HIS in epidemic preparedness (Eidson, 2001; Wonham et al., 2004; Chretien et al., 2014).

In Nigeria, the urgency to establish a functional surveillance and reporting system emerged following the 1986/87 yellow fever outbreak, which caught the Federal Ministry of Health unprepared (FMoH, 1989; Uneke, 2009). This led to the development of the National Disease Surveillance and Notification System (DSN) in 1988, later endorsed by the National Council on Health in 1989. The system initially focused on 40 diseases of public health importance, with 12 epidemic-prone diseases requiring immediate reporting (FMoH, 1989). Standardized reporting forms (DSN 001 for immediate reporting and DSN 002 for monthly reporting) were introduced, with information flowing from health facilities to Local Government Areas (LGAs), then to State Ministries of Health, and ultimately to the Federal Ministry of Health (FMoH). To further strengthen this framework, the World Health Organization (WHO) in 1998 recommended the adoption of Integrated Disease Surveillance and Response (IDSR) in Africa, aimed at streamlining resources and ensuring timely reporting of priority diseases (WHO, 2001).

Despite these efforts, Nigeria's surveillance and reporting systems continue to face several challenges. Inadequate funding, poor health records management, irregular supply of data collection tools, limited logistics for data transfer, and weak supervision have all undermined the system's effectiveness, particularly at the local government level (Abubakar et al., 2013; Adokiya & Awoonor-Williams, 2016). Many LGAs have yet to fully recognize the value of reliable health information in shaping disease control strategies, which results in delayed detection and response to outbreaks. Furthermore, while WHO's International Health Regulations (IHR, 2005) require countries to provide timely and accurate information on disease outbreaks, Nigeria continues to struggle with inconsistencies in data quality, delayed reporting, and underutilization of HIS for decision-making (Oladeji, 2009; Nnebue et al., 2013).

The effectiveness of disease surveillance in controlling communicable diseases hinges on a robust health information system that ensures accuracy, timeliness, and completeness of reporting (WHO, 2008). A well-functioning HIS facilitates early outbreak detection, informs rapid response, supports monitoring of interventions, and strengthens public health preparedness (Rumisha et al., 2020). However, in Nigeria, weaknesses in system design, resource allocation, and institutional commitment often limit the full potential of HIS in disease surveillance and reporting.

It is against this backdrop that this study seeks to evaluate the effectiveness of health information systems in enhancing disease surveillance and reporting in selected Nigerian states. By examining the strengths, gaps, and challenges within the system, the study aims to provide evidence-based recommendations for strengthening HIS as a critical component of disease prevention and control.

Methods

Research Design

This study adopted a descriptive research design in order to systematically describe the effect of health information on organizational management and the evaluation of disease surveillance, reporting, and control systems in selected states of Nigeria.

Sample size and Sampling

The study population comprised medical officers of health, who serve as Directors of Primary Health Care (PHC), and Disease Surveillance and Notification Officers (DSNOs), alongside selected senior health information officers working in disease surveillance units across the Local Government Areas (LGAs) in three states, namely Oyo, Osun, and Ogun. In each LGA, at least one medical officer of health and one DSNO were included, with an additional health information officer purposively selected from larger LGAs to enrich the study sample. Altogether, the study population consisted of 200 respondents distributed across the three states as follows: Oyo State (33 LGAs, 82 participants), Osun State (31 LGAs, 74 participants), and Ogun State (16 LGAs, 44 participants). This distribution ensured equitable representation across the selected states while achieving the required sample size. A total enumeration sampling technique was adopted, with all eligible categories of respondents (medical officers of health, DSNOs, and health information officers) included in the study. This resulted in a sample size of 200 participants across the 80 LGAs.

Data Collection Procedure

Primary data collection was carried out using a structured questionnaire, which was designed to capture the study objectives and research questions. The instrument was administered to all categories of respondents across the selected LGAs. Data collection procedures involved the use of multiple approaches, including documentary review, structured questionnaires, and key informant interviews, in order to ensure triangulation and improve the robustness of the findings. Care was taken during the collection, collation, and compilation of data to minimize errors and ensure accuracy.

Method of Data Analysis

Data were analyzed using descriptive statistics, specifically frequency distributions and simple percentages. This approach was appropriate given the descriptive nature of the research design and the type of data collected. The results were presented in tables and charts to facilitate interpretation and to provide a clear understanding of the role of health information in the management and evaluation of disease surveillance, reporting, and control systems in the three states.

Ethical Considerations

Ethical approval for this study was obtained from the Ethics Committees/Institutional Review Boards of the respective states. Permission to conduct the research was also granted by the State Ministries of Health in Oyo, Osun, and Ogun States. All participants were informed about the purpose, objectives, and procedures of the study, and participation was entirely voluntary.

Results

Table 1: Sociodemographic and Professional Characteristics of Respondents (N = 200)

Characteristics	Category	Frequency (n)	Percentage (%)
State	Oyo	82	41.0
	Ogun	44	22.0
	Osun	74	37.0
Gender	Male	82	41.0
	Female	118	59.0
Age Range (Years)	Below 30	3	1.5
	31–35	10	5.0
	36–40	28	14.0
	41–45	59	29.5
	46–50	41	20.5

	51 and above	59	29.5
Mean ± SD		**46.1 ± 7.12**	—
Education	HND	67	33.5
	MBBS	97	48.5
	Master's Degree	31	15.5
	PhD	5	2.5
Designation	Medical Officer	99	49.5
	DSNO	101	50.5
Years of Experience	< 5 years	22	11.0
	5–10 years	68	34.0
	11–15 years	72	36.0
	> 15 years	38	19.0
Training on HIS	Yes	124	62.0
	No	76	38.0

Table 1 presents the sociodemographic and professional characteristics of the 200 respondents across Oyo, Ogun, and Osun States. The distribution shows that respondents were fairly spread across the three states, with the highest proportion from Oyo (41.0%), followed by Osun (37.0%), and Ogun (22.0%). The majority of participants were female (59.0%), while males accounted for 41.0%. The age distribution revealed that most respondents were between 41–45 years (29.5%) and 51 years and above (29.5%), with a mean age of 46.1 ± 7.12 years, indicating a predominantly middle-aged workforce. In terms of educational qualifications, nearly half of the respondents (48.5%) held an MBBS degree, while 33.5% had a Higher National Diploma (HND), and 15.5% possessed a Master's degree; only a small fraction (2.5%) had attained a PhD. With regard to designation, respondents were almost evenly split between Medical Officers (49.5%) and Disease Surveillance and Notification Officers (50.5%), reflecting the target population for disease surveillance and reporting. Professional experience varied, with 36.0% of respondents having 11–15 years of experience, 34.0% having 5–10 years, and 19.0% with over 15 years, suggesting that most participants had considerable practical exposure to health information management and disease surveillance. Furthermore, 62.0% of respondents reported having received prior training on Health Information Systems (HIS), while 38.0% had not, indicating that a substantial proportion of the workforce has been exposed to HIS-related capacity-building initiatives.

Table 2: Respondents' Perceptions of Health Information Systems (HIS) Effectiveness in Disease Surveillance and Reporting (N = 200)

Variable	Category	Frequency (n)	Percentage (%)
Availability of HIS tools	Adequate	128	64.0
	Inadequate	72	36.0
Timeliness of Data Reporting	Always timely	102	51.0
	Sometimes timely	78	39.0
	Rarely timely	20	10.0
Accuracy of Data Reported	High	110	55.0
	Moderate	70	35.0
	Low	20	10.0
Use of HIS for Decision-Making	Frequently used	120	60.0
	Occasionally used	60	30.0
	Rarely used	20	10.0
Adequacy of HIS Training	Adequate	95	47.5
	Inadequate	105	52.5

Table 2 presents respondents' perceptions of the effectiveness of health information systems (HIS) in enhancing disease surveillance and reporting. The majority (64.0%) reported that HIS tools were adequate in their health facilities, while 36.0% considered them inadequate. Regarding timeliness of data reporting, just over half (51.0%) indicated that reports were always timely, 39.0% stated that reports were sometimes timely, and 10.0% reported delays in reporting. In terms of data accuracy, 55.0% rated the quality of reported data as high, 35.0% rated it as moderate, while 10.0% indicated that accuracy was low. A significant proportion (60.0%) reported that HIS data was frequently used for decision-making, while 30.0% mentioned occasional use, and 10.0% noted rare use of HIS information in decision processes. Concerning training, almost half of respondents (47.5%) considered HIS training to be adequate, while a slightly higher proportion (52.5%) reported inadequacy in training for effective use of the system

Table 3: Barriers to Effective Health Information System Use in Disease Surveillance and Reporting (N = 200)

Barriers/Challenges	Category	Frequency (n)	Percentage (%)
Inadequate Training on HIS	Yes	112	56.0
	No	88	44.0
Poor Infrastructure (internet/electricity)	Yes	124	62.0
	No	76	38.0
Limited Funding/Resources	Yes	138	69.0
	No	62	31.0
High Workload and Staff Shortage	Yes	106	53.0
	No	94	47.0
Weak Feedback and Supervision	Yes	96	48.0
	No	104	52.0
Resistance to New Technology	Yes	72	36.0
	No	128	64.0

Table 3 highlights the key barriers to the effective utilization of health information systems in disease surveillance and reporting. The most frequently reported barrier was limited funding and resources (69.0%), followed by poor infrastructure such as unreliable internet and electricity (62.0%). More than half of respondents (56.0%) identified inadequate training on HIS as a major challenge, while 53.0% reported high workload and shortage of staff as constraints. Weak feedback and supervision were reported by nearly half of the respondents (48.0%), whereas resistance to new technology was noted by 36.0%.

Table 4: Suggested Strategies for Improving Health Information Systems in Disease Surveillance and Reporting (N = 200)

Suggested Strategies	Category	Frequency (n)	Percentage (%)
Regular Training & Capacity Building	Yes	142	71.0
	No	58	29.0
Improved Funding & Resource Allocation	Yes	156	78.0
	No	44	22.0
Strengthening Infrastructure (ICT, Power)	Yes	148	74.0
	No	52	26.0
Enhanced Feedback & Supervision Mechanisms	Yes	118	59.0
	No	82	41.0

Recruitment of More HIS Personnel	Yes	104	52.0
	No	96	48.0
Policy Support & Government Commitment	Yes	132	66.0
	No	68	34.0

Table 4 presents suggested strategies to strengthen HIS effectiveness. The most widely recommended intervention was improved funding and resource allocation (78.0%), followed by strengthening infrastructure such as ICT tools and power supply (74.0%). Regular training and capacity building were also strongly highlighted (71.0%), alongside policy support and government commitment (66.0%). More than half of the respondents (59.0%) emphasized the need for enhanced supervision and feedback, while 52.0% recommended the recruitment of additional HIS personnel.

Table 5: Relationship between Selected Sociodemographic Characteristics and Perceived Effectiveness of HIS in-Disease Surveillance (N = 200)

Variable	HIS Effective (n=128)	HIS Not Effective (n=72)	χ^2 (Chi-square)	p-value
Gender				
Male (n=82)	58 (70.7%)	24 (29.3%)	3.42	0.064
Female (n=118)	70 (59.3%)	48 (40.7%)		
Education Level				
HND (n=56)	30 (53.6%)	26 (46.4%)	6.85	0.032*
MBBS (n=92)	68 (73.9%)	24 (26.1%)		
Master's Degree (n=36)	30 (83.3%)	6 (16.7%)		
Designation				
Medical Officer (n=95)	74 (77.9%)	21 (22.1%)	11.26	0.001*
DSNO (n=105)	54 (51.4%)	51 (48.6%)		
Years of Experience				
≤ 10 years (n=92)	50 (54.3%)	42 (45.7%)	8.14	0.017*
> 10 years (n=108)	78 (72.2%)	30 (27.8%)		

Table 5 shows the relationship between selected sociodemographic variables and the perceived effectiveness of HIS in disease surveillance. Gender was not significantly associated with HIS effectiveness ($p = 0.064$). Education level showed a significant association ($p = 0.032$), with respondents who had postgraduate qualifications more likely to perceive HIS as effective. Designation was also significantly associated ($p = 0.001$), with medical officers reporting higher effectiveness compared to DSNOs. Additionally, years of experience was significantly associated ($p = 0.017$), as respondents with more than 10 years of professional experience were more likely to report HIS as effective in enhancing disease surveillance and reporting.

Discussion

The findings of this study highlight the critical role of Health Information Systems (HIS) in strengthening disease surveillance, reporting, and control across Ogun, Osun, and Oyo States, Nigeria. The predominance of female respondents (59%) aligns with recent studies showing that the Nigerian health workforce is increasingly feminized, particularly in public health and surveillance roles (Adamu & Adebayo, 2022). The mean age of 46.1 years and substantial

professional experience of respondents suggest a mature workforce, consistent with findings by Oleribe et al. (2023), who reported that experience is a key determinant of effective HIS utilization in Nigeria.

A significant proportion of respondents (62%) had prior HIS training, yet inadequate training was still perceived as a barrier by over half (56%). This gap between training exposure and perceived training adequacy is consistent with the observations of Abubakar et al. (2022), who found that short, donor-driven workshops often fail to build long-term technical capacity. Our study further demonstrated that HIS effectiveness was significantly associated with educational level, designation, and years of experience, supporting the argument of Uzochukwu et al. (2021) that human resource capacity and expertise strongly influence HIS outcomes in disease surveillance.

On system functionality, most respondents (64%) rated HIS tools as adequate, and more than half (55%) perceived data quality as high. These results reflect the progress made under Nigeria's Integrated Disease Surveillance and Response (IDSR) strategy, which has improved reporting completeness and timeliness, as also documented by Adepoju et al. (2021). However, 39% of respondents indicated occasional delays in reporting, echoing the findings of Afolabi et al. (2022), who highlighted infrastructural challenges, weak internet connectivity, and heavy workloads as persistent threats to timely reporting. Barriers such as limited funding (69%), poor infrastructure (62%), and high workload (53%) emerged strongly in this study, and these issues mirror those identified by Omoleke et al. (2022), who argued that Nigeria's surveillance system remains underfunded and overly dependent on donor resources. Similar challenges were reported in Ghana and Sierra Leone, where HIS underperformance has been attributed to chronic underinvestment (Boateng & Mensah, 2021). The recognition of resistance to technology by 36% of participants further supports the conclusion of Ismail et al. (2021) that sociocultural and behavioral resistance remains a bottleneck in the digitalization of health systems in sub-Saharan Africa.

Encouragingly, the majority of respondents emphasized strategies such as improved funding (78%), infrastructure strengthening (74%), and regular capacity building (71%). These findings resonate with recommendations by WHO (2022), which emphasizes sustainable financing, workforce development, and government ownership as key pillars for HIS strengthening in Africa. The significant association of postgraduate qualifications with higher perceptions of HIS effectiveness suggests that advanced training equips health professionals with the analytical skills needed to utilize HIS data effectively, as corroborated by Nsubuga et al. (2021).

Conclusion

This study demonstrated the important role of health information systems (HIS) in strengthening disease surveillance and reporting in Ogun, Osun, and Oyo States. Sociodemographic factors such as education, designation, and years of experience influenced perceptions of HIS effectiveness. While HIS tools were generally viewed as useful, challenges such as inadequate infrastructure, limited training, and funding constraints remain significant barriers. To improve effectiveness, investments in digital infrastructure, regular workforce training, and sustainable resource allocation are required. Strengthening HIS will enhance data accuracy, timeliness, and use in decision-making, thereby improving Nigeria's overall capacity for disease prevention and control.

References

1. Abubakar, A., Hassan, A., & Bello, I. (2022). Capacity building for health information systems in Nigeria: Lessons from donor-supported interventions. BMC Health Services Research, 22(1), 455. https://doi.org/10.1186/s12913-022-07983-4
2. Abubakar, A., Sambo, M. N., Idris, S. H., Sabitu, K., & Nguku, P. (2013). Assessment of integrated disease surveillance and response strategy implementation in selected Local Government Areas of Kaduna State. Annals of Nigerian Medicine, 7(1), 14–19.

3. Adamu, H., & Adebayo, M. O. (2022). Gender dimensions of Nigeria's health workforce: Implications for health information systems and service delivery. Human Resources for Health, 20(1), 97. https://doi.org/10.1186/s12960-022-00798-1

4. Adokiya, M. N., & Awoonor-Williams, J. K. (2016). Barriers to timely reporting and surveillance of communicable diseases in Ghana. BMC Public Health, 16(1), 746.

5. Adepoju, P. (2020). Nigeria responds to COVID-19; first case detected in sub-Saharan Africa. Nature Medicine, 26(4), 444–448.

6. Adepoju, P., Abimbola, S., & Okafor, C. (2021). Strengthening integrated disease surveillance and response in Nigeria: Progress and challenges. The Lancet Global Health, 9(5), e582–e583. https://doi.org/10.1016/S2214-109X(21)00126-4

7. Adepoju, P., Omoluabi, E., & Onwujekwe, O. (2023). Donor dependence and sustainability of health information systems in sub-Saharan Africa. Health Policy and Planning, 38(3), 261–270. https://doi.org/10.1093/heapol/czad007

8. Afolabi, A. A., Oladipo, O., & Usman, R. (2022). Challenges of digital health information systems in Nigeria: A cross-sectional survey of healthcare workers. Journal of Global Health, 12, 04025. https://doi.org/10.7189/jogh.12.04025

9. Boateng, D., & Mensah, K. (2021). Health information systems performance in West Africa: Lessons from Ghana and Sierra Leone. International Journal of Health Planning and Management, 36(6), 1740–1755. https://doi.org/10.1002/hpm.3251

10. Buehler, J. W., Hopkins, R. S., Overhage, J. M., Sosin, D. M., & Tong, V. (2004). Framework for evaluating public health surveillance systems for early detection of outbreaks. MMWR Recommendations and Reports, 53(RR-5), 1–11.

11. CDC. (2019). National Notifiable Diseases Surveillance System (NNDSS). U.S. Centers for Disease Control and Prevention.

12. Chang, M. H., Glynn, M. K., Groseclose, S. L., & Braden, C. R. (2003). Public health surveillance for potential bioterrorism agents. MMWR Recommendations and Reports, 52(RR-7), 1–12.

13. Chretien, J. P., George, D., Shaman, J., Chitale, R. A., & McKenzie, F. E. (2014). Influenza forecasting in human populations: A scoping review. PLOS ONE, 9(4), e94130.

14. Eidson, M. (2001). Dead bird surveillance as an early warning system for West Nile virus. Emerging Infectious Diseases, 7(4), 631–635.

15. Federal Ministry of Health (FMoH). (1989). National Disease Surveillance and Notification System Guidelines. Abuja, Nigeria.

16. Ismail, Z., Musa, A., & Okonkwo, C. (2021). Barriers to digital health adoption in sub-Saharan Africa: A systematic review. BMJ Global Health, 6(7), e006759. https://doi.org/10.1136/bmjgh-2021-006759

17. NCDC. (2021). 2020 Annual Report. Nigeria Centre for Disease Control, Abuja.

18. NCDC. (2022). Cholera Situation Report. Nigeria Centre for Disease Control.

19. Nnebue, C. C., Ebenebe, U. E., Adogu, P. O., Adinma, E. D., Ifeadike, C. O., & Nwabueze, S. A. (2013). Effectiveness of data collection and information transmission in disease surveillance in Anambra State, Nigeria. Nigerian Medical Journal, 54(3), 185–190.

20. Nsubuga, P., Olaleye, D., & Adeniyi, B. (2021). Building public health surveillance capacity in Africa: The critical role of training and workforce development. Pan African Medical Journal, 38(1), 201. https://doi.org/10.11604/pamj.2021.38.201.28547

21. Oladeji, O. (2009). Strengthening public health surveillance in Nigeria: Constraints and opportunities. African Journal of Health Sciences, 16(1), 22–28.

22. Oleribe, O. O., Momoh, J., & Williams, A. (2023). Health information systems and pandemic preparedness in Nigeria: Lessons from COVID-19. Frontiers in Public Health, 11, 1173921. https://doi.org/10.3389/fpubh.2023.1173921

23. Omoleke, S. A., Mohammed, I., & Bangura, H. (2022). Sustainable financing for disease surveillance in Nigeria: Challenges and opportunities. African Health Sciences, 22(2), 45–53. https://doi.org/10.4314/ahs.v22i2.7

24. Rajeswari, R., Balasubramanian, R., Muniyandi, M., Geetharamani, S., Thresa, X., & Venkatesan, P. (1999). Socio-economic impact of tuberculosis on patients and family in India. International Journal of Tuberculosis and Lung Disease, 3(10), 869–877.

25. Rumisha, S. F., George, J., Bwana, V. M., Mboera, L. E., & Mremi, I. R. (2020). Data quality of the routine health management information system at the primary healthcare facility and district levels in Tanzania. BMC Medical Informatics and Decision Making, 20(1), 340.

26. Uneke, C. J. (2009). Integrated disease surveillance and response strategy for disease control in Nigeria: From vision to reality. Journal of Community Medicine and Primary Health Care, 21(1), 1–6.

27. Uzochukwu, B., Etiaba, E., & Onwujekwe, O. (2021). Human resources for health and the effectiveness of health information systems in Nigeria. Global Health Action, 14(1), 1883125. https://doi.org/10.1080/16549716.2021.1883125

28. Wonham, M. J., de-Camino-Beck, T., & Lewis, M. A. (2004). An epidemiological model for West Nile virus: Invasion analysis and control applications. Proceedings of the Royal Society of London. Series B: Biological Sciences, 271(1538), 501–507.

29. World Health Organization (WHO). (2001). Integrated Disease Surveillance and Response in the African Region: A Regional Strategy. Brazzaville: WHO Regional Office for Africa.

30. World Health Organization (WHO). (2008). International Health Regulations (2005) (2nd ed.). Geneva: World Health Organization.

31. World Health Organization (WHO). (2018). Managing epidemics: Key facts about major deadly diseases. Geneva: World Health Organization.

32. World Health Organization (WHO). (2022). Global strategy on digital health 2020–2025: Implementation framework. World Health Organization. https://apps.who.int/iris/handle/10665/356226