Review

Inaccessibility and low maintenance of medical data archive in low-middle income countries: Mystery behind public health statistics and measures

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ABSTRACT

Introduction: Africa bears the largest burden of communicable and non-communicable diseases globally, yet it contributes only about 1 % of global research output, partly because of inaccessibility and low maintenance of medical data. Data is widely recognized as a crucial tool for improvement of population health. Despite the introduction of electronic health data systems in low-and middle-income countries (LMICs) to improve data quality, some LMICs still lack an efficient system to collect and archive data. This study aims to examine the underlying causes of data archive inaccessibility and poor maintenance in LMICS, and to highlight sustainable mitigation measures.

Method: Authors conducted a comprehensive search on PubMed, Google scholar, organization websites using the search string "data archive" or "medical data" or "public health statistics" AND "challenges" AND "maintenance" AND "Low Middle Income Countries" or "LMIC". to Identify relevant studies and reports to be included in our review. All articles related data archive in low and middle income countries were considered without restrictions due to scarcity of data.

Result: Medical data archives in LMICs face challenges impacting data quality. Insufficient training, organizational constraints, and limited infrastructure hinder archive maintenance. To improve, support for public datasets, digital literacy, and technology infrastructure is needed. Standardization, cloud solutions, and advanced technologies can enhance data management, while capacity building and training programs are crucial.

Conclusion: The creation and maintenance of data archives to facilitate the storage of retrospective datasets is critical to create reliable and consistent data to better equip the development of resilient health systems and surveillance of diseases in LMICs.

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Contents

Introduction

Data is known to be an important tool for improvement of population health and health systems. Despite the introduction of electronic health data systems in low-and middle-income countries (LMICs) to improve data quantity and or availability, quality and ensure provision of financial costs to public health, some LMICs still have little or no system to efficiently collect and analyze data [1]. Furthermore, lack of important dataset obtained from data surveillances, censuses, surveys and experts in the field of medical informatics are challenges faced by these countries. The development of data archives to facilitate storage of retrospective datasets is essential to create reliable and consistent data to better equip the development of health systems [2].

Health information systems in developing countries are seen to experience more setbacks towards production of quality data due to lack of reliable health information. The Global Burden of Disease (GBD) incorporates a series of data sources to measure health loss in relation to injuries, diseases and risk factors among populations. However, challenges such as a lack of access to available public data and quality data input influences its management and analysis [2]. Several African countries depend on the use of surveys to provide estimates on the occurrence and frequency of diseases. For instance, Ethiopia, a low-income country in collaboration with the Institute for Health Metrics and Evaluation (IHME) has decided to improve the country's health data archive system. This would bolster the quality of healthcare service, promote health data measurements, and translate results into policies and interventions [2].

Frameworks such as the Health Metrics Network and DevInfo software has been supported by the World Health Organization (WHO), and United Nations Children Education Fund (UNICEF) for integration of large data systems into a repository [3]. Owing to an increase in the attainability of health data in LMICs, it is more pertinent for measures to ensure easy access and interpretation of data from various sources of health management information system (HMIS) [4].

Longitudinal health and demographic evaluation of population in low- and middle-income countries is carried out by The International Network for the Demographic Evaluation of Populations and Their Health (INDEPTH), which comprises a worldwide group of research centers. The INDEPTH is known to collect data via surveillance systems which are forwarded to a repository for documentation. This repository is known to expand over time based on provision of more data sets from studies carried out by the research centers [5]. It is also known to play a cogent role in provision of public health data from the LMICs population. Despite the non-representative property of the INDEPTH Data archive, it is important in its provision of impacts of health interventions and population characteristics with relation to their history [5]. In the last decade, several LMICs have embarked on plans to improve their Health Management Information System by digitizing datasets. While the success of INDEPTH has been recorded towards effective global surveillance of diseases, it can also reinforce usage of data systems to reduce loopholes caused by the HIMS [6]. This review discusses underlying causes of data archive inaccessibility and poor maintenance in LMICS, as well as provide recommendations to address them. Different terminologies such as medical data, medical record, health data and or health record will be used throughout the manuscript.

Significance of medical data archive maintenance in low- and middle-income countries

It's important to keep in mind that illness data archives go beyond merely keeping data, but also focus on making sure the information is useful, usable, and accessible to people who need it. In order to facilitate decision-making and direct public health interventions, medical data archive entails granting public health authorities, researchers, and other stakeholders' simple access to the data as well as making sure that it is correctly evaluated, understood, and conveyed.

Medical data archives can assist in facilitating more effective and efficient public health interventions in so many ways to improve health outcomes and building a more robust public health system overall. By enabling access to vital health data that can drive public health initiatives and inform decision-making, medical data archives impact a significant role in low- and middle-income countries (LMICs). Some of the impact include equitable data sharing which calls for the participation of those who provide the data, those who interpret and use the data generated by others, those who facilitate the data-sharing process, and those who derive and contribute to the benefit in order to work toward more equitable sharing of the public health benefits that data sharing brings [7].

Through medical data archives, health authorities can address imbalances existing in health care and enhance health outcomes for all communities by identifying discrepancies in illness burden and access to healthcare using medical data archives.

According to the World Health Organization, an efficient disease monitoring system is necessary to swiftly identify disease epidemics before they spread, claim lives, and become challenging to control. In emergency situations, such as in nations experiencing conflict or after a natural disaster, effective surveillance can enhance disease epidemic detection [8].

Health authorities can better track the spread of diseases and pinpoint regions that require action by collecting and preserving medical data. Medical data archives can also improve surveillance.

The development of efficient public health measures to stop the spread of diseases depends on this knowledge. Also, disease data archive enhances openness and accountability. It can also offer useful information to the public, policymakers, and healthcare professionals, enhancing openness and accountability in the healthcare system [9].

The gathering of data is frequently a time-consuming and expensive part of research; by preventing data duplication, databases that can be utilized again maximize the financial return on research effort [9]. Accuracy and quality of disease data can be increased with the use of disease data archives, which can help standardize data collection and management. This can offer a more solid basis for making decisions on public health.

In many developing nations, data is extremely valuable, but there isn't enough of it. Data sharing in public health on certain diseases can be re-used to gain fresh insights and identify new answers to development challenges [10]. For researchers looking to understand the underlying causes of diseases and create novel therapies and preventive measures, medical data archives can be a significant source of data. The development of new policies and programs can benefit from this as it can increase our understanding of diseases from a scientific perspective [9]. Moreover, medical data archives can offer information about the impact of disease on various communities, enabling more precise resource allocation to areas where it is most required for better Resource Allocation. Consequently, public health programs may run more smoothly and effectively.

Most importantly, collaboration across borders can be made easier through the sharing of data archives among healthcare professionals, researchers, and policymakers. This collaboration leads to better health outcomes on a worldwide scale.

Challenges associated with medical data archive maintenance in LMICs

Medical data archives remain an important factor to be considered when policies and decisions are to be taken around the health care system in LMICs. However, these data archives are porous, unorganized and shattered as a result of some underlying challenges making the quality, quantity, completeness, accuracy and timeliness of these diseases data questionable [11,12]. These challenges have been categorized to be behavioral, organizational and technical factors based on the core components of disease information (Fig. 1) [11,13].

Behavioral factors

Most LMICs lack adequately trained personnel that can handle, analyze and process the collected medical related data into information readable by the general public [12,14,15]. A study in India by Dehury and Chatterjee [16] documented lack of understanding of the collected diseases data among personnel resulting in incompleteness and low-quality diseases data archive. Similarly, Asah et al. [17] had reported lack of supervision and proper communication between senior level and lower level personnel resulting in falsification of data and wrong disease information. Additionally, intrinsic and extrinsic personnel motivation has also been reported by them.

Organizational factors

The challenges facing diseases data archive in LMICs is chiefly as a result of organizational, management and environmental factors including government policies, lack of human resources, financial and facilities constraints and poor awareness about diseases archive among the populace [12,18,19]. Pinchoff et al. [20] had reported the lack of a laboratory for proper diagnosis of malaria in Zambia as a factor impeding the archive of information on malaria disease. Human resources and structural facilities shortage in South African hospitals and maternity was reported by Nicol et al. [21] to affect data collection for archiving. Similarly, inadequate data storage and management systems as well as transportation have been implicated to delay the processing and transmission of diseases related information especially in areas with poor internet [22,23]. Additionally, staff incompetency, shortage of sophisticated equipment and lack of training have been posited by many authors to impede diseases archive in LMICs [24,25].

Technical factors

Technically, the unavailability of technical infrastructures hinders the archive process of disease information. Unfortunately, the few available trained personnel handling diseases data that are archived are faced with issues across data collection, transmission, analysis and publication of such information for public use. Researchers have reported technical challenges relating to limitation of data collection forms preventing the archiving of current diseases state [23,26]. Examples are the reports of Iguiñiz-Romero and Palomino and Abajebel et al. who reported lack of standardized and updated forms for emerging diseases data collection in Peru and Ethiopia respectively [27,28]. Similarly, Seitio-Kgokgwe et al. and Ward et al. had reported dearth and less accurate methods of data collection and reporting in diseases data in Uganda and Botswana respectively [29,30]. The limitation and unavailability of internet has also been faulted which make entry and data transmission through web-based tools an impossible mission in LMICs [31,32].

Current efforts

Several efforts are being geared toward improving data archives in LMIC. Notable among them include:

First, transitioning from paper-based documentation of health data to electronic health record (EHR). Some health facilities and institutions in LMICs are now abandoning the traditional paper-based data archive system, which is difficult to access and maintain due to environmental and physical damage, in favor of the conventional EHR system, which not only is easily accessible (through internet or Ethernet technologies) and maintained, but also facilitates update and transfer of archived data among health service providers, national health institutions, as well as bilateral and multilateral health organizations [33]. The growing popularity of this system is because of the dramatic increase in data collection on communicable and non-communicable diseases in LMICs. This can be exemplified by the COVID-19 pandemic, which fueled the need for an archiving system that enables remote transfer of epidemiological data from local to national to global level for efficient surveillance of the pandemic, assessment of the interventions implemented, and decision making [33]. It is worth noting that this system has been in use in developed nations for decades now. Previous studies have identified key factors limiting the widespread adoption in LMICs, including but not limited to a lack of expertise, a lack of stable electricity and a poor internet connection, and the cost of installation [34]. However, current reparatory efforts include extension of the 5 G network to LMICs and capacity building for relevant professionals.

Second, the design and development of central data-bases by LMIC Centers for Disease Control, such as the Africa Centre for Disease Control, has greatly improved data archiving in LMICs, where large scale epidemiological data and other health-related data are stored. This facilitates critical appraisal, analyses, and interpretations of such data in order to determine disease distribution, establish patterns and key determinants of diseases, and assess the efficacy and effectiveness of implemented control strategies. The
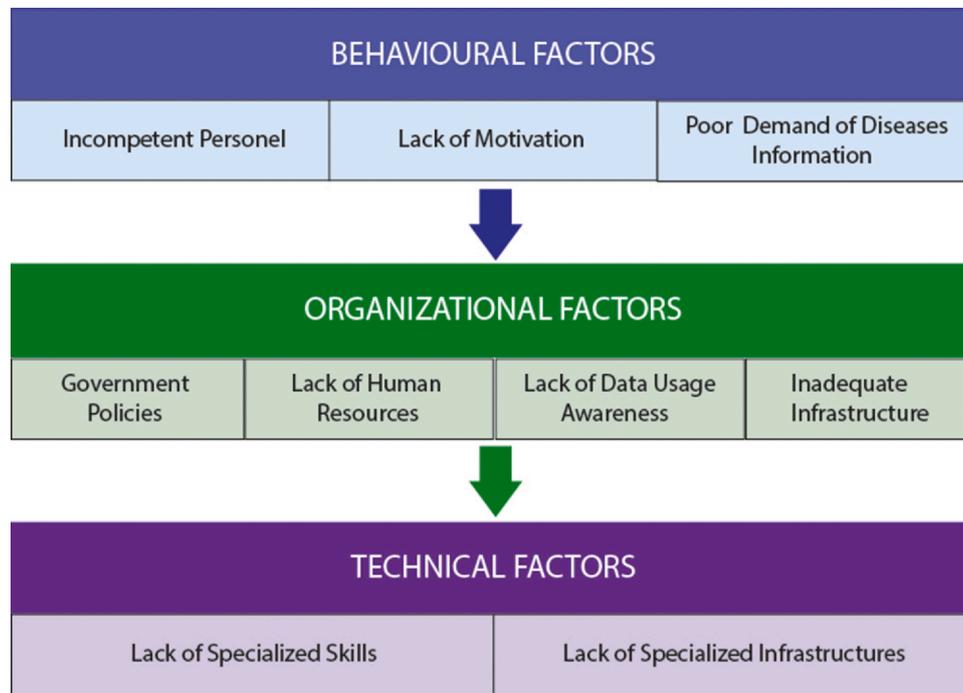
Fig. 1. Challenges facing diseases archives in LMICs. This figure illustrates challenges associated with disease archive maintenance in low- and middle-income countries.

Antiretroviral Treatment in Lower Income Countries (ART-LINC) collaboration, a network of treatment sites of the International Epidemiological Databases to Evaluate AIDS, Africa CDC COVID-19 Dashboard, Indian COVID-19 Dashboard and others are typical examples [35–37].

Third, collaborative efforts between LMICs and international organizations are ongoing to increase the competence of LMICs' healthcare workers, medical record officers, and other relevant workforce in disease data archiving and maintenance, through physical and online training, as well as the organization of workshops and seminars. The Informatics Training for Global Health program, run by Fogarty International Center (a US-based training center) in partnership with some LMICs, is one example of such collaborative training [38].

Another unique collaboration is the Global Digital Health Index (GDHI), a comprehensive tool that assesses the readiness and capabilities of countries to use digital technologies in the healthcare sector. The Global Digital Health Partnership developed the GDHI to provide a standardized framework for worldwide measuring and benchmarking digital health capabilities. It includes data from 23 LMICs classified according to an Overall Digital Health Phase, which comprehensively assesses a country's digital health capabilities on a scale of 0–5. (Fig. 2) This tool is precious for LMICs in identifying strengths and weaknesses in their digital health infrastructure, which can inform the development of tailored digital health strategies to improve archiving of disease data [39].

Recommendations

Access to reliable disease data archives in low- and middle-income countries (LMICs) is a critical challenge that hinders their ability to address unique clinical problems and limits global researchers' ability to learn from diverse populations. To overcome this challenge, leaders in healthcare digitization must support LMICs in contributing to publicly available datasets and enabling accurate data collection. Involving patients and marginalized communities in promoting digital literacy is essential to ensure their voices are heard, and varied demographics are represented in governance bodies.

Global investment in LMIC digitalization can improve the accuracy and fairness of collected data, reduce bias, and ensure accountability for proper data collection and sharing. Developing countries may want to consider incentives for foreign tech companies to conduct research and develop facilities to promote infrastructure development. The global AI community should also consider creating open-source software to promote proper data handling, anonymization, and governance standards.

Investing in technology infrastructure, such as electronic health records (EHRs), for data collection and sharing and surveillance, should be a priority for LMICs [40]. Cloud-based solutions, like AWS and Microsoft Azure, offer cost-effective and scalable solutions for maintaining health data archives. Standardizing data collection and management practices is also critical to ensure consistency and comparability across different healthcare systems and regions. The WHO's HMN has developed guidelines for health information systems, which can be used as a reference for implementing standardized data collection and management practices in LMICs.

To improve data sharing, promising new technologies, such as synthetic data or federated learning, have been widely suggested. Synthetic data and federated learning could potentially help researchers share health data publicly while better managing the risk of de-identification. However, there are still concerns regarding linkage risk, even with these technologies, and it is essential to balance resource allocation towards federated learning platforms and technologies with those allocated towards better tools for de-identification and standardized data curation.

The use of standardized data formats and application programming interfaces (APIs) can help ensure that health data archives can communicate and exchange data with other healthcare systems and applications. The Fast Healthcare Interoperability Resources (FHIR) standard, developed by the healthcare standards organization Health Level Seven International (HL7), provides a framework for interoperability between different healthcare systems and applications. The setback of poor internet connection can be tackled by modernizing and expanding the coverage of 4 G network across all LMICs, which has the advantages of long range communication, better availability and lower cost, compared to 5 G [41].
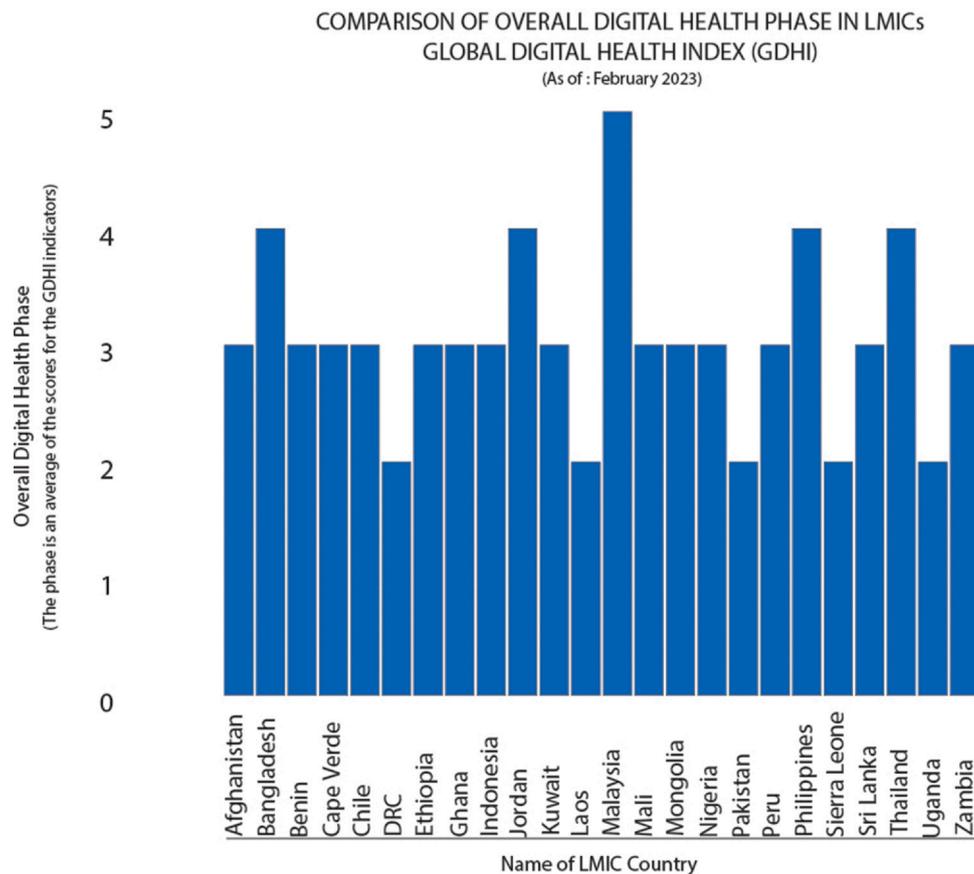
Fig. 2. Comparison of Overall Digital Health Phase in LMICs. This figure illustrates a comparison of the overall digital phase between low and middle income countries. Overall Digital Health Phase refers to the average of different phases of digital health adoption as determined by the Global Digital Health Index, which ranges from pre-adoption (Phase 0), early adoption (Phase 3) to advanced adoption (Phase 5).

Keeping this in mind, legal policy and data security frameworks must be put in place to strengthen the protection of PHI datasets from accidental leakage and potential malicious outside attacks. These policies should regulate stewards of PHI datasets that may enable re-identification via linkage with openly available datasets. Substantial penalties should be developed to punish any attempts to exploit the linkage of open medical data to re-identify patients or use PHI for commercial purposes, rather than for society's benefit, without patient consent.

Finally, building the capacity of healthcare professionals and IT personnel in LMICs is critical for maintaining and managing health data archives. Training and educational programs can help develop the necessary skills and knowledge needed to manage and maintain health data archives. Expertise in medical informatics and or biomedical data science is extremely important to transform medical data into more meaningful information. The information can eventually be utilized for many purposes which include but are not limited to disease prevention, monitoring and control which is of critical importance for decision making. The WHO and other international organizations offer training and capacity-building programs for healthcare professionals and IT personnel in LMICs which should be more widely promoted. Recruitment of unemployed healthcare professionals and engagement of community extension health workers should be considered to address the challenge of inadequate healthcare services delivery due to limited healthcare professionals.

Conclusion

Improving health data archives is critical for LMICs, but it poses challenges like limited funding, technological limitations, and lack of personnel training. LMICs can address these challenges through cloud-based systems, increased funding, personnel training, and standardized data practices. Transitioning to electronic health records can facilitate data transfer, and developing central databases and collaborations can improve maintenance. LMICs should invest in technology infrastructure, standardized data practices, and capacity building to enhance access to reliable disease data archives. Addressing these challenges will ultimately ensure equitable access to valuable health data for effective healthcare management and policy-making in LMICs.

CRediT authorship contribution statement

Conceptualization of Ideas: Adbdullahi Tunde Aborode, Toufik Abdul-Rahman, Wireko Andrew Awuah. **Data curation:** Toufik Abdul-Rahman. **Visualization:** Toufik Abdul-Rahman, Shankhaneel Ghosh, Gafar Babatunde Bamigbade. **Writing of initial draft:** Shankhaneel Ghosh, Lawa Lukman, Gafar Babatunde Bamigbade, Oluwaseyifunmi Valentina Oladipo, Ogbonna Ruth Amarachi, Omotayo Faith Olanrewaju, Soyemi Toluwalashe. **Review & editing:** Toufik Abdul-Rahman, Adbdullahi Tunde Aborode, Wireko Andrew Awuah, Ileana Lizano-Jubert, Kholis Abdurachim Audah, Teslyk T.P.

Declaration of Competing Interest

Authors wish to declare no conflict of interest.

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References

[1.] O'Neil S, Taylor S, Sivasankaran A. Data equity to advance health and health equity in low- and middle-income countries: a scoping review. Digit Health 2021;7. https://doi.org/10.1177/20552076211061922

[2.] Gebremedhin LT. Investment in health data can drive economic growth. Nat Med 2022;28(10):2000-2000. https://doi.org/10.1038/s41591-022-02022-8

[3.] Health Metrics Network, World Health Organization. Framework and standards for country health information systems. Published online Reprinted 2012 2008:63. Accessed February 22, 2023. ⟨https://apps.who.int/iris/handle/10665/43872⟩.

[4.] Hazel E, Wilson E, Anifalaje A, Sawadogo-Lewis T, Heidkamp R. Building integrated data systems for health and nutrition program evaluations: lessons learned from a multi-country implementation of a DHIS 2-based system. J Glob Health 2018;8(2):020307. https://doi.org/10.7189/jogh.08.020307

[5.] Herbst K, Juvekar S, Bhattacharjee T, et al. The INDEPTH data repository: an international resource for longitudinal population and health data from health and demographic surveillance systems. J Empir Res Hum Res Ethics 2015;10(3):324–33. https://doi.org/10.1177/1556264615594600

[6] Sahay S. Big data and public health: challenges and opportunities for low and middle income countries. Commun Assoc Inf Syst 2016;39(1). https://doi.org/10.17705/1CAIS.03920

[7] Edelstein M., Lee L.M., Herten-Crabb A., Heymann D.L., Harper D.R. Strengthening Global Public Health Surveillance through Data and Benefit Sharing - Volume 24, Number 7—July 2018 - Emerging Infectious Diseases journal - CDC. doi:10.3201/eid2407.151830.

[8] Surveillance in emergencies. Accessed February 22, 2023. ⟨https://www.who.int/emergencies/surveillance⟩.

[9] Rani M, Buckley BS. Systematic archiving and access to health research data: rationale, current status and way forward. Bull World Health Organ 2012;90(12):932–9. https://doi.org/10.2471/BLT.12.105908

[10] Improving public health with open data. Published January 10, 2011. Accessed February 22, 2023. ⟨https://blogs.worldbank.org/developmenttalk/improving-public-health-with-open-data⟩.

[11] Dehnavieh R, Haghdoost A, Khosravi A, et al. The District Health Information System (DHIS2): a literature review and meta-synthesis of its strengths and operational challenges based on the experiences of 11 countries. Health Inf Manag J Health Inf Manag Assoc Aust 2019;48(2):62–75. https://doi.org/10.1177/1833358318777713

[12] Hoxha K, Hung YW, Irwin BR, Grépin KA. Understanding the challenges associated with the use of data from routine health information systems in low- and middle-income countries: a systematic review. Health Inf Manag J 2022;51(3):135–48. https://doi.org/10.1177/1833358320928729

[13] Kumar M, Gotz D, Nutley T, Smith JB. Research gaps in routine health information system design barriers to data quality and use in low- and middle-income countries: a literature review. Int J Health Plann Manag 2018;33(1):e1–9. https://doi.org/10.1002/hpm.2447

[14] Flora OC, Margaret K, Dan K. Perspectives on utilization of community based health information systems in Western Kenya. Pan Afr Med J 2017;27(180). https://doi.org/10.11604/pamj.2017.27.180.6419

[15] Bernardi R. Health information systems and accountability in Kenya: a structuration theory perspective. J Assoc Inf Syst 2017;18(12). https://doi.org/10.17705/1jais.00475

[16] Dehury RK, Chatterjee SC. Assessment of health management information system for monitoring of maternal health in Jaleswar Block of Balasore District, Odisha, India. Indian J Public Health 2018;62(4):259. https://doi.org/10.4103/ijph.IJPH_203_17

[17] Asah FN, Nielsen P, Sæbø JI. Challenges for Health Indicators in Developing Countries: Misconceptions and Lack of Population Data. In: Choudrie J, Islam MS, Wahid F, Bass JM, Priyatma JE, editors. IFIP Advances in Information and Communication Technology, Vol 504. Springer International Publishing; 2017. p. 593–604. doi:10.1007/978-3-319-59111-7_48.

[18.] Nemser B. Data-informed decision-making for life-saving commodities investments in Malawi: A qualitative case study. Malawi Med J 2018;30:111–9. https://doi.org/10.4314/mmj.v30i2.11

[19] Radin AK, Abutu AA, Okwero MA, et al. Confronting challenges in monitoring and evaluation: innovation in the context of the global plan towards the elimination of new HIV infections among children by 2015 and keeping their mothers alive.

JAIDS J Acquir Immune Defic Syndr 2017;75:S66. https://doi.org/10.1097/QAI.0000000000001313

[20] Pinchoff J, Larsen DA, Renn S, et al. Targeting indoor residual spraying for malaria using epidemiological data: a case study of the Zambia experience. Malar J 2016;15(1):11. https://doi.org/10.1186/s12936-015-1073-9

[21] Nicol E, Bradshaw D, Uwimana-Nicol J, Dudley L. Perceptions about data-informed decisions: an assessment of information-use in high HIV-prevalence settings in South Africa. BMC Health Serv Res 2017;17(2):765. https://doi.org/10.1186/s12913-017-2641-1

[22] Mboera LEG, Rumisha SF, Mlacha T, Mayala BK, Bwana VM, Shayo EH. Malaria surveillance and use of evidence in planning and decision making in Kilosa District, Tanzania. Tanzan J Health Res 2017;19(3). https://doi.org/10.4314/thrb.v19i3.7

[23] Scott V, Gilson L. Exploring how different modes of governance act across health system levels to influence primary healthcare facility managers' use of information in decision-making: experience from Cape Town, South Africa. Int J Equity Health 2017;16(1):159. https://doi.org/10.1186/s12939-017-0660-5

[24] Ledikwe JH, Reason LL, Burnett SM, et al. Establishing a health information workforce: innovation for low- and middle-income countries. Hum Resour Health 2013;11(1):35. https://doi.org/10.1186/1478-4491-11-35

[25] Shiferaw AM, Zegeye DT, Assefa S, Yenit MK. Routine health information system utilization and factors associated thereof among health workers at government health institutions in East Gojjam Zone, Northwest Ethiopia. BMC Med Inf Decis Mak 2017;17(1):116. https://doi.org/10.1186/s12911-017-0509-2

[26] Rasmussen SL. Plans and "off-plan activities": Exploring the roles of data and situated action in health planning in Burkina Faso. Electron J Inf Syst Dev Ctries 2018;84(5):e12049. https://doi.org/10.1002/isd2.12049

[27] Iguiñiz-Romero R, Palomino N. Data do count! Collection and use of maternal mortality data in Peru, 1990–2005, and improvements since 2005. Reprod Health Matters 2012;20(39):174–84. https://doi.org/10.1016/S0968-8080(12)39605-5

[28] Abajebel S, Jira C, Beyene W. Utilization of Health Information System at District Level in Jimma Zone Oromia Regional State, South West Ethiopia. *Ethiop J Health Sci* Publ Online 2011. https://doi.org/10.4314/ejhs.v21i3

[29] Seitio-Kgokgwe O., Mashalla Y., Seloilwe E., Chida N. Utilization of the District Health Information Software (DHIS) in Botswana: From paper to electronic based system. 2016 IST-Afr Week Conf. Published online May 2016:1–10. doi:10.1109/ISTAFRICA.2016.7530690.

[30] Ward K., Mugenyi K., Benke A., et al. Enhancing Workforce Capacity to Improve Vaccination Data Quality, Uganda - Volume 23, Supplement—December 2017 - Emerging Infectious Diseases journal - CDC. doi:10.3201/eid2313.170627.

[31] Chikumba P, Rasmussen S. Manag Use Health Inf Malawi Burkina Faso: role Technol 2016:1–9. https://doi.org/10.1109/ISTAFRICA.2016.7530625

[32] Njuguna J, Kamau N, Muruka C. Impact of free delivery policy on utilization of maternal health services in county referral hospitals in Kenya. BMC Health Serv Res 2017;17(1):429. https://doi.org/10.1186/s12913-017-2376-z

[33] Khubone T, Tlou B, Mashamba-Thompson TP. Electronic Health Information Systems to Improve Disease Diagnosis and Management at Point-of-Care in Low and Middle Income Countries: A Narrative Review. Diagnostics 2020;10(5):327. https://doi.org/10.3390/diagnostics10050327

[34] Akhlaq A, McKinstry B, Muhammad KB, Sheikh A. Barriers and facilitators to health information exchange in low- and middle-income country settings: a systematic review. Health Policy Plan 2016;31(9):1310–25. https://doi.org/10.1093/heapol/czw056

[35] IeDEA International epidemiology Databases to Evaluate AIDS. IeDEA International epidemiology Databases to Evaluate AIDS. Published February 7, 2023. Accessed February 22, 2023. ⟨https://www.iedea.org/⟩.

[36] Coronavirus Disease 2019 (COVID-19) – Africa CDC. Accessed February 22, 2023. ⟨https://africacdc.org/covid-19/⟩.

[37] Coronavirus in India: Latest Map and Case Count. Accessed February 22, 2023. ⟨https://www.covid19india.org⟩.

[38] Archive: Informatics Training for Global Health (ITGH) - Fogarty International Center @ NIH. Fogarty International Center. Accessed February 22, 2023. ⟨https://www.fic.nih.gov:443/Programs/Pages/informatics.aspx⟩.

[39] Global Digital Health Index. Accessed February 24, 2023. ⟨http://index.digitalhealthindex.org/indicators_info⟩.

[40] Ferry AM, Davis MJ, Rumprecht E, Nigro AL, Desai P, Hollier LHJ. Medical documentation in low- and middle-income countries: lessons learned from implementing specialized charting software. Plast Reconstr Surg – Glob Open 2021;9(6):e3651. https://doi.org/10.1097/GOX.0000000000003651

[41] 45. say PLH your. Africa's 5G challenge. Published January 19, 2023. Accessed June 10, 2023. ⟨https://www.datacenterdynamics.com/en/analysis/africas-5g-challenge/⟩.