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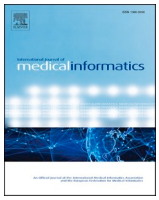

District health information system (DHIS2) as integrated antimicrobial resistance surveillance platform: An exploratory qualitative investigation of the one health stakeholders' viewpoints in Ethiopia

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ABSTRACT

Introduction: There is an unmet need for One Health (OH) surveillance and reporting systems for antimicrobial resistance (AMR) in resource poor settings. District health information system, version 2 (DHIS2), is a globally recognized digital surveillance platform which has not been widely utilized for AMR data yet. Our study aimed to understand the local stakeholders' viewpoints on DHIS2 as OH-AMR surveillance platform in Jimma, Ethiopia which will aid its further context specific establishment.

Methods: We performed an exploratory qualitative study using semi-structured key informant interviews (KIIs) in Jimma Zone at Southwest Ethiopia. We interviewed 42 OH professionals between November 2020 and February 2021. Following verbatim transcription of the audio recordings of KIIs, we conducted thematic analysis.

Results: We identified five major themes which are important for understanding the trajectory of OH-AMR surveillance in DHIS2 platform. The themes were:
(1) Stakeholders' current knowledge on digital surveillance platforms including DHIS2.
(2) Stakeholders' perception on digital surveillance platform including DHIS2.
(3) Features suggested by stakeholders to be included in the surveillance platform.
(4) Comments from stakeholders on system implementation challenges.
(5) Stakeholders' perceived role in the process of implementation.
Despite several barriers and challenges, most of the participants perceived and suggested DHIS2 as a suitable OH-AMR surveillance platform and were willing to contribute at their current professional roles.

Conclusions: Our study demonstrates the potential of the DHIS2 as a user friendly and acceptable interoperable platform for OH-AMR surveillance if the technology designers accommodate the stakeholders' concerns. Piloting at local level and using performance appraisal tool in all OH disciplines should be the next step before proceeding to workable format.

1. Introduction

Antimicrobial resistance (AMR) is currently one of the major global One Health (OH) challenges which acknowledges the interdependence among human health, animal health, and shared ecosystem for its containment [1]. Therefore, the success of containment of the local,

Abbreviations: HISP, Health information systems program; DHIS2, District health information system software-2; e-HMIS, Electronic health management information system; eCHIS, Electronic community health information System; SSA, Sub-Saharan Africa.

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national and global spread of AMR depends largely on a technically sound, timely and integrated surveillance system. Only a comprehensive surveillance system can afford required data for all aspects of AMR such as effectiveness of antibiotic therapies, stewardship program or programmatic interventions in various settings [2]. Unfortunately, existing local or global AMR surveillance systems lack an integrated OH approach [3], which means synchronized human, animal and environmental resistance data in the same surveillance network are missing. World Health Organization (WHO) recognized Africa, especially countries in sub-Saharan Africa (SSA) and South-East Asia, as the regions without established AMR surveillance systems [4]. Apart from the absence of OH-AMR surveillance in low and middle-income countries (LMICs), the existing AMR data and surveillance networks also show various flaws such as data based on discordant laboratory methods and reporting systems, lack of sustainability due to economic constraints and inadequate technical resources [5]. Ethiopia, our study site in SSA, initiated its first laboratory-based sentinel surveillance for AMR in four sites in July 2017 following the approval of a national AMR surveillance plan in the same year [6]. However, several implementation challenges were detected within the first year regarding real time data capture and transfer, laboratory supplies and communication between sentinel and co-ordination sites [7]. The national surveillance plan also does not follow the OH approach [8], including no veterinary and environmental AMR data capturing. In this context, the need for a widely acceptable, user-friendly and low-cost sustainable OH-AMR surveillance platform in LMICs, especially in Africa and Asia, is evident.

To achieve an effective interdisciplinary approach, the surveillance platform must be capable of flexible and uncomplicated AMR data archiving, analyzing and sharing [9]. The digital health information system (HIS) has significantly enhanced the quality and cost-effectiveness of disease or service reporting through health system surveillance to a greater extent [10]. Digital HIS supported AMR surveillance system will be effective in identification of better treatment modalities, monitoring of AMR trend, policy guidance and real time resource allocation. HIS usually deals with either health data at personal level such as electronic medical records (EMR) or health system data at population level for decision making such as district health information software, version 2 (DHIS2) [11]. DHIS2 was chosen as the surveillance platform to be investigated in our study for multiple reasons. Firstly, it is the leading global health information system that fulfils the criteria of a digital global public good and is already utilized by more than 60 countries for health system management [12]. The open source web-based nature of DHIS2 has shaped its user-friendly interface comprising various utilities such as health system and logistic data sharing and management from remote health centres, users at multiple levels, monitoring and evaluation of existing programs with geographic information system (GIS) based mapping and its ability to work offline [10,11,13]. The ongoing effort for interoperability and data integration of DHIS2 with two other widely utilized AMR tools such as WHONET [14] and the Global Antimicrobial Resistance Surveillance System (GLASS) makes it more operational and universal [15]. Most importantly, DHIS2 is being implemented as an integral part of electronic Health Management Information System (e-HMIS) of Ethiopia mainly for reporting of disease burden, service delivery and logistic allocation [16]. Therefore, utilization of DHIS2 as OH-AMR surveillance platform in Africa will be a potential and scalable approach.

As DHIS2 allows to report health indicators at real time from local health facilities with data deposition in the central server, more integration of DHIS2 in the HMIS of developing countries is much required [17]. However, the previous experiences of implementing DHIS2 in several countries identified multiple challenges, mainly technical problems and stakeholders' acceptance and preparedness [11]. When Kenya experienced its transition of health system surveillance from eIDSR-electronic Integrated Disease Surveillance and Response to DHIS2, the data reporting timeliness was increased by 21 % and the completeness by 17 % in counties where refresher training was provided and perception developed [18]. This example shows that feasibility (preparedness) research, proper training and perceptions of the stakeholders and end users are crucial to measure the functionality of any newly installed programs. While many African countries (e.g. Tanzania, Zambia, Ethiopia, Kenya, Ghana, Liberia, South Africa, Malawi, South Sudan, Cameroon, Nigeria) [19] are currently using DHIS2 in their health system reporting, it has great potential to capture the OH-AMR data in such settings if the perspectives of OH-AMR stakeholders on this system are identified. Therefore, we aimed to conduct an exploratory qualitative study for understanding the viewpoints of local OH-AMR stakeholders in Jimma, Ethiopia, and whether they consider DHIS2 as a feasible and acceptable surveillance platform and would be willing to contribute for its further context specific establishment.

2. Methods

2.1. Study design and setting

A qualitative cross-sectional study design comprising key informant interviews (KIIs) was conducted in Jimma, the largest city in the Oromia region at Southwest Ethiopia from November 2020 to February 2021. This is part of a comprehensive mixed method OH study to understand the transmission pathways of AMR among healthy humans, animals and their surrounding environment along with the integrated surveillance potential of DHIS2 as OH-AMR platform [20]. We have chosen Jimma as the study site due to the existing user groups and infrastructure of DHIS2 and established academic partnership between Jimma University and University of Oslo [21]. In addition, it is one of the selected sites for the piloting of DHIS2 for AMR surveillance in Africa [22].

2.2. Recruitment and data collection

Based on the discussion with local collaborators, literature and spectrum of qualifications available in Jimma, Ethiopia, we identified six types of OH stakeholders who are important for the implementation of DHIS2 in AMR surveillance (Table 1). These local OH-AMR stakeholders whom we considered as **our Key Informants (**KIs) are mainly from academic institutions, local health offices and relevant project staff. A discussion/interview guide was developed to extrapolate relevant information from these KIs **(**Supplementary Appendix 1**)**. Our interview guide which is available in English was finalized after reviewing the relevant literature and discussion with the research team. We also piloted the guide to interview six participants (one from each category) to further polish the guide and interview process. Then we conducted semi-structured interviews in English language among the KIs. English was chosen as the language of interview due to the higher qualification of all interviewees (minimum qualification was masters up to doctoral level education). In these interviews, we investigated the current knowledge and perceptions of participants regarding digital surveillance and DHIS2, their suggestions and inputs to implement DHIS2 as OH-AMR surveillance tool as well as the possible challenges in

Table 1
Key informants' distribution based on One Health disciplines.

Professional background	Number of respondents	Sampling procedure
Physician/Public health professionals (P)	8	Purposive
Veterinarian (V)	5	Purposive
Environmental professionals (E)	5	Purposive, snowball
Administrative personnel in academia (A)	8	Purposive, convenient
Data managers (D)	8	Purposive, snowball
Laboratory experts (L)	8	Purposive
Total study participants	N = 42	

this aspect and finally their willingness to contribute in the implementation phase. The participants provided their response based on their experience and knowledge. All interviews were conducted by the first author (MA) to maintain similar comprehension level and to reduce interviewer bias. MA has medical degree and masters in OH with long experience in research fieldwork (more than 15 years). He is working in mixed methodology for the last 7 years and is supervised by the research team members who have extensive experience in the current research topic. Four members of the research team are professors who are expertise in OH, AMR, laboratory science and informatics and do research in Africa (ZM, SS, ASW and CG) whereas another member is infectious disease specialist and associate professor working on AMR (EKR).

In addition, at the planning phase of the project, the research team members visited the study site to build rapport and to be acquainted with the local OH-AMR stakeholders with the help of local team members. Before conducting interviews, the team members placed in Jimma again introduced the interviewer to the key informants and administrative personnel in the local authorities. This process made the study participants' recruitment much convenient. Each participant signed a written informed consent prior to interview. The face-to-face interviews were conducted at the key informants' duty station and the usual duration of each interview was 1 h. We continued the enrolment process until the obtained data reached the point of saturation with no further new information.

2.3. Qualitative analysis

Following verbatim transcription of the audio recordings of KIIs, NVivo 12 software (QSR International, Melbourne, Australia) was used for line-by-line coding and analysis of the anonymized data. Thematic analysis [23] was conducted which included the understanding of the pattern of data, iterative coding to identify the major themes and description of the themes by illustrative quotes [24].

3. Results

Data obtained from KIIs helped to understand the key informants' knowledge, perception and acceptability of an integrated digital AMR surveillance platform such as DHIS2 and the feasibility of its context-specific establishment. It also provided important insights into the challenges of this platform from some of the current users. The summary of themes (Table 2) and the obtained information are described below-

Table 2
Summary of the themes obtained from the key-informants.

Serial	Theme	Sub-theme
Theme 1	Knowledge about digital surveillance	Knowledge about DHIS2
Theme 2	Perceptions on digital platforms	Perceptions on DHIS2
Theme 3	Suggested features in a OH-AMR surveillance platform and programmatic input	i) Features recommended by the current DHIS2 users in Ethiopia. ii) Recommendations for AMR data input in the customized DHIS2 platform iii) Recommended administrative and programmatic inputs from key informants
Theme 4	Possible implementation challenges	i) Implementation challenges at employee (personal) level ii) Implementation challenges at institutional level
Theme 5	Perceived role of the participants in the DHIS2 implementation phase	Perceived role at different level

3.1. Knowledge about digital surveillance and DHIS2

Most of the participants were familiar with the term and concept of a digital surveillance system but had limited or no prior experience of using it. Public health professionals with administrative roles at academic institutions, data managers and laboratory experts had better idea about digital platform mainly due to participation in various trainings, meetings, reporting obligations and communications with national authorities. However, fewer key informants were aware of the DHIS2 platform **(**Fig. 1**).**

'If you ask me about that DHIS2, then yes I know. I think we are in DHIS2 right now and they have been collecting data from data managers, zonal data managers, and with the emergence of COVID'.- **(A1)**

'Hmm as I told you, I am involved in a digital platform for TB where we collect samples and report them as a national platform online. For DHIS2, I have heard about it.' – **(L1)**

However, the majority of the stakeholders in AMR surveillance have no user experiences in DHIS2.

'Yes I know EMR only, it was made and I was part of it too. It is to give all reports to patient electronically. But I don't know about DHIS2'- **(P1)**

Unfortunately, in Jimma, academics and researchers from veterinary and environmental disciplines have limited knowledge on surveillance platforms.

'I heard from my colleague last year that our university is working on a digital surveillance, but I don't know the exact things though. I have also heard about DHIS2 from a student, but I don't know the application.' – **(V1)**

'*Hmm, yes, digital platform, last year I participated in a survey which used mobile phone but the software used, not sure. I have heard today about DHIS2 from you.'* – **(E1)**

3.2. Perceptions on digital platforms including DHIS2

We received positive feedback from all key informants about utilization of digital platforms for surveillance and they perceive the electronic reporting system such as DHIS2 as a pathway of accessible, timely and quality data flow.

'A digital platform like DHIS2, which will be like user friendly and easy, easy to use, very clear interface to use, that will be important.' –**(L2)**

The study participants also considered digitalization of AMR surveillance as a mean for better diagnostics and antibiotic stewardship, which will improve treatment outcomes and efficiency of the practitioners and institutes.

'Yes, we need digital help with the new platform. It should guide the physicians to use antibiotics rationally.' – **(A4)**

'I think this is very important for the government in order to make awareness, to have good understanding about the pattern of the antimicrobial agents. So I think it is very important to utilize DHIS2 technology which also makes it easier to manage different patterns.' – **(E2)**

3.3. Suggested features in a OH-AMR surveillance platform and programmatic input

We received technical recommendations and coordination of the data synchronization, monitoring and evaluation from the current users, mostly from the data management professionals. Other key informants provided suggestions regarding possible data input about AMR in the system.

3.3.1. Features recommended by the current DHIS2 users in Ethiopia

The current users have recommended developing the AMR platform as a separate application in DHIS2, but it must be compatible with other health system data on disease and service delivery currently captured by it. Some features in the current platform could be improved, such as mapping, data validation tools, disease registration application etc.

'*There are many features in DHIS2 but some features are not functional in our country. For example, maps are not fully functional; the ministry says it is*

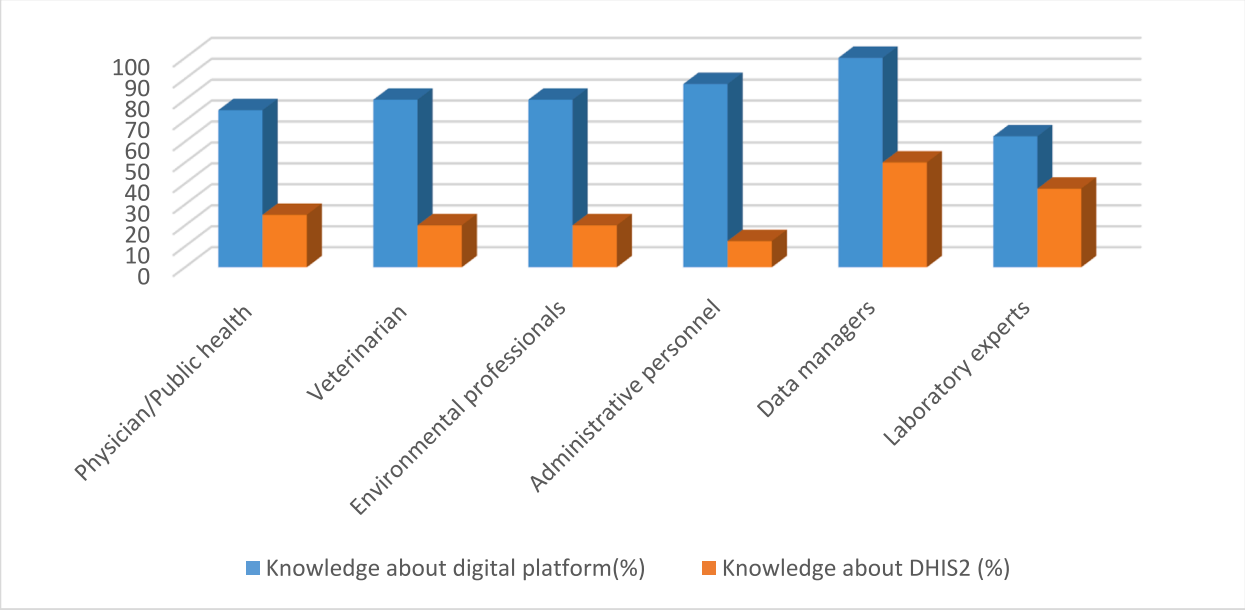

Fig. 1. Different professionals' knowledge on digital surveillance platforms and DHIS2.

under development. There is also plan-setting features', partially we started but not comprehensive. We can only check timeliness and completeness of data but can't check the content completeness that means we can check only representative completeness.' – **(D1)**

'*Disease registration app is not easy to use now. The other one is the customized data set for the country to analyze or download facilities' report and to manipulate one time that is still difficult. For example, we have 37 facilities and if we want to download or analyze 12 months' data of those facilities, it is difficult. The existing app does not allow us to download at a time. There is also network problem and interruption of power. We don't have any backup like UPS or generator. We need to solve these.*'- **(D2)**

3.3.2. Recommendations for AMR data input in the customized DHIS2 platform

As per suggestions of some key informants, the important demographic and clinical variables for both humans and animals such as age, sex, sample type, clinical features, and treatment history, laboratory findings etc., should be included as mandatory fields. In addition, the laboratory and sample collection standard operating procedures (SOPs) should be preserved in the platform. If different organizations use different methods, the platform may be customized. The list of clinically significant bacteria and genetic sequencing data (if possible) should also be added. AMR data quality control mechanism should be inbuilt in the system, which can identify the major errors instantly. For example, the extreme values in drug sensitivity test cut-off must be flagged immediately. The interviewees also emphasized on the inclusion of the source of data or sample with sampling time and sample collectors' code, data entry persons along with relevant laboratory details for data monitoring purpose.

'So what I need to see is which drug is resistant, other one is type of antimicrobials that are resistant for that type of bacteria, drug sensitivity test also if there is methods there as well, SOP for drug tests. I don't know if it is possible to use this platform with sequencing data, because nowadays drug resistance testing are shifting from culture to molecular techniques like target generated.' – **(L3)**

The clinicians/ public health professionals suggested to include treatment guidelines for diseases caused by MDR pathogens and to update regional and national data of the OH-AMR burden to follow the trend. The environmental professionals consider DHIS2 as an impeccable opportunity to include environmental AMR data.

'For me I think I should be able to see the burden of disease or pathogens at national level …other may be, we also include the part of One Health…as we use different drugs for humans and animals but both are antibiotics. The burden is different but connected. Also some other diseases have different gene transfers… maybe same pathogens may have different vulnerability…so any report or case report could be adapted in the platform.' – **(P2)**

'I want to see the relation between or to see how the environment is aggravating or minimizing the problems related with AMR, and how the environment is connected with human health, animal health and also how it is resistant generally in the environment. And the types of AMR in the environment such as MDR bacteria in soil, water, air should be linked to public health.' – **(E3)**

3.3.3. Recommended administrative and programmatic inputs from KIIs

All key informants suggested customizing the DHIS2 platform as an offline application, with effective support system (pool of responsible focal persons and technical staffs) and mostly usable by portable devices due to lack of adequate internet and frequent interruption of power supply.

'So here in our locality, there is no internet with regards to use. So if it is offline, then so many people can use it… and also portable just using applications. It should be easily downloadable by google store. Also you can see here, we are using mobile parking without using internet or any payment, so if it is prepared like that with only codes, without using internet or money. If there is one port server in one area and they can access it using mobile devices and can call by using support number.' – **(D3)**

'We use the technical teams at the regional level. They solve the problem by phone. By now there is only one person recruited by the zonal level as internship by developers and partner who supports the facility in terms of DHIS2.' – **(D4)**

3.4. Possible implementation challenges

Most of the key informants have identified some subjective barriers such as lack of motivation and awareness at both employee and institutional level, which need to be addressed before its implementation.

'The first thing is that we as an institution, are not aware of the significance of this trait. If you are not aware and committed, you don't allocate budget, you don't commit yourself to the actions.' – **(A3)**

Almost all participants have emphasized on training, availability of uninterrupted internet, and electricity, improvement of the software, technical support and digital skills as prerequisites to start the

surveillance platform.

'If it is web based platform…that means requiring electricity and internet network…then it will be a challenge for implementing any digital system. We don't have any backup like UPS or generator. Also as long as you give trainings before on boarding people working on it, it will be fine.' – **(L4)**

Resource allocation, both human and materials such as AMR diagnostic tool and reagents, with adequate and sustainable funding is the most practical and important factor according to the interviewees.

'Nobody is responsible for the budget…for that reason.. sometimes facilities lack. sometimes the office and sometimes I pay for internet myself. There we had agreement with the Ethiopian telecom after that…before 2–3 years… but now there is no validated time for this at the health center level. Again, before starting, we have taken the data based training for 4–5 days 2 years ago, after that no any training.' – **(D5)**

The lack of OH operationalization in the health system is a major barrier in the Ethiopian context. Particularly, the animal health and environmental sector have no AMR surveillance system in place, and no databases or digital platforms are being used.

'I think one health is yet not applied in our settings. This kind of research is done individually who are interested. But as an institution, I don't think we have coordinated efforts.' –**(A2)**

Another important barrier is that the e-HMIS is not functioning at all levels of the national health system **(**Fig. 2**).** Data from the primary health care (PHC) setting, mainly the health posts, are recorded in paper format which are sent to health centers on monthly basis [25]. In fact, the health data are transformed to digital format manually at woreda (district) level and therefore the data beyond this level are not real time data. Based on our interview data, health centres provide disease report and service delivery report on a monthly basis and tuberculosis report quarterly, whereas the health posts provide service delivery reports quarterly which are manual. The health centres also send an annual report about logistics including equipment, drugs and human resources, which should be more frequent. To obtain AMR data from PHC level, the surveillance and reporting plan needs to be adapted. Also, the integration of the Ethiopian calendar (which has 13 months and is different from Gregorian calendar) in DHIS2 for the weekly and monthly reporting of AMR surveillance might be a challenge.

3.5. Perceived role of the participants in the DHIS2 implementation phase

The key informants' views on the implementation of the DHIS2 platform for OH-AMR surveillance are quite encouraging. The academic researchers have shown interest in DHIS2 mainly in three ways: 1) self-learning and utilization in their projects, 2) collaboration with and dissemination of the platform to other research groups in the same organization or different organizations at national or global level, and 3) utilization as a teaching module for the students (in the form of learning by secondary data and using in postgraduate students' research).

'*My role will be supporting students and residents in usage of this platform, if it is friendly actually… and for the application in their practice. As I said my roles as a teacher too….so once I understand it, I pass it to the students. Second, I will monitor the implementation of it as I am working as a clinician. And I will use it as a part in my research also, so we can develop better empirical management of the drugs.'* – **(P4)**

The participants who are in administrative roles are willing to raise awareness and motivation at both individual and institutional level. Some of them have proposed to establish a taskforce to oversee the program activities including training, until its full implementation and to play a key role in the communication and data synchronization among multidisciplinary teams.

'Yeah, my role would be the first one to create sort of awareness and knowledge for the staff. And the second one, I'd be happy to establish a taskforce, which oversee this task until it will be fully implemented. I will work with other similar committees or stakeholders to synchronize, like there will be animal related antimicrobial resistance. So, data synchronization, or key synchronization would be my role.' – **(A1)**

Laboratory experts vowed to utilize DHIS2 with dedicated workers and computer, which will reduce their manual work burden and error. Though they are very much interested in this platform, they emphasized on the data completeness from clinicians before the laboratory analysis.

'I can contribute in providing some space, human resource and facilitate any other aspects that I can do as a head of school and a microbiologist. Also, I have a role in designing the research for example what is the contribution or effect of this digital system for patient outcome point of view, from community point of view or from teaching point of view. So using these three aspects, I can contribute to sustainability and use these digital platforms to cooperate with people who are using this system and communicate with other university, higher officials. – **(L1)**

Data management personnel are open to any cooperation required specially for facilitating technical infrastructure and support such as providing training and technical problem solving to other staffs, preparation of dedicated hardware like computers, tablets, mobiles and updated information on the website both in English and local languages.

'I can contribute what I can regarding my experience and using my knowledge. All what I can, I am with you.' – **(D3)**

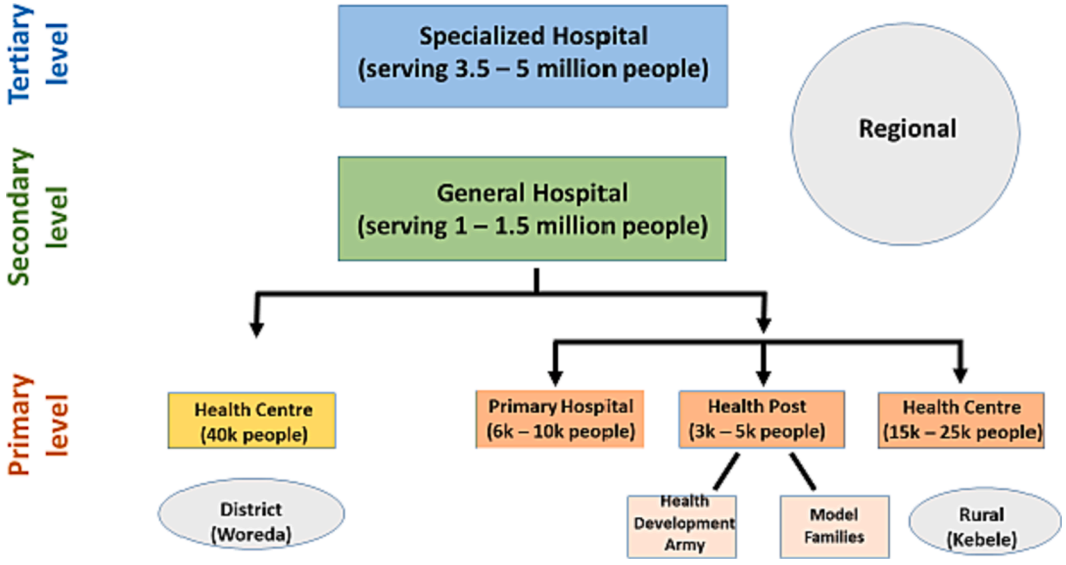

Fig. 2. Tiers of the health system in Ethiopia. adopted from Annis & Ratcliffe, 2019 [26].

4. Discussion

Based on the thematic analysis and study findings, the perception of the participants about the importance of OH-AMR surveillance and use of a digital platform such as DHIS2, is impressive, and well accepted by the relevant stakeholders. Such level of perception and presence of DHIS2 in the country's health system management for more than a decade definitely make it a strong and feasible tool for AMR surveillance. However, the knowledge level on DHIS2 is not satisfactory except the data management professionals. Though the laboratory personnel, physicians and academic administrative staffs have user experience of DHIS2 to some extent, it is evident that most of the veterinarians and environmental professionals have not used this platform yet. Therefore, a formal and uniform orientation of the DHIS2 platform in general and its potential to use as OH-AMR surveillance platform must be ensured at user and stakeholder level from PHC to central government. In addition, the suggested features in the platform should be further discussed with them before implementation. The willingness of the key informants to contribute in the implementation of DHIS2 at a local level is commendable and stands for a justifiable and strong argument of its acceptability.

4.1. Implementation challenges at system level and possible roadmap to succeed

When thinking of the implementation of the DHIS2 AMR surveillance module in LMICs, we suggest addressing the current challenges in the system based on users' feedback. At present, the DHIS2 platform cannot deal with a major component of AMR surveillance, the genetic sequencing data. The timeliness, completeness and quality assurance of collected data are also major issues in the current platform for which the poor internet network and level of digital skill of users, irregular training, inadequate budget, absence of power backup and some features in the software along with insufficient technical and logistic support specially at PHC settings are identified as contributing factors. These findings are supported by other studies conducted in Ethiopia [27–29]. A recent study completed in Jimma also concluded that the PHC units in all districts exhibited delayed, inconsistent and incomplete data in the HMIS [30]. Previously the under-reporting of Maternal, Newborn & Child Health (MNCH) data in HMIS from Oromia region had also been documented [31].

Considering all odds to implement DHIS2 as OH-AMR surveillance platform, we are hopeful about its feasibility to incorporate many suggestions of the KIIs. Several features supporting offline data entry or data entry at settings with limited power or internet supply are being developed. For example, DHIS2 team have developed 'Android data capture' app for mobile devices which is capable of offline data entry and can be uploaded to the DHIS 2 server later when the internet service is available including mobile data [32]. Similarly, the 'DHIS 2 web data entry module' (the usual data entry platform) has also the offline data entry feature but in this case, initial internet connectivity is required to start the data entry [32].

4.2. Implementation challenges at stakeholder level and possible roadmap to succeed

The implementation barriers at stakeholder level are major outcomes of this study. Interestingly, motivation and awareness have emerged as the prioritized factors in this regard, even more than technical support. In a recent study among the members of the performance monitoring team of DHIS2 in Ethiopia, only 121 out of 264 study participants (45.8 %) showed high levels of commitment for data quality assurance and reporting [33]. This can also be related with the study findings from many other African countries such as Malawi, Uganda, the Democratic Republic of Congo, Zambia, Ghana etc. for understanding the performance barriers of digital platform implementation [34–38]. In Zambia, the country specific integrated surveillance strategy with dedicated human resource and budget allocation at all levels were the contributing factors for successful program implementation, whereas lack of effective coordination, infrastructure and training hindered the optimum outcomes [36]. The constraints are almost similar in Uganda such as insufficient funding, training and coordination with frequent transfer of trained personnel but the staffs admitted the impact of training is enormous for knowledge generation and motivation in the surveillance tasks [37]. A mixed method study on DHIS2 in Malawi showed unacceptable timeliness (40.2 %) of monthly reporting and focused on weekly reporting, training and adequate resource for better implementation [35]. Clinicians and veterinarians can regularly follow the AMR data to avoid empirical treatment and to reduce resistance. Unfortunately, more than two-fifth of Ethiopian health workers do not utilize the health system data, and those who receive proper training, standard guidelines and regular supervision, are more likely to practice data utilization [39]. We argue that DHIS2 data on OH-AMR surveillance should be utilized at all user levels to make it a sustainable program and to enhance the participation, acceptability and community benefit from the system. Regarding the implementation of DHIS2 at all tiers of health system in Ethiopia, the prospect is inspiring. In a recent study conducted on this topic in Eastern Ethiopia [29], the DHIS 2 was found to be implemented in 80 % of public health facilities. Nevertheless, there are no alternatives of continuous feedback and constructive supervision, frequent reporting, regular training, sustainable program with fixed but trained staff, adequate funding, any form of incentives and providing standard guidelines are recommended from the beginning.

Another important reflection obtained from this study was the lack of coordination among the relevant stakeholders of AMR surveillance, both at the local and national level. Multidisciplinary or OH approach is not practiced in local AMR research or surveillance. Currently, no data sharing policy or mechanism exists at the study site and the absence of animal health or environmental AMR surveillance in the national action plan may be one of the major reasons. The recent study on the AMR preparedness in SSA has also identified this gap and has recommended to develop and implement national action plans for OH-AMR surveillance [40]. OH capacity building is particularly important for DHIS2 if it is designed to accommodate multidisciplinary AMR data. The progress of such initiatives is also inspiring in recent years, though many steps yet to go. Recently, a One Health Surveillance and Response Unit comprising human and animal health workers at community level has been formed in Adadle district [41]. Apart from the local case study, adoption of National One Health Strategic Plan (2018–2022) by National One Health Steering Committee and the expansion of the OH coordination to 7 Regions, 7 Zones, and 17 districts are encouraging steps of OH operationalization at national level [42]. Therefore, the National One Health Steering Committee and the technical working groups on AMR under its supervision need to be engaged during DHIS2 implementation.

We conducted the KIIs as they are knowledgeable informants for their expertise in technical, supervisory and implementation role in OH-AMR surveillance. Assessing feasibility and acceptability of digital platforms among such stakeholders is always recommended before final implementation of any new program. The gradual implementation phases in the form of sensitization with the local stakeholders, feasibility assessment, piloting, updating with technical and user community feedback, training and guideline development are the key endorsements from the participants. The implementation of DHIS2 in similar settings like Uganda and Mali have followed the same pathway [43,44]. Our current study will therefore be considered as the initial assessment of the DHIS2 for AMR surveillance in Africa. We believe that the results of this study are relevant to many LMICs who share the same socioeconomic, digital infrastructure and literacy. However, the scope must be adjusted with the health system tiers in the respective countries though the implementation challenges are believed to be mostly the same.

4.3. Limitations

This study has several limitations. We interviewed OH-AMR stakeholders only in a single region, which may not be representative for the whole country. Furthermore, all the key informants belong to academic, research or administrative institutions at regional level, which may not cover all information from primary and secondary tiers of the national health system. We used only KIIs and English as interview language whereas inclusion of other methods such as quantitative survey, structured observations, focus group discussions and in-depth interviews in local language would strengthen the research.

5. Conclusion

DHIS2 is considered as the most widely used health system reporting tool whereas AMR is the most alarming global health issue. DHIS2 has the potential to synchronize all sorts of AMR data and to act as standardized OH surveillance system. Taking the implementation barriers into consideration and solving them, DHIS2 can be the most user friendly and acceptable interoperable platform in the resource poor settings. Piloting at local level and gradual scaling at national level with enhanced alignment among OH disciplines should be prioritized for the AMR containment.

Public interest summary

Antimicrobial resistance (AMR) is a multidisciplinary global health issue causing high mortality and morbidity worldwide whereas the environment acts as the major transmission hub. Therefore, the effective use of integrated surveillance system comprising data from all these disciplines (referred as 'One Health-OH') has utmost importance for the containment of this problem. However, resource poor settings are disproportionately affected by AMR infections and are badly in need of user friendly, cost effective, interoperable and sustainable surveillance platform. The open source DHIS2 has the potential to be utilized in this aspect and is already in use in many low- and middle income countries for other health system reporting. Nevertheless, the views and perceptions of relevant OH stakeholders are crucial before its pervasive deployment as an OH-AMR surveillance system. In this context, we conducted an exploratory qualitative study to interview 42 OH professionals in Jimma, Ethiopia, to understand their viewpoints on this topic.

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CRediT authorship contribution statement

Muhammad Asaduzzaman: Conceptualization, Methodology, Funding acquisition, Data curation, Formal analysis, Investigation, Validation, Visualization, Writing – original draft, Writing – review & editing. **Zeleke Mekonnen:** Conceptualization, Methodology, Resources, Supervision, Validation, Writing – review & editing. **Ernst Kristian Rødland:** Conceptualization, Supervision, Validation, Writing – review & editing. **Sundeep Sahay:** Conceptualization, Validation, Writing – review & editing. **Andrea Sylvia Winkler:** Conceptualization, Methodology, Validation, Writing – review & editing. **Christoph Gradmann:** Supervision, Project administration, Validation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Ethical approval

Regional Ethics Committee (REC) in Norway (reference number 28914/2019) and the Jimma University Institutional Review Board (reference number IHRPGD 785/20) approved this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijmedinf.2023.105268.

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