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A WORKFLOW TO DEVELOP AND IMPLEMENT AN E-HEALTH INFORMATION SYSTEM IN WAR-TORN COUNTRIES: A CASE STUDY IN IRAQI KURDISTAN

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ABSTRACT

Conflicts and terrorism, especially when protracted, can deeply debilitate countries' security and safety, with multidimensional impact even on the public healthcare systems. The long-term effects can last for years after the cessation of emergencies, with health data not available and / or not fully reliable, causing targeted health interventions to be almost non-existent. Despite health information systems (HIS) being paramount in contributing to national security by guiding public health decision-makers, policy formulation, resource allocation and quality control, many Middle East countries, especially when they are faced with security instability, at present still do not collect electronic records. As a case study from the field, we describe the workflow - development, implementation, challenges and lessons learned - to create, maintain and advance a HIS in the Iraqi Kurdistan, a war-torn region in the Middle East. After a pilot phase, in 2018, a HIS based on the open-source software District Health Information System 2 (DHIS2) was set up in the region. It collects diseases registered in public health facilities and health data coded using the international WHO nomenclature ICD-10. The HIS was adapted to the local scenario, with user interfaces provided in Arabic and Kurdish-Sorani languages. The Pentaho Data Integration tool was used to effectively automate the process of data integration and bulk import from local systems already in use. The aim of this study is to provide lesson learned from the field to support evidence-based public health decisions even in other war-torn countries.

Keywords: *Public health; epidemiological surveillance; e-health; electronic records; District Health Information System 2 (DHIS2)*

1. INTRODUCTION

In the recent years, the traditional meaning of security has moved to wider scopes, including global health coverage. As a matter of fact, in 2014, the Global Health Security Agenda (GHSA) has been endorsed at both national and international levels to accelerate progress toward a world safer and securer through promotion of health. Therefore, global security has become a worldwide priority (GHSA, 2022). This implies that more acceptable, tangible and mainstream interpretations of national security exist. This is particularly the case for war-torn countries or countries emerging from wars, where years of conflict have deeply debilitated public health systems, with long-term effects on populations' health, which last for years after the cessation of emergencies (Gialloreti *et al.,* 2020).

Electronic health information systems (HIS) are paramount for guiding public health decision-makers in policy formulation, resource allocation and quality control (WHO, 2014a). Electronic health records (EHR) also entail demographic, social, political, and economic advantages; however, registration systems are not

implemented at scale (WHO, 2021a). As a result, it becomes challenging to generate accurate data on even the most basic health indicators (Mahapatra *et al*., 2007; AbouZahr *et al*., 2007). As an example, Iraq is suffering from what has been defined as the "single most critical failure of development over the past 30 years" (Setel *et al*., 2007), i.e., lack of demographic and epidemiological information, such as vital statistics on birth, disease, mortality, and cause of death. As reported by Asaad *et al*. (2020), civil registration systems in Iraq have never been formally evaluated until 2012, when the World Health Organization (WHO) requested an assessment. The evaluation showed a system malfunction, particularly concerning the completeness of birth and death registrations and the causes of death. The WHO offered some recommendations to improve the quality of the system. One of them was to envisage the computerization of the system as the only way to produce accurate and consistent data.

In 2005, the new Constitution of Iraq recognized the Autonomous Region of Iraqi Kurdistan (KRI) and its Kurdistan Regional Government (KRG) as part of the Republic of Iraq. In KRI, health service delivery and health financing mix public-private participation and investments. The Ministry of Health (MoH) of the KRI government follows the Iraqi MoH's basic organizational structure and system. The KRG decides health policies implemented by MoH (Shabila *et al*., 2010).

The current health situation of the KRI population is still not well known. Health data is collected sporadically and usually only in aggregated form; the available information is generally inferred by means of patchy surveys' estimations (RAND Corporation, 2014a). The consequence is a paucity of reliable health statistics and epidemiological surveillance being almost non-existent, limiting decision-makers considerations to guide the country. Health policies are often based on insufficient evidence (Lopez & Setel, 2015), while the impact of the provided care is not efficiently monitored or evaluated (EMRO, 2006; Webster, 2011). Therefore, much effort in data registration and evaluation is needed to guarantee a well-functioning public health system in Iraq and ensure universal health coverage (UHC) (WHO, 2014a). WHO is already supporting regional initiatives in the Eastern Mediterranean Region to develop national HIS and foster progress in expanding digital public health (WHO, 2014b; Murray *et al*., 2020).

After a two-year pilot phase, in 2018, the operational phase of a project for developing a health information system in Iraq was launched (Emberti Gialloreti *et al*., 2020). This case study describes the workflow - development, implementation, challenges, and lessons learned - to create, maintain and advance an e-health tool setup in the Primary Health Centers (PHC) and Public Hospitals (PH) of the Iraqi Kurdistan (KRI) to develop a digital health monitoring and epidemiological surveillance system.

2. MATERIALS AND METHODS

2.1 Conceptual Design of the Required Statistics

In the KRI, public health data - if collected - is mainly paper-based. Hence, format, accuracy, completeness, and accessibility of information are among the main challenges when processing health statistics. Data collected in PHC or PH - when present - are only in aggregated form. In order to overcome the challenge of aggregated data, an informatic system was set up to collect all the individual diseases registered during each diagnostic examination. The main advantage of this approach is that different levels of aggregation can be applied according to the requirements (Sahay *et al*., 2019). The system also collects data on births, deaths, and vaccinations.

2.2 Choice of the Suitable Tool

A free and open-source software platform for collecting, managing, analyzing and using data was employed, which is the District Health Information System 2 (DHIS2) (DHIS2, 2019). DHIS2 is among the world's largest health management information system platforms used by 72 low- and middle-income countries (Sahay *et al*., 2019). It adopts the WHO International Classification of Diseases as the primary standard for data reporting (Rashidian, 2019). The DHIS2 platform was chosen because it allows users to enter data directly from the periphery on the central servers, using only a web browser or a mobile app on even slow or

discontinuous internet connections. It also shows real-time statistics about entered data and supports external app development. Security and privacy are intrinsic to the DHIS2 open-source software. Furthermore, data security is guaranteed by the deployment of providers certified by the University of Oslo, which carries out a scheduled vulnerability assessment and penetration tests.

DHIS2 offers three different approaches for data acquisition (Sahay *et al*., 2019):

a) Aggregated data acquisition: It allows the quick collection of bulk data but without the possibility of generating more detailed statistics later.
b) Events acquisition with the person's registration: This approach stores data with the maximum granularity. However, in KRI, there is still no citizens' unique ID code.
c) Event data acquisition without registration: It allows the registration with the maximum granularity while allowing aggregations later and without privacy concerns for the patients.

In order to decide which approach was more suitable for this HIS, some of these approaches were tested using a small subset of health facilities. Eventually, the chosen implementation was based on the acquisition of event data without registration, where the recording of patients' data is not needed. Events are recorded using the DHIS2 Capture App.

A folder ID connected to the patient's folder in the specific hospital / health center (Health Unit) is introduced to avoid multiple registrations of the same events. This code is unique for the health unit and can be connected to the patient's personal data information only by the physicians of the health unit where the patient is visited and is treated. For all other users of the platform, the patient is anonymized.

2.3 Choice of the Appropriate Paradigm of DHIS2

Before choosing the most suitable paradigm, several prototypes were created based on different models. This was essential to test and compare the obtained output and to evaluate if it tallies with our main requirements as follows:

a) Statistical results used for decision making.
b) Easiness to enter data even with slow or discontinuous internet connections.
c) Flexibility to create different views starting from the same raw data.
d) Possibility to check and correct the entered data in case of errors.
e) Possibility to expand some metadata during later stages and not only during planning.

2.4 Setting up the HIS Skeleton

Five main statistical topics were chosen, and five DHIS2 programs were created: Births, Immunizations, Disease Surveillance (diseases diagnosed at health centers), Hospital Discharges (diseases diagnosed in hospitals), and Deaths.

2.5 Identification of the Nomenclature and Creation of the Local Language Version

The international WHO nomenclature was used to code the health events, i.e., the *International Statistical Classification of Diseases and Related Health Problems, 10th Rev. (ICD-10)* (WHO, 2016). It is recognized as the global standard for health data, clinical documentation, and statistical aggregation. In order to adapt the system to the local scenario—the language spoken in Iraqi Kurdistan is mainly Kurdish-Sorani, with Arabic often used when dealing with medical terms—the first step was to make the system usable for people who do not understand English. The required elements for the translation in Kurdish and Arabic languages are presented in Table 1.

Table 1: Required elements when translating and adapting the HIS into non-Latin-script alphabets.

Development stage	Target	Elements and challenges of the stage
1. Database language	Developed specifically for this HIS	# Labor intensive: all the names of the construction. elements—data elements, programs, option sets, etc.—had to be translated into Kurdish and Arabic. # The implementation team could define it without modifying the basic software platform.
2. Interface language	Developed to implement it in the software platform	# Usable only if the language is already present in the software platform. # Arabic was already present in the DHIS2 implementation, but not Kurdish-Sorani. # All interface strings had to be translated into Kurdish. # The DHIS2 team was requested to add Kurdish in both the software platform and the translation system. # After this intervention, a Kurdish personalized translation was created. # The Java developers were requested to add the Kurdish-Sorani language to the underlying Java library since it was not present. # After this intervention, all strings were translated for the interface and database elements.
3. Diagnosis coding into ICD-10 and translation	Developed to provide support to the local staff performing data entry	# Training of medical doctors about ICD-10 disease coding. # Training of data entry personnel about the electronic use of ICD-10 codes. # Setting upcoded disease lists tailored for each specific data entry unit.

2.6 Training and Interaction with the Local Personnel

Before a new center started working on the system, the local health authority had to equip the health centers with hardware and internet connections fully. This step was also essential to engage the local authorities to participate in the process, guaranteeing the future sustainability of the project. Subsequently, the local staff was trained in coding and data entry (Table 1). The training sessions were held in each KRI province through plenary meetings with presentations and frontal lessons. Afterwards, on-the-job training was conducted at each unit's facility (PHC or PH) for one week while upgrading the IT infrastructure. User's manuals were provided in the two languages used (Arabic and Kurdish-Sorani). The main activities for setting up a new data entry unit into the HIS are summarized in Figure 1.

2.7 Importing Bulk Data from Hospital Databases

Since PHC did not have any information system before this project, the system had to be built from scratch. Contrariwise, some PH already had their system, which was usually very basic (usually a simple spreadsheet) and without the possibility to interact with other systems beyond the hospital itself. An ad-hoc tools were developed to import data into the HIS since DHIS2 is interoperating with the databases and other systems using application programming interface (API) integration and bulk data import. Since PH's existing electronic systems were different from hospital to hospital, a single logic for API integration and data import process / flow could not be applied. Therefore, the process had to be dealt with each dataset as a separate case, and for each flow, a different logic had to be applied to accomplish the process. The main challenges of this process were quality of data received, records with blank fields (i.e., date, age, diagnosis), records with the wrong disease diagnosed field, lack of existing translations for Arabic and Kurdish diseases mapping of ICD-10 codes, and diseases diagnosed fields in Arabic and Kurdish having different spellings. The Pentaho Data Integration (PDI) tool was used to automate data integration and bulk import effectively (HITACHI, 2022).

PDI provides extract, transform and load (ETL) capabilities, making acquiring data using different sources and their subsequent cleaning and transformation faster and more consistent by using a uniform format. In our case, PDI was used for the data migration from different local application databases to our centralized KRI region Health Monitoring System, the KRG-HIS. A screenshot of a Pentaho elaboration processing for one hospital, with the different phases of data transformation and checks, is shown in Figure 2.

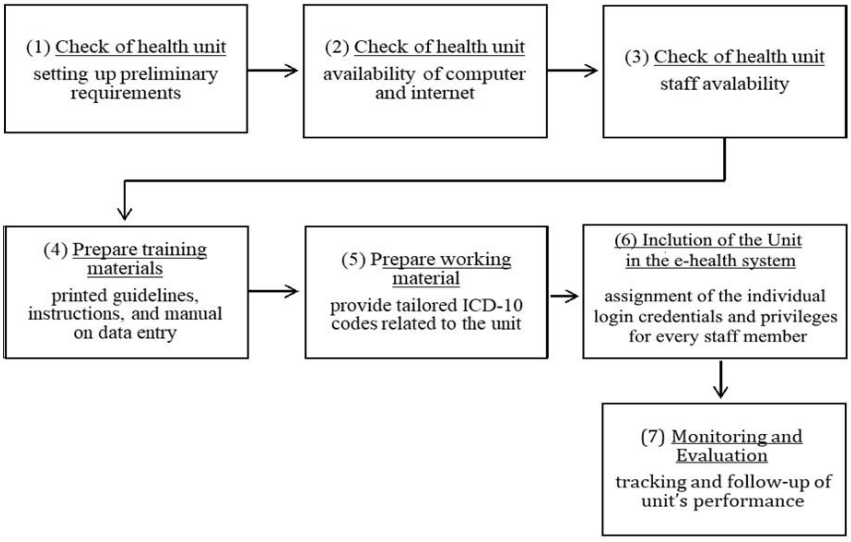

Figure 1: Flowchart for setting up a data entry unit into the HIS.

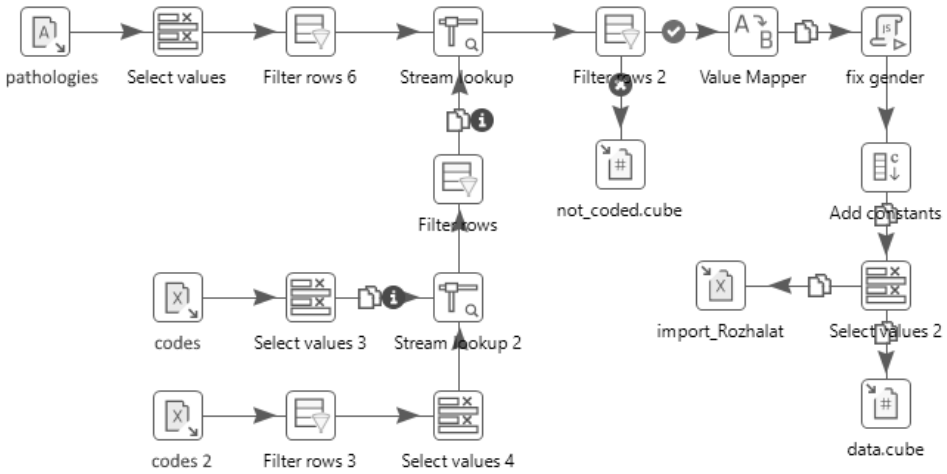

Figure 2: Data transformation and import screenshot from the Pentaho tool for the Rozhalat Hospital.

The steps taken for the data import from each hospital were: (1) Manual analysis, cleaning, and preparation of the data; (2) Creation of a program / job to perform data extraction, translation, mapping and importing into the DHIS2 platform (Figure 3).

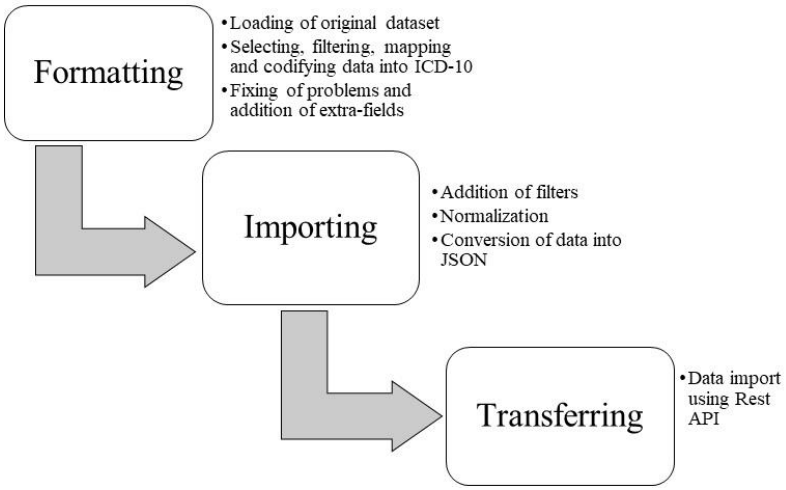

Figure 3: Data import activities flowchart.

2.8 Data Check and Statistics Generation

The caseload of each unit is checked daily. Any suspicious case or unexpected change in the regularity of cases entered can be rapidly detected, and inconsistent data is monitored. Each center's staff has to be trained to be accurate and focused on entering data regularly and correctly into the system. As in the DHIS2 software, the user statistics are limited, and there are no internal tools to evaluate the user's activities. The entered events were regularly downloaded, and statistics were performed using external data processing. A rapid question / answer mechanism was created by setting up communication groups between the operational centers, local teams, and international experts (using Viber, WhatsApp, and other messaging tools).

2.9 Request for the Features to the DHIS2 Platform Developers

DHIS2 constantly evolves thanks to a large developer community coordinated by HISP at the University of Oslo (Dias, 2020). During the implementation and use of the HIS, various challenges on the DHIS2 software were found and reported to the developers, and new features were requested. For example, a request has to be made to develop a dimension to create different groupings of ICD-10 diagnoses used for classification / aggregation of the event diagnosis by ICD-10 Chapters (I-XXII), ICD-10 letters (A-Z), WHO Global Health Estimates, (WHO, 2021b), or other aggregations based on specific disease groups.

2.10 Ethical Considerations

The HIS was developed following the national and regional laws. The *WHO Guidelines on Ethical Issues in Public Health Surveillance* (WHO, 2017a) was followed. At this stage, the institutional review board of the University of Rome Tor Vergata (Italy) waived any requirements for further ethical approval.

3. RESULTS

The pilot phase of the HIS started in 2016, while the operational phase was activated in 2018. Figure 4 shows the login user interface and system dashboard.

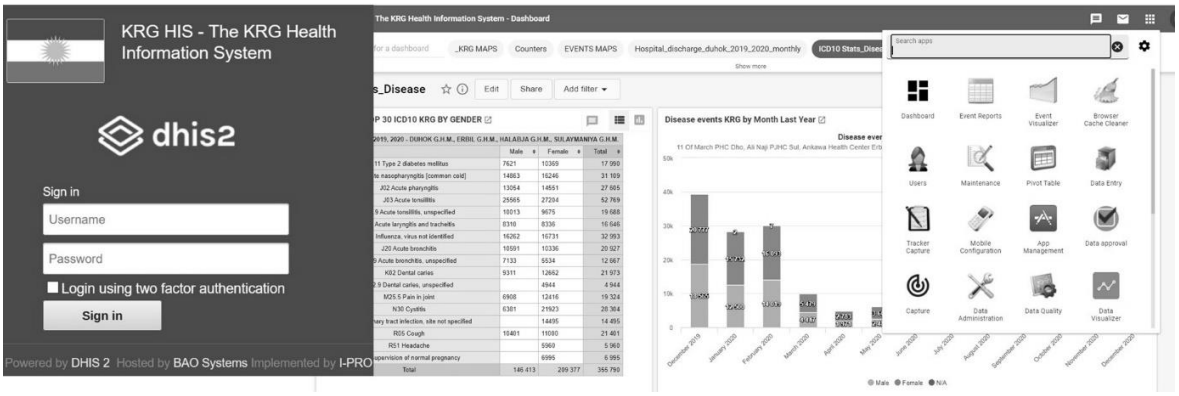

Figure 4: Login user interface and system dashboard.

By the end of December 2021, 128 health centers (94 PHC, 30 PH, and four Registration Bureau of Births and Deaths-RBBD have been included and are active in the HIS (Table 2), covering at present nearly the 50% of the overall public health facilities of the area.

Table 2: Cumulative distribution of the health units activated by year.

Governorate	2016	2017	2018	2019	2020	2021	Health Units Type		
							PHC	PH	RBBD
Duhok	7	10	11	27	35	58	46	11	1
Hawler	9	10	11	17	17	23	17	6	-
Halabja	1	1	1	3	4	8	3	3	2
Sulaimaniya	10	10	10	16	16	39	28	10	1
Totals	**27**	**31**	**33**	**63**	**72**	**128**	**94**	**30**	**4**

The system gathers more than 1,200,000 disease events from the PHC and about 370,000 from PH. The 15 most common diagnoses gathered within the PHC since the beginning of the project are shown in Table 3. They cover almost half of all accesses to the PHCs (Emberti Gialloreti *et al*., 2020).

Table 3: Top 15 ICD-10 diagnoses gathered in the HIS within the PHC.

Diagnosis (ICD-10)	Number of events
Acute tonsillitis (J03)	79,384
Influenza, virus not identified (J11)	60,913
Acute nasopharyngitis -common cold (J00)	57,732
Cystitis (N30)	36,743
Acute pharyngitis (J02)	39,225
Dental caries (K02)	24,754
Cough (R05)	37,982
Acute bronchitis (J20)	26,228
Acute tonsillitis, unspecified (J03.9)	51,651
Pain in joint (M25.5)	27,957
Type 2 diabetes mellitus (E11)	35,732
Acute laryngitis and tracheitis (J04)	22,474
Urinary tract infection, site not specified (N39.0)	51,305
Acute bronchitis, unspecified (J20.9)	33,256
Supervision of normal pregnancy (Z34)	8,450
Totals	**593,786**

3.1 Tailoring Structural Elements Based on The Health Units' Feedback

As feedback from the units began to flow in, functional enhancement and additions to the initial programs were detected. For example, for some Emergency Departments, it was necessary to introduce an "Admission Mode" in the "Hospital Discharges" program. Overall, the program that received the most feedback for changes was the "Births" program. Before the project implementation, basic information was received from health managers about the required statistics and analyses. However, after starting the data acquisition, the features which were more meaningful and enforced could be evaluated.

3.2 Developing A Culture for Data Actions

Seminars and training sessions have been conducted to increase the overall process among the public health personnel. By 2020, 258 people were trained: 142 medical doctors, 53 administrative staff, 36 nurses, 12 statisticians, seven information scientists, six public health specialists, and two pharmacists.

Furthermore, during these years, 734 medical doctors, nurses, statisticians, and public health officials in the region have been trained on public health, epidemiological surveillance and the DHIS2 system. A key aspect of the program is to guarantee the project's continuity and sustainability by establishing a team of highly specialized experts to direct the entire system once the local authorities manage it. In order to broaden the local team of experts, for the academic year of 2018 / 2019, six PhD positions have been granted, related to the project itself: three in *Nursing Sciences and Public Health* and three in *Computer Science, Control and Geoinformation*, under the University of Rome Tor Vergata, Italy.

4. DISCUSSION

Reliable and timely health information is one of the six building blocks of a health system (WHO, 2007). It is essential for guiding public health decision-makers and policy formulation for allocating resources according to actual health priorities. Including data on all the vital statistics in the setting-up of the HIS is a priority for timely identification of health requirements (WHO, 2014a; ESCAP, 2019). In the era of big data, data collection is just the initial challenge, which should be followed by the need to make good use and sense of what has been collected (Hazel *et al*., 2018).

Alongside the direct and short-term effects of war, conflicts and terrorism, the long-term effects could have devastating consequences for public health, such as the erosion of countries' ability to target health interventions and to be prepared for future emergencies (Moramarco *et al.,* 2020).

Being a war-torn country, one of the Iraq's main priorities is reconstructing a full-fledged public health system based on reliable and complete health data (WHO, 2017b). In recent years, the Iraqi Ministry of Health has endeavored to employ e-health to support the healthcare sector in the country. However, the implementation plan is still in the preliminary phase (Jaber *et al*., 2014). Nevertheless, some Iraqi health authorities declared that the vision of building an efficient healthcare system throughout the development of e-health is a key element for modern policy development, decision-making, and regulatory oversight (MoPKRG, 2013). Several studies have highlighted that there is an urgent need to develop an integrated HIS to support KRI policymakers in public health (Anthony *et al*., 2013).

The choice of the DHIS2 platform met most of the core requirements for the local settings. A highly specialized local team has been established to "train the trainers" and ensure the system's self-sufficiency in the future. The public health and engineering specialists trained under two PhD programs should guarantee the project's future continuity and sustainability with hundreds of other trained operators (RAND, 2014b). Continuous supervision of the centers and constant dialogue with key stakeholders, which consider the specific contextual requirements, are paramount elements to implement HIS successfully (Fennelly *et al*., 2020).

By the beginning of 2022, the system has covered at least half of all primary health centers, family health centers and public hospitals of the region. KRG-HIS has the potential to become one of the broadest sentinel surveillance systems in the Middle East, since it will provide high-quality information needed for national and sub-national planning, policy implementation, as well as monitoring health outcomes and services. The future scale-up to overall Iraq will be essential to support the rebuilding and reorganization of an efficient public health system.

However, it should be noted that in 2020, the COVID-19 pandemic partially disrupted the routine KRG-HIS delivering system. Almost all of the PHC clinical activities (including data entry) were put on hold. Some PHCs were converted into COVID-19 specialized centers, while PHs with Intensive Care Units were identified as COVID-19 hospitals (Stefania *et al*., 2020). Nevertheless, by December 2020, most of the PH and PHC have restarted collecting data.

At present, data in the system is currently captured only by event and cannot be linked to a specific person due to the lack of unique identity numbers (ID) for each citizen. Nevertheless, the software is already prearranged to include ID. Since the system has been set in an unstable geopolitical area, the future local and international scenarios will play essential roles in the sustainability and scaling up of the project.

5. CONCLUSION

Global health security is an international priority that must undergo planning and resource mobilization to address gaps, implement activities and scale-up programs to achieve impact. Within its scope, the rebuilding of an effective healthcare system in war-torn countries is a long-term process that requires multiple actions and actors, with epidemiological surveillance being the cornerstone. A functioning e-health system for epidemiological surveillance is a key instrument to managing complex and fluid health situations in the medium and long term while preparing to respond and cope with future emergencies.

The presented case study on KRG-HIS reports challenges and lessons learned in developing a tailored tool for e-health in a war-torn region, the Iraqi Kurdistan, offering suggestions to software developers and public health actors in other similar regions who aim to build data systems that support evidence-based decision-making.

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