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Leveraging Digital Health Interventions to Enhance Prevention, Response and Control of Public Health Emergencies in Low and Middle-Income Countries

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Table of Contents

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Editorial to JHIA Vol. 8 (2021) Issue 1

Nicky Mostert
Nelson Mandela University, Gqeberha, South Africa

The 2020/2021 edition of the HELINA (HEaLth INformatics in Africa) conference was held from 18 – 22 October 2021 as a blended virtual and in-person conference in Kampala, Uganda due to the COVID-19 pandemic. The conference was hosted by the Uganda Health Informatics Association (UgHIA) in partnership with the Makerere University, School of Public Health, the Ministry of Health (MOH), Uganda and HELINA.

The conference theme focused on "**Leveraging digital health for public health emergencies within routine care in Low- and Middle-Income Countries**" and was inspired by the COVID-19 pandemic. The aim was to provide a platform to showcase interventions in the following areas:

- Digital health initiatives and implementations for public health emergencies, clinical care and surveillance;
- Maturity models, approaches and assessment tools for digital health evaluation;
- Community-level digital health solutions in public health emergencies;
- Health information exchange: Open standards, interoperability, data privacy and security, ethical considerations, policy & governance issues including legal and regulatory;
- Open Source Software in healthcare delivery, surveillance and public health emergencies;
- eLearning and digital health training for capacity building;
- Innovations for remote patient monitoring and care (Telemedicine); and
- Data science: big data and analytics in healthcare, surveillance and public health emergencies.

Review Process

The organizers of the conference invited original submissions in the following categories: full research papers; work in progress papers; or case study/experience presentations. A total of 44 submissions in these categories were received. A double blind peer review process was used for evaluating each full research and work in progress paper. These submissions were anonymized before being submitted to reviewers according to their area of expertise. The Scientific Programme Committee based their final decision on the acceptance of each submission on the recommendations and comments from reviewers. Accepted submissions were then sent back to the authors for revision according to the reviewers' comments. This review process resulted in the following acceptance rates:

Full research papers: 43% acceptance rate (14 received, 6 accepted)
Work in progress papers: 80% acceptance rate (5 received, 4 accepted)
Case studies and experience papers: 88% acceptance rate (25 received, 22 accepted)

In order to be included in the conference proceedings, an accepted paper had to be presented at the conference, either virtually or in person. Authors also had to submit their final camera-ready papers after incorporating reviewer comments in order to be included in the proceedings. Unfortunately, only 5 of the 6 accepted full research papers, and 20 of the work in progress-/cases study-/experience papers were received and included in these proceedings.

Nicky Mostert
HELINA 2021 SPC Chair
29.12.2021

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Journal of Health Informatics in Africa

Utilisation d’une base de données numérique d’auscultations cardiaques pour la recherche d’associations entre les anomalies auscultatoires et échocardiographiques chez les enfants porteurs de cardiopathies congénitales

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Introduction : L’auscultation cardiaque et l’échocardiographie sont essentielles pour l’évaluation des cardiopathies congénitales. L’utilisation d’outils numériques (stéthoscopes électroniques, logiciels de traitement et d’annotation) permet l’enregistrement audio des auscultations cardiaques, améliore leur écoute et favorise leur description détaillée. L’objectif de cette étude était de rechercher les associations qui existeraient entre les anomalies retrouvées à l’auscultation cardiaque et les paramètres échocardiographiques chez les enfants porteurs de cardiopathies congénitales, en s’appuyant sur une base de données d’auscultations annotées.
Méthodologie : Une étude transversale descriptive a été réalisée au Centre Mère et Enfant de la Fondation Chantal Biya. Les enfants porteurs de cardiopathies congénitales non corrigées étaient inclus. Les sons issus de l’auscultation cardiaque de ces enfants ont été enregistrés et permis de constituer une base de données d’auscultations cardiaques. Les bruits d’intérêt issus de ces auscultations ont été décrits et annotés par un cardiopédiatre à l’aide d’un logiciel de traitement et d’annotation d’enregistrements audios. Ces enfants ont ensuite bénéficié chacun d’une échocardiographie. Les associations qui existaient entre les anomalies retrouvées à l’auscultation cardiaque et les paramètres échographiques ont été recherchées chez les enfants porteurs de communication interventriculaire (CIV), de sténose valvulaire pulmonaire (SVP) ou de persistance du canal artériel (PCA) isolées.
Résultats : 54 enfants ont été recrutés, soit 324 enregistrements audios pour une durée totale de 121 minutes. Les enfants de 29 jour à moins de 3 ans représentaient 51,9 % des participants. À l’auscultation, 51 patients (94,4 %) avaient un souffle cardiaque et 6 patients (11,1%) avaient un éclat du B2 pulmonaire. Les cas de CIV, PCA et SVP isolés représentaient respectivement 37%, 20,4% et 11,1% des participants. Il existait une différence statistiquement significative entre ces trois groupes de pathologies isolées par rapport au foyer où le souffle avait une intensité maximale à l’auscultation cardiaque (p=0,005). Par contre, il n’y avait pas d’association statistiquement significative entre l’intensité du souffle et les différents gradients de pression ainsi qu’avec la pression artérielle pulmonaire moyenne pour ces trois groupes de pathologies isolées. Enfin, l’éclat du B2 n’était pas associé de manière statistiquement significative à la pression artérielle pulmonaire moyenne chez les patients ayant une CIV isolée.
Conclusion : L’utilisation d’outils numériques permet d’améliorer l’expérience et les performances en auscultation cardiaque. Il servent comme support pour la description d’anomalies de l’auscultation cardiaque et facilitent ainsi la recherche d’associations entre les anomalies retrouvées à l’auscultation cardiaque et les paramètres échocardiographiques. Le foyer d’auscultation où le souffle est perçu avec une intensité maximale pourrait permettre de prédire la nature de la cardiopathie pour les trois groupes de pathologies isolées étudiées.

Mots clés : Cardiopathie congénitale, auscultation cardiaque, échocardiographie, stéthoscope électronique.

1. Introduction

Les cardiopathies congénitales sont des anomalies structurelles macroscopiques du cœur et/ou des grands vaisseaux intrathoraciques, avec un retentissement potentiel sur les fonctions physiologiques [1]. Elles affectent environ un million d’enfants par an dans le monde avec une prévalence généralement admise de

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8/1000 naissances [2–4]. En Afrique, le nombre d'enfants atteints de cardiopathies congénitales est largement sous-évalué [5].

L'échocardiographie représente le goal standard en matière de diagnostic des malformations cardiaques [6] mais son accès reste difficile au sein des pays à ressources limitées. Toutefois, le souffle cardiaque est souvent le premier signe à l'examen clinique de cardiopathies congénitales [7,8]. Des études ont montré que comparé à l'échographie, l'auscultation cardiaque est plus efficiente pour différentier les souffles organiques des souffles fonctionnels [9–11].

Ainsi, mettre en exergue les associations qui existeraient entre les anomalies présentes à l'auscultation cardiaque chez les enfants porteurs de cardiopathies congénitales d'une part et les paramètres échocardiographiques retrouvés d'autre part, pourrait aider au dépistage précoce et efficient de ces pathologies dans les contextes de pays à ressources limitées.

La mise en évidence de ces associations peut se faire à travers l'utilisation du numérique. En effet, l'auscultation a bénéficié de l'avènement du stéthoscope électronique au travers de ses fonctions d'amplification, de filtrage et de stockage des enregistrements lors de l'auscultation [12,13]. Son utilisation permettrait d'améliorer la qualité et l'écoute des enregistrements au cours de l'auscultation. De plus, l'utilisation d'un logiciel de traitement et d'annotation des enregistrements audios améliorerait leur écoute, la visualisation de leurs caractéristiques et permettrait de fournir une description détaillée desdits enregistrements [14,15].

En s'appuyant sur une base de données d'auscultations annotées, l'objectif de cette étude était de rechercher les associations qui existeraient entre les anomalies retrouvées à l'auscultation cardiaque et les paramètres échocardiographiques chez les enfants porteurs de cardiopathies congénitales.

2. Méthodologie

2.1. Design de l'étude

Une étude transversale descriptive a été menée au Centre Mère et Enfant de la Fondation Chantal Biya (CME-FCB) de Yaoundé sur une période de 9 mois, allant d'octobre 2018 à juin 2019. Les sons issus de l'auscultation cardiaque d'enfants porteurs de cardiopathies congénitales ont été enregistrés et permis de constituer une base de données d'auscultations cardiaques. Les bruits d'intérêt issus de ces auscultations ont été décrits et annotés par un cardiopédiatre à l'aide d'un logiciel de traitement et d'annotation d'enregistrements audios. Ces enfants ont ensuite bénéficié chacun d'une échocardiographie. Les associations qui existeraient entre les anomalies retrouvées à l'auscultation cardiaque et les paramètres échographiques ont été recherchées.

2.2. Participants, critères d'inclusion et d'exclusion

Dans cette étude était inclus : (i) tout enfant porteur de cardiopathie congénitale connue ou de découverte récente n'ayant reçu aucune correction chirurgicale ou médicale et (ii) âgé de 18 ans au plus. Les patients exclus étaient (i) ceux ayant des données auscultatoires ou échocardiographiques incomplètes à l'issue des investigations , (ii) les patients présentant une pathologie aiguë (fièvre, anémie) au moment de l'étude et (iii) les patients présentant à l'échographie cardiaque une cardiopathie acquise associée à leur cardiopathie congenitale (cardiopathie rhumatismale, sequelles valvulaires d'endocardite, séquelles de myocardite).

2.3. Échantillonnage

Il s'agit d'une étude pilote et un échantillon de convenance de 50 enfants a été choisi.

2.4. Procédure

Formation au maniement des outils numériques.

Un opérateur a été formé préalablement au maniement des outils numériques utilisés pour l'enregistrement et l'annotation des auscultations cardiaques. Il s'agissait : (i) du stéthoscope électronique 3M Littmann® 3200, (ii) de son logiciel dédié Littmann® Stethassist et (iii) du logiciel Audacity® version 2.2.2.

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Recrutement.

Les sujets répondant aux critères d'inclusion étaient sélectionnés au sein des registres du service de cardiologie du CME-FCB par tirage aléatoire. Leurs parents étaient contactés par téléphone. Les buts de l'étude leurs étaient expliqués et il leur était remis des fiches d'information et de consentement éclairé. Tous les enfants dont le consentement était approuvé par au moins un des parents/tuteurs légal étaient retenus dans l'étude.

Auscultations cardiaques et enregistrements.

L'auscultation cardiaque était réalisée chez chaque patient au repos, en position assise et dans une salle calme. Le stéthoscope électronique 3M Littmann® 3200 et son logiciel dédié Littmann® Stethassist était utilisé pour connecter le stéthoscope électronique à un ordinateur portable et réaliser des enregistrements audios d'auscultations cardiaques. Les foyers d'auscultation cardiaque évalués étaient : (i) le foyer aortique, (ii) le foyer pulmonaire, (iii) le foyer tricuspide, (iv) le foyer mitral, (v) le foyer d'Erb et (vi) le foyer sous-claviculaire gauche. Le foyer d'Erb était enregistré durant minute tandis que les autres foyers étaient enregistrés pendant 30 secondes. Six fichiers audios étaient ainsi enregistrés pour chaque patient. L'ensemble d'enregistrements audios a permis de constituer une base de donnée numérique d'auscultations cardiaques.

Annotation des enregistrements audios d'auscultations cardiaques.

Les enregistrements ont été anonymisés puis transmis à un cardiopédiatre pour écoute et annotation à l'aide du logiciel Audacity® version 2.2.2. Il s'agit d'un logiciel de traitement audio utilisé pour écouter et annoter des enregistrements audios. Ce logiciel dispose de fonctionnalités telles que l'amplification, le filtrage et la visualisation (figure 1). L'annotation par le cardiopédiatre a permis d'identifier pour chaque patient les signaux physiologiques du cœur (bruits normaux du cœur, temps respiratoires) et les signaux anormaux ou pathologiques (souffles cardiaques et éclat du B2 au foyer pulmonaire). Pour chaque patient, il devait déterminer la présence ou non des signaux pathologiques. En cas de présence d'un souffle, il devait préciser : son foyer, son intensité et sa temporalité.

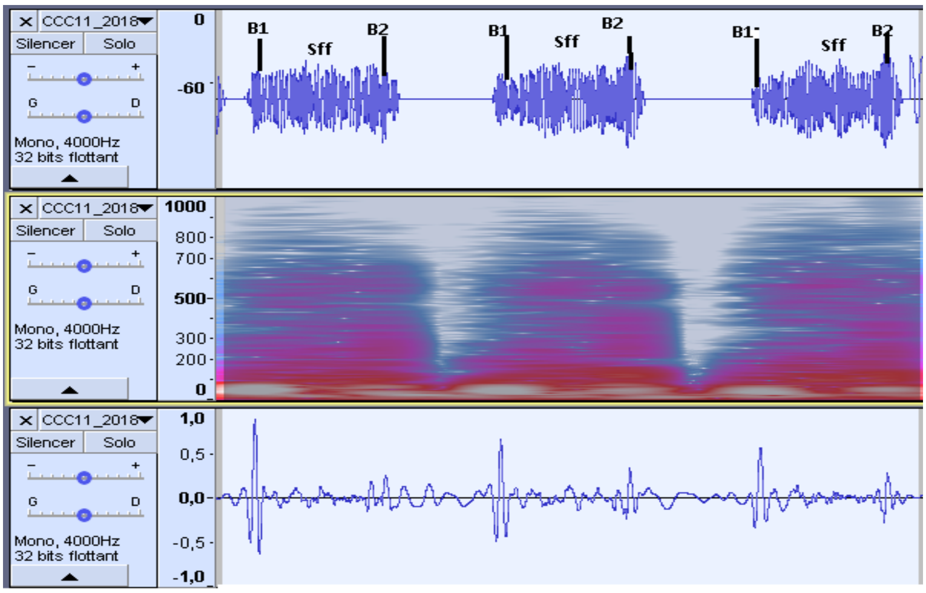

Figure 1 Copie d'écran du logiciel Audacity® montrant un phonocardiogramme mettant en exergue un souffle d'allure rectangulaire qui occupe l'ensemble de la systole (communication interventriculaire chez un nourrisson de 10 mois).

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Réalisation des échographies cardiaques.

Un examen d'échographie cardiaque complète a été réalisée chez chaque patient. Cette échographie avait pour but de déterminer: (i) le diagnostic lésionnel, (ii) la vitesse du flux de régurgitation de la valve pulmonaire, (iii) le gradient de pression au travers de l'anomalie septale, (iv) le gradient de pression transvalvulaire pulmonaire et (v) le gradient de pression transcanalaire. (vi) La pression artérielle pulmonaire moyenne (PAPm) était déduite du flux de régurgitation de la valve pulmonaire par l'équation de Bernoulli : PAPm = 4VmaxIP2 (VmaxIP : flux de régurgitation de la valve pulmonaire).

2.5. Collecte de données

Les données ont été collectées à travers un questionnaire. Ce questionnaire comprenait des sections relatives à l'identification du patient, à la description de l'auscultation cardiaque et à la description des paramètres échocardiographiques.

2.6. Critères de jugement

Les variables de l'auscultation cardiaque étaient : (i) la localisation du foyer d'auscultation où le souffle avait une intensité maximale c'est-à-dire là où il était le mieux perçu (aortique, pulmonaire, tricuspidienne, mitrale, sous claviculaire gauche ou au niveau du foyer d'Erb) ; (ii) l'intensité de ce souffle (faible pour les intensités 1 et 2, modérée pour l'intensité 3 et forte pour les intensités 4 à 6) ; (iii) son temps (systolique, diastolique ou continu) ; et (iv) l'éclat du B2 (absent ou présent). Les variables échocardiographiques étaient : (i) le diagnostic lésionnel (nature de la cardiopathie), (ii) les gradients de pression trans-septale (au travers de l'orifice septale), transvalvulaire pulmonaire et transcanalaire, et (iii) la pression artérielle pulmonaire moyenne (PAPm).

Les associations ont été recherchées uniquement chez les sujets porteurs de communication interventriculaire (CIV), de persistance du canal artériel (PCA) et de sténose valvulaire pulmonaire (SVP) isolées. Il s'agissait de : (i) l'association entre la localisation (foyer d'auscultation cardiaque) du souffle où l'intensité est maximale et le diagnostic lésionnel (nature de la cardiopathie à l'échocardiographie) ; (ii) l'association entre l'intensité du souffle et le gradient de pression trans-septal chez les patients ayant une CIV isolée; (iii) l'association entre l'intensité du souffle et le gradient de pression transvalvulaire pulmonaire chez les patients ayant une SVP isolée; (iv) l'association entre l'intensité du souffle et le gradient transcanalaire chez les patients ayant une PCA isolée; (v) l'association entre l'intensité du souffle et la pression artérielle pulmonaire moyenne (PAPm) chez les patients ayant une CIV isolée; et (vi), l'association entre l'éclat de B2 et la PAPm chez les patients ayant une CIV isolée.

2.7. Analyses statistiques

Les données ont été saisies à l'aide du logiciel Epidata v.3.1 et analysées à l'aide du logiciel IBM-SPSS v.22 pour Windows. Les variables continues étaient exprimées en médiane avec intervalles interquartiles (Q1-Q3) tandis que les variables catégorielles étaient exprimées par des fréquences. Les associations entre les variables catégorielles ont été exprimées par le test exact de Fisher ou le test du Chi-2. Les associations entres les variables continues et les variables catégorielles ont été recherchées par les analyses de la variance selon Kruskall Wallis et le test U de Mann-Whitney. Le seuil de significativité statistique était fixé à $p<0,05$.

3. Résultats

Au total, 54 patients ont été recrutés, soit 324 enregistrements audios recueillis pour une durée totale de 121 minutes. Les enfants (de 29^{e} jour à moins de 3 ans) représentaient 51,9 % des participants, suivis de 22,22 % d'enfants de 3 ans à moins de 6 ans. À l'auscultation cardiaque, 51 patients (94,4 %) avaient un souffle cardiaque (tableau 1) et 6 patients (11,1%) avaient un éclat du B2 pulmonaire.

Les cas de CIV, PCA et SVP isolés représentaient respectivement 37%, 20,4% et 11,1% des participants. Les différents gradients de pression et la pression artérielle pulmonaire moyenne pour les cas de CIV, PCA et SVP isolés sont illustrés dans le tableau 2.

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Trois quarts des souffles de CIV étaient perçus de manière maximale au foyer de Erb. Il existait une différence statistiquement significative entre les trois groupes de pathologies isolées (CIV, PCA, SVP) par rapport au foyer où le souffle avait une intensité maximale à l'auscultation cardiaque (p=0,005), tableau 3.

Il n'y avait pas d'association statistiquement significative entre l'intensité du souffle et les gradients de pression trans-septal, transvalvulaire, transcanalaire et la pression artérielle pulmonaire moyenne chez les patients ayant une CIV isolée, une SVP isolée, une PCA isolée et une CIV isolée respectivement. De plus, l'éclat du B2 n'était pas associé de manière statistiquement significative à la pression artérielle pulmonaire moyenne chez les patients ayant une CIV isolée (tableau 4).

Table 1 Caractéristiques des souffles perçus à l'auscultation cardiaque

Variables (N=51)	**n**	**(%)**
Localisation du souffle		
Pulmonaire	21	41,2
Erb	19	37,3
Sous-claviculaire G	6	11,8
Aortique	4	7,8
Tricuspidien	1	2,0
Intensité du souffle		
Faible	25	49,0
Moyenne	12	23,5
Forte	14	27,5
Temps du souffle		
Systolique	45	88,2
Continu	5	9,8
Diastolique	1	2,0

Table 2 Caractéristiques écho-cardiographiques des cardiopathies congénitales

Variables (N=54)	**n**	**%**
Cardiopathies non cyanogènes	**46**	**85,2**
Communication interventriculaire (CIV)	20	37,0
Persistance du canal artériel (PCA)	11	20,4
Sténose valvulaire pulmonaire (SVP)	6	11,1
Communication interauriculaire (CIA)	3	5,6
CIV + PCA	3	5,6
CIV + SVP	2	3,7
CIA + SVP	1	1,9
Cardiopathies cyanogènes	**8**	**14,8**
Tétralogie de Fallot	4	7,4
Atrésie tricuspidienne (AT)	1	1,9
CIV + CIA + AT	1	1,9
Tronc artériel pulmonaire	1	1,9
Atrésie pulmonaire à septum ouvert (APSO)	1	1,9
Gradients de pression et PAPm	**n**	**Médiane (Q1-Q3)**
Gradients de pression trans-septal (CIV isolée) - mmHg	18	58,3 (11,75 - 89,75)
Gradients de pression transvalvulaire pulmonaire (SVP isolée) - mmHg	6	60 (31,25-72,0)
Gradients de pression transcanalaire (PCA isolée) - mmHg	11	78 (60 ,0-108,0)
Pression artérielle pulmonaire moyenne – PAPm (CIV isolée) - mmHg	14	5,5 (3,36-11,68)

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Table 3 Association entre le foyer d'auscultation cardiaque où le souffle a une intensité maximale et le diagnostic lésionnel (nature de la cardiopathie)

Foyers d'auscultation avec souffle d'intensité maximale	Aortique	Pulmonaire	Erb	Tricuspide	Sous-claviculaire gauche	p
CIV	1 (5%)	3 (15%)	15 (75%)	1(5%)	0 (0%)	0,005
PCA	1 (16,7%)	3 (50%)	0 (0%)	0 (0%)	2 (33,3%)	
SVP	1 (9,1%)	5 (45,5 %)	1(9,1%)	0 (0%)	4 (36 ,4%)	

Table 4 Associations entre intensité du souffle et gradients et entre éclat du B2 et PAP m.

Variables				p
	Intensité souffle			
	Faible	Moyenne	Forte	
Gradient de pression trans-septal (CIV isolée) - mmHg	7,8	12,3	10,6	0,37
Gradient de pression transvalvulaire pulmonaire (SVP isolée) - mmHg	3,0	4,0	4,0	0,80
Gradient de pression transcanalaire (PCA isolée) - mmHg	5,1	9,0	6,0	0,35
Pression artérielle pulmonaire moyenne – PAPm (CIV isolée) - mmHg	6,3	4,3	10,8	0,69
	Eclat du B2			
	Présent	Absent		
Pression artérielle pulmonaire moyenne – PAPm (CIV isolée) - mmHg	3	8		0,29

4. Discussion

L'auscultation cardiaque est un des outils utilisé pour l'évaluation initiale des cardiopathies congénitales de l'enfant. Au cours de l'étude, une base de données de 54 enregistrements audios d'auscultations cardiaques a pu être constituée à l'aide d'un stéthoscope électronique. Ces enregistrements ont été décrits et annotés par un cardiopédiatre à l'aide d'un logiciel de traitement et d'annotation d'enregistrements audios. Tous ces outils numériques permettent d'améliorer l'écoute et l'analyse des enregistrements audios pour améliorer l'expérience et les performances en auscultation cardiaque. Ceci ouvre de nouvelles perspectives en matière de soins (amélioration de l'aide au diagnostic) et d'enseignement (amélioration de l'apprentissage de l'auscultation). Noponen et al en 2007, ont démontré que l'analyse de phono-spectrogrammes améliorait la précision de l'évaluation primaire d'un souffle et permettait d'éduquer les étudiants et les cliniciens inexpérimentés [16]. Andrés et al en 2011 ont mis en évidence l'amélioration des performances diagnostiques chez les étudiants du second cycle qui utilisaient les outils de visualisation des signaux auscultatoires [17].

Dans cette étude, il a été retrouvé une association statistiquement significative entre la nature de la lésion et le foyer d'auscultation où était perçu le souffle avec une intensité maximale. Ces résultats rejoignent ceux de l'abondante littérature sur la sémiologie des souffles [18–21] et suggèrent qu'une auscultation fine chez un enfant porteur de cardiopathie congénitale permet de poser le diagnostic lésionnel. L'intensité d'un souffle est le reflet du degré de turbulence du flux sanguin au sein de la structure traversée. Elle est donc maximale au siège de la lésion puis diminue progressivement au mètre carré de distance parcourue [22]. De plus, chez certains enfants porteurs de cardiopathies congénitales, on ne retrouve aucune turbulence. Cela peut expliquer pourquoi des lésions (même relativement graves), peuvent passer inaperçues et être diagnostiquées tardivement. Dans notre série trois enfants ayant des cardiopathies congénitales isolées, soit un ayant une AT et deux ayant une CIA ne présentaient aucun souffle. À l'échocardiographie, ils ne présentaient pas de gradient de pression au niveau de l'anomalie septale pour les enfants ayant une CIA ni au niveau de la tricuspide pour les enfants ayant une AT.

L'intensité du souffle est fonction : des dimensions de l'orifice ou du vaisseau au travers duquel le flux sanguin s'écoule, du volume sanguin s'écoulant et du différentiel de pression au travers de l'orifice. Il n'existait pas d'association statistiquement significative entre l'intensité du souffle et les gradients de

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pression trans-septale, transvalvulaire, transcanalaire et la pression artérielle pulmonaire moyenne chez les patients ayant une CIV isolée, une SVP isolée et une PCA isolée respectivement. Nous pouvons supposer qu’il existait une hétérogénéité dans le diamètre des anomalies septales, valvulaires ou canalaires chez les patients de cette étude. Danford et al en 1999 se sont intéressés spécifiquement à la SVP isolée et ont pu établir qu’en s’appuyant sur le souffle, l’expertise d’un cardiologue permettait de la distinguer des autres lésions cardiaques sans pour autant que cela soit suffisant pour grader la sévérité de cette pathologie [23]. Phoon et al en 2017 quant à eux, ont obtenu des résultats différents. Ils ont démontré que l’examen clinique permettait d’évaluer avec précision les gradients de pression dans les cas de CIV et de SVP isolés ou associés à d’autres lésions [24].

Enfin, l’éclat du B2 n’était pas associé de manière statistiquement significative à la pression artérielle pulmonaire moyenne chez les patients ayant une CIV isolée. Cobra et al en 2016 avaient retrouvé des résultats similaires dans une étude menée sur des patients porteurs de pneumopathie interstitielle [25]. Chan et al en 2013 dans une étude cas-témoins, avaient retrouvé une relation entre les caractéristiques acoustiques des bruits B1 et B2 et la sévérité de la PAPm [26]. Dans cette étude, la PAPm avait été évaluée par cathétérisme fournissant ainsi une meilleure précision au cours de sa mesure.

5. Conclusion

Au terme de cette étude, nous pouvons affirmer que l’utilisation d’outils numériques permet d’améliorer l’expérience et les performances en auscultation cardiaque. Ils favorisent l’enregistrement des sons issus de l’auscultation, améliorent l’écoute et servent de support pour la description et l’analyse des anomalies de l’auscultation cardiaque. Leur utilisation comme support de description et d’analyse des anomalies de l’auscultation cardiaque a permis de rechercher les associations entre les anomalies retrouvées à l’auscultation cardiaque et les paramètres échocardiographiques. Une association statistiquement significative a été retrouvée entre la nature de la lésion et le foyer où est perçu le souffle cardiaque avec une intensité maximale. Ainsi, le lieu (foyer d’auscultation) où le souffle est perçu avec une intensité maximale pourrait permettre de prédire le diagnostic lésionnel (nature de la cardiopathie) en ce qui concerne les trois groupes de pathologies isolées étudiées (CIV, PCA et SVP).

6. Limites de l’étude

Les principales limites de notre étude sont : la faible taille de l’échantillon due à des contraintes budgétaires (financement limité pour les échocardiographies) et le caractère subjectif de l’interprétation de l’auscultation cardiaque qui peut dépendre de l’expérience du médecin, des conditions et de la qualité des enregistrements audios.

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Journal of Health Informatics in Africa

eHealth Architecture based Health Data Exchange: Ethiopia DHIS2 and SmartCare

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Background and Purpose: Blueprint of national level arrangement of health system components in Ethiopia is depicted in the eHealth Architecture (eHA). The lack of practical implementation experience is limiting Ethiopia's ability to move toward maturing the architecture. In this study, the team was set out to explore practical implementation and scaling solutions that leverage open standards and tools. Two major components of the eHA are used to demonstrate the health data exchange, legacy Electronic Medical Record (EMR) system and national electronic Health Management Information System (HMIS) instances. HMIS contains 53 data sets used by more than 35, 000 health facilities serving at different layers of the health sector, including health posts, health centres, hospitals and other facilities to deliver reports of various types. It is the major source of information by the Federal Minister of Health. Main purpose of this study is to exploit potentials and overcome challenges that focus on health data exchange patterns of national eHA.

Methods: Thorough assessment of related works is conducted with national and local perspectives. eHA based health data exchange model is developed leveraging open tools and standards. HAPI FHIR is adopted to extract local relational EMR data to FHIR messaging. It is an open source, and java-based HL7 FHIR implementation. With the main focus on scalability of design, the team developed a strategy for mapping local data elements to FHIR resources and created an OpenHIM based mediator. Components with high impact factor on national level health data quality are selected to demonstrate the developed model. Evaluation method to compare interoperability based and manual tally sheet based data entry is conducted. Top 10 diseases were used to test and evaluate the experiment.

Results: The developed model adhering to national eHA data exchange patterns resulted to enhanced data quality. Data quality in terms of timelines, accuracy, completeness and cost parameters over 12 months of production EMR data for top ten disease classifications were examined. Scalable local EMR data to FHIR resource data element mapping was developed using HAPI FHIR library. Its effectiveness was proven as it effectively mapped the elements for the identified FHIR resources. Study results also showed use of eHA interoperability patterns produced enhanced HMIS data quality and established reusable data exchange modules with national impact. Though Ethiopia has standardized national classification of disease, adopted from World Health Organization ICD-10, our extensive experiment revealed fragmented efforts toward health data reporting has resulted in inconsistent data elements. To overcome the challenge, the study suggests using national terminology service instances with capability to cascade concepts at facility level.

Conclusions: The study asserts use of open global standards and tools facilitates maturity of national eHA. Scalable health data exchange model was developed and tested with the major data source components of eHA, EMR and the national HMIS instances. In conclusion, interoperability of those systems significantly fosters national eHA maturity.

Keywords: Health Data Exchange, EMR Interoperability, EMR FHIR Support, HAPI FHIR, Legacy EMR, Commercial EMR

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1. Introduction

1.1. Background

The Health Sector in Ethiopia has been long working to enhance health care service delivery through digital solutions. The sector with its partners has been rolling out different projects in different parts of the health system to support the realization of the Ethiopian Health Sector Transformation Plan (HSTP) [1] [2]. So far, various Health Information Systems (HIS) are introduced, and different studies are conducted to support the HIS activities in leveraging emerging technologies for better health services.

An Information Revolution Roadmap(IRR) was prepared and implemented, as one of the four pillars of the HSTP, to support the digitization and information use of the sector [3] [4]. The IRR agenda is to realize the methods and practices of collecting, analyzing, presenting, and disseminating information. One of the fruitions of the roadmap is the Ethiopian eHealth Architecture (eHA) [5]. The eHA defines guidelines and principles to facilitate the standardization and interoperability of HISs. It is developed to plan for and consider future needs and embrace global data exchange practices. Conventional practices are often focused on local implementation needs with little concern for interoperability and data sharing across systems.

In low resource settings, HISs are introduced for data collection needs. Such silo systems are not designed for future expansion and data sharing needs, making it challenging to retrospectively incorporate emerging national and international data exchange needs. On the other hand, replacing existing systems with new systems pose feasibility challenges including challenges of data migrations, budget constraints and resource scarcity. This creates a juxtaposition of constraints; the need for legacy/commercial systems integration that puts the health sector in a better position yet the associated cost for doing that is not feasible. Development of an architected solution to enable the integration of those disparate systems with the simplest effort is needed. Large scale and impactful digital healthcare projects need to be supported and backed by studies that explore demonstration of pragmatic approaches, solutions, findings, outcomes that create a strong foundation for the approaches of the large-scale projects. HISs and standards that play a significant role in early adoption of eHA include Electronic Medical Recording (EMR), Health Management Information System (HMIS), Health Information Exchange (HIE) and the widely accepted health data exchange HL7 standard, Fast Healthcare Interoperability Resources (FHIR).

The introduction of an EMR system has played a great role in the enhancement of health service quality [6] [7]. International organizations such as PEPFAR are beginning to encourage a move toward use of patient-level data [8] and countries are promoting the implementation of national scale EMR [9]. But, the nationwide implementation of EMR in the context of health information exchange and interoperability has been given minimum priority [10] [6]. The main challenges that come with legacy system transformation are universal patient identification, data safety, and technical complexity concerning standards definition, data structure, and terminology harmonization. On the other hand, there is also an issue of nationwide implementation modality whether to consider a single central information exchange platform or a federated architectural design [11] [10].

Recent trends show developing countries are increasingly involved to introduce local and global goods to the health sector. In Ethiopia, before the implementation of DHIS2, there were two different homemade electronic applications. As new requirements emerge the systems are not adoptable to entertain the high data demand and information use. For this reason, the FMOH endorsed DHIS2, a globally known platform, as a country wide HMIS software to collect, validate, analyze, and present aggregate data [12]. Point of service applications, such as EMR systems, are data sources for national level HMIS systems. Suitable interoperability scheme that considers the national eHA data exchange patters and utilize health data standards is vital to bring about a significant change.

Interoperability is a mechanism by which two or more systems interact to exchange information and work together [13] [14] [15]. This usually leads to a central repository where data is collected and persisted from which data analysis is to be carried out. This in hand, enables retrieval of important information visualized to depict trends that help the health sector how and when to act in certain situations [11]. Scalable and incremental health information architecture that leverages an interoperability layer to facilitate information exchange and orchestration among HIS without a major change of technology and design paradigm is needed [16] [17] [18]. The major improvements are availability of longitudinal patient medical records and the exchange of aggregated reports in-between point-of-service application and routine health information systems [12] [10] [19] [20]. Different practices have been implemented as a showcase and

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prototype to the real-world interoperability of systems. Some of them focus on a specific use case reporting such as mortality or other wellness data. A different use case is to utilize wearable devices as a source of data for EMR system [21] [22]. Data extracted from EMR systems is relevant for other third party systems depending on their needs. In order to use such data, persisted and transiting messages need to be standards based. One of the widely used messaging standards to share resources between HISs is FHIR [23].

FHIR (HL7, 2020) is an interoperability specification that ties health care systems with a common and standardized representation of resources. It enables those systems to communicate as they understand what information is communicated and what is expected in response to a request [24] [25] [26]. Regardless of data representation and persistence of data within a health system, the specification aims to have a common format during communication with other systems. This ultimately helps health systems to be able to provide correct and timely data. FHIR is a data model and representational state transfer (RESTful) API which is developed with the experience from HL7 ancestors, HL7 V2 and HL7 V3. In recognition of today's industry best practices for complex business systems design, it employs iterative and incremental development processes, referred to as agile approach, and utilizes RESTful principles [21].It is based on web technologies that have already widespread acceptance and utilizes existing integration tools and methods.

1.2. Objectives

The purpose of this study is to establish patterns for implementing and scaling solutions of major HISs data exchange in low and limited resource settings. In this study we aim to show the existing infrastructure and coordination of eHA components in a holistic approach and trigger the concerned the concerned bodies for informed long and short term planning toward eHA maturity. In this study, the following major tasks are performed:-

- Assess global open standards data exchange trends and their application in low and resource limited settings.
- Develop adaptation strategy of open health data exchange in low resource environments
- Enable legacy facility and community based HISs to expose health data for use in the broader health context
- Develop a reusable common mediation module for sharing data

2. Materials and methods

2.1. Related works

To understand the current trends on health data exchange patterns, the team reviewed literature and observed global practices. Keywords and phrases were used to identify potentially related articles and results that spanned more than 15 journals were obtained. The team discussed on highly related papers and identified technical patterns and approaches. We have observed a trend to move toward use of patient-level data for calculation of HMIS metrics [27] [28]. Another trend is integration of national HMIS and point-of-service EMR systems with scalability, efficiency, messaging standards and use of open tools as a targets of achievement [17] [29] [9] [30] [27] [28]. The identified trends, automated indicator reporting and mapping EMR data elements to FHIR resource elements are two important challenges identified at implementation level.

A middle layer FHIR server using HAPI FHIR was implemented to enable the interoperability of an EHR system with bedside(i2b2) clinical warehouse(CDW) [27] [31]. Warehouse data model is represented as an entity-attribute-value model, though the java implementation is based on regular relational tables. After manually inspecting the local database, mapping of data elements from the i2b2 CDW to FHIR resources has been achieved with java hibernate persistent entities for each FHIR resource. A more general approach is proposed by [10] that utilize NLP methods to map EHR data, structured and unstructured, to FHIR Models as opposed to similar solutions that are specific to clinical domains. Data annotation is carried out that is used to compute over and pass through NLP based pipeline, NLP reusable modules that transform the input data based on the annotations. UIMA, a software framework to analyse unstructured content, is used to reuse and develop modules that transform the annotated data. HAPI FHIR is used to expose the processed data. The experiment is conducted on MedicationStatement FHIR resources. Observed difficulty

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of mapping EHR elements to FHIR elements, as EHR elements are numerous to work with [17] suggests automation means to perform this task with minimum human intervention. The study used a reconfigurable setting using semantic and morphological similarity computation to map EHR and FHIR elements. With an aim of exposing processed extracted health data with a single FHIR server, element mapping is explained in terms of equivalence to name, element type, and resource representation similarity during the computational processing.

Study results show data quality and process efficiency enhancements are achieved through health data exchange and interoperability [28] [27]. In terms of FHIR data exchange, promising milestones are achieved to map local data with FHIR resource elements [17] [10]. But Use of custom data representation and integration of systems using a direct link (point-to-point) puts a challenge to repeat the same effort during scale up. On the contrary, an architectural approach toward national health data interoperability as a holistic approach to address the challenges associated is crucial [32].

The rapidly growing and increased global acceptance of FHIR standard has instigated studies to target automated approaches for legacy and commercial EHR systems to benefit from FHIR containers. Main challenges have revolved around unpredictability of data representation on legacy and commercial EHR systems. Mapping of local data elements with FHIR resources is a great deal of work but reusability in production systems is also an important determinant. The general objective of our study is to develop a health data exchange model suited for low resource settings with reusable common data exchange modules that drive an overall workflow harmonization at a regional and national scale. It aims to reduce efforts of data exchange modules rework by utilizing heuristic inputs and automatically mapping local data elements of an EHR to FHIR resources, to ease usage of the system in practical environments.

2.2. Current state assessment method

The team conducted an assessment to identify barriers of eHA components HIE and interoperability adhering to the eHA architectural specification. The goals of the assessment were to identify systems capable of being piloted to meet data exchange needs through:

- identification of health data exchange needs that can be supported by the data source
- identification of barriers to health data exchange
- identification of eHA components that are currently in use
- assessment of capabilities for data sharing
- assessment of the accuracy and completeness of the data source

The team followed similar methodology to [33], where onsite observation of health facilities and authors own experience is used to conceptualize local, national and international perspectives. The team also assessed the current status of eHA to identify components that are currently in use and considered FMOH trust for data utilization for a larger impact. Besides, we considered systems that can have better contribution to the known need for data sharing and are able to be piloted using real data.

2.3. Health data exchange model

Health data exchange and interoperability is the driving factor toward eHA maturity. Our model used the existing national eHA as a basis. The core aspects of our study spanned the eHA components including point-of-service applications, the interoperability layer and shared HIS components. To demonstrate our model, we used adoption maturity of HISs from each layer and utilized reference technologies of each HIS component to implement our demonstration. The eHA is based on an interoperability layer to enable registry services and point-of-service applications to communicate and exchange data. The team assessed eHA components current adaptation status in practice in alignment with needs of the FMOH to select important HISs for our study. An important challenge is taken to involve legacy HIS in order to affirm a pragmatic conclusion is reached.

2.4. Technology

The Ethiopia eHA outlines the overall health data exchange patterns and shows implementation technologies of each HIS component. Consequently, as per the eHA guidelines, OpenHIM

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(http://openhim.org/), an open source software, is an interoperability layer reference implementation technology. The national HMIS, DHIS2, from the shared services layer and SmartCare, an EMR system, are selected for their adoption maturity to conduct our study. The team adopted HAPI FHIR to expose SmartCare EMR local data, which involves developing EMR and FHIR resource data element mapping strategy. To demonstrate the data exchange of selected components for the identified use case, the team developed a Disease Registry Mediator[1] to retrieve data from the FHIR server, make aggregation and transformation of the data. Finally the mediator sends a monthly aggregate report to DHIS2 using the DHIS2 API, Figure-1 shows the integration model.

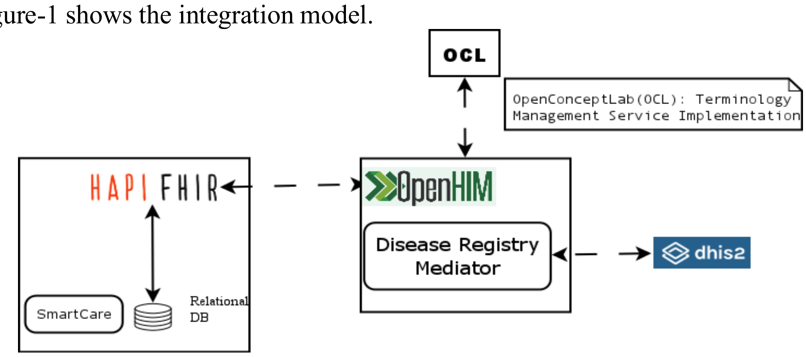

Figure 1. Health data exchange model

2.5. Test and evaluation method

In adherence to eHA guidelines and use of reference technologies, the team implemented integration testing for the identified use case and conducted experiments in a real world environment and production HISs. The major emphasis is given on the overall health data exchange and the impact in data quality and scalability of local data and FHIR data element mapping. A comparison of data retrieved by the adopted FHIR server and manually inspected data from the tally sheet is conducted to assess the data quality, data demand and information availability. Relevant dimensions of data quality were assessed and compared with the manual practice. Hence implementation feasibility in terms of cost, time, and technical capacity associated with collecting and aggregating the data and human resource needs are investigated to the proposed solution. These evaluation criteria examine durability and long term use of the integration model in support of functionality and capability of HISs seamless integration.

3. Results

The main aim of our experiment is to enable eHA components to exchange data adhering to eHA principles. Analysis of our experiment is explained in three major actions taken. First, the eHA contains point-of-service applications in its lower layer. The point-of-service applications are main data sources to the top most layers, the shared services or registries layer. Accordingly, in this study legacy EMR system is used as a data source. It is a closed source desktop application that lacks an API to exchange data. In order to overcome this challenge, we leveraged HAPI FHIR library and developed new data element mapping scheme to extract data from relational database. Second, in this study, we used the most common data exchange use case to implement data exchange adhering to eHA principles that leverage the interoperability layer. A mediator is developed that triggers health data exchange to extract data from HAPI FHIR API, make aggregation and submit to a national HMIS instance. Thirdly, we conducted data quality assessment on the existing practices to exchange health data. This is used to show the significance of our study and illustrate the existing need for data quality improvement.

3.1. Standards based legacy EMR data extraction

Making use of standards based health data exchange and interoperability is a foundation for effective and sustainable approach. Following our assessment, FHIR is a de-facto standard for health data exchange with

[1] https://github.com/haftamuk/openhim-mediator-SmartCare-DHIS2-DiseaseRegistry-Data

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growing acceptance and implementation cases across various countries. HAPI FHIR is built for an extensive use and realization of HL7 FHIR standard powering interoperability. It is an open source java based implementation with RESTFull interface and abstraction of local data using FHIR resources. In addition to exchange local data adhering to FHIR standard, it provides security implementation to enable clients to authenticate themselves. Harnessing the capabilities with an extended use in commercial and legacy EMR systems, in this study, the team developed EMR local data and FHIR resources mapping scheme. HAPI FHIR is adopted4 to expose SmartCare local relational data.

An approach to map local EMR data with FHIR resource data elements involved creating java entities for each identified FHIR resource. To minimize duplication of effort and reuse implementations java persistent entities is not used as it will require refactoring during different EMR instances. Tested and readymade SQL queries for the identified FHIR resources provided by the database administrator are used to retrieve data from the relational database. Result set of the query was then parsed to instantiate objects and build a collection of objects. This data element mapping model requires creating java entities for each FHIR resource. Incorporation of dynamic query is an important aspect for scalability and flexibility properties of the integration. Only the SQL query to the corresponding FHIR resources and use cases at hand need to be modified during scale up efforts. Thereby, deployment of the adopted HAPI FHIR server in other EMR instances requires adjusting the raw sql queries accordingly. The intention is to ease the scale-up of our implementation to regional and national level. The developed legacy EMR data extraction scheme is tested on Patient and Condition resources that are relevant for the identified use case demonstration. In order to not create an additional layer, the adopted FHIR server was deployed within a similar machine where the EMR is deployed for demonstration purpose. FHIR web API was used to access the resources and expected results were obtained, which proved effectiveness of the developed standards based data extraction scheme.

3.2. eHA based health data exchange

In order to demonstrate the results, an experiment using eHA data exchange patterns with the most common use case is conducted. We selected the national HMIS, and an EMR to demonstrate the data exchange. DHIS2 is a web-based national HMIS implementation. It contains 53 data sets used by more than 35, 000 health facilities serving at different layers of the health sector, including health post, health center and hospitals, to deliver reports of various types and it is the major source of information by the FMOH. To limit the scope of the implementation, we demonstrated the implementation in Ayder Comprehensive Specialized Hospital and considered all data elements that are reported using DHIS2. The hospital uses SmartCare, an electronic medical record system. It is windows based desktop application with a centralized database. The integration model is reached adhering to Ethiopia's eHA in consultation with experiences of open source software, and thorough investigation of the international community groups working on similar studies, OpenHIE(https://ohie.org/). We selected disease registry reporting use cases to demonstrate the integration model as it is one of the most widely used datasets utilized by multiple work units including outpatient departments (OPD) to report monthly disease registry data. We observed that OPD transactions are more requiring follow-up of updates in daily basis and building the report received from each department is made monthly by the HMIS department. Of the dataset registration forms provided in DHIS2, disease registry reporting is the most time consuming operation. In the selected use case, data entry is filled in aggregation of gender and age groups(six age groups to each gender) for each disease classifications, a total of more than 4000 disease classifications. Selection of the disease registry data set is also reinforced as EMR is a typical source of such data. For those reasons we chose to consider integration of DHIS2 and SmartCare on disease registry reporting as a use case.

Table 1. Ayder comprehensive specialized hospital profile

Location	Mekelle, Tigray, Ethiopia
Services	IPD and OPD
Staff	Over 2,165
Patient Flow	Over 170, 000

The data exchange model involved development of a disease registry data exchange mediator. The selected use case operates on two FHIR resources, Patient and Condition. Targeted FHIR resources, with only minimized elements that are relevant to disease registry reporting include resourceType, id, identifier,

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code and subject for Condition Resource and resourceType, identifier, code, gender, and birthDate for Patient Resource. In adherence to patients data policy and health data regulations in general, the exchanged data was anonymous making the integration scenario applicable. The data exchange workflow involved is shown in (Figure 2).

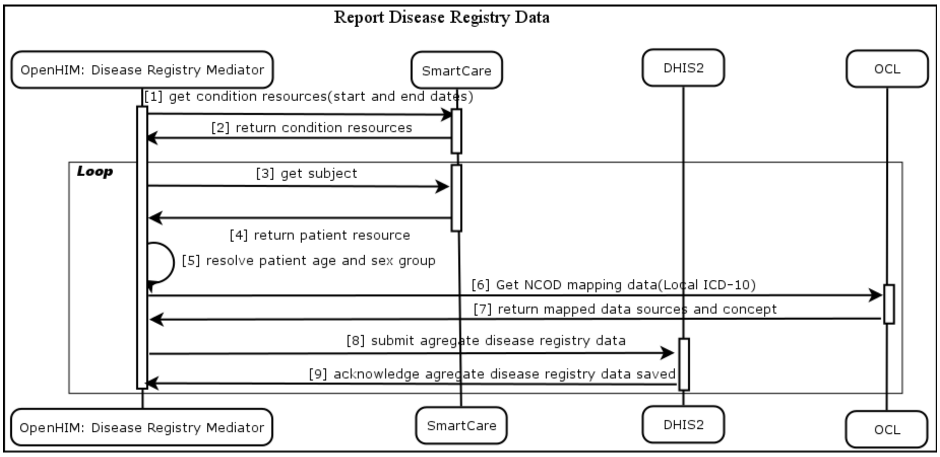

Figure 2. Disease registry aggregate data report workflow

The data exchange mediator utilized a terminology management services to resolve disease classification mismatch of the two systems. In this study, we found that for the range of dates provided as parameters of a web request, an aggregate report is built and sent to DHIS2. We observed the submitted data via DHIS2 Disease registry dataset report for the selected work unit and is accurate in comparison to the manually inspected expectation of aggregate data values.

3.3. Data quality gap assessment

In order to show the significance of this study, we conducted data quality assessment in the existing data exchange approach.The evaluation was conducted on 12 months of data, from September 2019 to August 2020. The report entries of the disease registry are extracted from DHIS2 and the equivalent EMR entries via the HAPI FHIR based adapter in order to compare and contrast using data quality and efficiency parameters. Having inspected the data values for top ten disease classifications, their summed value is used for comparison (Figure 3). We used HAPI FHIR web API to retrieve Condition resources bound to start and end time of registration.

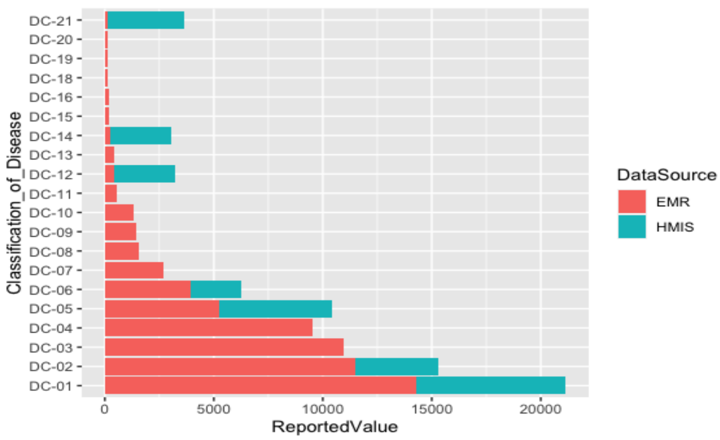

Figure 3. Top-10 disease registry report data - HMIS and EMR

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We have observed the tally based entry has resulted in a significant increase in the reported number for the first, second, fifth and six disease classifications. The cause of this difference can be seen in three perspectives, firstly how effectively the physicians are using the EMR, secondly accuracy of recorded data in the tally sheet and thirdly how much similarity exists in coding disease classification in both systems. Though reports of the first and last months may be affected by late reports, the approach to use sum of 1 year data for comparison should compensate the late reports. In practical sense, manual tally based aggregate reporting from different OPD departments is time taking and agreeably reports may be delayed to be reflected in the national HMIS instance. Coding mismatch is the main source of reporting difference. This implies aggregate reports at various levels lack accuracy. We found different disease classification levels and diseases aggregation values are summed manually in the HMIS tally sheet. This caused data inconsistency for aggregation of specific disease value category does not have harmonized guidelines. This is also reinforced as physician's free text is manually inspected in the tally sheet. As data is handed from primary source to extended level, quality is compromised. Tally sheet is collected from the hospital departments and sub departments, compiled and submitted to the HMIS department. As different layers of data sources exist raw data values can change in the process causing mismatch and inconsistency. In this study, the main aim is to show the data quality problems that practically exist. We observed the data available in the HMIS system is not exact reflection of the data available in the EMR. Now the intention is not to stress on which data source is accurate but how the manual tally based data exchange in fragmented systems is a cause of data quality problem. The assessment proved a significant data quality improvement can be achieved using eHA based health data exchange.

4. Discussion

Substantiating the practical implementation and obtained results of this study, we found important eHA aspects that support moving toward interoperability. To explore the need for interoperability of currently fragmented legacy systems, we experimented on the most practiced eHA components, HMIS and EMR systems. Leveraging open tools such as HAPI FHIR leads to effective and reusable outcomes. The current manual systems and processes for HMIS disease reports require an expert to register case data to the OPD register and tally according to disease, age, and gender disaggregation. This manual process has been a source of different kinds of errors. Besides client follow-up, nurse professionals were assigned to dedicate OPD to handle the activity of disease registration and reporting. This resulted in health care professionals that were overburdened in the process of data collection and aggregation. Currently, DHIS2 software is manually populated even though data is available in corresponding systems. This manual process results in autonomous systems that lack integration, duplication of effort, and inevitable human errors. Despite the human resources dedicated to reporting, aggregated reports collected from each OPD in the HMIS department were facing different data quality issues as the collected data is questionable, time-consuming and error-prone. The ability of HISs to interoperate and exchange data minimizes the overburden, duplication of effort, eliminates human errors and most importantly assures data quality.

One of the important works to underpin national level harmonized report is the development of national disease classification, an adoption from WHO's ICD-10. This needs to be cascaded to the facility level where EMR systems should utilize similar classifications and provide appropriate mapping information. In this study, we observed disease classification coding differences that ultimately impact factuality of the service delivery report. This mismatch did not impacted our study as it dealt with only top-10 diseases, the team managed to manually inspect and map the elements using OCL[2], a terminology management system hosted in a cloud, to retrieve reports by changing request parameters.

Demonstration of FHIR and local EMR data mapping was conducted only with FHIR Patient and Condition resources and two Java entities were created to support these FHIR resources. To demonstrate on a larger scale with more use-cases, relevant FHIR resources and FHIR Implementation Guides should be identified beforehand. The focus of our study was to demonstrate the methodological aspect for mapping FHIR resources with EMR local data and assure the scalability.

We took the first step to demonstrate Ethiopia eHA components data exchange and interoperability and explored their practical challenges. The team has also identified and reflected on important concerns identified in the process. These include harmonization of National Classification of Disease (NCOD) and

[2] https://www.openconceptlab.org

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cascading use of terminology to health service delivery facilities. It is highly emphasized that use of standards and scalable approaches of health data exchange play an invaluable role towards eHA maturity.

Finally Interoperability involves multiple systems communicating and sharing information and that requires establishing health data and information security policy and regulations. This becomes prevalent when thinking about the scale up of activities for a broader impact. Reusable mediator development and using consistent approaches to avail health data from point-of-service systems play an important role in health data reports and support facilitating health data exchange. Taking appropriate measures to assure technical solutions can be scaled to support use-cases is a significant driver toward maturing eHA.

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Leveraging technology to support HELINA Education Working Group activities

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Abstract. Background and Purpose: Working groups implementing activities for health informatics associations need the right technological infrastructure to support the range of activities they conduct. In this paper, we describe the approach taken and results achieved in developing the technology-based infrastructure to support HELINA Education Working Group activities.
Methods: Technological infrastructure needs for the EWG were guided by work sets for the WG. In collaboration with the technical team, the technology tools were identified with a bias towards opensource tools. The waterfall model was used for the development of needed features.
Results: Tools implemented to support the HELINA EWG included a website (*HELINAnet*), a discussion forum (*HELINAtalk*), an eLearning and content organization platform *(HELINALearn), social media accounts (Twitter, LinkedIn and Facebook), a* video conferencing platform based on Zoom, an email-based google mailing list (helina-ewg@googlegroups.com), and an electronic newsletter. Metrics of use were maintained.
Conclusions: The approach taken to implement the technological infrastructure to support EWG activities can serve as a demonstrative model that could be employed by other HELINA WG, as well as the larger organization.

Keywords: Health Informatics, Education, Working Group, Technology

1. Introduction

Health informatics (HI) is “the interdisciplinary study of the design, development, adoption, and application of information technology (IT) innovations in healthcare services delivery, management, and planning” [1]. As countries begin to embrace HI, robust country-, regional- and continent-level organizations and associations have emerged. These organizations support systemic advancement in the field and provide the networks needed to build HI communities of practice by promoting interaction among professionals within the field. Further, they enhance use of evidence-based approaches for digital health interventions to improve health outcomes for individuals and populations, while facilitating dissemination of practical and relevant knowledge to professionals and stakeholders.

Examples of large and well-established HI organizations across the world are: (a) the American Medical Informatics Association (AMIA) [2]; (b) American Health Information Management Association (AHIMA)[3]; (c) Asia eHealth Information Network (AeHIN) [4]; (d) Pan-American Health Organization (PAHO) [5]; and (e) the International Medical Informatics Association (IMIA) [6]. In Africa, the Pan-African Health Informatics Association is the IMIA-affiliated HI association that supports the regional HI

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associations. Established in 1993, HELINA subscribes in full to IMIA's vision that "there will be a worldwide systems approach for healthcare" [7]. HELINA aims to promote African countries to develop National Health Informatics Societies, develop education and research programs that are within the African context, and support sustainable development of HI and eHealth in Africa. HELINA is made of member-country HI organizations, including: Botswana, Burundi, Cameroon, Ghana, Ivory Coast, Kenya, Uganda, South Africa, Mali and Rwanda. Corresponding member country organizations include: Algeria, Benin, Democratic Republic of Congo, Guinea, Madagascar, Senegal, Tanzania, Zambia, and Zimbabwe.

As of 2021, the Education Working Group (EWG) was one of the most active working groups (WG) in HELINA. This WG brings together members from HELINA countries with an interest in education and capacity-building in HI for the African region. To meet the WG goals, the EWG needed robust mechanisms to support its key functions and activities. Among the functions were: (a) robust mechanisms to engage country partners and working group members, (b) easy mechanisms to curate knowledge-bases to enable organization of content relevant to HI in Africa, (c) platforms to allow information sharing with members, and (d) mechanisms to support networking among members. Unfortunately, adequate infrastructure to support these activities did not exist, for example the organization website at the time, was purely static with no interactive features such as news feeds, upcoming events, online conferencing resources and dynamically generated content. In this paper, we describe the approach taken and results achieved in developing the technology-based infrastructure to support HELINA EWG activities. The approach taken can serve as a demonstrative model that could be employed by other HELINA WG, as well as the larger organization.

2. Materials and methods

2.1. Defining HELINA EWG needs

The infrastructure and technologies needed by the HELINA EWG were primarily guided by long-standing work sets for this WG. Among the key EWG work sets were: (1) supporting development of HI curricula; (2) developing a repository of training materials in HI; (3) compiling a database of HI curricula from Africa; (4) developing a repository of tools to enable the development of curricula at Masters level;
(5) supporting education and training in HI using Web 2.0 technologies; (6) providing free access to events for African HI participants; (7) developing a network of authors within each HELINA country to mentor others in scientific publications in HI; and (7) developing short-term certification programs in HI. With the emergence of the COVID-19 pandemic, it became imperative to support online-based modalities for meeting and education. Further, the EWG needed seamless synchronous and asynchronous modalities to share information with its membership.

2.2. Identifying needed technologies

A pragmatic approach was used in selecting the technologies to be implemented to support the outlined activities of the EWG. This approach aligned with the first five steps for technology selection defined by the Digital Clarity Group and others [8]. These steps included: (1) validating the need – done consultatively with EWG members, (2) compiling requirements – guided by identified needs, (3) determining focal needs – which involved prioritizing requirements, (4) creating a technology shortlist – with a focus on open-source technologies as appropriate, or those that were well familiar to most HELINA members, and (5) creating a service provider shortlist – for hosting the code repository, project management, and web-based features.

2.3. Development and Implementation of technology

The traditional Waterfall approach was used in developing the technology infrastructure [9]. Once functional requirements and technologies to use were identified, the team embarked on development, testing and implementation of the new platform, using services provided by a collaborating organization with the EWG. Testing and validation of features were conducted first by usability testers and then by the

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EWG member team, with changes made based on inputs. The final infrastructure was then availed for use to support the EWG activities.

2.4. User engagement metrics

There are a number of metrics that measure user engagement. Lehmann et al. categorize user engagement measuring approaches into three groups, namely: self-reported engagement, cognitive engagement, and online behaviour metrics [10]. Moreover, user engagement metrics can indicate popularity (e.g. # of visits), activity (e.g. time spent) and loyalty (e.g. # of returns). We report online behaviour metrics that reflect on popularity, awareness and use of the various technology-based modalities implemented to support HELINA EWG activities. Additional metrics are also provided to indicate activities conducted to promote user engagement.

3. Results

The resulting core technology infrastructure had several key features, with most of the features organized around the HELINAnet website to support EWG activities [11]. Below we describe these key features and how they have been employed by the HELINA EWG and community.

3.1. HELINAnet Website

The EWG HELINAnet website, based on WordPress [12], provides the overall base for the EWG infrastructure. The website's first key role is to provide general information that pertains to the EWG and the larger HELINA (Figure 1) [11]. To this end, HELINAnet outlines the EWG's key areas of focus, selected WG achievements and ongoing activities. The website further provides links to the social media platforms of LinkedIn and Twitter that are used by the EWG as modalities to disseminate information. There is a calendar that is updated with information on relevant educational and capacity-building activities, including conferences, paper submission deadlines, and webinars, among others. In addition, HELINAnet has functionality to support short articles, via blogs. HELINAnet is currently translatable from English to Portuguese and French to support French and Portuguese-speaking members. Security to the website is provided using a Jetpack service that includes Akismet anti-spam application, as well as VaultPress for backup and security

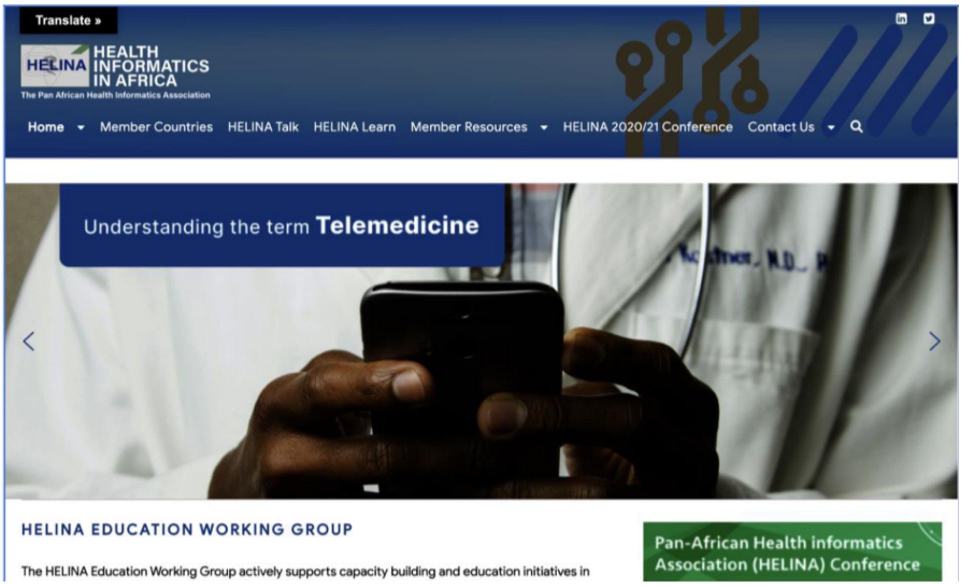

Figure 1. Screenshot of part of *HELINANet* landing page

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3.2. *HELINATalk* Discussion Form [13]

To support active yet asynchronous communication of members while maintaining active engagement, we implemented an online forum based on the opensource Discourse platform [14]. Discourse supports easy assignment of roles, including support for moderated discussions. It allows members a chance to self-register, and to suggest and contribute to ongoing conversations (Figure 2).

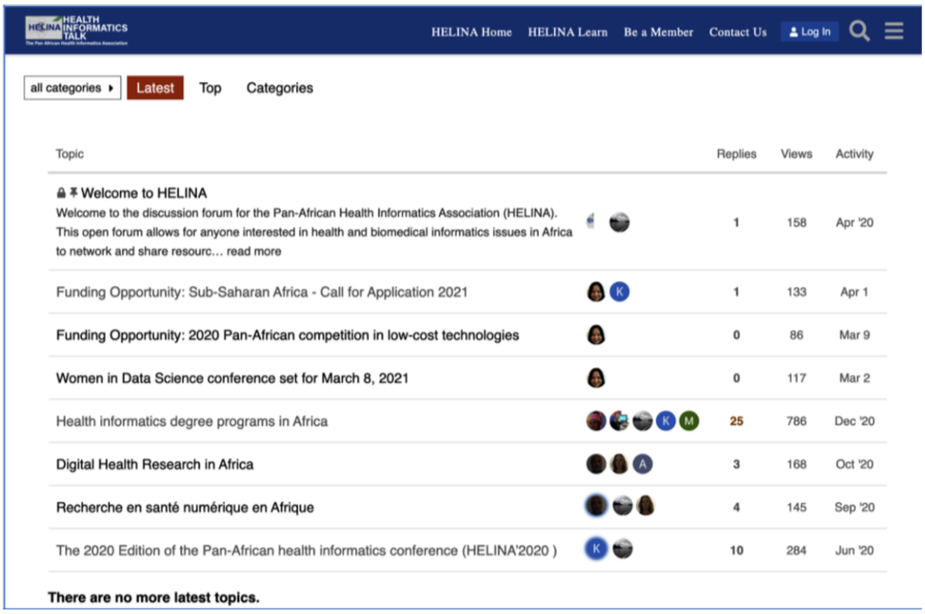

Figure 2. HELINATalk discussion forum screenshot

3.3. *HELINALearn* eLearning and Knowledge Management Platform [15]

HELINALearn is an instance of the widely used opensource Moodle eLearning platform,[16] and is well-suited for organizing content, especially those targeting educational activities. This platform allows for creation of courses, quizzes, and other learning modalities. It also includes various roles and easy organization and re-use of information. The EWG used HELINAnet to organize content in several key domain areas, but these are easily configurable (Figure 3).

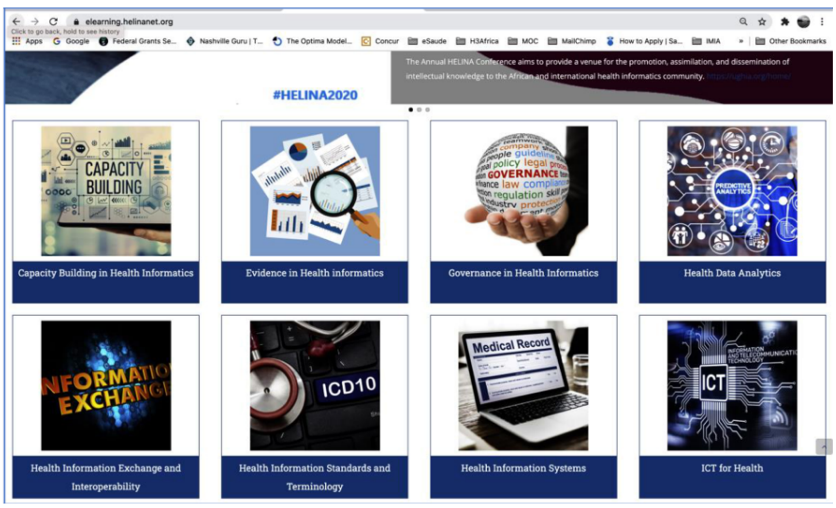

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Figure 3. HELINATalk discussion forum screenshot

3.4. HELINA Zoom conferencing resource

The EWG recognized the need to support synchronous communication for its members, especially in the age of the COVID-19 pandemic where in-person meetings were not as feasible and with the wide geographical distribution of members. In addition, this platform could be used for distance learning and for educational Webinars by the WG. While there was a preference for opensource conferencing system, it was felt that most users were familiar with the Zoom conferencing platform [17], and often already had it installed. As such, this platform was selected for use. The service was availed to EWG members, who could request session slots to use the Zoom platform through the HELINAnet website, with a WG administrator scheduling the meeting on behalf of the requestor. Meetings were categorized as either open or closed, with open meeting details posted both on the HELINA zoom meetings calendar and social media platforms.

3.5. HELINA EWG Google Group

An email-based mailing list, helina-ewg@googlegroups.com, that is based on Google Groups, was created to support mailing to individuals interested in staying abreast of information relevant to the EWG. Through this mailing list, the EWG could share push-based information to members. The mailing list provided functionality for individuals to unsubscribe from it. Deliberate effort was made to limit communication, with most communication disseminated as a bi-weekly newsletter (see VI below).

3.6. HELINA EWG Newsletter

The HELINA EWG newsletter is used to highlight a variety of items of interest, such as: relevant scientific publications and grey literature; upcoming conferences and deadlines and HI job opportunities and grants. The newsletter also invites engagement to members by highlighting how they can directly participate and contribute to the EWG activities and navigate the HELINAnet website.

User engagement metrics.

Most of the features went live in mid-2020. Table 1 provide metrics for the various outlined features between Jan 2021 – May 2021.

Table 1. Metrics for user engagement with technology infrastructure for HELINA EWG

Metric	Feature	Number
# of HELINA Forum users	*HELINATalk*	53
# of discussion topics on the forum	*HELINATalk*	8
# of responses to forum topics	*HELINATalk*	44
# of views on topics on the forum	*HELINATalk*	1,619
# of EWG twitter followers	Tweeter handle: @helinanet	85
# of tweets	Tweeter handle: @helinanet	261
# of content categories	*HELINA Learn*	10
# of members in mailing list	Google Groups: helina-ewg@googlegroups.com,	71

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4. Discussion

Working groups provide the fuel that run activities for HI organizations. However, these WG need to be equipped with the tools to adequately support their activities and members. After identifying gaps in tools available for its needs, the HELINA EWG developed, implements and oversees the continued support of the technology infrastructure it needs. The implemented features are likely not just relevant to the EWG, but can be leveraged by any other HELINA WG, as well as the larger association. This work should thus ideally serve as a model for the larger HELINA organization on what infrastructure to put in place for use by all member organizations and WG participants. In the interim, other HELINA WG can implement the basic components such as discussion forums, mailing lists and social media platforms as they look forward to an integrated technology infrastructure that encompasses all metrics displayed in Table 1.

Developing and implementing infrastructure is just part of ensuring increased and continued engagement in WG activities. A robust dissemination and user engagement strategy is needed, with the associated human and financial resources to ensure that support for creating and updating content is available. The efforts underway to support the HELINA secretariat need to prioritize resources for the technological infrastructure for the organization. Without an active and engaged membership, these organizations will fail in a major mission of ensuring a vibrant community of practice in HI.

The online behavioural metrics used to measure user engagement in this paper reveal increased user involvement over time, but there is still plenty of room for growth. This paper utilized online behaviour metrics to assess the engagement of users in the various platforms. Such metrics will help inform progress in increasing member engagement, and additional ones will likely be needed to support granular analysis of feature use. Over time, engagement of more users will help define additional infrastructure needs, or changes to the technologies employed.

Lehmann et al postulate that although online behaviour metrics provide a sense of user interaction, they do not provide additional information as to why users engage with a particular aspect. Higher numbers usually suggest an indication of more engagement of users. A study conducted by Garett et al. identified 20 design elements that affect user engagement [18] and of these, among the key design elements that affect user engagement in websites that were employed for the HELINAnet website were; (a) content utility; (b) accurate information; and (c) user interaction. Some of these elements are not only applied to the improved website but also to information shared on HELINA social media platforms and the EWG newsletters. As such, it was ensured that content disseminated in the website, social media platforms as well as newsletters was in sync, up to date, useful, interesting, and accurate.

5. Acknowledgements

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6. Statement on conflicts of interest

No conflicts of interest were registered

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Journal of Health Informatics in Africa

Improving health literacy in rural Africa through mobile phones: a systematic literature review

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Abstract. Background and Purpose: Mobile phones have been used to support healthcare systems through various mobile health (m-health) applications. In Africa, m-health initiatives have been used in many interventions, including education and awareness, clinical and non-clinical decision support systems, epidemic outbreak tracking, training of healthcare workers and remote monitoring, and many others. But despite the great enthusiasm around m-health, few studies have examined the use of mobile phones to improving health literacy in rural areas in Africa.
Methods: We performed a literature review using SCOPUS and Google scholar, combined with manual searching methods to search for studies related to m-health initiatives in Africa. The systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) protocol. Four steps were followed to identify relevant publications related to the contribution of mobile technologies in improving health literacy :(1) Database selection (2) Keyword search, (3) Study selection and (4) Data extraction.
Results: In our study, we found 5 studies related to health literacy and mobile technologies in Africa. However, none of them were focused on health literacy and mobile technologies in rural areas of Africa. This result provides insights of future studies to conduct.
Conclusions: We found that m-health initiatives were so far not inclusive. It appears that few m-health solutions integrate local languages in the development of m-health solution. The mhealth initiatives need to be implemented based on the local realities, so experimental studies are desired to test the adaptability of mhealth projects and to explore any adjustments required.

Keywords: mhealth, health literacy, mobile phone, rural areas, Africa.

1. Introduction

Much research has developed around the concept of health literacy, defined as a set of cognitive and social skills that determine an individual's motivation and ability to access, understand, evaluate, and use the information and services necessary for their health [1]. It is usual to distinguish three dimensions of health literacy: the capacity to obtain information (communicative literacy), to understand it (functional literacy) and to use it (critical literacy). Health literacy refers to the ability of individuals to access, understand, assess and use the information and services necessary for their health. since the launch of mobile phones three decades ago; the latter has been used to support healthcare systems through various mobile health (m-health) applications. Despite this great enthusiasm around m-Health, few studies have examined the use of mobile phones to improve health literacy in Africa. This PhD project aims to explore the use of mobile health to improve health literacy in rural communities that will lead to a design of a mobile health implementation framework based on literature reviews, field studies, and feedback from knowledgeable professionals in Sub-Saharan African countries, as well as global experts. We suggest that by integrating local languages and considering local realities in the implementation of mobile health projects, health services will be more accessible to rural communities, and that they contribute to a better common future

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and a sustainable development for all. To address these challenges, in September 2015, the United Nations (UN) adopted 17 goals to be achieved by 2030 to ensure sustainable development for all. Achieving "Good Health and Well-being" for all is part of the importance of these goals. In recent years, evidence from many reports has demonstrated the crucial role that mobile phones can play in achieving sustainable development goals [2]. By taking advantage of the rapid growth of mobile phones in recent years, Africacould achieve the Sustainable Development Goals by improving health literacy in rural areas. While mobile technologies offer these new opportunities for accessing health information and self-managementof health conditions, as far as we know, few studies have examined so far, the use of mobile phones to improve health literacy in Africa.

2. Current status of health literacy in sub-saharan Africa

Every day, everyone is called upon to make decisions that influence their health and that of those around them: seeing a doctor, walking to work, eating more fruit, seeing friends, requesting a help service for their accommodation, undergoing medical treatment. To make enlightened choices in an increasingly complex society, we need to have information. Learning to promote health requires the mobilisation, sometimes simultaneous, of many skills: reading, writing and calculating, but also communicating, solving problems, evaluating the information found, applying information based on one's own life context.

The Agency for Healthcare Quality and Research (AHQR) published a report on Health Literacy [3], which shows that very few developing countries have objectively measured health literacy or its impact of health.

A multinational study was conducted in 14 countries in sub-Saharan Africa to measure health literacy. This large Survey examined the demographic characteristics associated with health literacy in Africa. The data used to measure health literacy was collected between 2006 and 2015. The total number of people included in the study was 224,751 people aged between 15 to 49[4].. The prevalence of health literacy was found to be high at 35.77%. For women, it was 34.08% and 39.17% for men; less than or equal to primary education 8.93%, is part of secondary education 69.40% and completes secondary 84.35% [4]. But it should be notated that health literacy levels variated from country to country, from 8.51% in Niger to 63.89% in Namibia[4]. E-health solutions, linked to the increasing digitization of the country (95% mobile penetration), are a way to overcome the challenges of rural health literacy.

3. Mobile phones as health literacy enabler in rural areas

Over the past decades, Africa has experienced a rapid transition in terms of mobile connectivity. For instance, the number of smartphone owners has almost doubled between 2016 (336 million) and 2020 (660 million), with a penetration rate of 55% [5]. The penetration and growth rates of mobile technologies has resulted in a serious impact on the healthcare sector. According to the mobile industry Group Special Mobile Association (GSMA, 2016), more than 1123 mobile phone-based projects were planned to be implemented to improve healthcare systems and service delivery [6]. These projects, known as "m- Health" projects, have mostly invaded the health landscape of developing countries as eight out of ten projects are based in Africa. In 2015, South Africa alone registered more than 81 projects (GSMA, 2015). In term of investment, the global market of m-Health in Middle-East and Africa reached USD 1.23 Billion and projected to reach USD 5.78 Billion by 2025[7]. This enthusiasm around m-Health follows aspirations of healthcare actors to provide more effective, efficient and equitable healthcare services and information—especially to the most disadvantaged communities in rural areas. With the complexity of healthcare systems nowadays, healthcare services are spending less time to support patients. In rural areas, patients with limited resources face multiple challenges to acquire, understand and use the information they need to make decisions related to their health (health literacy). Consequently, it is about 83% of African population (from rural areas) that are excluded from healthcare services because of the low health literacy level[8]. According to the World Wellbeing Association (WHO), wellbeing education alludes to "the intellectual and social abilities that decide the inspiration and capacity of people to acquire, comprehend, and use data in a way that advances and keeps up great wellbeing" [9]. Mobile technologies can enable patients especially with low health literacy, to gain rapid access to the information patients want and need to maintain and improve

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their health. Mobile health (m-health) describes the use of portable electronic devices with software applications to provide health services and manage patient information. In Africa, the high penetration rate of mobile phones and the increasing coverage of the mobile network bring prospects, and mobile devices can no longer be ignored in health delivery and disease prevention workflows. The global m-health market is predicted to grow to 213.6 billion by 2025, and Sub-Sahara Africa (SSA) is forecast to be the fastest growing region in the world[10]. Opportunities for mobile technologies to play a formal role in health services are increasingly being recognised. At this point, it is worth acknowledging some initially celebrated m-health successes in Africa were built on the unprecedented uptake of mobile services. For instance, the use of mobile phones and social networks in Nigeria has recently been particularly helpful in fighting efficiently against the Ebola outbreak in the country [11].

4. Methods

To answer our first question about the existing m-health and health literacy-related initiatives in rural Africa, a systematic literature review was performed following the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) methodology [12]. We searched for studies related to the terms "health literacy" and "mobile technology". The following protocol, which consists offour steps, was followed: (1) database selection; (2) keyword search; (3) study selection; and (4) data extraction and analysis.

4.1. Database Selection

To perform our systematic review, we used the SCOPUS database [13] and Google Scholar [14]. These databases provide access to science, technology and medicine (STM) journal articles and to the references included in these articles allowing researchers to search both forward and back in time.

4.2. Keyword Search

We performed our study on 10 February, 2020 using Boolean Operators ("AND", "OR") with selected keywords to search in the titles, abstracts and keywords of every published article related to health literacy and mobile technology. These following combinations were used to perform our search in the Scopus database:

(TITLE-ABS-KEY ("health literacy" OR "ALL synonyms of health and literacy") AND ("mhealth" OR "Mobile health" OR "mobile technolog*" OR "telemedicine"))

For Google Scholar, the same combination was used, and we added some additional keywords:

"health literacy" OR "ALL synonyms of health and literacy") AND "mobile health" OR "mobile technology" OR "e-health" AND "Africa" AND "ALL synonyms of rural area"

4.3. Study Selection

After performing the keywords search, we chose to select only English language publications. Due to the rapid growth of mobile technology, we limited our literature review to studies published between 2011 and2021. No author restriction was imposed.

4.4. Data Extraction

We exported data related to the "title", "abstract", "keywords", "author", "publication date", "country of origin" to a coma separated format. Then, we screened the full text of all publications according to the following criteria:

- Studies focused on mobile technology and health literacy; otherwise they were excluded.
- studies targeting public health issues in Africa;

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- studies related to health literacy and mobile technology in rural areas were included;

We carefully analysed the publications according to the criteria mentioned above, and the resulting selecteddata were changed to CSV format files [15]. We excluded studies that do not meet the above criteria.

5. Results and discussion

5.1. Results

By performing our research using the identified keywords, 1139 publications were found in the Scopus database and 67 in Google Scholar. Once the duplicates were removed, there were 1206 articles left for screening. We screened titles and abstracts of all 1206 articles, and we found that 1052 studies from the Scopus database and 37 from Google scholar were not related to mobile technology and health literacy in Africa. Therefore, we excluded 1089 articles in total, and 117 were left for full-text screening.

After screening the full text of the 117 articles, we included 48 studies. After a second screening, we found that only five were related to health literacy and mobile technology in rural areas. After analysing these five studies, we noticed that they were not specifically intended to improve health literacy in rural areas or communities. Figure 1 summarises the method used and our findings. The initial lookup query for the review displayed 1206 results for the two databases. After the principal stage (title and dynamic assessment and disposal of copies), the number was decreased to five. When we started the full-text survey, we zeroed in our investigation on distributions that addressed the utilisation of versatile innovation to improve wellbeing proficiency in rustic zones of Africa.

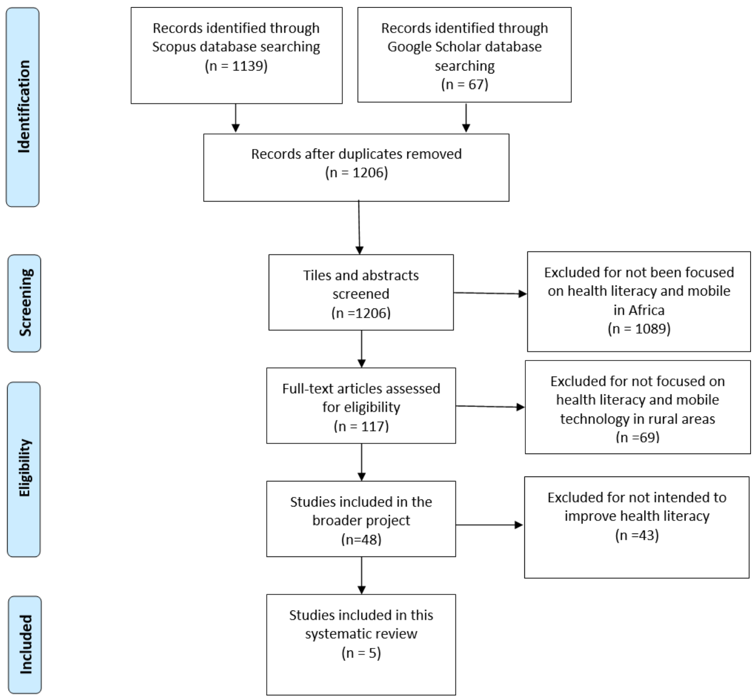

Figure 1. The method used for the systematic literature review.

5.2. Discussion

Over 1206 publications, we only detected 5 (0.41 %) articles that were related to mobile technology and health literacy in rural areas of Africa. The other reviewed articles 1201 (99.58%) were not intended to improve health literacy in rural areas of Africa. This finding highlights the need for conducting studies related to improving health literacy in rural communities of Africa. E-health solutions, in connection with

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the growing digitisation of the country (95% mobile penetration). Mobile health is a way to overcome challenges in rural areas, even as private and public actors seek to intensify their digital transformation. For developing countries and in Africa in particular, this technology requires the direct involvement of populations. Some of the benefits for the African health system will include:

- Participate in the inclusion of rural communities into the health service through the use of local languages.
- Facilitate the accessibility of information through the availability of low-cost technology like mobile phones.
- Improve public health surveillance through awareness and campaigns carried out in local languages.

To transform these advantages, especially for the benefit of rural populations in Africa, more study has to be done. Most studies we found in this review were conducted in English speaking countries in Africa although a few field studies were in French speaking countries in West Africa. Our future study will address this literature gap.

6. Conclusions, limitations and future research

Between 2011 and 2021, 1206 different publications related to health literacy and mobile technology were published in the SCOPUS and Google Scholar databases. All these studies confirmed the significant role that mobile technologies can play to improve health literacy. However, the existing studies on mobile technologies were country or continental level. The five studies we found which focused on Africa, provided a comprehensive overview of mobile technologies in health systems in African countries. Unfortunately, we did not find specific frameworks that address the use of mobile technologies in improving health literacy in rural areas.

To fill this literature gap, our next study would be to design an implementation framework for mobile technologies in rural areas. The results obtained from the literature review indicate that despite the enthusiasm that mobile health technologies have persisted in Africa in recent years, very few previous studies have examined the contribution of them to improving health literacy in rural areas of Africa. This literature review also shows the need for more precise studies on the integration of local languages into mobile technologies to improve health literacy. Finally, it highlights the important role that health literacy plays in achieving the 2030 SDGs. This research has some limitations because we used only one database to conduct our systematic literature review, so we could not find more studies. For our future studies, we should consider doing a combination of many databases, not on a single database.

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Journal of Health Informatics in Africa

Assessing the Knowledge and Practice of E-Tracker Among Nurses in the Ho Municipality

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Background and Purpose: Electronic health is an integration of technology in healthcare delivery to facilitate its service delivery. It ranges from the use of desktops to handheld devices to facilitate care, data capture, and data transmission. Due to the wide ranges of technology usage in varieties of services, the healthcare industry is not left behind. It improves upon quality of data generations to facilitate proper decision making. The current study aimed at evaluating the knowledge and practice of e-tracker among nurses in the Ho Municipality of the Volta region of Ghana.
Methods: A descriptive cross-sectional approach was used. Simple Random Sampling technique was used to recruit the participants and a semi-structured questionnaire was used to capture the desired data. Data collected was entered using EpiData 3.0 and further exported into Stata 16 IC for analysis. Results were presented using tables and graphs.
Results: 129 (69.3%) of the nurses had high knowledge of e-tracker while 42 (22.6%) had high e-tracker usability. 66 (35.5%) of nurses synchronized data immediately after entry while 114 (61.3%) do not ask clients whether if they had been enrolled onto the e-tracker for their first visit. Nurses who consulted District (HI) were 4.9 [COR=4.9; CI(95%)=2.45 – 9.63; p-value=0.000] and 6.8 [AOR=6.8; CI(95%)=2.78 – 16.53; p-value=0.000] times to have high knowledge than their counterparts that did consult their in-charges for assistance.
Conclusions: Though there was a high knowledge level of e-tracker among nurses in the Ho municipality there was a very low usability of e-tracker among nurses.

Keywords: E-health, M-health, Health technology.

1. Introduction

Electronic health (e-health) is an application of technology in healthcare practice which aimed at improving upon the health service delivery to enhance quality of care [1], and above all quality of data generation during and after care [2].

Mobile health is a form of e-health [3] which most appropriately uses handheld technological devices in providing healthcare [4]. It is becoming more acceptable in healthcare delivery globally [5], and its application to monitoring health conditions has enormously improved upon the quality of data generation [2]. As technology assists in the generation of data easily [6], it will eventually take over entirely the health sector to properly manage health generated data [7] as a result of the Internet of Things (IoT). [8] [9], Though healthcare providers believed that e-health enhances their work as compared to traditional methods [10], the longer in years a Nurse manager works the less the computer skills [11].

It was also evidenced that, 43.0% of nurses were able to use mobile health (m-health) for reminders appointment [5]. And 28.1% and 40.4% of medical students and practitioners had good knowledge and attitude of m-health respectively [12].

In late 2018, the Ghana Health Service in collaboration with United States Agency for International Development (USAID) (evaluates for health) and Good Neighbors Ghana (Korea) implemented and deployed the e-tracker system in all government facilities that do report into the District Health Information

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Management System 2 (DHIMS 2) to assist service providers to enter data directly using mobile handheld devices especially in Child Welfare Clinics (CWCs) in the Volta Region of Ghana.

Data is an important tool in healthcare service delivery [13], and using handheld devices to capture and transmit health data is something that improves upon the quality of health data generation [14] to support good decision making [15]. That is, decisions in themselves are meaningless unless are formulated based on the availability of quality data.

The quality of any captured data depends on the data source [16], and thus, if the people at the front desk of offering services do not have the knowledge of the application they use [17], it becomes so difficult for them to manage the system well enough and thus rather creates a lot of data inconsistencies in the generation process [18] and any health decision or policy that may be implemented will not be the desired health need of the population involved since good decision depends on good data [19] [20].

As a result, there is the need to understand a system (e-tracker) and practice it well enough to avoid repetition of service at different centres. For instance, if immunizations records are not uploaded and the same child visits another facility, it is likely that the same vaccines will be given to the child which will lead to more complications.

The current study however aimed to 1) determine the knowledge of caregivers on e-tracker 2) determine the e-tracker usability of caregivers and 3) identify the factors affecting the practice of e-tracker among nurses in the Ho Municipality of the Volta region of Ghana.

Findings of the current study could serve as a basis for other researches and also help in the exploration of the knowledge and usability of E-tracker among nurses in the Ho Municipality.

2. Materials and methods

The current study adopted a descriptive cross-sectional approach which is one of the observational study designs that measure both the exposure and outcome of interest at a point in time within a specified population [21]. The study was carried out in the Ho Municipality which lies between latitudes 6 º 20" N and 6 º 55" N and longitudes 0 º 12'' E and 0 º 53'' E. The municipality is divided into five sub-municipalities. The study comprised healthcare providers who were responsible for providing care with the use of a handheld device deployed. Any of the nurses who is responsible for the use of the e-tracker and consented to the study was interviewed. Staff that were sick, at the late period of pregnancy, national service personnel, and NABCO personnel were not interviewed. Sample size of 194 was computed. Simple random sampling technique was used to select the desired participants. Semi-structured questionnaire was used to collect the data. Respondents were called on phone (phone interview) and the link of the questionnaire (google forms) was sent to their WhatsApp lines (for those who preferred that). Those who followed the link sent to them wrote their initials of name to illustrate their consent. Verbal (oral) consent was then used for those who preferred to and answered the questionnaires through phone calls. Phone interviews were entered using EpiData version 3.0. Google forms interviews were downloaded in Excel format. Both were cleaned using Stata 16 IC (College Station, Texas 77845 USA).

Knowledge of E-tracker assessment was generated from seven questions (generated by the author) which was pre-tested among ten nurses ahead of the data collection. Responses were coded into zero (wrong answer) and one (correct answer). These were summed up and grouped into two category scores of high knowledge (above the mean value) and low knowledge (below the mean value) knowledges with a mean score of 3.5. E-tracker usability was computed by using the System Usability Scale (SUS), a ten-question which was computed. For questions 1, 3, 5, 7, and 9, their score (Likert scale) which is 0 to 4 was computed by scale value minus 1. For questions 2, 4, 6, 8 and 10, score was subtracted from 5. The corresponding values were summed and further multiplied by 2.5 to estimate above and below average score with an average score of 68 and a score of more than 68 as above average and score of less than 68 as below average [22]. There were questions to determine factors affecting the practice. Chi-square was run to identify the significant associations between the knowledge level and the demographic characteristics, and knowledge level and factors affecting practice of e-tracker. At a confidence level of 95%, a p-value less than 0.05 was considered statistically significant. Logistic regression was then carried out to determine the odds of exposures to the outcome. Results were however presented using tables and graphs.

Ethical clearance was sought from the Ghana Health Service Ethics Review Committee (GHS-ERC) with ethical number GHS-ERC 012/04/20.

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3. Results

186 respondents responded to the questionnaire in all. 102 (54.8%) of the respondents were in the age group of 30 to 34 years, 162 (87.1%) being females, 138 (74.2%) were married, 156 (83.9%) were holding Certificate, and 144 (77.4%) were CHN's. 126 (67.7%) practiced for more than five years, 162 (87.1%) have spent not more than five years at their current facility, and 102 (54.8%) have been using smartphone for more than five years (Table 1).

Table 1: Demographic characteristics of respondents

Variable	Frequency N = 186	Percent
Age: Mean (SD)	31.9 (±4.4)	
Age group		
<30 years	42	22.6
30 - 34 years	102	54.8
>=35 years	42	22.6
Sex		
Male	24	12.9
Female	162	87.1
Marital Status		
Single	48	25.8
Married	138	74.2
Qualification		
Certificate	156	83.9
Diploma/Bachelor	30	16.1
Cadre		
CHN	144	77.4
Midwife	18	9.7
Others	24	12.9
Length of practice		
<=5 years	60	32.3
>5 years	126	67.7
Length at current facility		
<=5 years	162	87.1
>5 years	24	12.9
Smartphone use		
<=5 years	84	45.2
>5 years	102	54.8

Figure 1 below showed that 129 (69.3%) of the respondents had high knowledge and 57 (30.7%) had low knowledge of e-tracker. Detailed knowledge is illustrated in Table 2.

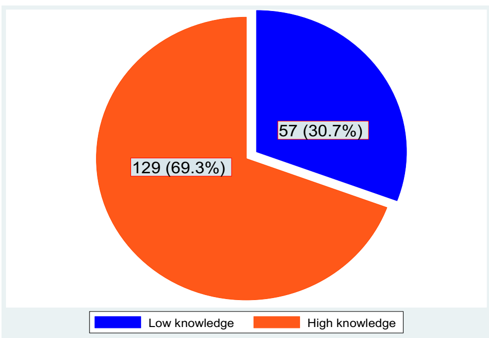

Figure 1: Knowledge level of respondents

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Age group (X^2=10.748; p-value=0.005), Sex (X^2=4.8568; p-value=0.028), Qualification (X^2=6.3045; p-value=0.012), Cadre (X^2=31.5839; p-value=0.000), and Length of practice in years (X^2=15.6111; p-value=0.000) were significantly associated with the knowledge level of respondents (Table 2).

Table 2: Detailed Knowledge level of respondents

Knowledge Level of e-tracker	**Low N = 57 n (%)**	**High N = 129 n (%)**	**X^2 (p-value)**	**COR (95% CI) p value**	**AOR (95% CI) p value**
Age group					
<30 years	18 (31.6)	24 (18.6)		**Reference**	**Reference**
30 - 34 years	21 (36.8)	81 (62.8)		2.9 (1.33, 6.29) **0.007**	1.1 (0.32, 3.99) 0.853
>=35 years	18 (31.6)	24 (18.6)	10.748 (**0.005**)	1.0 (0.42, 2.37) 1.000	0.2 (0.04, 1.05) 0.057
Sex					
Male	12 (21.1)	12 (9.3)		**Reference**	**Reference**
Female	45 (78.9)	117 (90.7)	4.8568 (**0.028**)	2.6 (1.09, 6.21) **0.032**	3.7 (1.17, 11.84) **0.026**
Marital Status					
Single	19 (33.3)	29 (22.5)		**Reference**	
Married	38 (66.7)	100 (77.5)	2.4318 (0.119)	1.7 (0.87, 3.43) 0.121	
Qualification					
Certificate	42 (73.7)	114 (88.4)		**Reference**	**Reference**
Diploma/Bachelor	15 (26.3)	15 (11.6)	6.3045 (**0.012**)	0.4 (0.17, 0.82) **0.014**	1.5 (0.37, 5.92) 0.579
Cadre					
CHN	30 (52.6)	114 (88.4)		**Reference**	**Reference**
Midwife	14 (24.6)	4 (3.1)		0.1 (0.02, 0.25) **0.000**	0.1 (0.01, 0.19) **0.000**
Others	13 (22.8)	11 (8.5)	31.5839 (**0.000**)	0.2 (0.09, 0.55) **0.001**	0.2 (0.05, 0.56) **0.003**
Length of practice					
<=5 years	30 (52.6)	30 (23.3)		**Reference**	**Reference**
>5 years	27 (47.4)	99 (76.7)	15.6111 (**0.000**)	3.7 (1.89, 7.10) **0.000**	7.4 (2.40, 22.80) **0.001**
Smartphone use					
<=5 years	24 (42.1)	60 (46.5)		**Reference**	
>5 years	33 (57.9)	69 (53.5)	0.3099 (0.578)	0.8 (0.45, 1.57) 0.578	

Figure 2 below showed that 42 (22.6%) of the respondents scored above average and 144 (77.7%) scored below average of the e-tracker usability scale. Detailed e-tracker usability is illustrated in Table 3.

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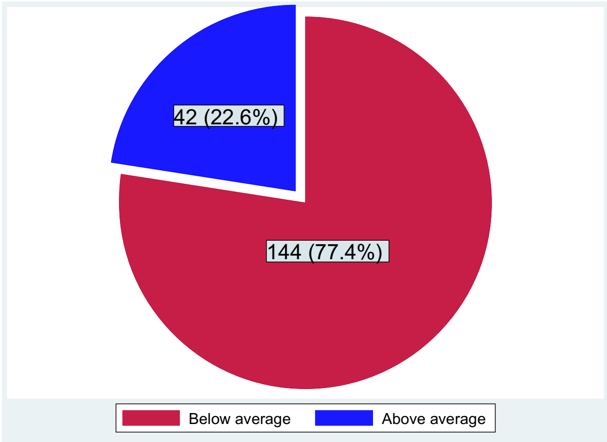

Figure 2: System (e-tracker) usability scale

Age group (X^2=12.9508; p-value=0.002) and length of practice in years (X^2=8.0189; p-value=0.005) were significantly associated with system (e-tracker) usability of respondents (Table 3).

Table 3: Detailed System (e-tracker) usability scale

Average usability scale of e-tracker	**Below average N = 144 n (%)**	**Above average N = 42 n (%)**	**X^2 (p-value)**	**COR (95% CI) p value**	**AOR (95% CI) p value**
Age group					
<30 years	36 (25.0)	6 (14.2)		**Reference**	**Reference**
30 - 34 years	84 (58.3)	18 (42.9)		1.3 (0.47, 3.51) 0.623	0.6 (0.17, 2.23) 0.458
>=35 years	24 (16.7)	18 (42.9)	12.9508 (**0.002**)	4.5 (1.56, 12.97) **0.005**	1.8 (0.42, 7.30) 0.440
Sex					
Male	18 (12.5)	6 (14.3)		**Reference**	
Female	126 (87.5)	36 (85.7)	0.0923 (0.761)	0.9 (0.32, 2.32) 0.761	
Marital Status					
Single	42 (29.2)	6 (14.3)		**Reference**	
Married	102 (70.8)	36 (85.7)	3.7607 (0.052)	2.5 (0.97, 6.30) 0.058	
Qualification					
Certificate	120 (83.3)	36 (85.7)		**Reference**	
Diploma/Bachelor	24 (16.7)	6 (14.3)	0.1363 (0.712)	0.8 (0.32, 2.20) 0.712	
Length of practice					
<=5 years	54 (37.5)	6 (14.3)		**Reference**	**Reference**
>5 years	90 (62.5)	36 (85.7)	8.0189 (**0.005**)	3.6 (1.42, 9.10) **0.007**	3.2 (0.92, 11.44) 0.068

Receiving any coaching (X2=15.2018; p-value=0.000), e-tracker seen as a double work (X2=12.7312; p-value=0.002), the person immediately consulted if encountering a difficulty (X2=22.2155; p-value=0.000), and e-tracker helps in writing reports (X2=35.6652; p-value=0.000) were all statistically significance with knowledge level of respondents Table 4.

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Table 2: Factors affecting e-tracker practice

Knowledge Level of e-tracker	Low N = 57 n (%)	High N = 129 n (%)	X^2 (p-value)	COR (95% CI) p value	AOR (95% CI) p value
Have you ever received any coaching?					
Yes	21 (36.8)	87 (67.4)		**Reference**	**Reference**
No	36 (63.2)	42 (32.6)	15.2018 (**0.000**)	0.3 (0.15, 0.54) **0.000**	1.6 (0.61, 4.15) 0.345
Do you have access to internet all the time?					
Yes	8 (14.0)	28 (22.8)		**Reference**	
No	49 (86.0)	95 (77.2)	1.8549 (0.173)	0.6 (0.23, 1.31) 0.177	
Is the e-tracker seen as a double work?					
Yes	37 (64.9)	107 (82.9)		**Reference**	**Reference**
No	8 (14.0)	16 (12.4)		0.7 (0.27, 1.75) 0.436	1.6 (0.56, 4.63) 0.373
No idea	12 (21.1)	6 (4.7)	12.7312 (**0.002**)	0.2 (0.06, 0.49) **0.001**	0.9 (0.22, 3.75) 0.887
If you have encountered a difficulty with the system, who do you immediately consult?					
In charge	30 (52.6)	24 (18.6)		**Reference**	**Reference**
District HI	27 (47.4)	105 (81.4)	22.2155 (**0.000**)	4.9 (2.45, 9.63) **0.000**	6.8 (2.78, 16.53) **0.000**
Do you take tablet to the field?					
Yes	25 (43.9)	47 (36.4)		**Reference**	
No	32 (56.1)	82 (63.6)	0.9187 (0.338)	1.4 (0.72, 2.57) 0.339	
Do you have good computer skills?					
Yes	21 (36.8)	51 (39.5)		**Reference**	
No	36 (63.2)	78 (60.5)	0.1208 (0.728)	0.9 (0.47, 1.70) 0.728	
Does the e-tracker help in writing your reports?					
Yes	20 (35.1)	52 (40.3)		**Reference**	**Reference**
No	7 (12.3)	59 (45.7)		3.2 (1.27, 8.28) **0.014**	5.0 (1.70, 14.78) **0.004**
No idea	30 (52.6)	18 (14.0)	35.6652 (**0.000**)	0.2 (0.11, 0.50) **0.000**	0.2 (0.07, 0.47) **0.001**

4. Discussion

Generally, there was relatively high knowledge of e-tracker among nurses in the Ho municipality (69.3%). Comparing to similar studies that found that 8.9% of nurses are familiar with m-health in Lagos State [5] and 28.1% of medical students and practitioners having good knowledge of m-health in Iran [12]. The huge difference in the knowledge might be as a result that in Lagos State, the nurses were not trained before the survey was carried out as it was in the Ho municipality. In Iran, the knowledge level was divided in three categories whereby the current study was divided into two categories. Age group was an associated factor that determined the knowledge level of nurses. Female nurses also have higher odds of high knowledge than male nurses (COR = 2.6; AOR = 3.7). Age was agreed as a factor affecting knowledge of computer skills among nurse managers however, disagreed with female nurses having higher odds of having computer skills [11]. CHN's have a better understanding of the e-tracker hence were more knowledgeable of the e-tracker than the other cadres. Midwives were 90% (AOR=0.1, p-value=0.000) less to have high knowledge as those with others which include; Physician Assistants (PAs), Enrolled Nurses (EN's) among others were 80% (AOR=0.2, p-value=0.003) less to have high knowledge. This might be because most of the services that are rendered by the CHN's such as Child Welfare Clinics (CWC's) are imputed into the system and reminders are usually set and used to track those that will be due to services within a particular day. To be able to meet these demands of the service since no child is to be left out in the vaccine-

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preventable diseases vaccines, it increases their exploitation of the system and eventually makes them to better understand the use of the system. Nurse who practiced more than five years had a better understanding of the system than those practicing for five years or less (COR=3.7, p-value=0.000; AOR=7.4, p-value=0.001) whiles the length of smartphone usage does not influence knowledge of e-tracker. The reason may be that the e-tracker was designed based on the manual register that the nurses use to record services they have offered into. Therefore, the longer one practiced, the familiarization with the register. Thus, as the system is just the replicate of the manual register in an electronic form, it does not demand how long a nurse used a smartphone to be able to use the system but rather the familiarization of the manual register helps in the filling of electronic one and also the necessary steps to be taken to avoid mistakes using the system. The current finding however disagrees with Adatara et al., which found that the longer a nurse manager works the less the computer skills [11]. This contradiction might have to do with the outcome of interest. While the current study was looking at e-tracker which is a form of ICT tool, Adatara et al., took into consideration the general computer usage such as MS Word, and HAMS among other applications. Moreover, it sampled only nurse managers at secondary facilities as the current study looked at the CHPS, Health Centers, and the hospitals and sample nurses in general without any category.

There was relatively low e-tracker usability as only 22.6% of the nurses had above average of the system usability score. This implies that majority of the nurses cannot use the system on their own without consulting others despite the knowledge. A study found the practice and knowledge of health information technology among nurses as 42.0% and 32.2% respectively which showed higher practice against knowledge score [12]. In an eight questions checklist in Burundi, 94.2% of healthcare workers agreed and strongly agreed to communicate to other colleagues using mobile devices with the least adoption of 51.2% that agreed and strongly agreed to monitoring and treating clients using mobile devices [23]. This study however, did not combine the questions as in the case of the current study. However, the current study agreed with Rahimi et al., which also reported that there was challenges with Technology Acceptance Model (TAM) such as telemedicine among health workers which does not guaranteed them to work effectively without an assistance [24]. In the current study, e-tracker usability was highly influenced by age group (X^2=12.9508; p-value=0.002) and length of practice (X^2=8.0189; p-value=0.005). Nurses who were thirty-five years or above were about five times (COR = 4.5) to have above average usability compared to nurses less than thirty years and those who practiced more than five years were about four times (COR = 3.6) to score above the average compared to those who practiced five years or less. This might be as a result that those nurses who were old happened to have spent longer periods in the service and eventually understood the terrain of the work especially the register and thus, their knowledge of expertise helped them to be able to follow the e-tracker and with minimal efforts, they can keep going with the system without much technical support.

Coaching or training has an associated factor with knowledge of e-tracker among nurses. For nurses that received coaching, it increased their level of understanding the e-tracker and hence increases their knowledge level as nurses who were not coached were about 70% less to understand the e-tracker as desired. This is because the lack of nurses engagement in technology training sessions decreases their confident level to cope with the current demand of the application of technology in the health industry [25]. The e-tracker was seen as a double work for the nurses. This is because it is just a replicate of their manual register and the same client's data that will be entered into the e-tracker will again be entered into their hardcopy registers. This hinders some of the nurses from entering especially if they go for outreach services without the tablet. It was more evidenced as 74.5% of physicians having burnout symptoms in Canada reported HER as a key factor contributing to it [26]. The personnel a nurse contacted if he or she has a challenge with the e-tracker affected his or her knowledge level of the e-tracker. Those who sought help from the District (HI) had a higher knowledge to understand the e-tracker than those who got help from theirs in charges (COR = 4.9; AOR = 6.8). This might be that some of the in-charges themselves have challenges to understand the system to talk of guiding someone else with it. And perhaps as the District (HI) was part of the deployment team, they happened to have a better understanding, and since the District doubles as the next reporting organizational level of the Ghana Health Service, the District seemed to have authority over them. Nurses who disagreed that the e-tracker helped in writing their reports were higher to have high knowledge of the e-tracker than nurses who agreed it helped in writing reports. This might be as a result that though they know the e-tracker they do not do the entries on time and thus, the system has no value for them as far as their report writing is concern. This is because if some are still entering back locks,

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then there is no way the system can be of any help to them in writing their current reports. The majority of the nurses do not have internet connectivity all the time and this hinders their usage of the e-tracker. This is because even if a client comes and there is the need to search for the client's details, it becomes very difficult to get the details, and to reduce the increase in waiting time, services are rendered without the search and this increases the chance of duplication. Though access to the internet has no statistical significance.

In conclusion, majority of the nurses in the Ho Municipality has high knowledge of e-tracker whereby there was very poor e-tracker usability. As nurses were coached, their level of understanding the e-tracker were increased. The e-tracker was seen as a double work and thus hinders its performance and this eventually led to the system not providing any benefit as far as report writing is concern. Limitations were that the current study was susceptible to recall bias on the part of the participants since there was no room for practical observations and whether a participant has ever used an e-health system before was not measured. And to the best of our knowledge the current study was the first to assess the e-tracker deployment and thus recommends that; there should be regular in-service training to enhance the nurses' ability to use the system on their own. The government should see to the internet stability for proper synchronization and searching.

5. Acknowledgements

Nurses at the Ho Municipality.

6. Statement on conflicts of interest

There is no conflict of interest as far as the current study is concern.

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Leveraging Digital Health Interventions to Enhance Prevention, Response and Control of Public Health Emergencies in Low and Middle-Income Countries

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