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ORIGINAL RESEARCH

Data Interoperability Assessment Model for Health Information System in South African Public Healthcare

Authors' Contribution:
A – Study design;
B – Data collection;
C – Statistical analysis;
D – Data interpretation;
E – Manuscript preparation;
F – Literature search;
G – Funds collection

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Abstract

Background and Aim of Study: *The increasing use of information technologies in healthcare has enhanced communication between its stakeholders and has also reduced health cost. As a result, data interoperability has become a priority which has increased the need to assess whether health information systems (HIS) used are interoperable enough to support this call. The aim of the study: to assess the data interoperability of the HIS used in the South African public healthcare.*

Material and Methods: *Based on the conceptual model with the constructs of core, policy, societal, engagement as well as acceptance and use readiness and parameters of functional, syntactic and semantic interoperability, a measuring instrument in the form of closed-ended questionnaire was designed. Statistical data was collected from Information Technology personnel in three district hospitals of Gauteng Province in South Africa.*

Results: *Hypotheses 1, 3 5, 6a and 6c predicted the influence of core readiness, societal readiness, use readiness functional interoperability and semantic interoperability on HIS data interoperability readiness respectively and were all accepted. Hypothesis 2, 4 6b predicted the influence of policy readiness, engagement readiness and syntactic interoperability on HIS data interoperability readiness and were all rejected.*

Conclusions: *The developed model can be used to enhance research on data interoperability that is a major challenge in the use of information technology in healthcare. The sharing of information among different levels of medical personnel is essential for healthcare quality, efficiency, and safety of care provided to a patient. To enable this, systems should be able to connect and exchange information with each other without limitation. Such also enables better workflows, reduce ambiguity, and allows data transfer among systems and healthcare stakeholders.*

Keywords: *health information systems, interoperability assessment, interoperability parameters, readiness assessment, South African healthcare*

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Introduction

In today's information age with increasing digitization, information technology (IT) has become an indispensable part of healthcare institution. IT has the potential to improve the health of patients and the performance of providers. This will lead to improved quality, cost savings, and greater patient engagement in their own healthcare (Richemond & Huggins-Jordan, 2023). As result, health institutions in South Africa (SA) are also implementing different IT solutions to improve their health data management systems to enhance healthcare service delivery. However, this various health information technology they implement run independently and lack uniform data standards as different suppliers provide them and, thus, have different architectures, databases, and infrastructures (Torab-Miandoab et al., 2023).

South Africa, classified as a middle-income country, grapples with legacy systems functioning in isolation, presenting challenges in safeguarding sensitive information, including patient privacy (Peng & Goswami, 2019). Hence, this fragmented approach to data management poses significant obstacles to safeguarding patient privacy and protecting sensitive information. Health information systems are not integrated, which underpins the fact that information systems are operating in silos (Torab-Miandoab et al., 2023). South Africa's health information systems are not integrated, and although they currently use schemas that could potentially help patient information be shared, the issue of systems working in silos makes it difficult for patient information to be shared. This creates a serious challenge with data interoperability. As a result, a number of these electronic health information systems (HIS) used in some hospitals are unable to interoperate with each other for data synchronization and exchange (Savage & Savage, 2020).

According to Torab-Miandoab et al. (2023), although the adoption of HIS has improved the quality of healthcare information and services, the interoperability of these systems still requires attention. The inability to allow the interoperability of health data and to have a comprehensive, interoperable supporting infrastructure can be addressed through standardization. Standardization in this context enables automatic data interchanges to enhance smart hospitals and improve decision-making. Further, the high rate, speed, and volume of big data further shows the need for standardized formats that in turn enable systems to interoperate (Richemond & Huggins-Jordan, 2023). It is therefore critical that healthcare address standards to improve and address the current data fragmentation. Dixon et al. (2020) highlight that interoperability improves effective organizational communication and the integration of efforts. This shows that interoperability of health information systems is a major factor for enabling healthcare institutions to improve medical service delivery.

Currently, SA is working on initiatives to standardize the National Health Insurance System (NHI) to improve data quality and exchanges of data (Naidoo et al., 2023). The implementation of an Electronic National Health Insurance can be used to facilitate the tracking of patients with the intention to enhance accuracy of data and completeness of healthcare. The importance of health in society cannot be overemphasized, and the corresponding data is expected to be extremely relevant and of good quality. According to Tsegaye and Flowerday (2021), it is important to understand patient data so that more prominent decisions may be taken to improve the use of integrated patient information. Interoperability occurs only when there is interaction between the systems at three levels: functional, syntactic, and semantic interoperability (Blobel & Scott, 2018). Despite the three-level view of interoperability, drivers thereof should be taken into consideration. Management issues are of the utmost importance for aligning interoperability initiatives with national priorities in the healthcare sector. This includes investments in interoperability initiatives, strategies, policies, service, standards, and infrastructure (Savage & Savage, 2020).

Accessibility to large quantities of accurate health data is required to understand medical and scientific information in real-time, evaluate public health measures before, during, and after times of crisis as well as preventing medical errors. Much as this is so, there are challenges towards easy accessibility and sharing of health data (Savage & Savage, 2020). Among these challenges is the lack of proper guidance is the functional interoperability in the healthcare sector (Szarfman et al., 2022). Additionally, Tsegaye and Flowerday (2021) also note that there is limited research on addressing interoperability when implementing technologies in healthcare. They indicate that although the South African healthcare institutions use schemas, health information systems are not interoperable as they do not exchange information among each other.

There is a plethora of literature on the use of technologies in health that has been conducted worldwide and in the South African perspectives. Kante and Ndayizigamiye (2021) work was on the analysis on the national digital health strategy for South Africa relating to the use of the Internet of Medical Things (IoMT) in healthcare. Their study focused on examining situational, structural, cultural, and environmental factors. Their study revealed that most research has been concentrating on the adoption of technologies in health but paying little attention on their interoperability. They recommended that national digital health strategy should provide a framework for the adoption and use of HIS as well as the interoperability and compatibility of these systems with the existing technologies.

The study of Mbunge et al. (2022) on the virtual healthcare services and digital health in South Africa indicated that six factors, namely perceived usefulness, perceived ease-of-use, organization, environment, technology, innovation, and vendor management influence readiness of private health sectors to adopt HIS. They however noted that challenges of infrastructural and technology, organizational and financial issues, policy and regulatory challenges, cultural and resistance as well as interoperability impede successful implementation of HIS. They recommended for the need to adjust eHealth policies to accommodate effective use of innovative technologies in healthcare that enables resources sharing. However, this can only be achieved if the implemented HIS are interoperable enough to enable the sharing of resources among health facilities.

Achieng and Ruhode's (2023) investigated the context-based factors that influence HIS implementation in resource-constrained public hospitals. Their study identified factors including implementation of policies, planning and support strategies, analysis of healthcare information systems suitability as well as interoperability. The study observed that interoperability is essential plays a role of standards, protocols, technologies, and mechanisms that allow data to flow between diverse systems with minimal human intervention since it enables diverse systems to communicate with each other and share information in real time. Their study recommended for more studies to investigate the compatibility and interoperability of health information systems for successful implementation, especially in public sectors.

Several theoretical models have been developed to explain users' behavioural intentions to accept and use technologies. Consequently, various research studies have been conducted to address interoperability readiness in healthcare (Achieng & Ruhode, 2023). Additionally, there are frameworks and models that have been developed specifically to inform technology readiness. Among them are Technology Reading Index (TRI) (Parasuraman, 2000), that explains the overall state of mind resulting from a gestalt of mental enablers and inhibitors that collectively determine a person's predisposition to use new technologies (Bakirta & Akkas, 2020).

Other studies have depended on TRI either by replicating or extending it to conduct research on technology readiness. In each studies, some factors have been added either from the literature or other theories and frameworks of technology acceptance and use (Robin et al., 2020).

Researchers Nilsen et al. (2020) used the TRI by introducing new factors such altitude, education and training, technology compatibility to address issues of interoperability, inadequate infrastructure, and lack of standardization.

Five constructs of core readiness, policy readiness, societal readiness, engagement readiness, and use and acceptance readiness were identified and derived from literature. Additionally, interoperability levels were reconceptualized into three perspectives and included in the conceptual model these are Functional, Syntactic, and Semantic interoperability. The attributes of the readiness factors were derived from literature in this manner: a. Core readiness attributes: Need to change, Education and training, Awareness, Willingness to change, E-health project planning, Trust on the use of technology (Yusif et al., 2020). Policies readiness attributes: Socio-political, technical, and regulatory factors, Legislature and political economy (Kouroubalia et al., 2019; Pypenko & Melnyk, 2021; Tsegaye & Flowerday, 2021). Societal readiness attributes: Sociocultural factors, Interaction among members, Local communities (Yusif et al., 2020; Ilorah et al., 2017). Engagement readiness (Yusif et al., 2020; Ilorah et al., 2017) attributes: Physical accessibility, and acceptability of services, Communication experiences (Ennis-Cole, Cullum and Iwundu, 2018), Socio-economic (Ogundeji, Ohiri and Agidani, 2018), Resistance to change/ Need to change. The last readiness construct is Acceptance and Use Readiness with attributes: Education and training, Willingness to change, Training of users, Cultural settings of diverse population groups in the society (Yusif et al., 2020; Ilorah et al., 2017).

Tsegaye and Flowerday (2021) suggested that interoperability levels due to functional interoperability will influence the interoperability readiness of health information system data. In terms of semantic interoperability, a health system that is semantically integrated allows the exchange of data among organizations and their internal ecosystems by ensuring that the data exchanged is interpreted correctly and does not miss its meaning (de Mello et al., 2022).The syntactic level on the other hand enables the exchange of data by supporting the same protocol in a standardized format (Villarreal et al., 2023).

These constructs are presented in the Figure 1, showing the hypothesis derived from the constructs.

The aim of the study. To assess the data interoperability of the Health Information System used in the South African public healthcare.

Materials and Methods

Based on the conceptual model, a close-ended questionnaire was developed to collect data from three district hospitals in Gauteng province, South Africa. The questionnaire was distributed online using Survey Monkey. For ethical purposes, and to protect privacy and anonymity, a link was sent to the contact person at each district hospital who then distributed it to the respondents using their mailing lists. Respondents filled the questionnaire and on completion they clicked the submit button that delivered the completed questionnaire in the Survey Mokey database.

Population and Sampling

The targeted population for this study consisted of individuals who were actively involved or uses HIS and are somehow knowledgeable about the data sharing between health facilities. These were basically IT professionals, data quality mentors, medical professionals, and administration professionals. From the pre-exploratory study conducted, it was revealed that there are approximately fifty individuals in each hospital that form the category of the participants of this study, making the overall population of this study to be 150. Based on the Krejcie and Morgan (1970) tool for determining the sample size of the finite population, a sample size of 108 respondents was needed for data collection. Simple random sampling was then used to distribute the Survey Monkey link to the respondents.

Questionnaire Coding

Before data analysis was conducted, the questionnaire was coded to allow easy transcription in the statical package. Analysis was conducted using the Statistical Package for Social Scientists (SPSSv25). The questionnaire coding was as follows. Core Readiness was coded as CRead and its four attributes as CRead – CRead4, Policy Readiness as PRead and its three attributes as PRead1 – PRead3, Societal Readiness as SRead and its three attributes as SRead1 – Sread3, Engagement Readiness as Eread and its four attributes as ERead1 – ERead4, Acceptance and Use Readiness as AURead and its three attributes as AURead1 – AURead3. The Functional Interoperability was coded as FunInt and its three attributes as FunInt1 – FunInt3, Semantic Interoperability as SemInt and its three attributes as SemInt1 – SemInt3 and the Syntactic Interoperability also known as Data Ontology was coded as SynInt and its three attributes as SynInt1 – SynInt3.

Results and Discussion

Table 1 presents a detailed analysis of frequencies of the respondents' demographics and situational variables.

Table 1

Frequencies of Respondents' Demographics

Variables	Item	Frequency		
		Person	Percent	Cumulative percent
Gender	Female	69	55.6	55.6
	Male	54	43.5	99.2
	Response	1	0.8	100.0
	Total	124	100.0	–
Age	21–30 years	27	21.8	21.8
	31–40 years	64	51.6	73.4
	41–50 years	23	18.5	91.9
	50 years and above	9	7.3	99.2
	Response	1	0.8	100.0
	Total	124	100.0	–
Working experience	0–3 years	13	10.5	10.5
	12 years and above	30	24.2	34.7
	4–7 years	37	29.8	64.5
	8–11 years	43	34.7	99.2
	Response	1	0.8	100.0
	Total	124	100.0	–
Organization duration	0–3 years	38	30.6	30.6
	12 years and above	20	16.1	46.8
	4–7 years	42	33.9	80.6
	8–11 years	23	18.5	99.2
	Response	1	0.8	100.0
	Total	124	100.0	–
Job position	Administration professional	14	11.3	11.3
	Data quality mentor	8	6.5	17.7
	IT professional	47	37.9	55.6
	Medical professional	14	11.3	66.9
	Other	40	32.3	99.2
	Response	1	0.8	100.0
	Total	124	100.0	–
Involvement in planning / implementation	No	83	66.9	66.9
	Response	1	0.8	67.7
	Yes	40	32.3	100.0
	Total	124	100.0	–
Experience in usage of health information system	No	68	54.8	54.8
	Response	1	0.8	55.6
	Yes	55	44.4	100.0
	Total	124	100.0	–
Awareness of health information system data interoperability	No	80	64.5	64.5
	Response	1	0.8	.8
	Yes	43	34.7	34.7
	Total	124	100.0	–

Regression Analysis

Regression analysis explains the relationship between two or more variables of interest (Creswell & Creswell, 2018). From the model summary, the overall prediction of the model to inform HIS data interoperability readiness assessment was 86.1% (R^2=0.861).

Table 2 presents results of the regression analysis. The regression analysis explains each construct's contribution to the overall prediction of the model.

Table 2
Regression Analysis

Model	Unstandardized coefficients		Standardized coefficients	*t*	Sig.	Collinearity statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	0.199	0.181	–	1.102	0.274	–	–
PRead	0.030	0.084	0.031	0.355	0.723	0.214	4.677
CRead	0.266	0.074	0.252	3.589	0.001	0.328	3.051
SRead	0.100	0.062	0.116	1.983	0.040	0.311	3.212
ERead	0.070	0.082	0.072	0.856	0.394	0.227	4.403
AURead	0.354	0.064	0.423	5.498	0.000	0.272	3.675
FUNInt	0.300	0.046	0.356	6.501	0.000	0.539	1.856
SEMInt	-0.188	0.081	-0.157	-2.307	0.023	0.348	2.872
SYNInt	0.027	0.056	0.021	0.476	0.635	0.835	1.198

Note. *Dependent variable – HISDIRead; VIF – variance inflation factor; PRead – policy readiness; CRead – core readiness; SRead – societal readiness; ERead – engagement readiness; AURead – acceptance and use readiness; FUNInt – functional interoperability; SEMInt – semantic interoperability; SYNInt – syntactic interoperability.

Results in Table 2 indicates that with the exception of policy readiness (PRead), engagement readiness ERead and syntactical interoperability the rest of the constructs showed that they have a significant contribution to the overall prediction of the model. Additionally, all the values of the Variance Inflation Factor (VIF) were below the recommended value for multicollinearity to exist implies that there was no multicollinearity. By using the critical ration *t*-value demonstrated in Table 2, the testing of the hypotheses was deduced as presented in Table 3.

Table 3
Hypotheses Testing

Hypothesis	Results	Action
H1: Core readiness has a direct influence on health information system data interoperability readiness	P = 0.001 < 0.05	Accepted
H2: Policies readiness has a direct influence on health information system data interoperability readiness	P = 0.723 > 0.05	Rejected
H3: Societal readiness has a direct influence on health information system data interoperability readiness	P = 0.040 < 0.05	Accepted
H4: Engagement readiness has a direct influence on health information system data interoperability readiness	P = 0.394 > 0.05	Rejected
H5: Acceptance and Use Readiness has a direct influence on health information system data interoperability readiness	P = 0.000 < 0.05	Accepted
H6a: Interoperability levels due to functional interoperability will influence health information system data interoperability readiness	P = 0.000 < 0.05	Accepted
H6b: Interoperability levels due to syntactic interoperability will influence health information system data interoperability readiness	P = 0.635 > 0.05	Rejected
H6c: Interoperability levels due to semantic interoperability will influence health information system data interoperability readiness	P = 0.023 < 0.05	Accepted

The final model with the constructs of core, societal, acceptance and readiness, and the parameters of functional and semantic interoperability is shown in Figure 2.

Figure 1

The Conceptual Model for Data Interoperability Assessment for Health Information System in South African Public Healthcare

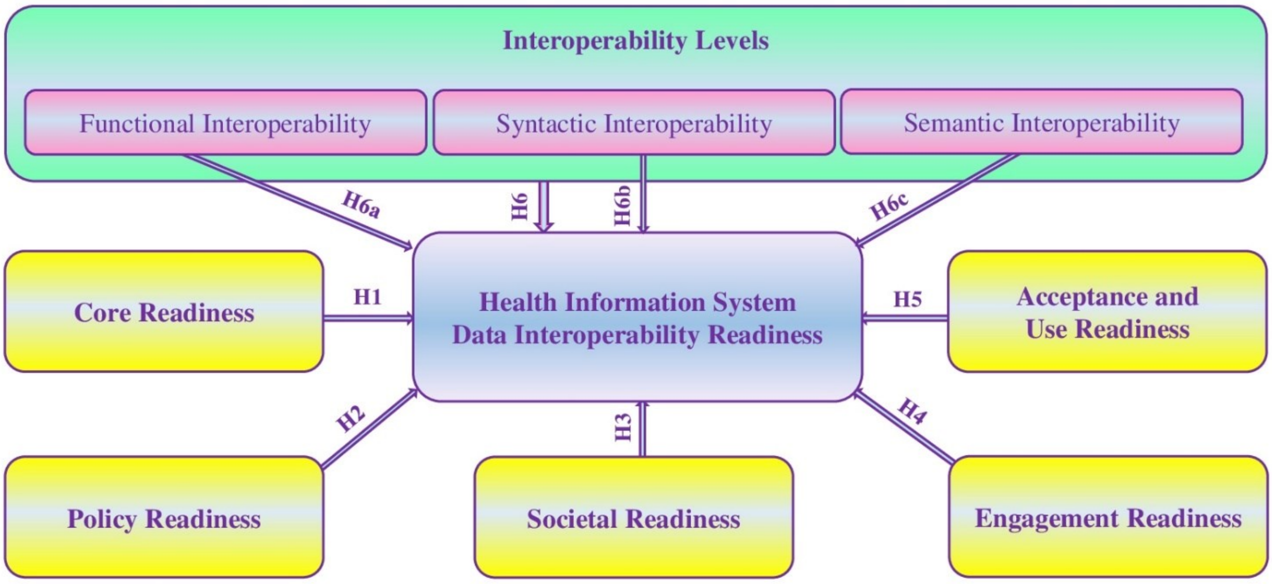
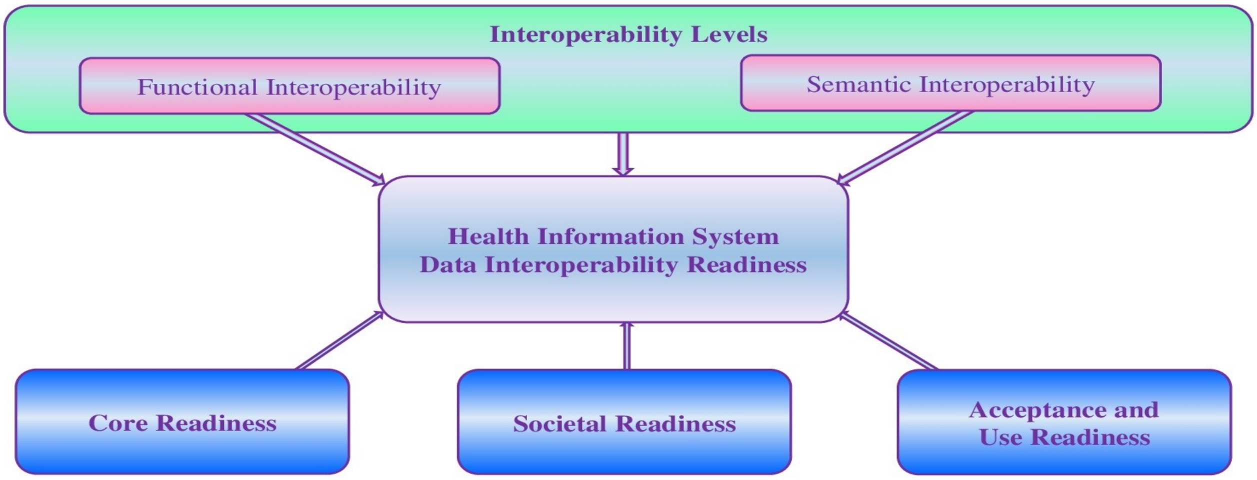


Figure 2

The Final Model for Data Interoperability Assessment Model for Health Information System in South African Public Healthcare



This study sought to assess interoperability readiness in South African public health. Interoperability plays a major role in today's interconnected world, as it enables health institutions to communicate and exchange data effectively and efficiently. With interoperability, health institutions may have improved data sharing and collaboration, enhanced data quality, increased efficiency, lower costs, improved user experience, and better security and privacy (Savage & Savage, 2020; Torab-Miandoab et al., 2023). To maximumly benefit from interoperability, health institutions need to focus on creating a culture of collaboration and data sharing and investing in technology solutions that enable seamless data exchange between different systems and devices. This section discusses the results of the study in relation to the five hypotheses that were set to assess the interoperability readiness in South African public hospitals.

The first hypothesis (H1) theorized that core readiness has a direct influence on HIS data interoperability readiness. This hypothesis was accepted. The acceptance of this hypothesis implies that with the increasing digitization it is almost becoming impossible for health institutions to operate without the use of technology. results of the study are in agreement with those of other researchers such as (Achieng & Ruhode, 2023; Khubone et al., 2020; van Heerden & Young, 2020) who indicated that digital solutions in health should be implemented with interoperability in mind to enable collaborations and information sharing especially in the resources constrained areas. Hence, they emphasized the role of core readiness in achieving interoperability readiness.

The second hypothesis (H2) predicted the influence of policy readiness on HIS data interoperability readiness. This hypothesis was rejected. Policy readiness which refers to government commitment regarding governance, standards, and legal infrastructure. The implementation of technology in healthcare is often frequently expected to raise the standard of healthcare services. The rejection of this hypothesis implies that policies are paramount for the implementation of HIS but may not have a role in the architecture and operation of the system as many policy makers are not actually the users of the system. The findings of this study don't align with those of other researchers such as (Achieng and Ruhode, 2023; Kgasi & Kalema, 2014; Tsegaye & Flowerday, 2021) who found policy significant and indicated that good policies should set standards that should be followed before. During and after the implementation of HIS.

The third hypothesis (H3) predicted the influence of societal readiness on HIS data interoperability readiness. This hypothesis was accepted. The acceptance of this hypothesis emphasizes the need to involve users when implementing a technological innovation. Such involvement is key for ensuring that high quality healthcare and reliable services are implemented to meet the users day to day needs. It also ensures trust, and confidence during use and the planning of the suitable training for the users. The findings of this study concur with those of previous researchers such as (Khubone et al., 2020; Robin et al., 2020; Udekwe et al., 2021) who found society readiness significant and indicated that technological systems may fail when they meet resistance originating from users' negative attitudes towards the technology especially when the users were not involved in the implementation process.

The fourth hypothesis (H4) predicted the direct influence of engagement readiness on HIS data interoperability readiness. This hypothesis was rejected. The rejection of this hypothesis implies that health institutions do not need to plan for engagement as it should be part and partial of the implementation process. When users are involved, engagement comes automatically as each user will feel that he/she is part of the whole process. The findings of this study concur with those of many other researchers such as (Udekwe et al., 2021; Villarreal et al., 2023) who also note that much as engagement readiness stimulates effective implementation planning that avoids financial losses, effort, time delays and, dissatisfaction among stakeholders. Its role may be reduced if users involvement is taken as part of the implementation process.

Hypothesis H5 theorized the influence of the acceptance and use readiness on HIS data interoperability readiness. This hypothesis was accepted. The acceptance of this hypothesis implies that any form of technology needs to be accepted, adapted, adopted and then used. Acceptance and use are very critical in the technology implementation journal regardless of what technology is being implemented. The findings of this study are in agreement with those other researchers such as (Achieng & Ruhode, 2023; Naidoo & Naidoo, 2021; Robin et al., 2020) who indicated that the use of HIS is influenced by the level of system simplicity and user-friendliness. They indicated that, if the HIS is effectively used implementation of interoperability will be faster as users will be eager to share information and collaborate with others.

The interoperability levels were based on to hypothesize three relationships. H6a predicted that interoperability levels due to functional interoperability will influence HIS data interoperability readiness. This hypothesis was accepted. The acceptance of this hypothesis may imply that fragmented data fail to achieve the full potential of digital health, therefore today's world healthcare facilities do their best to deliver the best patient experience.

Without a proper interoperability structure, exchanging patient-related data becomes impossible in such cases. The foundational level is a basic level of exchange of data hence, the foundational level will assist in improving patient information. The findings of this study agree those of Rajkumar et al. (2022); Tsegaye and Flowerday (2021) who suggested that interoperability levels due to functional interoperability will influence the interoperability readiness of health information system data. This level of interoperability only ensures that information is transmitted and does not indicate anything about data representation.

Hypothesis H6b predicted the influence of interoperability levels due to syntactic interoperability to have an influence on HIS data interoperability readiness. This hypothesis was rejected. During sharing and collaboration, it is anticipated that there will be an exchange of information. These exchanged messages would need to be transmitted using a structure and syntax that are recognized by both the sender and the receiver systems. As a result, there must be an agreed on uniform data format for sharing and integrating different applications based on their respective structures (Lehne et al. 2019). The findings of this study are contrary to those of other researchers, such as Tsegaye and Flowerday (2021) and Rajkumar et al. (2022) who indicated that to achieve a meaningful exchange of health data, it is essential to have semantic and syntactic interoperability along with technical interoperability.

The last hypothesis H6c predicted the influence of semantic interoperability on HIS data interoperability readiness. This hypothesis was accepted. The acceptance of this hypothesis suggests that semantic interoperability is the foundation of healthcare and focuses on clear and unambiguous semantics and standardized medical terminologies.

Therefore, it is always better to use data with a clear and well-defined structure. To ensure the security of the exchanged data, semantic interaction is the best choice, as it allows interoperability at the highest level. The findings of this study are consistent with those of other researchers - such as Tsegaye and Flowerday (2021) who suggested that semantic interoperability levels will influence HIS data interoperability readiness since to allows the exchange of data among health institutions there is a need to ensure that data exchanged is interpreted correctly and does not miss its meaning.

Conclusions

Interoperability in the field of health care is still in its infancy and such has led to many legacy systems that worsens the already existing information silos and has consequently led to skyrocketing of healthcare costs, poor health service delivery due to delayed decision making. However, implementing interoperability in healthcare systems faces numerous challenges ranges from privacy and security Concerns to data quality and integrity. Overcoming the barriers health institutions need to leverage models like the one developed in this study to have a better understanding of how best interoperability could be implemented with minimal challenges.

More still, leveraging interoperable frameworks will enhance data accuracy, efficiency, and ultimately improve patient outcomes.

It is, therefore, important to note that interoperability serves as the backbone of a typical healthcare delivery system. Interoperability plays a crucial role in enhancing data accuracy, efficiency, and patient outcomes within the healthcare ecosystem. Improved interoperability in healthcare systems can have significant positive impacts on patient care, data security, and overall healthcare system efficiency.

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Ethical Approval

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