Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Sensors International 3 (2022) 100152

Contents lists available at ScienceDirect

Sensors International

journal homepage: www.keaipublishing.com/en/journals/sensors-international

Are we there yet? Unbundling the potential adoption and integration of telemedicine to improve virtual healthcare services in African health systems

Elliot Mbunge [a,*], Benhildah Muchemwa [a], John Batani [b]

[a] Department of Computer Science, Faculty of Science and Engineering, University of Eswatini, Private Bag 4, Kwaluseni, Eswatini
[b] Faculty of Engineering and Technology, Botho University, Maseru, Lesotho

ARTICLE INFO

Keywords:
COVID-19
Telehealth
Telemedicine
Health digital technologies
Africa

ABSTRACT

Since the outbreak of COVID-19, the attention has now shifted towards universal vaccination to gracefully lift strict COVID-19 restrictions previously imposed to contain the spread of the disease. Sub-Saharan Africa is experiencing an exponential increase of infections and deaths coupled with vaccines shortages, personal protective equipment, weak health systems and COVID-19 emerging variants. Some developed countries integrated telemedicine to reduce the impacts of the shortage of healthcare professionals and potentially reduce the risk of exposure, ensuring easy delivery of quality health services while limiting regular physical contact and direct hospitalization. However, the adoption of telemedicine and telehealth is still nascent in many sub-Saharan Africa countries. Therefore, this study reflects on progress made towards the use of telemedicine, virtual health care services, challenges encountered, and proffers ways to address them. We conducted a systematic literature review to synthesise literature on telemedicine in sub-Saharan Africa. The study revealed that telemedicine provides unprecedented benefits such as improving efficiency, effective utilization of healthcare resources, forward triaging, prevention of medical personnel infection, aiding medical students' clinical observation and participation, and assurance of social support for patients. However, the absence of policy on virtual care and political will, cost of sustenance of virtual health care services, inadequate funding, technological and infrastructural barriers, patient and healthcare personnel bias on virtual care and cultural barriers are identified as limiting factors to the adoption of virtual health care in many African health systems. To alleviate some of these barriers, we recommend the development of robust policies and frameworks for virtual health care, the inclusion of virtual care in the medical school curriculum, supporting virtual care research and development, increasing health funding, removing monopolisation of telecommunication services, developing of virtual health solutions that address eccentricities of African health systems.

1. Introduction

The outbreak of coronavirus disease 2019 (COVID-19) brought a transformative shift in many health systems globally posing unprecedented challenges and opportunities to improve healthcare services delivery. The virus was declared a public health emergency and a global public health concern by the World Health Organization (WHO) on January 30th, 2020 [1]. Immediately after the pronouncement, many countries imposed stringent measures including social distancing, the mandatory wearing of face masks in public places [2], self-isolation and quarantine of suspected and positive individuals, a temporary ban of public gatherings [3], closure of borders, sanitization, temperature checking strategic entry points [4] and curfews to reduce further transmission and the catastrophic impact of the virus. However, COVID-19

* Corresponding author.
E-mail address: mbungeelliot@gmail.com (E. Mbunge).

Production and hosting by Elsevier

https://doi.org/10.1016/j.sintl.2021.100152
Received 6 September 2021; Received in revised form 2 December 2021; Accepted 2 December 2021
Available online 7 December 2021

measures like lockdowns, self-isolation, quarantine and stay-at-home with unintended consequences, such as widening economic inequalities, abuse of substances [5], mental health problems [6], and exacerbating poor medical outcomes. The sustainability of such measures coupled with socio-economic impact in many regions has been contentious and presented various complications which subsequently led to varying COVID-19 responses [7]. This can lead to partial adherence to COVID-19 measures because of misdistribution of COVID-19 relief aid, emerging psychological consequences of the pandemic, poor sanitation [8], informal settlements, poverty and food insecurity, political and social unrests, religious and cultural activities, extended households and weak health systems [9].

The containment of the pandemic was solemnly relying on prevention measures and the utilization of digital health technologies. However, the successful development of COVID-19 vaccines brought a glimpse of hope, as countries thrive to vaccinate populations to attain herd immunity [10]. Nevertheless, this glimmer of hope seems to be elusive in some parts of sub-Saharan Africa as the vaccination process encounters challenges. These include shortage of vaccines [11], vaccine hesitancy [12], limited access and supply, high cost of vaccines and insufficient funding [13], inequitable distribution of vaccines [14], lack of community engagement, conspiracy theory, competing livelihoods activities [15] and low vaccination coverage [16]. Also, emerging COVID-19 variants retards progress made during the first wave and second wave as evident by the exponential increase of infections in sub-Saharan Africa. As COVID-19 variants spread across Africa, it is becoming clear that responses require action beyond the health sector and must be tailored to the local situation [17] by effectively integrating telehealth and telemedicine solutions in health systems. For instance, virtual wards and telemedicine have been utilized for remote monitoring of patients with COVID-19 to avoid further hospital of patients with mild and manageable symptoms [18]. Such patients are managed at home, their oxygen levels are remotely monitored to reduce the burden on overwhelmed healthcare professionals and health facilities. Telehealth involves the use of technology for remote healthcare [19]. Telemedicine is a subset of telehealth that focuses on the use of electronic information and telecommunication technologies (ICTs) to support and promote long-distance clinical health care [20]. COVID-19 necessitates the use of telehealth and telemedicine solutions to circumvent the challenges associated with in-person care through virtual health care. These technologies provide remote patient monitoring, consultation capture, storage, process and transmission of patient health data, and establish communication between healthcare professionals and patients. The integration of telemedicine in African health systems can reduce the impacts of the shortage of healthcare professionals and potentially reduce the risk of exposure thereby protecting health workers from COVID-19 infection [21]. Such innovations can substantially improve and ensure easy delivery of quality health services while limiting regular physical contact and direct hospitalization. However, the adoption of telemedicine and telehealth is still nascent in many sub-Saharan Africa countries as compared to other countries [22] despite their overwhelming benefits in providing virtual healthcare services to vulnerable healthcare systems especially in resource-constrained settings during COVID-19. Interestingly, there is still limited literature on the potential integration of telehealth and telemedicine in sub-Saharan Africa health systems. This study aimed to provide a comprehensive review on the potential and effective integration of telemedicine in sub-Saharan Africa health systems during COVID-19 while introspecting at the implementation barriers. Therefore, this study sought to achieve the following objectives:

- To explore virtual health services delivered through telemedicine in sub-Saharan Africa during the pandemic
- To investigate challenges and barriers hindering effective integration of telemedicine in sub-Saharan Africa health systems
- Propose recommendations for effective integration of telemedicine in sub-Saharan Africa health systems

The remainder of the paper is structured as follows: Section 2 presents the methodology adopted to carry out the review. Section 3 discusses virtual healthcare services delivered through telemedicine, barriers and challenges for effective integration of telemedicine in sub-Saharan Africa health systems. Section 4 presents recommendations for the effective integration of telemedicine. Finally, the conclusion is presented in Section 5.

2. Materials and method

The study adopted the preferred reporting items for systematic reviews and meta-analyses (PRISMA) model [23]. The PRISMA has been extensively utilized health field to conduct systematic reviews [24]. The steps of the PRISMA model guided the literature search in various electronic databases on the utilization of telemedicine in sub-Saharan Africa health systems to improve virtual care during the COVID-19 pandemic.

2.1. Search strategy

We searched published papers in the following online electronic databases; IEEE Xplore Digital Library, ACM Digital Library, Google Scholar, PubMed, Science Direct, and Springer Link. The search keyword used is as follows: "*telemedicine*" OR "*telehealth*" OR "*digital health technology*" OR "*e-health*" OR "*electronic health*" AND "*COVID-19*" OR "*coronavirus disease*" OR" *SARS-CoV-2*" OR" *severe acute respiratory syndrome coronavirus 2*" AND "*Africa*" OR "*sub-Saharan Africa*".

2.2. Study selection

We extracted 150 articles from electronic databases, as shown in Fig. 1. The selected articles were screened based on the following: title and abstract. We selected published peer-reviewed articles available from the onset of COVID-19 to 31 August 2021. Incomplete articles, opinion pieces, and non-peer-reviewed articles, and articles without English translations were excluded from the study. To ensure that all relevant articles were included in the study, the authors performed a citations chain for each article retrieved. Duplicate articles were removed from a pool of articles (see Fig. 1).

2.3. Eligibility criteria and quality assessment

After the selection of relevant articles, authors further assessed articles' abstracts independently, and 34 articles were considered for review eligibility. We further assessed full-text articles for eligibility and removed 3 articles. Only 31 articles were considered in this study. The study included published articles mainly for the utilization of telemedicine in African health systems to improve virtual care during the COVID-19 pandemic. Steps followed to report the number of published articles are presented in a PRISMA flow diagram as shown in Fig. 1.

3. Discussion of results

All the relevant data from the selected articles were extracted and synthesized in response to the research objectives. Published articles on telemedicine adoption and utilization in Africa health systems are shown in Table 1. From Table 1, we determined the percentage of articles based on the study type as shown in Fig. 2.

This shows most published articles included in this study were review papers(n = 10), with 33% followed by cross-sectional studies (n = 7).

3.1. Virtual healthcare services offered through telemedicine during COVID-19 in sub-Saharan Africa

Table 1 shows that several countries in Africa have been utilizing telemedicine to provide virtual care while reducing secondary transmission and minimizing in-person care. Several reviews conducted by

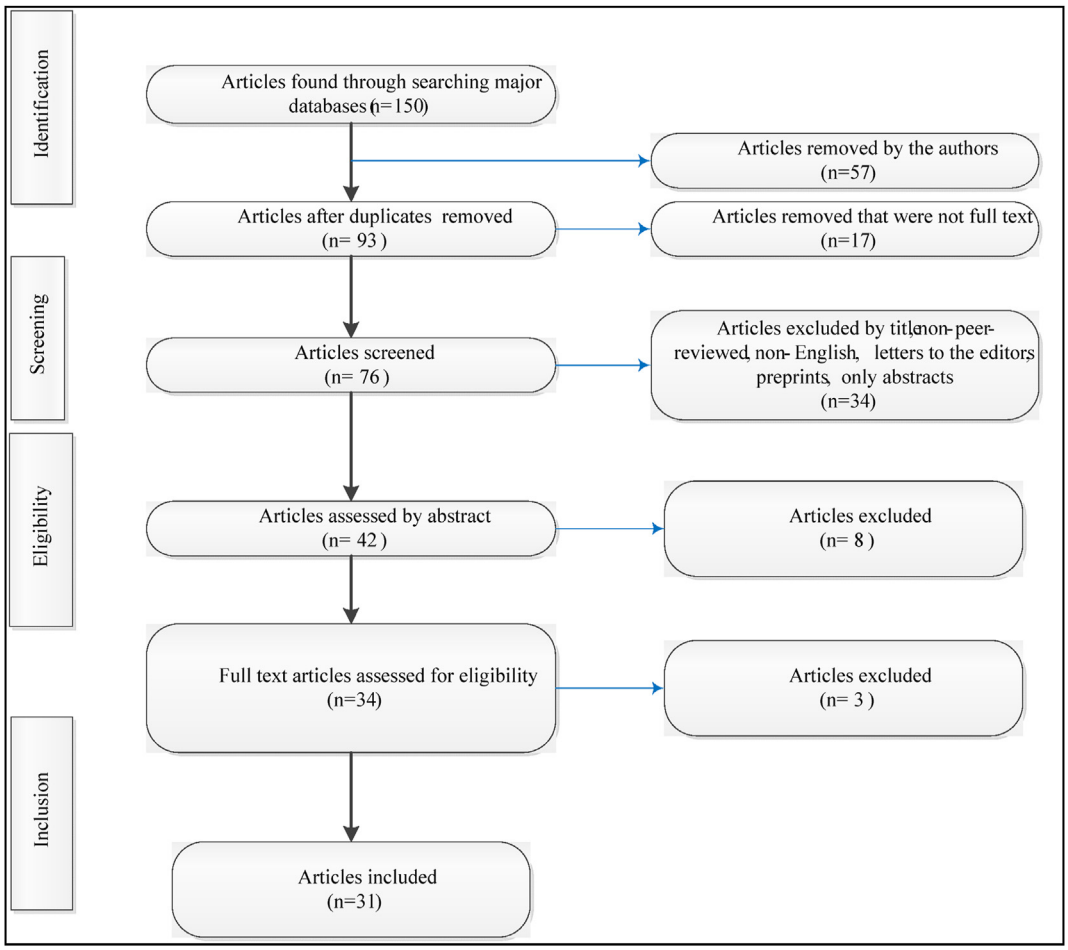

Fig. 1. PRISMA flow diagram.

different authors including [20,28,32,40,48,49] reflect that telemedicine can substantially improve the quality of healthcare even under COVID-19 restrictions and measures. This study reveals that telemedicine can be used for various purposes such as telemonitoring, teleconsultation, tele-diagnosing, tele-screening and establishing real-time communication between healthcare professionals and COVID-19 patients in quarantine facilities, self-isolation centers and at home, as shown in Fig. 3. For instance, a retrospective and prospective study conducted by Ref. [36] posit that telemedicine has been used in obstetrics and gynaecology in Zimbabwe during a lockdown period. In obstetrics and gynaecology, telemedicine is used in prenatal care, maternal and fetomaternal monitoring, fetal echocardiography, monitoring of chronic medical conditions in pregnancy and reproductive medicine. Their study states that the utilization of telemedicine reduced the cost of healthcare reduces hospital and consultation visits for minor conditions and increases access to specialist consultation. However, their study noted that it was difficult to entirely eliminate the physical examination of the patient, difficult in prescribing tests and medications electronically and sometimes the unwillingness of health care funders to pay for teleconsultation services. In Nigeria, a cross-sectional study conducted by Ref. [45] states that telemedicine has been used for teleconsultation with COVID-19 patients with mild symptoms. Teleconsultation service has been prominently utilized in various countries in sub-Saharan countries such as Botswana [31], Gambia [25], Uganda, Kenya, Ethiopia [39], Cameroon [44] and South Africa.

Several reviews, perspectives and commentaries included in this study show that telemedicine can potentially transform health systems to reduce the burden on healthcare professionals and also minimize the risk of exposure to the virus. Virtual healthcare services such as otolaryngologic practice during COVID-19 [26], teledermatology [31], tele-education, teleconsultation, teleradiology, telecardiology, teleophtamology, tele-oncology, and telepsychiatry [32], teleneurology [35] and tele-rheumatology [51]. Virtual health care alleviates the shortage of personal protective equipment through virtual telecare, reducing nosocomial infection due to reduction of clinic visitation especially in COVID-19 management units, protecting medical personnel from virus infection, and re-establishing undergraduate medical students clinical observership and medical care participation that has been halted due to the pandemic [53].

3.2. *Barriers and challenges for the effective adoption of virtual healthcare*

a) Infrastructural and technological barriers

The successful adoption of virtual health care requires the availability and reliability of underlying technologies like the Internet, ICT infrastructure, and reliable electricity supply. Technological barriers to the adoption of virtual health in Africa include poor internet connectivity [54], unreliable electricity supply [22,31,55], insufficient or unavailability of ICT infrastructure, inadequate or inappropriate virtual health infrastructure [49,56] and high cost of telecommunication equipment [36]. Additionally, malfunctioning of computing devices due to technical problems is a hindrance to the utilization of telemedicine and telehealth [30].

b) Limited knowledge and awareness

The popularity of virtual healthcare depends upon the knowledge that the important stakeholders have about it. Stakeholders like

Table 1
Telemedicine utilization in sub-Saharan Africa health systems.

Ref	Study type	Study context	Virtual health care service	Noted Challenges and risks
[25]	Cohort	Gambia	Virtual ward, teleconsultation for COVID-19 patients.	Difficulty to maintain optimal staffing to operate the virtual ward system and lack of continued funding to sustain the additional staffing, consumables and logistics required for the system and internet penetration in the most resource-limited setting is sometimes patchy and could impede the success of the system.
[22]	Commentary	Africa	Remote video consultation and chats.	Poor internet connection, lack of education about telemedicine, instability of basic infrastructure with special emphasis on the electric supply and shortage of healthcare professionals. The limited knowledge possessed by Africans about telemedicine is one of the reasons why it is still unpopular in many African countries.
[26]	Commentary	Africa	Otolaryngologic practice during COVID-19.	Internet network connectivity and affordability of smartphones since the majority of the populace lives in rural areas. Equipment such as flexible pharyngolaryngoscopes and video-otoscopes are not supported by remote telemedicine.
[27]	Commentary	Africa	Telecare sexual and reproductive health services.	Lack of specialized telemedicine equipment and internet services in several parts of SSA, unpaid healthcare services rendered through telemedicine.
[28]	Review	Africa	Quality of care	Ethical issues such as privacy, dehumanization by virtualizing patients and care, confidentiality, consent, and security were raised. Regulatory and policy issues such as Licensure, credentialing, liability and malpractice, conflicts of interest, technological certification standards and device regulation, and conflicting state rules affect the utilization of Telemedicine and telehealth.
[29]	Review	Africa	Telecare	Shortage of trained personnel in telehealth, digital divide, digital illiteracy, and lack of finance to buy airtime
[38]	WHO Report	Africa	Universal access to care	Lack of telehealth and telemedicine policies, Policymakers, health authorities and health practitioners are not fully aware of the potential benefits of the use of Telehealth and Telehealth for health. Weak ICT infrastructure and services within the health sector, the inadequate human capacity to plan and apply eHealth solutions, limited awareness of eHealth and weak leadership and coordination.
[30]	Perspective	Botswana	Oral health, dermatology, radiology, and cervical cancer screening	Malfunctioning of mobile devices due to different technical and connectivity problems. Cultural misalignment between IT and healthcare providers
[31]	Cross-sectional	Botswana	Teleconsultation	Low levels of computer literacy, unstable electrical power, lack of clinical and technical expertise, poor acceptance of the services by the users.
[32]	Review	Africa	Teleeducation, teleconsultation, teledermatology, teleradiology, telecardiology, teleophtamology, teleoncology, and telepsychiatry	Technological, organization barriers, legal and regulatory barriers, financial barriers such as limited medical budget, high cost of telemedicine and ICT infrastructure, high tariffs on telecommunication and import duties, and high cost of electricity supply, maintenance cost, high cost of telemedicine services and lack of funding. Cultural barriers such as digital divide, digital illiteracy, awareness gap, socio-cultural differences, perceptions, and resistance to change.
[33]	Cross-sectional	Uganda	Tele-education	The unavailability of telemedicine regulations and policies in the country.
[34]	Perspective	Africa	Tele-education, telecardiology,tele-ultrasonography, teledermatology, telepsychiatry, tele-ophthalmology and rehabilitation	Legal and ethical issues
[35]	Perspective	Africa	Teleneurology	Financing costs, Ethics Issues, data protection policies and budgetary allocation
[36]	Supplementary	Zimbabwe	Teleconsultation, tele-monitoring, and tele-expertise (Obstetrics and Gynaecology)	Lack of technological devices, network connectivity and digital illiteracy.
[37]	Review	Zimbabwe	e-prescribing, patient scheduling, patient referrals and telehealth systems	Lack of ICT infrastructure, violation of doctor-patient privacy, shortage of basic medical facilities, lack of active e-health policy
[38]	Conference	Namibia	Remote patient consultation	Poor network coverage and financial constraints cannot allow for video conferencing because videos need a large amount of data
[39]	Cross-sectional	Ethiopia	Remote consultation, access to medical information, remote sensing, and continuing education	Underdeveloped communication infrastructure
[40]	Review	Ethiopia	Diagnosis, treatment, and prevention of diseases, research, evaluation and continuing education of health care providers	Lack of laws and regulations regarding the use of e-health, level of ICT education, socioeconomic factors, cultural factors, costs, ICT infrastructure, technical support, unstable power supply and internet connection
[41]	Cross-sectional	Ethiopia	Communication of medical expert knowledge to distant remote locations where it is needed but lacking medical experts, costs, and accessibility issues	Users' lack knowledge of the technology. Lack of skills and understanding of the concept by the healthcare workers.
[42]	Cross-sectional	Nigeria	Consultations between patients and healthcare workers, emergency calls in experimental innovations like telesurgery	Lack of finance and lack of awareness of telemedicine services and shortage of ICT resources.
[43]	Review	Nigeria	For diagnosing and treating Patients remotely	Security and privacy issues
[44]	Cross-sectional	Cameroon	teleconsultation	Lack of regulatory regulations and training to frame and ease access to the use of telemedicine
[45]	Cross-sectional	Nigeria	Virtual care	

(*continued on next page*)

Table 1 (*continued*)

Ref	Study type	Study context	Virtual health care service	Noted Challenges and risks
				Lack of internet connection, low internet tariffs, and uninterrupted electricity. No guidelines that guarantee the patients data security, privacy, and confidentiality
[46]	Commentary	Africa	Mental health (counselling, consultation)	No guidance on the use of telemedicine for the delivery of mental healthcare, there is no standard of service delivery for telemedicine platforms in mental health care, and a lack of clarity regarding liability.
[47]	Concordance study	Kenya	Remote diagnosis of diseases	High logistical and economical barriers to accessing health care
[48]	Review	Africa	Teledermatology	Absence of strategic government policies, incompatibility of skills and digital knowledge
[49]	Review	Africa	Virtual doctor consultations	Resistance to telemedicine, infrastructural barriers, and the lack of policy and budgetary support as main deterrents to the current implementation of Telemedicine
[50]	Commentary	Africa	Virtual COVID-19 vaccines monitoring	Lack of political commitment, poor infrastructure, and inadequate resources, it has promising potentials to facilitate prompt access to the COVID-19 vaccine, routine follow-up post-vaccination, and surveillance in Africa
[20]	Review	Africa	Universal virtual healthcare	The absence of policy and political will, inadequate funding, cost of sustenance of telehealth services, patient and healthcare personnel bias on telehealth, willingness to pay and lack of political will.
[51]	Correspondence	Africa	Telerheumatology	Intermittent internet connection, digital divide and shortage of computing devices.
[52]	Review	Africa	Provision of universal virtual healthcare	Lack of supporting telemedicine framework and policies, digital barriers, and patient and healthcare personnel biases.

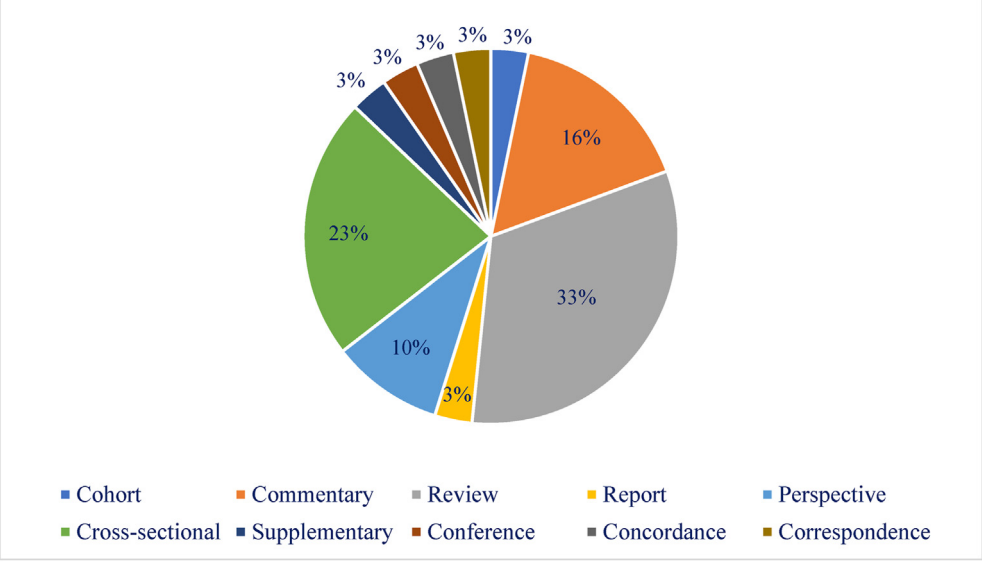

Fig. 2. Distribution of articles based on study type.

policymakers, health practitioners and health authorities need to appreciate the importance and role of telemedicine to minimize the inertia of adoption and prioritization of virtual healthcare. Decision-makers need to have enough knowledge about virtual healthcare for them to prioritize such projects. Previous studies revealed that limited knowledge about telemedicine and telehealth makes the technologies unpopular in Africa [22,41]. Moreover, digital illiteracy and shortage of personnel trained in virtual healthcare also affect the utilization of virtual healthcare technologies in Africa [29].

c) Organizational barriers

The organizational barriers to virtual health care adoption in Africa include lack of knowledge and training on virtual healthcare, limited stakeholder engagement in virtual health solutions, lack of health care professional competency and strategic planning. The lack of virtual healthcare buy-in by medical practitioners and institutions also hinders the adoption of virtual healthcare solutions [57]. Moreover, some organizations are not ready to accept electronic solutions in healthcare, a phenomenon referred to as lack of e-readiness. Weak leadership that cannot coordinate virtual healthcare interventions also affects the utilization of telemedicine and telehealth [38].

d) Lack of funding

A switch to virtual care requires additional infrastructure, consumables and logistics tailored for virtual care. The Internet is also a central part of virtual healthcare. However, most resource-constrained settings cannot afford the requirements of setting up a virtual healthcare system, which impedes the adoption and success of virtual care in Africa [25]. Even when the initial funding is available, it may not always be available to sustain such virtual healthcare systems. The lack of funding affects the availability of specialized virtual healthcare equipment [27]. The health sector is often underfunded in terms of budgetary allocations by the

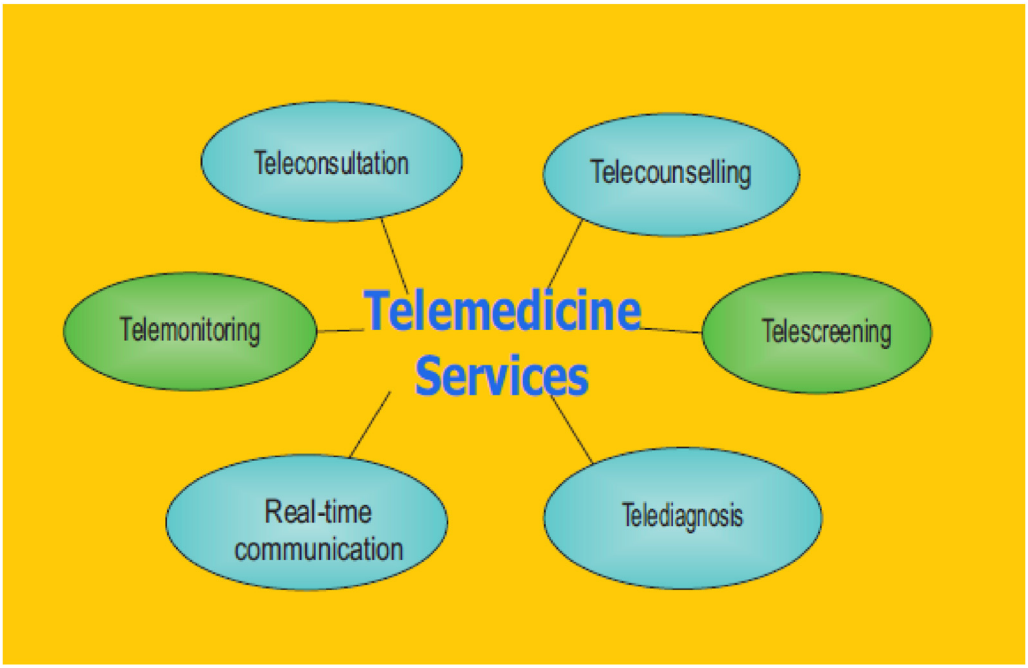

Fig. 3. Telemedicine services.

central governments, making it difficult to fund virtual healthcare projects [35].

e) Legal and Regulatory barriers

There is generally a lack of policy, and regulations to support virtual healthcare across Africa [58]. This is exacerbated by the lack of active e-health policies [21] and legal frameworks which subsequently affect the implementation of telemedicine and telehealth systems at all levels in many health sectors [37]. Such frameworks include security, privacy and protection of patients' medical data, ethical and specific electronic health legislations. Regulatory barriers also include challenges associated with the licensing of virtual healthcare solutions [59]. Moreover, the lack of technological certification standards and device regulation as well as inconsistent provincial or state rules hamper the adoption and utilization of virtual healthcare [28]. Some African countries do not have clear policies (at the of writing) about telemedicine and telehealth, for example, Uganda does not have telemedicine regulations and policies [33]. There is a lack of standards on using telehealth for mental healthcare and also it is not clear on whom the liability of using such systems lies [58].

f) Resistance by healthcare practitioners and the community

Healthcare professionals can resist a shift from the traditional healthcare provision approach to virtual care since they are used to the traditional approach [37]. The resistance could also be a result of a lack of knowledge about the potential benefits of virtual healthcare and how it works [55] and could also be attributed to the organizational culture [49] that may not seem to promote digital transformation. This resistance to change can thwart the implementation of virtual care in Africa [55]. Also, a study conducted by Ref. [49] posits that language barriers may contribute to resistance to telemedicine uptake.

g) Digital divide and digital illiteracy

The digital divide existing in Africa makes the chances of success of telemedicine and telehealth skewed towards some areas than others, especially rural areas are on the receiving end as they usually have a more unreliable electricity supply [45], unreliable telecommunication network or not connected at all [31]. There is a significant gap in the ownership of digital devices and digital skills between urban and rural residents in Africa. Such a digital divide creates telemedicine awareness gaps due to socio-economical differences.

h) Ethical issues

Ethics are critical to any technological interventions to healthcare in any part of the world and they have been a hindrance to the adoption of digital health for many innovations. The use of telepathy and telemedicine services may potentially violate doctor-patient privacy and other ethical issues like confidentiality, consent and security [28,43] often make digital health interventions fail. Therefore, these ethical issues need to be addressed [60]. Also, virtualizing patients and care is seen by some to be de-humanization [28], thus affecting the potential adoption and utilization of such technologies in many health systems.

3.3. *Telemedicine adoption: lessons learnt from other regions*

COVID-19 continues to transform the telemedicine landscape with breathtaking speed in Europe and America, contrary to the reluctance that existed before the pandemic [61–65]. Telemedicine developments and adoption had been happening at a slow pace before the pandemic [61]. For instance, about 74% of Americans were either unaware of telemedicine or had no access prior COVID-19 pandemic [66]. However, a study conducted in the United States of America in 2020 revealed that almost 50% of the participating physicians had used telemedicine, compared to a paltry 18% in 2018 [67]. In addition, healthcare services delivery has undergone tremendous changes owing to the COV ID-19-induced travel restrictions and social distancing requirements; and telemedicine has proven its utility during this period [62]. Countries such as Switzerland, Germany and Israel adopted telemedicine to improve health services delivery while observing social distancing and other measures [68]. For instance, in Germany, telemedicine has been utilized in pediatric surgery to avoid interruption of treatment to selective patients with different ailments such as hemangioma, gastrointestinal disorders, urological diagnoses among others during COVID-19 [69]. In Switzerland, telemedicine services have been used for

tele-triaging that enables remote pre-screening of potentially infected patients and eliminates unnecessary transmission risks [70].

Despite the success stories of telemedicine in other regions like Europe and America, there are challenges and impediments faced during the implementation phase which the Sub-Saharan African region can learn from. Such challenges include resistance and controversy over the accuracy of tele-diagnosis [61], data protection and privacy issues, and legal and ethical issues. Remote health monitoring systems have multiple vulnerability layers, for example, patient consent, security and confidentiality of transmitted data and physicians' access to, and competency in interpreting data and their ability to respond to problems [71]. Moreover, emerging risks such as failure of equipment and systems, patient non-adherence, data inaccuracy or unreliability, potential loss of patient data confidentiality, lack of physicians' familiarity with particular platforms, and delays in physicians' response have been reported in some regions [71,72]. Also, concerns over security and reliability of the telemedicine [73], inadequate representation of electronic services in reimbursement tariffs [74], lack of interoperability between the telemedicine systems and existing healthcare systems also hamper the adoption of the technology for daily clinical practice [70]. These concerns mainly stem from security issues related to the repository of electronic medical records and are usually ascribed to a lack of specific legislation. However, patients with chronic illness are generally less concerned about privacy than healthy; and emphasize more on rapid communication with clinicians to outweigh the health risks [75]. However, a warning to patients at the very beginning of the conversation through telemedicine services should be enough to address these issues.

The successful utilization of telemedicine in developed countries has been greatly associated with effective integration of innovative strategies and technological infrastructure [76], compliance with the privacy and billing regulations, temporarily lifting of restrictive barriers [77], increasing awareness of the safety and efficacy of telemedicine [78] and training healthcare professionals. To expedite the utilization of telemedicine, many developed countries crafted guidelines that support and promote the adoption of telemedicine to improve access to healthcare services amidst the COVID-19 pandemic [79]. One of the issues that negatively affected the adoption of telemedicine in Europe and America is the lack of reimbursement policy for medical insurers to adapt to remote services [44]. Therefore, SSA medical insurance companies can adapt the reimbursement policies to incentivize physicians, and streamline the reimbursement requirements [71]. Finally, to deal with the legal and ethical considerations of telemedicine. informed patient consent must be a prerequisite to apply home tele-monitoring [71,80,81]. Based on these experiences of other regions, the SSA region can learn and implement the following lessons and recommendations.

4. Recommendations for the effective integration of telehealth and telemedicine in sub-Saharan Africa

This study noted that despite the broadening scope of telemedicine and rapid roll-out during the COVID-19, systemic issues such as organizational readiness, including digital maturity, licensing, regulatory hurdles, reimbursements, ability to be used by all groups, including the oldest and those with disabilities, infrastructural issues and geographical and digital disparities in telemedicine adoption warrant urgent attention [59]. To alleviate these impediments, we, therefore, make the following recommendations for the effective integration of telehealth and telemedicine in sub-Saharan Africa.

Firstly, WHO together with other international health players should spearhead the utilization of telemedicine and telehealth in Africa by conducting training workshops with critical healthcare stakeholders like healthcare practitioners and decision-makers on the potential role of telemedicine on providing quality healthcare in Africa, among other benefits. This will address issues of limited knowledge and also help minimize the resistance to virtual healthcare. Secondly, sub-Saharan health regulatory authorities together with WHO should craft generic standard telehealth and telemedicine policy or framework to guide the implementation of virtual healthcare interventions in Africa. The policy or framework could address such issues as security, privacy, confidentiality, liability, standards and licensing of digital health devices and software [82,83]. However, the crafting of such a generic policy/-framework by WHO can help accelerate the utilization of virtual healthcare in Africa by providing the missing regulations or a template that can accelerate the creation of one by individual countries.

Thirdly, there is a need for scrapping or subsidizing import duties on telemedicine and telehealth equipment by governments to encourage the use of virtual healthcare solutions. Since funding is one of the challenges faced by African health players in adopting telemedicine and telehealth, the scrapping of duties would reduce the overall cost of importing the requisite virtual health equipment. International health agencies and health ministries may set the budget for telemedicine, mobile resources for telemedicine and develop a self-sustained health system model for telehealth and telemedicine [76]. Alternatively, these organizations can equip a few public referrals hospitals that will exclusively provide virtual healthcare services and use them as case studies to convince those who are sceptical of telemedicine and telehealth. If such hospitals provide excellent services, it would be easier to convince those who initially resisted using telemedicine and telehealth.

Fourthly, there is a need to create and expand community networks to bridge the existing digital divide in many Africa countries through multisectoral and multidisciplinary consultative processes involving all key stakeholders, including the users and beneficiaries. Setting up community ICT centers in resource-constrained areas can bridge the digital divide and potentially improve access to virtual healthcare services. Such centers can also be used to equip rural residents with ICT skills through training.

Lastly, regulatory authorities should provide robust but not inhibitive regulatory procedures. These procedures should handle the approval of telemedicine and telehealth innovations and interventions by providing a robust but clear testing framework to check if such interventions meet the minimum ethical and regulatory requirements before they are deployed. The ethical and regulatory requirements should be clear for all stakeholders for accountability purposes. The robust testing of virtual healthcare solutions can tremendously help convince patients and healthcare practitioners to utilize telemedicine services.

5. Conclusion and future work

The imposed COVID-19 restrictions and measures such as social distancing, recursive lockdown, stay-at-home, restrictions on the movement of people, limited face-to-face consultation and hospitalization exacerbate healthcare inequalities. Telehealth especially telemedicine has been the mainstay of patient care by offsetting the decline in outpatient visits [59], circumventing the spread of COVID-19 and decongesting healthcare facilities during the pandemic while providing critical virtual patient continuity and limiting exposure to healthcare professionals and hospitalization. Telemedicine services include tele-education [84], teleconsultation, teledermatology, teleradiology, telemonitoring, tele-expertise, telecardiology, teleophthalmology, tele-oncology, and telepsychiatry significantly improve the delivery of healthcare services especially during the pandemic where physical contact is minimal. The study revealed that telemedicine provides unprecedented benefits including improving efficient, effective utilization of healthcare resources, forward triaging, prevention of medical personnel infection, aiding medical students' clinical observation and participation, and assurance of social support for patients. However, the integration of telemedicine in health systems is not immune to challenges such as ethical issues, technological, organization barriers, legal and regulatory barriers, cultural barriers and financial barriers. To alleviate these challenges, we recommend the development of robust policies, frameworks for virtual health care, the inclusion of virtual care in the medical school curriculum, supporting virtual care research and development,

increasing health funding, remove monopolisation of telecommunication services. It is evidenced that the expansion and use of telemedicine are increasing rapidly in sub-Saharan African as more pilot projects persist beyond the pandemic. There is a need to build resilient equitable access to telemedicine services that fit the peculiarities of Sub-Saharan Africa as part of the public health response to virtual healthcare especially in the advent of future pandemics. Therefore, future efforts should be centred around increasing telemedicine access as well as virtual care to people living in impassable [85], marginalized communities and under-resourced areas.

Declaration of competing interest

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

References

[1] Y.S. Malik, S. Sircar, S. Bhat, K. Sharun, K. Dhama, M. Dadar, et al., Emerging novel coronavirus (2019-nCoV)—current scenario, evolutionary perspective based on genome analysis and recent developments, 40:68–76, https://doi.org/10.1080/01652176.2020.1727993, 2020.

[2] S. Rab, M. Javaid, A. Haleem, R. Vaishya, Face masks are new normal after COVID-19 pandemic, Diabet. Metab. Syndr. Clin. Res. Rev. 14 (2020) 1617–1619, https://doi.org/10.1016/J.DSX.2020.08.021.

[3] E. Mbunge, R.C. Millham, M.N. Sibiya, S.G. Fashoto, B. Akinnuwesi, S. Simelane, et al., Framework for ethical and acceptable use of social distancing tools and smart devices during COVID-19 pandemic in Zimbabwe, Sustain. Oper. Comput. 2 (2021) 190–199, https://doi.org/10.1016/J.SUSOC.2021.07.003.

[4] E. Mbunge, S. Simelane, S.G. Fashoto, B. Akinnuwesi, A.S. Metfula, Application of deep learning and machine learning models to detect COVID-19 face masks - a review, Sustain. Oper. Comput. 2 (2021) 235–245, https://doi.org/10.1016/J.SUSOC.2021.08.001.

[5] E. Mbunge, Effects of COVID-19 in South African health system and society: an explanatory study, Diabet. Metab. Syndr. Clin. Res. Rev. 14 (2020) 1809–1814, https://doi.org/10.1016/J.DSX.2020.09.016.

[6] B. Pfefferbaum, C.S. North, Mental health and the covid-19 pandemic, 383:510–2, https://doi.org/10.1056/NEJMP2008017, 2020.

[7] T. Dzinamarira, B. Nachipo, B. Phiri, G. Musuka, COVID-19 vaccine roll-out in South Africa and Zimbabwe: urgent need to address community preparedness, fears and hesitancy, Vaccines 9 (2021), https://doi.org/10.3390/VACCINES9030250, 250 2021;9:250.

[8] E. Mbunge, S. Fashoto, B. Akinnuwesi, C. Gurajena, A. Metfula, Challenges of social distancing and self-isolation during COVID-19 pandemic in Africa: a critical review, SSRN Electr. J. (2020), https://doi.org/10.2139/SSRN.3740202.

[9] L. Tyson, W. Hardeman, G. Stratton, A.M. Wilson, J. Semlyen, The effects of social distancing and self-isolation during the COVID-19 pandemic on adults diagnosed with asthma: a qualitative study. https://doi.org/10.1177/13591053211012766, 2021.

[10] I. Chitungo, M. Mhango, E. Mbunge, M. Dzobo, T. Dzinamarira, Digital technologies and COVID-19: reconsidering lockdown exit strategies for Africa, PAMJ (2021), https://doi.org/10.11604/PAMJ.2021.39.93.29773, 3993 2021;39.

[11] J.B. Nachega, N.A. Sam-Agudu, R. Masekela, MM van der Zalm, S. Nsanzimana, J. Condo, et al., Addressing challenges to rolling out COVID-19 vaccines in African countries, Lancet Glob. Health 9 (2021) e746–e748, https://doi.org/10.1016/S2214-109X(21)00097-8.

[12] S. Cooper, H van Rooyen, C.S. Wiysonge, COVID-19 vaccine hesitancy in South Africa: how can we maximize uptake of COVID-19 vaccines?. https://doi.org/10.1080/14760584.2021.1949291, 2021.

[13] D.E. Lucero-Prisno III, I.O. Ogunkola, U.F. Imo, Y.A. Adebisi, Who will pay for the COVID-19 vaccines for Africa? Am. J. Trop. Med. Hyg. 104 (2021) 794, https://doi.org/10.4269/AJTMH.20-1506.

[14] J.N. Nkengasong, N. Ndembi, A. Tshangela, T. Raji, COVID-19 vaccines: how to ensure Africa has access, Nature 586 (2021) 197–199, https://doi.org/10.1038/d41586-020-02774-8, 5867828 2020.

[15] E. Mbunge, S.G. Fashoto, B. Akinnuwesi, A. Metfula, S. Simelane, N. Ndumiso, Ethics for integrating emerging technologies to contain COVID-19 in Zimbabwe, Hum. Behav. Emerg. Technol. (2021), https://doi.org/10.1002/HBE2.277.

[16] P. Adepoju, Africa prepares for COVID-19 vaccines, Lancet Microbe 2 (2021) e59, https://doi.org/10.1016/S2666-5247(21)00013-6.

[17] S. Mehtar, W. Preiser, N.A. Lakhe, A. Bousso, J.-J.M. TamFum, O. Kallay, et al., Limiting the spread of COVID-19 in Africa: one size mitigation strategies do not fit all countries, Lancet Glob. Health 8 (2020) e881–e883, https://doi.org/10.1016/S2214-109X(20)30212-6.

[18] J. Thornton, The "virtual wards" supporting patients with covid-19 in the community, BMJ 369 (2020), https://doi.org/10.1136/BMJ.M2119.

[19] J.P. Kronenfeld, F.J. Penedo, Novel Coronavirus (COVID-19): telemedicine and remote care delivery in a time of medical crisis, implementation, and challenges, Transl. Behav. Med. 11 (2021) 659–663, https://doi.org/10.1093/TBM/IBAA105.

[20] D. Babalola, M. Anayo, D.A. Itoya, D. Babalola, M. Anayo, D.A. Itoya, Telehealth during COVID-19: why Sub-Saharan Africa is yet to log-in to virtual healthcare? AIMS Med. Sci. (2021) https://doi.org/10.3934/MEDSCI.2021006, 146 2021;8:46–55.

[21] P. Das, A. Sharma, Deployment of telemedicine as another mitigation tool during the COVID-19 pandemic in India, Publ. Health Prac. 2 (2021) 100167, https://doi.org/10.1016/J.PUHIP.2021.100167.

[22] K.B. David, J.K. Solomon, I. Yunusa, B.K. Lawal, C.S. Marshal, M. Okereke, et al., Telemedicine: an imperative concept during COVID-19 pandemic in Africa, Pan. Afr. Med. J. 35 (2020) 129, https://doi.org/10.11604/PAMJ.SUPP.2020.35.25281.

[23] D. Moher, A. Liberati, J. Tetzlaff, D.G. Altman, T.P. Group, Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement, PLoS Med. 6 (2009), e1000097, https://doi.org/10.1371/JOURNAL.PMED.1000097.

[24] R.E. O'Dea, M. Lagisz, M.D. Jennions, J. Koricheva, D.W.A. Noble, T.H. Parker, et al., Preferred reporting items for systematic reviews and meta-analyses in ecology and evolutionary biology: a PRISMA extension, Biol. Rev. (2021), https://doi.org/10.1111/BRV.12721, 0–000.

[25] O. Wariri, U. Okomo, C. Cerami, E. Okoh, F. Oko, H. Jah, et al., Establishing and operating a 'virtual ward' system to provide care for patients with COVID-19 at home: experience from the Gambia, BMJ Glob. Health 6 (2021), e005883, https://doi.org/10.1136/BMJGH-2021-005883.

[26] T.S. Ibekwe, A.J. Fasunla, Telemedicine in otorhinolaryngological practice during COVID-19 pandemic, Niger. Med. J. 61 (2020) 111, https://doi.org/10.4103/NMJ.NMJ_201_20.

[27] K.A. Oyediran, O.A. Makinde, O. Adelakin, The role of telemedicine in addressing access to sexual and reproductive health services in sub-Saharan Africa during the COVID-19 pandemic, Afr. J. Reprod. Health 24 (2020) 49–55.

[28] B. Kaplan, REVISITING HEALTH INFORMATION TECHNOLOGY ETHICAL, LEGAL, and SOCIAL ISSUES and EVALUATION: TELEHEALTH/TELEMEDICINE and COVID-19, Int. J. Med. Inf. 143 (2020) 104239, https://doi.org/10.1016/J.IJMEDINF.2020.104239.

[29] R.E. Scott, M. Mars, Smart Homecare Technology and TeleHealth Dovepress Telehealth in the developing world: current status and future prospects, Smart Homecare Technol. TeleHealth 3–25 (2015), https://doi.org/10.2147/SHTT.S75184.

[30] K. Ndlovu, R. Littman-Quinn, E. Park, Z. Dikai, C.L. Kovarik, Scaling up a mobile telemedicine solution in Botswana: keys to sustainability, Front. Publ. Health 2 (2014) 275, https://doi.org/10.3389/fpubh.2014.00275.

[31] B. Ncube, M. Mars, R.E. Scott, The need for a telemedicine strategy for Botswana? A scoping review and situational assessment, BMC Health Serv. Res. (2020), https://doi.org/10.1186/S12913-020-05653-0, 201 2020;20:1–8.

[32] J.E. Dodoo, H. Al-Samarraie, A.I. Alzahrani, Telemedicine use in sub-Saharan Africa: barriers and policy recommendations for covid-19 and beyond, Int. J. Med. Inf. 151 (2021) 104467, https://doi.org/10.1016/J.IJMEDINF.2021.104467.

[33] V.M. Kiberu, R.E. Scott, M. Mars, Assessment of health provider readiness for telemedicine services in Uganda, 33–41, https://doi.org/10.1177/1833583177749369, 2018, 48.

[34] M. Mars, Telemedicine and advances in urban and rural healthcare delivery in Africa, Prog. Cardiovasc. Dis. 56 (2013) 326–335, https://doi.org/10.1016/j.pcad.2013.10.006.

[35] P.B. Adebayo, O.J. Oluwole, F.T. Taiwo, COVID-19 and teleneurology in sub-Saharan Africa: leveraging the current exigency, Front. Publ. Health (2021) 1082, https://doi.org/10.3389/FPUBH.2020.574505, 0.

[36] J. Moyo, G. Madziyire, Use of telemedicine in obstetrics and gynaecology in Zimbabwe during a lockdown period, Pan. Afr. Med. J. 35 (2020), https://doi.org/10.11604/PAMJ.SUPP.2020.35.2.23675.

[37] S.S. Furusa, A. Coleman, Factors influencing e-health implementation by medical doctors in public hospitals in Zimbabwe, SA J. Inf. Manag. (2018), https://doi.org/10.4102/sajim.v20i1.928.

[38] A.R. Dansharif, N. Dlodlo, N. Angula, A Mobile Telehealth Application for Rural Namibia, 2018. IST-Africa Week Conf IST-Africa 2018 2018:1–9.

[39] S. Demessie Bogale, H.K. Tamiru, Telecommunication network architecture for telemedicine in Ethiopia and its applicability, Artic Int. J. Eng. Tech. Res. (2020).

[40] G.G. Sagaro, G. Battineni, F. Amenta, Barriers to sustainable telemedicine implementation in Ethiopia: a systematic review, Telemed. Rep. 1 (2020) 8–15, https://doi.org/10.1089/tmr.2020.0002.

[41] K. Biruk, E. Abetu, Knowledge and attitude of health professionals toward telemedicine in resource-limited settings: a cross-sectional study in North west Ethiopia, J. Healthc. Eng. (2018), https://doi.org/10.1155/2018/2389268, 2018.

[42] I. Arize, O. Onwujekwe, Acceptability and willingness to pay for telemedicine services in Enugu state, southeast Nigeria, 3:205520761771552, https://doi.org/10.1177/2055207617715524, 2017.

[43] F. Ekanoye, T. Olokunde, F. Ayeni, V. Nina, C. Donalds, V.W.A. Mbarika, Telemedicine diffusion in a developing country: a case of Nigeria, Sci. J. Publ. Health 5 (2017) 341–346, https://doi.org/10.11648/j.sjph.20170504.20.

[44] K. Armand, A. Gaël, N. Marcien, N. Wilson, M. Reine, N. Claude, Telemedicine and COVID-19: experience of medical doctors in Cameroon, Am. J. Health Med. Nurs. Prac. 6 (2021) 32–37, https://doi.org/10.47672/AJHMN.666.

[45] K.I. Adenuga, N.A. Iahad, S. Miskon, Towards reinforcing telemedicine adoption amongst clinicians in Nigeria, Int. J. Med. Inf. 104 (2017) 84–96, https://doi.org/10.1016/J.IJMEDINF.2017.05.008.

[46] P. Adepoju, Africa turns to telemedicine to close mental health gap, Lancet Digit Health 2 (2020) e571–e572, https://doi.org/10.1016/s2589-7500(20)30252-1.

[47] R. Qin, R. Dzombak, R. Amin, K. Mehta, Reliability of a telemedicine system designed for rural Kenya, 177–81, https://doi.org/10.1177/2150131912461797, 2012, 4.

[48] T.Y. Akintunde, O.D. Akintunde, T.H. Musa, M. Sayibu, A.E. Tassang, L.M. Reed, et al., Expanding telemedicine to reduce the burden on the healthcare systems and poverty in Africa for a post-coronavirus disease 2019 (COVID-19) pandemic reformation, Glob. Health J (2021), https://doi.org/10.1016/J.GLOHJ.2021.07.006.
[49] I. Chitungo, M. Mhango, M. Dzobo, K. Denhere, M. Chimene, G. Musuka, et al., Towards virtual doctor consultations: a call for the scale-up of telemedicine in sub-Saharan Africa during COVID-19 lockdowns and beyond, Smart Health 21 (2021) 100207, https://doi.org/10.1016/J.SMHL.2021.100207.
[50] M. Okereke, A.O. Babatunde, S.T. Samuel, I.O. Ogunkola, Y.G. Mogessie, D.E. Lucero-Prisno, et al., Applications of telemedicine in the supply and distribution of COVID-19 vaccines in Africa, J. Glob. Health 11 (2021) 1–4, https://doi.org/10.7189/JOGH.11.03039.
[51] F. Caso, A del Puente, N. Girolimetto, M. Tasso, C. Caso, R. Scarpa, et al., Improving telemedicine and in-person management of rheumatic and autoimmune diseases,during and after COVID-19 pandemic outbreak. Definite need for more Rheumatologists. Response to: 'Can telerheumatology improve rheumatic and musculoskeletal disease service delivery in sub-Saharan Africa?' by Akpabio et al, Ann. Rheum. Dis. (2020), https://doi.org/10.1136/ANNRHEUMDIS-2020-218472 annrheumdis-2020-218472.
[52] I. Chitungo, M. Mhango, E. Mbunge, M. Dzobo, G. Musuka, T. Dzinamarira, Utility of telemedicine in sub-Saharan Africa during the COVID-19 pandemic. A rapid review, Hum. Behav. Emerg. Technol. (2021), https://doi.org/10.1002/HBE2.297.
[53] D. Babalola, M. Anayo, D.A. Itoya, D. Babalola, M. Anayo, D.A. Itoya, Telehealth during COVID-19: why Sub-Saharan Africa is yet to log-in to virtual healthcare? AIMS Med. Sci. (2021) https://doi.org/10.3934/MEDSCI.2021006, 146 2021;8: 46–55.
[54] E. Mbunge, I. Chitungo, T. Dzinamarira, Unbundling the significance of cognitive robots and drones deployed to tackle COVID-19 pandemic: a rapid review to unpack emerging opportunities to improve healthcare in sub-Saharan Africa, Cogn. Robot 1 (2021) 205–213, https://doi.org/10.1016/J.COGR.2021.11.001.
[55] J.E. Dodoo, H. Al-Samarraie, A.I. Alzahrani, Telemedicine use in sub-Saharan Africa: barriers and policy recommendations for covid-19 and beyond, Int. J. Med. Inf. 151 (2021) 104467, https://doi.org/10.1016/j.ijmedinf.2021.104467.
[56] M. Okereke, A.O. Babatunde, S.T. Samuel, I.O. Ogunkola, Y.G. Mogessie, D.E. Lucero-Prisno, et al., Applications of telemedicine in the supply and distribution of COVID-19 vaccines in Africa, J. Glob. Health 11 (2021) 1–4, https://doi.org/10.7189/JOGH.11.03039.
[57] E. Mbunge, S. Jiyane, B. Muchemwa, Towards emotive sensory Web in virtual health care: trends, technologies, challenges and ethical issues, Sens. Int. 3 (2022) 100134, https://doi.org/10.1016/J.SINTL.2021.100134.
[58] P. Adepoju, Africa turns to telemedicine to close mental health gap, Lancet Digit Health 2 (2020) e571–e572, https://doi.org/10.1016/S2589-7500(20)30252-1.
[59] S. Bhaskar, A. Nurtazina, S. Mittoo, M. Banach, R. Weissert, Editorial: telemedicine during and beyond COVID-19, Front. Publ. Health (2021) 233, https://doi.org/10.3389/FPUBH.2021.662617, 0.
[60] E. Mbunge, T. Dzinamarira, S.G. Fashoto, J. Batani, Emerging technologies and COVID-19 digital vaccination certificates and passports, Publ. Health Prac. 2 (2021) 100136, https://doi.org/10.1016/j.puhip.2021.100136.
[61] S.M. Reingold, A. Hadjipanayis, D. van Esso, S. del Torso, H.J. Dornbusch, A. de Guchtenaere, et al., COVID-19 era effect on pandemic and post-pandemic pediatric telemedicine use: a survey of the European academy of pediatrics research in ambulatory settings network, Front. Pediatr. 9 (2021), https://doi.org/10.3389/fped.2021.713930.
[62] J. Wosik, M. Fudim, B. Cameron, Z.F. Gellad, A. Cho, D. Phinney, et al., Telehealth transformation: COVID-19 and the rise of virtual care, J. Am. Med. Inf. Assoc. 27 (2020) 957–962, https://doi.org/10.1093/jamia/ocaa067.
[63] D.S.W. Ting, L. Carin, V. Dzau, T.Y. Wong, Digital technology and COVID-19, Nat. Med. 26 (2020) 459–461, https://doi.org/10.1038/s41591-020-0824-5.
[64] R. Bashshur, C.R. Doarn, J.M. Frenk, J.C. Kvedar, J.O. Woolliscroft, Telemedicine and the COVID-19 pandemic, lessons for the future, Telemed. e-Health 26 (2020) 571–573, https://doi.org/10.1089/tmj.2020.29040.rb.
[65] A. Taha, B. Saad, B. Enodien, M. Bachmann, D.M. Frey, S. Taha-Mehlitz, The development of telemedicine and eHealth in surgery during the SARS-CoV-2 pandemic, Int. J. Environ. Res. Publ. Health 18 (2021) 11969, https://doi.org/10.3390/ijerph182211969.
[66] G. Truex, As Telehealth Technology and Methodologies Mature, Consumer Adoption Emerges as Key Challenge for Providers, 2019.
[67] Merrit Hawkins, Survey: Physician Practice Patterns Changing as A Result of COVID-19, Merrit Hawkins Website, 2020.
[68] Z. Grossman, G. Chodick, S.M. Reingold, G. Chapnick, S. Ashkenazi, The future of telemedicine visits after COVID-19: perceptions of primary care pediatricians, Isr. J. Health Pol. Res. 9 (2020) 53, https://doi.org/10.1186/s13584-020-00414-0.
[69] G. Lakshin, S. Banek, D. Keese, U. Rolle, A. Schmedding, Telemedicine in the pediatric surgery in Germany during the COVID-19 pandemic, Pediatr. Surg. Int. 37 (2021) 389–395, https://doi.org/10.1007/s00383-020-04822-w.
[70] V. Nittas, V. von Wyl, COVID-19 and telehealth: a window of opportunity and its challenges, Swiss Med. Wkly. (2020), https://doi.org/10.4414/smw.2020.20284.
[71] J. Ackrivo, L. Elman, J. Hansen-Flaschen, Telemonitoring for home-assisted ventilation: a narrative review, Ann. Am. Thorac. Soc. 18 (2021) 1761–1772, https://doi.org/10.1513/AnnalsATS.202101-033CME.
[72] B. Stanberry, Legal and ethical aspects of telemedicine, J. Telemed. Telecare 12 (2006) 166–175, https://doi.org/10.1258/135763306777488825.
[73] F. Röthlisberger, R. Sojer, T. Zingg, O. Rayki, Die Digitalisierung aus Ärztesicht (Teil II), Schweizerische Ärztezeitung (2018), https://doi.org/10.4414/saez.2018.17377.
[74] C.S. Davis, E.A. Samuels, Continuing increased access to buprenorphine in the United States via telemedicine after COVID-19, Int. J. Drug Pol. 93 (2021) 102905, https://doi.org/10.1016/J.DRUGPO.2020.102905.
[75] L. Garattini, M. Badinella Martini, M. Zanetti, More room for telemedicine after COVID-19: lessons for primary care? Eur. J. Health Econ. (2020) 183–186, https://doi.org/10.1007/S10198-020-01248-Y, 222 2020;22.
[76] G. Nittari, R. Khuman, S. Baldoni, G. Pallotta, G. Battineni, A. Sirignano, et al., Telemedicine practice: review of the current ethical and legal challenges, Telemed. e-Health 26 (2020) 1427–1437, https://doi.org/10.1089/TMJ.2019.0158/ASSET/IMAGES/LARGE/TMJ.2019.0158_FIGURE1.JPEG.
[77] A. Kichloo, M. Albosta, K. Dettloff, F. Wani, Z. El-Amir, J. Singh, et al., Telemedicine, the current COVID-19 pandemic and the future: a narrative review and perspectives moving forward in the USA, Fam. Med. Commun. Health 8 (2020) 530, https://doi.org/10.1136/FMCH-2020-000530.
[78] R. Sosnowski, H. Kamecki, S. Joniau, J. Walz, Z. Klaassen, J. Palou, Introduction of telemedicine during the COVID-19 pandemic: a challenge for now, an opportunity for the future, Eur. Urol. 78 (2020) 820, https://doi.org/10.1016/J.EURURO.2020.07.007.
[79] Royal College of Paediatrics and Child Health, COVID-19 - guidance for community settings, RHCP Webiste (2020).
[80] K.A. Bauer, The ethical and social dimensions of home-based telemedicine, Crit. Rev. Biomed. Eng. 28 (2000) 541–544, https://doi.org/10.1615/CritRevBiomedEng.v28.i34.330.
[81] N. Ambrosino, M. Vitacca, M. Dreher, V. Isetta, J.M. Montserrat, T. Tonia, et al., Tele-monitoring of ventilator-dependent patients: a European respiratory society statement, Eur. Respir. J. 48 (2016) 648–663, https://doi.org/10.1183/13993003.01721-2015.
[82] A.R.A. Aiken, J.E. Starling, R. Gomperts, M. Tec, J.G. Scott, C.E. Aiken, Demand for self-managed online telemedicine abortion in the United States during the coronavirus disease 2019 (COVID-19) pandemic, Obstet. Gynecol. 136 (2020) 835, https://doi.org/10.1097/AOG.0000000000004081.
[83] E. Mbunge, R.C. Millham, M.N. Sibiya, S. Takavarasha, Diverging mobile technology's cognitive techniques into tackling malaria in sub-Saharan Africa: a review, 679–99, https://doi.org/10.1007/978-3-030-90318-3_54, 2021.
[84] R. Latifi, V. Azevedo, A. Boci, A. Parsikia, F. Latifi, R.C. Merrell, Telemedicine consultation as an indicator of local telemedicine champions' contributions, health care system needs or both: tales from two continents, 27:200–6, https://HomeLiebertpubCom/Tmj, 2021, https://doi.org/10.1089/TMJ.2019.0290.
[85] E. Mbunge, B. Muchemwa, S. Jiyane, J. Batani, Sensors and healthcare 5.0: transformative shift in virtual care through emerging digital health technologies, Glob. Health J (2021), https://doi.org/10.1016/J.GLOHJ.2021.11.008.