Sokoine University of Agriculture

PhD Thesis

Digital Health Education on Epidemiology of *Taenia solium* Cysticercosis in Iringa-Tanzania

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DIGITAL HEALTH EDUCATION ON EPIDEMIOLOGY OF *TAENIA SOLIUM* CYSTICERCOSIS IN IRINGA-TANZANIA

Thesis submitted to Sokoine University of Agriculture in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

By

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EXTENDED ABSTRACT

Taenia solium cysticercosis (TSC) is a parasitic disease caused by larvae of the pork tapeworm, *Taenia solium*. It is common in low- and middle-income countries. The disease is transmitted through ingestion of food or water contaminated with the tapeworm's eggs or through direct contact with contaminated objects or the worm infected individuals. One effective approach to raise community awareness about the disease is digital health education, the technology disseminates health information and services to a wider audience. Digital health technology provides an opportunity for communities to engage with physicians for consultation, access medical care, follow-up on treatments, and report health emergencies. In Tanzania, digital health education suggested the strategy for endemic *T. solium* cysticercosis (TSC) control. The disease cause human disabilities even death, also it affects pig industry by causing unsafe and unwholesome pork. The digital health education technology can potentially improve socio-cultural settings and lifestyles influencing TSC epidemiology in endemic communities. However, utilization of digital health in Tanzania is inconsistent. This study aimed at assessing the impact of digital health education intervention on porcine cysticercosis prevalence and on associated household factors in endemic rural communities for management decisions.

A baseline cross-sectional study was carried at Izazi, Migoli, and Mlowa wards of Iringa District Council, in April-May, 2018, to evaluate the practices promoting porcine cysticercosis transmission. The survey was a quasi-controlled field trial with pre- and post-intervention assessments for porcine cysticercosis and the associated household practices. The focus was on socio-cultural practices and lifestyles related to the life cycle of *T. solium*, such as household pig management, sanitation and hygiene practices, pork preparation and consumption. Upon visits, respondents provided information guided with questionnaire, observational checklist used for observation study. Pigs were bleed for Enzyme-Linked

Immunosorbent Assay (ELISA) analysis to detect the parasite antigen glycoprotein that indicated *T. solium* cysticercosis prevalence. Immediately after the baseline study, digital health intervention conducted at Migoli and Izazi wards. A door-to-door video show of animations on *T. solium* cysticercosis and taeniosis educational messages presented using tablets. The tablets were then left in the intended ward offices for voluntary learning. Furthermore, free internet access was provided in designated offices for unsupervised community access to online health education using smartphones or tablets. Post-intervention assessment was then conducted 25 months after commencement of the intervention study in July, 2021. The intervention effect was analysed based on the post-intervention and the baseline data collected with the same procedures described earlier. Digital health technology adoption in health information, health learning, and managing health issues, was also investigated as a cross-sectional study involving 78 public service health offices in the 26 regions of Tanzania's mainland. The survey involved a face-to-face visit and through questionnaire. In places researchers couldn't afford to visit, an electronic questionnaire was distributed via email. The gathered information concerned the experience and the use of digital technologies in health services.

The survey showed 33 (37.9%) households had latrines without restrictions to entrance and with limited water supply for handwashing, 42 (57.5%) pigpens didn’t maintain pigs indoors, and 52 (15%) households allowed pigs to roam freely. Averagely, 22.3 ± 3.44% pigs were tested positive for porcine cysticercosis, and 53.4% households surveyed had at least one seropositive pig. Porcine cysticercosis was significantly associated with free-roaming pigs ($OR=2.426$; $p \leq 0.05$) and poor-quality pens ($OR=1.75$; $p \leq 0.05$). The digital health intervention significantly increased pig confinement ($p=0.026$) and improved the quality of pigpens ($p=0.025$), but it didn’t improve the quality of household latrines ($p=0.453$) nor the prevalence of porcine cysticercosis ($p=0.231$). The survey also found Tanzanians ($n=191$, 91.0%) were preferring digital mobile and internet-enabled tools for personal and official health services. The adoption of digital health services was determined by the availability (n=137, 65.2%), accessibility (n=75, 35.7%), internet connection (n=196, 93.3%), affordability (n=198, 94.3%), and interest of using social media (n=189, 90.0%). Digital health services use was associated with individual's primary occupation (p=0.002, 95% CI), availability of digital health materials (p=0.001, 95% CI), affordability of internet use (p=0.006, 95% CI), and preference of internet, short message system (SMS), and phone calls on health information search (p=0.020, 95% CI). It was also associated with living in areas having reliable electricity (p=0.049, 95% CI).

Persistent seropositive pigs suggest traditional lifestyle promotes *T. solium* worm life cycle. The latrines without entrance restrictions and with limited water supply for hand-washing after toilet, indicate lack of knowledge about safe and hygiene latrine use, hence neglect of safety. It implies community lacks skills to construct and properly use of good latrines made with locally available materials. Sensitization on proper construction and sanitary use of latrines is required. The free-roaming pigs or kept in poorly constructed pens indicates lack of information on benefits of raising pigs under total confinement. Training on good pig management practices is crucial to improve the situation. The practices in the studied community perpetuate *Taenia solium* life cycle and risk them to infection. Unrestricted entrances latrines, limited water for hand-washing, free-roaming scavenging pigs, and/or pigs escape from confinement poses for TSC infection. Pigs are coprophagous, they become exposed to *T. solium* eggs by eating feces of human tapeworm carriers who contaminate land with *T. solium* eggs. The uncomfortable constructed latrines prompt people to less or not use them, resulting defecation in bushes that favor *T. solium* eggs dispersal. The digital health education was effective in improving pig confinement (p=0.026) and quality pigpens, as pigs were kept indoors during post-intervention study visits. Therefore, digital health intervention is recommended among important strategies in disseminating knowledge aimed at *T. solium* and other related diseases control in wider communities. Remote communities in mainland Tanzania hardly practice digital health services due to electricity, network, and internet constraints. Marginalized communities can't afford costs associated with the necessary hardware and internet access. Therefore, digital health applicability in such communities requires public and private sector partnership.

In Tanzania, digital health services are preferred for learning and addressing health problems; however, availability, accessibility, affordability, and internet connection hinder. Thus, socio-cultural practices surveillance and sustainable health education are mandatory when planning for TSC control.

IKISIRI KUU

Minyoo-tegu ya nguruwe (TSC) ni ugonjwa unaosababishwa na minyoo aina ya tegu wanaoitwa kwa kitaalamu *Taenia solium* (Tegu) ambao wanaishi katika utumbo wa binadamu, lakini hatua ya ukuaji wa minyoo hao yaani funza/lava huwapata nguruwe na binadamu pia. Ni ugonjwa ulioenea katika nchi zenye kipato cha chini na cha wastani. Ugonjwa huu huambukizwa kupitia kula chakula au maji yaliyo na mayai ya minyoo ya tegu. Mbinu mojawapo yenye ufanisi wa kuongeza uelewa wa jamii kuhusu ugonjwa huu ni elimu ya afya kwa njia ya kidigitali, teknolojia inayosambaza habari za afya na huduma kwa hadhira kubwa. Teknolojia ya afya kidigitali hutoa fursa kwa jamii kushirikiana na wataalamu wa afya kwa mashauriano, kupata huduma za matibabu, kufuatilia matibabu, na kuripoti dharura za kiafya. Nchini Tanzania, elimu ya afya kidigitali imependekezwa kama mkakati endelevu wa kudhibiti minyoo-tegu ya nguruwe. Ugonjwa huu husababisha ulemavu na hata kifo kwa binadamu, pia huathiri sekta ya nguruwe kwa kupelekea uzalishaji wa nyama isiyo salama na isiyofaa kwa matumizi. Teknolojia ya elimu ya afya kidigitali inaweza kuboresha mazingira ya kijamii na utamaduni na hivyo kubadilisha epidemiolojia ya TSC katika jamii zenye milipuko ya ugonjwa huu. Hata hivyo, matumizi ya afya kidigitali nchini Tanzania hayakubaliki kikamilifu. Utafiti huu ulilenga kutathmini jinsi ambavyo kuhusisha elimu ya afya kwa njia ya kidigitali inaweza kuathiri kiwango cha uwepo wa minyoo-tegu ya nguruwe, na uwepo wa tabia za jamii zinazohusika na milipuko ya ugonjwa huu, kwa ajili ya kusaidia udhibiti.

Utafiti wa kung’amua hali halisi ulifanyika katika vijiji vya Izazi, Migoli, na Mlowa katika Halmashauri ya wilaya ya Iringa, kuanzia Aprili-Mei, 2018, ili kutathmini mazoea yanayozidisha uenezaji wa minyoo-tegu ya nguruwe. Utafiti huo ulikuwa ni upembuzi na tathmini ya kabla ya kuingilia kati kwa minyoo-tegu ya nguruwe na mazoea yanayohusiana na kaya. Utafiti huu ulilenga kung’amua mazoea ya jamii na mtindo wa maisha unaohusiana na mzunguko wa maisha wa mnyoo, kama vile usimamizi wa nguruwe katika kaya, usafi na

mazoea ya usafi, maandalizi na matumizi ya nyama ya nguruwe. Wakati wa ziara, washiriki walitoa taarifa zilizoongozwa na maswali, orodha ya ukaguzi iliyotumika kwa utafiti wa uangalifu. Nguruwe walichukuliwa sampuli za damu kwa ajili ya uchunguzi kwa kutumia teknolojia ya Enzyme-Linked Immunosorbent Assay (ELISA) ili kugundua antijeni ya vimelea ambayo ilionyesha uenezi wa minyoo-tegu ya nguruwe ya *T. solium*. Mara tu baada ya utafiti wa msingi, utekelezaji wa elimu ya afya ya kidigitali ulifanyika katika vijiji vya Migoli na Izazi. Maonyesho ya filamu fupi za kuelimisha kaya na kwa kutumia michoro maalumu juu ya ugonjwa wa minyoo-tegu ya nguruwe ya *T. solium* na ujumbe wa elimu wa Mnyoo tegu mpevu (taeniosis) zilitolewa kwa wananchi kwa kutumia vishikwambi. Vishikwambi vilihifadhiwa katika ofisi zilizokusudiwa za kijiji kwa ajili ya kujifunza kwa hiari. Zaidi ya hayo, mtandao wa intanenti wa bure ulitolewa katika ofisi zilizotumika kwa elimu ya afya mtandaoni kwa kutumia simu za rununu au vishikwambi. Tathmini baada ya utekelezwaji wa elimu ulifanyika miezi 25 baada ya kuanza kwa utafiti wa utekelezaji wa elimu mwezi Julai, 2021. Athari ya utekelezaji wa mpango wa elimu ziliangaliwa kulingana na matokeo yaliyopatikana baada ya utekelezaji wa mpango wa elimu wa awali, matokeo yalikusanywa kwa njia sawa na taratibu zilizoelezwa awali. Pia, mchango wa teknolojia ya afya kidigitali katika habari za afya, kujifunza kuhusu afya, na kushughulikia masuala ya afya, ulichunguzwa kama utafiti wa msalaba unaohusisha ofisi 78 za afya za umma katika mikoa 26 ya Tanzania bara. Utafiti ulihusisha mahojiano ya uso kwa uso na kupitia kwa kutuma swali. Katika maeneo ambayo watafiti hawakuweza kumudu kutembelea, maswali yalitumwa kwa njia ya elektroniki kupitia barua pepe. Taarifa iliyokusanywa ilihusu uzoefu na matumizi ya teknolojia ya kidigitali katika huduma za afya.

Utafiti ulionyesha kuwa kaya 33 (37.9%) zilikuwa na choo bila milango inayofungika na upatikanaji mdogo wa maji ya kunawa mikono, Mabanda 42 (57.5%) ya nguruwe hayakuweza kudhibiti nguruwe wabaki bandani muda wote, na kaya 52 (15%) ziliruhusu nguruwe kutembea ovyo. Kwa wastani, asilimia 22.3 ± 3.44 ya nguruwe walionekena kuwa na ugonjwa wa minyoo-tegu ya nguruwe, na 53.4% kati ya kaya zilizotembelewa zilikutwa zina angalau nguruwe mmoja aliyekuwa na viashiria vya maambukizi. Minyoo-tegu ya nguruwe ilihusishwa zaidi na nguruwe wanaozurura (OR=2.426; $p \leq 0.05$) na wanaoishi kwenye mabanda mabovu (OR=1.75; $p \leq 0.05$). Utekelezaji wa mpango wa elimu ya afya ya kidigitali uliboresha ufugaji wa nguruwe kwa nguruwe kufungiwa bandani (p=0.026) na kupelekea kuwa na ubora wa mabanda ya nguruwe (p=0.025), lakini haikuiboresha ujenzi na matumizi ya choo cha kaya (p=0.453) wala kupunguza kiwango cha minyoo-tegu ya nguruwe (p=0.231). Utafiti pia uligundua kuwa Watanzania (n=191, 91.0%) walipendelea simu za rununu na intaneti kwa huduma za afya za kibinafsi na rasmi. Matumizi ya huduma za afya kidigitali yaliathiriwa na upatikanaji (n=137, 65.2%), ufikiaji (n=75, 35.7%), muunganisho wa intaneti (n=196, 93.3%), uwezeshaji wa kifedha (n=198, 94.3%), na hulka binafsi ya kutumia mitandao ya kijamii (n=189, 90.0%). Matumizi ya huduma za afya ya kidigitali yalihusishwa na kazi kuu ya mtu binafsi (p=0.002, CI ya 95%), upatikanaji wa vifaa vya afya ya kidigitali (p=0.001, CI ya 95%), uwezeshaji wa matumizi ya intaneti (p=0.006, CI ya 95%), na upendeleo wa utaftaji wa habari za afya kupitia intaneti, mfumo wa ujumbe mfupi (SMS), na simu (p=0.020, CI ya 95%). Pia ilihusishwa na kuishi katika maeneo yenye umeme wa kuaminika (p=0.049, CI ya 95%).

Nguruwe kuendelea kuwa na viashiria vya juu vya ugonjwa wa minyoo-tegu ya nguruwe ilionekana kuhusishwa na mtindo wa maisha wa jadi, ambao unachangia katika mzunguko wa maisha wa minyoo ya *T. solium*. Uwepo wa vyoo bila milango inayofungwa na upatikanaji mdogo wa maji kwa kunawa mikono baada ya choo, unaonyesha ukosefu wa uelewa kuhusu matumizi salama na ya usafi ya choo, hivyo kutokutilia maanani usalama. Hii inamaanisha jamii inakosa ujuzi wa kujenga na kutumia vizuri vyoo bora vilivyotengenezwa kwa vifaa muhimu na rahisi vinavyopatikana mahali husika. Uhamasishaji kuhusu ujenzi sahihi na matumizi safi ya choo unahitajika. Nguruwe wanaozurura au wanaowekwa katika mabanda yasiyoundwa vizuri unaonyesha ukosefu wa taarifa kuhusu faida za kufuga nguruwe kwa kuwafungia ndani. Mazoea katika jamii iliyohusika kwenye utafiti yanakuza mzunguko wa maisha ya mnyoo wa *T. solium* na kuwaingiza katika hatari ya maambukizi. Nguruwe ni wanyama wanaokula uchafu, na hivyo kujihatarisha kula mayai ya *T. solium* kwenye kinyesi cha binadamu walioathirika. Vyoo vilivyojengwa vibaya huwafanya watu wapunguze matumizi ya vyoo au kutokutumia kabisa, hivyo kuchochea watu kwenda kujisaidia haja kubwa kwenye misitu ambayo inasaidia usambazaji wa mayai ya *T. solium*.

Elimu ya afya kidigitali ilikuwa na ufanisi katika kuboresha njia za ufugaji kwa nguruwe (p=0.026) na ubora wa mazizi ya nguruwe, kwani nguruwe walikuwa wanashikiliwa ndani wakati wa ziara za utafiti baada ya kuingilia kati. Kwa hiyo, utekelezaji wa mpango wa elimu ya afya kidigitali inapendekezwa kama moja ya mikakati muhimu katika kusambaza elimu inayolenga *T. solium* na magonjwa mengine yanayohusiana katika jamii kubwa. Jamii za pembezoni mwa Tanzania bara mara chache hutumia huduma za afya za kidigitali kutokana na vikwazo vya umeme na upatikanaji wa intaneti. Jamii za pembezoni haziwezi kumudu gharama zinazohusiana na vifaa muhimu na upatikanaji wa intaneti. Hivyo, matumizi ya afya kidigitali katika jamii kama hizo yanahitaji ushirikiano kati ya sekta ya umma na binafsi.

Nchini Tanzania, huduma za afya za kidigitali zinapendelewa kwa ajili ya kujifunza na kutatua matatizo ya afya; hata hivyo, upatikanaji, ufikiaji, uwezeshaji wa kifedha, na muunganisho wa intaneti unazuia.

DECLARATION

I, Flora Francis Kajuna, do hereby declare to the senate of Sokoine University of Agriculture that, this thesis is of my original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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Flora Francis Kajuna **Date**

(PhD Candidate)

The above declaration is confirmed by;

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Prof. Helena A. Ngowi **Date**

(Supervisor)

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Dr. Beda J. Mwang'onde

(Supervisor)

LIST OF PUBLISHED PAPERS/MANUSCRIPTS

Paper 1: Kajuna, F.F., Mwang'onde, B.J., Holst, C., Ngowi, B., Noll, J., Winkler, A.S. and Ngowi, H.A., 2020. Socio-cultural practices related to Taenia solium taeniosis and cysticercosis epidemiology in endemic areas. Tanzania Veterinary Journal, 35(2), pp.1-13.

Paper 2: Kajuna, F., Mwang'onde, B.J., Holst, C., Ngowi, B., Sukums, F., Noll, J., Winkler, A.S. and Ngowi, H., 2022. Porcine cysticercosis Sero-prevalence and factors associated with its occurrence in southern highlands, Tanzania. Scientific African, 17, p.e01382.

Paper 3: Kajuna, F., Mwang'onde, B., Holst, C., Ngowi, B., Sukums, F., Noll, J., Winkler, A.S. and Ngowi, H., 2023. Effects of a Digital Health Literacy Intervention on Porcine Cysticercosis Prevalence and Associated Household Practices in Iringa District, Tanzania. Pathogens, 12(1), p.107.

Manuscript 1**:** Kajuna, F., Mwang'onde, B., Holst, C., Ngowi, B., Sukums, F., Noll, J., Winkler, A.S. and Ngowi, H., 2023. Determinants for Adoption of Digital Health Information Exchange on Diseases Control in Tanzania. The Frontiers in Digital Health Journal.

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DEDICATIONS

This thesis is dedicated to my parents; Mr. Francis Kajuna and Ms. Bellina Ndyema.

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ABBREVIATIONS AND SYMBOLS

Ab-ELISA	Antibody based Enzyme Linked-Immunosorbent Assay
Ag-ELISA	Antigen based Enzyme Linked-Immunosorbent Assay
AI	Artificial Intelligence
CI	Confidence Interval
COVID 19	Coronavirus disease, 2019
DHIS	District Health Information Software
DigI	Digital Inclusion
ELISA	Enzyme-Linked Immunosorbent Assay
FAO	Food and Agriculture Organization
ICT	Information Communication Technology
MoHCDGEC	Ministry of Health, Community Development, Gender, Elderly and Children
NCC	Neurocysticercosis
NGO	Non-Governmental Organisation
NIMR	National Institute for Medical Research
OD	Optic Density
REA	Rural Energy Agency
SMS	Short Message Service
SUA	Sokoine University of Agriculture
SDGs	Sustainable Development Goals
TCRA	Tanzania Communications Regulatory Authority
TSTC	*Taenia solium* taeniosis and cysticercosis diseases
UN	United Nations
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

A good information exchange system is crucial for promoting better community health. It enables the dissemination of accurate health information, facilitates timely response to disease outbreaks, and enhances healthcare delivery. According to a study by Kaplan *et al*. (2010), effective information exchange is essential for improving patient outcomes and reducing healthcare costs. Health information exchange is basically essential in public health upkeep as it helps health stakeholders to interact and through information exchange, public health services and diseases surveillances are attained (Shapiro *et al*., 2011).

Health information industry started around 1928 (Gibson *et al*, 2015) by American Surgeons who wanted to improve record standards created by clinical settings in hospitals and other medical settings. During that period, health information was predominantly paper-based, necessitating additional time for processing and retrieval from cabinets. Later on, an electronic medical record system was developed around 1972, although it failed to be widely utilized after its onset due to high operating costs (Salenius *et al*., 1992). In around 1990, internet and computer use emerged worldwide, innovators found opportunity to implement programs of faster and easier information access and at an affordable cost. At that era, online health information was introduced (Evans, 2016). Today, the demand for electronic or digital health information is increasing, aligning with nationwide efforts to improve the quality, safety, and efficiency of health care delivery. Electronic or digital health information is now the preferred option for facilitating diseases diagnosis, reporting and treatment (Birkhead *et al.,* 2015). Digital health technology is employed for consultation, medical care, and follow-up treatments, including reporting for health emergences (Monaghesh and Hajizadeh, 2020).

1.2 Digital Health

Digital health involves electronic application in processing and facilitating health information exchange, for easier and faster reach to and from health decision makers in health maintenance. Electronic laboratories (Shapiro *et al*., 2011), artificial intelligence (Lee and Yoon, 2021), telemedicine (Falzon *et al*., 2016; Karimuribo *et al*., 2017; Monaghesh and Hajizadeh, 2020) and afya data (Karimuribo *et al*., 2017) are some examples of digital health applications. Digital health facilitates diseases diagnosis, educating and in connecting health stakeholders such as physicians and health care providers in treatments, consultation and in reporting health cases. Electronic laboratory is an example of digital health technology used to save time in reporting the public health investigations based on epidemiological data. Meanwhile Telemedicine and Afya data help to contact health service providers and receivers through telecommunication that minimises time and costs of face-to-face contact.

Artificial Intelligence (AI) is the computer technology used in solving different human tasks, as multiple digital technologies has been trending recently in health care. Its machinery technologies are used in data management, clinical documentation and in research publication. Robotics AI technology has been used in treatment of invasive surgeries while robotic process automation is used in information processing (Davenport and Kalakota, 2019). Thus, AI is currently the option in health institutions in saving time, manpower and in attaining patient good learning situation and diagnosis (Lee and Yoon, 2021). Digital health has several benefits but also there are challenges on its application.

1.3 The Use and Challenges of Digital Health Technology

Worldwide digital health technology is used in care-delivery and offering health services (Sharma et al., 2018). The Digital Health Global Strategy of 2020–2025 is emphasizing majority people to benefit from universal health coverage for self-health care taking (Kostkova 2015). Also, the World Health Organization has required humans to have better protection from health emergencies to enjoy better health and well-being (WHO, 2021) therefore, digital health is applied in facilitating the task. It is an opportunity for health professionals to use it in audios, videos, pictorial, animations, and in audio visual webinars during offering health education (Chiswell et al., 2016). Although the technology is potentially used in early diagnosis of chronic diseases (Campbell, 2015), it is limited by: ICT infrastructure (WHO, 2021), unavailability and inaccessibility of digital tools (TCRA, 2018), the lack of technical skills, the country policy, wealth and health reasons, the socio-cultural behaviour and the individual perceptions (Besse and Kenny, 2020; Cummins and Schuller, 2020). Tanzania as other countries is facing these challenges and there are on-going efforts to overcome the identified and hidden challenges for public health promotion.

1.4 Experience of Digital Health in Tanzania

Digital health innovations are used to simplify and promote health decisions and ensuring public health: by supporting the welfare of the entire population, ensures security and protects from the spread of infectious disease and environmental hazards, and helps to ensure access to safe and quality care to benefit the population. The same on governmental responsibilities: deploying quarantine, mandatory immunization laws, and regulatory authorities. Residents are encouraged to do things that benefit their health (e.g., physical activity) or create conditions to promote good health, and requiring certain actions (e.g., food safety) (Shapiro *et al*., 2011; Monaghesh and Hajizadeh, 2020). Countries have been strongly promoting digital health innovations even before the emergency of the pandemic COVID-19 to sensitize public awareness on emerging diseases, epidemics and pandemics for protection and control (Kelly *et al.*, 2019). In Tanzania, digital health promotions lie in parallel with motivations for network connections, facilities and power supply (Kajirunga and Kalegele, 2015; Mibei *et al*., 2017) also on research innovations for health hazards identification diagnosis and control. In achieving for digital health education, information exchange and disease surveillance, Tanzania has incorporated human resource management sector in implementing the District Health Information Software (DHIS) (Nsaghurwe *et al*., 2021). Likewise, the demand of digital tools (Computer, television, mobile phones and radio) in various issues including health issues is increasing (TCRA, 2018). Radios, Mobile phones and television are used regularly in health information gathering (Busagala, 2013), subject to network coverage.

The mobile networks coverage in Tanzania occupies 83% of the 885,800 square km (Besse and Kenny, 2020) and only a small portion of rural remote (17%) is yet to be covered or is digitally divided. Densely populated areas in urban and peri-urban have network coverage. While the limited network and internet coverage area is considered to have poor revenue generated per cell tower (Besse and Kenny, 2020). Hence, the limited digital network and internet area is divided from digital opportunities (Sedoyeka, 2016) including digital health education.

1.5 Digital health benefits and challenges in Tanzania

Digital health supports organization of information and data related to health and it is applied in studying the country health status. In health education it enhances easy and quick flow of information and data from community to decision makers (Karimuribo *et al*., 2017). Digital health technology provides communities with awareness, identification, reporting, protection and prevention of unhealthy conditions. “Afya data” is an example of the technology applied in detection and reporting health disasters from remote places for quick decisions or controls (Karimuribo *et al*., 2017). Smartphones and tablets are widely used in health learning programs including self-care practices for conditions recovery (Muroff *et al*., 2017; Johnston *et al*., 2019). Digital health technology also facilitates trainings on medications (Muroff *et al*., 2017) and simplifies physical contact of patients and service providers for consultation and treatment (Snoswell *et al*., 2020).

The Tanzania National e-Health strategy of 2013 to 2018 supported digital health to improve citizen’s health and social welfare. The aim was to reach all households with essential health and social welfare by 2026 (MoHCDGEC, 2021). However, challenges including the lack of electronic data that weakens information exchange (Nsaghurwe *et al*., 2021) and the one-way flow of information and data from health facilities to national level (Silaa and Schalkwyk, 2018) minimizes digital health utilization. In addition, limited digital programs and computer information system that are only well established at national level and less in districts (Mahundi *et al*., 2011) weakens its utilization. In addition, the digital skilled staffs in health sectors are multiple tasked hence they are limited to concentrate in digital information management. Likewise, donor preferences make digital health attention to diseases of interest (Mahundi *et al*., 2011), though Tanzanians are switching to digital health in solving health issues.

1.6 Digital health by Tanzanians

Since the learning through digital health is trending, patients prefer searching digital health information before they go for treatments (Bujnowska-Fedak and Węgierek, 2020). Likewise, digital health education is used in educating communities on endemic diseases and diseases of high public health concern (Sherman *et al*., 2020; Holst *et al.,* 2021). Digital health education was applied in Tanzania, through “The Vicious Worm,” program to health stakeholders and students to learn on the control of *Taenia solium* worm (Ertel *et al*., 2017; Hobbs *et al*., 2019). The training program improved and retained knowledge to trainees (Hobbs *et al*., 2019). The digitally provided education hastened learning and widened information spread (Ren *et al*., 2017; Bhyat *et al*., 2021). The animations, audio and or videos had special attraction during health information presentation (Meppelink *et al*., 2015). In Tanzania, audio information penetrates far in villages, where radios and or mobile phones are capable of accessing radio frequencies and are widely used in information searching (Mtega, 2018). Therefore, public health training programs involving radios and television are important in disseminating information widely in urban and in some remote places (Mtega, 2018). While health education was suggested the best option for *Taenia solium* cysticercosis control (Ngowi *et al*., 2017; Mwape, 2018), animations and videos were recommended effective methods in planning for digital health training in communities (He´bert *et al*., 2020; Holst *et al*, 2021). Digital health education through animations improved awareness on *Taenia solium* control (Ertel *et al*., 2017; Holst *et al.,* 2021).

1.7 *Taenia solium* Parasite

T. solium is a cestode worm belonging to phylum Platyhelminthes, family Taeniidae, genus *Taenia*. The known genotypes of *T. solium* worm include: the one reported in Africa and Latin America, and the other which has been reported in Asia (Ito *et al.,* 2021). The adult worm is dorsoventrally flattened, elongated and resembling a tape measure. The worm has a spherical shaped head (scolex), the thin and short neck of about 5-10mm and the elongated body (strobila) made with chain of segments (proglottids). Adult worm is approximately 2-7 meters long (Sciutto *et al*., 2000). The scolex is 1mm in diameter and it is made with two rows of organized hooks (22 to 32 hooks per row) for attachment to the host's intestinal mucosa. The head has four muscular suckers that attach to the host intestine. New segments emerge at the neck after the head. As they grow and elongate, they widen and become more constricted distally, where they eventually mature. Each segment (proglottid) whether new, immature or matured is approximated to be 2.1 to 2.5mm long and 2.8 to 3.5 mm wide. From the neck to distally, the emerged proglottids undergo maturity and self-fertilized to produce multiple viable eggs. The matured fertilized proglottid with viable eggs (a gravid proglottid) measures 3.1 to 10 mm long and 3.8 to 8.7 mm wide. This gravid segment detaches from the segments chain while contain approximately 50,000 to 60,000 fertilized eggs (Flisser, 2013). The detached matured segment(s) either one or in a chain of two to six proglottids, tend to split to release eggs or they keep intact into a distal part of human intestine. When infected human defecates on open ground, the exposed faeces with the eggs or proglottid contaminate the environment.

The released worm eggs are spherical shaped, microscopic in nature, and with the size of 26 to 34 µm diameter (Jimenez *et al*., 2010; Flisser, 2013). The eggs contain the oncosphere surrounded by the oncospheral membrane, which is covered with double-walled striated membrane for protection (the embryophores). This embryophores is composed of prismatic keratin blocks (that makes the egg its radial appearance) and with the colloid vitellum layer protects the egg (Jimenez *et al*., 2010; Mendlovic *et al*., 2014). The membranes are tolerable to sunny and rainy environment for even more than four months. The oncosphere is armed with six typical embryonic hooklets (hence called a hexacanth embryo). If it happens eggs are ingested, the ingested eggs' hatch is facilitated by the presence of bile salts (Mendlovic *et al*., 2014) in the upper intestinal part of human, primates, pigs and even dogs. The hatched eggs produce microscopic hexacanth embryo (oncosphere) that penetrate intestinal mucosa to lodge in tissues and become the cysticercoid. The lodged cyst resembles a small colourless fluid filled ball of about 1 cm diameter, having a tiny white material on its centre. This vesicular cysticerci (larvae) can vary in shape from ovoid to irregular (racemose) depending on the tissue they are deposited. Initially they appear vesicular semi-translucent but later become opaquer as host tissues develop capsule. When the cyst starts to degenerate, the vesicular fluid becomes opaque and dense (colloidal), and the edges of the cyst become irregular and shrink to form granular / nodular cyst. Later, calcification from the cephalic portion progresses to the vesicular wall, to leave a round, whitish, calcified granulomas. The viable cysticercus is a single white evaginated protoscolex, surrounded by spherical shaped translucent membrane with clear fluid to reach the size of 2 cm in diameter (Sciutto *et al*., 2000). While a degenerated cyst is irregular in shape, opaque or densely filled fluid and it is smaller in size. But a calcified cyst appears spherical white nodule with a calcified material within. The life of a parasite depends on the interaction between the parasite itself, the hosts and the environment.

Taenia solium has three stages in life cycle. The adult lives in small intestine of *Homo sapiens* (Bobes *et al*., 2014; Thomas *et al*., 2019), where it obtains the necessaries for life. Upon ingestion of raw or undercooked pork with viable cyst, human naturally become the definitive host harbouring the adult tape worm (taeniosis). The ingested viable cyst encysts to expose scolex (the worm head) that has hooks for attachment to the intestinal mucosa of human small intestines where the parasite is harboured and mature (Flisser, 2013). The evaginated scolex that attached to intestines develops subsequently to an adult worm, in approximately 8 to 12 weeks' time.

T. solium is hermaphrodite; it produces fertilized eggs that become exposed to the environment through faeces from human carriers of the adult worm. A carrier may shed several proglottids, up to 8 per single shed and a single proglottid may contain more than 50,000 viable worm eggs. This carrier continues to shed worm eggs to the environment for a period corresponding to worm life span and the dispersed eggs complete maturation in the environment. Animals such as pigs, dogs, cats, bush pigs and monkeys, also human, accidentally ingest the viable eggs upon feeding on the contaminated feeds or food with human faeces contained eggs. The ingested eggs hatch to hexacanth embryo in the upper part of small intestine of these animals and human. The embryo penetrates the gastrointestinal tissues to blood circulation and lodge in tissues having high blood supply. The lodged embryo in tissue develops to larva stage (the cyst). The cysticerci usually localized in striated muscles of the psoas, triceps brachii, tongue, internal and external masseters and it may also lodge in diaphragm, cardiac muscle, and in the brain (Pawlowski, 2002).

The presence of *Taenia solium* in human small intestine is sometimes asymptomatic, although it may cause a taeniosis. A person with taeniosis may develop clinical signs resembling signs of other disease conditions, such as: anaemia, loss of appetite, cutaneous nodules like appearance, constipation, emaciation etc.

Taenia solium cysticercosis occurs in both human and pigs. The disease is clinically revealed with neurological symptoms (Bobes *et al*., 2014), especially when the cyst degenerates in brain leading to recurrent headache, seizure, incoordination and epilepsy.

1.8 Distribution and Burden of *Taenia solium*

Taenia solium is globally distributed. It is endemic in the central and Southern part of Africa, in Latin America and in the South and South East Asia (Braae *et al.*, 2014; Devleesschauwer *et al*., 2017). The parasite is most prevalent in low-income countries where hygiene is poor, sanitation is compromised and there is substandard pig rearing system including free roaming pig keeping. It was believed the parasite has been eliminated in Europe and in the United States of America (USA) (Devleesschauwer *et al*., 2017), although there are existing neurocysticercosis (NCC) cases resulted from local transmission in some countries such as Spain, Eastern Europe and Portugal. The existing NCC cases in these countries are said to increase with a trend of cases caused by local transmission from imported cases via immigrants who are tapeworm carriers from endemic areas (Gabriël *et al*., 2015).

Different studies presented porcine cysticercosis prevalence in Tanzania and neighbouring countries of western and southern part of Africa (Ngowi *et al*., 2017; Gabriël *et al*., 2018; Soto *et al.,* 2021). The reported worm endemic regions in Tanzania include of northern (Boa *et al* 1992; Ngowi *et al*, 2004; Mwang'onde *et al* 2018), central (Maganira *et al.,* 2020) and the southern highlands (Kabululu *et al*., 2020). The endemic state of *Taenia solium* is attributed to ignorance associated with sociocultural settings and poverty, which limits access to diagnostic facilities. The inadequate disease management capacity and the absence of appropriate prevention measures and control strategies predispose the area to endemic state. *Taenia solium* is maintained with the existing tapeworm carriers who are practising unsanitary, poor hygiene and consumption of uninspected raw or undercooked pork. Taeniosis conditions result to health problems such as abdominal discomfort, anaemia and body reaction for the one harbouring the worms. Human tapeworm carriers are the source of pigs' infection with cysticercosis. Cysticercosis creates economic, health and social burden to societies. Porcine cysticercosis hinders pork production by reducing meat quality (Mkupasi *et al.,* 2013) and creates fear to pork consumers. *Taenia solium* cysts in human and pigs cause several conditions depending with the lodged location in body tissues. They may cause blindness, hearing problem, and recurring headache, cutaneous nodules like appearance, paralysis and epilepsy (Langa *et al*., 2022). If cysts lodge in the organs of the central nervous system, they can lead to a condition known as neurocysticercosis. People affected with neurocysticercosis are vulnerable to social immobility (Mwang'onde *et al.,* 2018). The disease reduces physical and moral participation in social events and the sick people spend much to seek for wellbeing. Neurocysticercosis (NCC) is a vital effect of *Taenia solium* which causes up to 30% epilepsy cases in humans in endemic areas (WHO, 2020). The parasite was ranked the most important foodborne causing threat, since NCC is considered the main cause for deaths from food borne parasitic diseases (WHO/FAO, 2014).

1.9 Strategies and challenges for Control of *Taenia solium*

The worldwide approach for elimination of *T. solium* and its effects is based on interventions that interact with the stages of a worm life cycle and the predisposing risk factors. The known predisposing risk factors include: the consumption of uninspected and undercooked or raw pork, human with taeniosis practising open defecation, poor hygiene, and the poor pig management (Kajuna *et al*., 2022; Maganira *et al* 2020).

One of the important control strategies suggested is the community health education (Mwape, 2018). Health education helps to improve awareness on the worm, its effects and control measures. Health education to public has a vital role in providing knowledge and sensitize on strategies and methods to control (Ngowi *et al.,* 2008). The control of this parasite basically involves a regular meat inspection and consumption of the inspected and well-cooked pork

(Mkupasi *et al*., 2013; Sithole *et al.,* 2020), regular latrine/toilets use, sanitation and good hygiene. Poor pig management predispose them to cysts infection (Komba *et al*., 2013), hence pig confinement in good shelters while supplementing them with feed and providing them with regular veterinary services reduces chances of pigs' infection. Although health education is promising method for the control of *Taenia solium* and its effects, there is a challenge for a sustainability of a regular provision of such education to community.
Availability of diagnostic facilities is also the best strategic weapon to fight against the parasite (Ngowi *et al*., 2019). Diagnostic facilities help to detect for the status and to facilitate the awareness of the situation in time for control measures. Some European countries and Northern Americans claimed to achieve the control and eradication of *T. solium* cysticercosis through diagnosis, sensitization and the application of sanitary conditions, and including the implementation of functional slaughterhouse control systems (Gilman *et al.,* 2012; Thomas *et al*., 2019). The diagnostic facilities in developing countries are limited to some few centres; the referral hospitals and research laboratories while in remote endemic areas misses.

In developing countries, communities with poor economic status and some kind of social-cultural practices create room for unsanitary practices (Carabin and Traoré *et al*., 2014) that risking to infection. Taeniosis and cysticercosis diseases caused by *T. solium* worm are identified as diseases emanated by ignorant and poverty (Thomas *et al*., 2019), since unawareness of these diseases' epidemiology and the poor pig production investment supports worm's life cycle, especially in endemic areas (Ngowi *et al.,* 2019). Having cysticercosis-infested pigs indicates poor management, causing pigs to access open deposited human faeces of a tapeworm carrier. Though human and pig population treatments with anthelminthic drugs and/or immunotherapy reported to improve the situation (Winskill *et al*., 2017; Kabululu *et al*., 2020), still *T. solium* worm eradication requires proper and regular human faecal disposal (sanitary latrine use) and other several proposed control measures. There still challenges on massive anthelmintic drug administration and immunization of human and animals due to traditional believes and perception on the drugs and vaccines (Derua *et al*., 2018), but also it is the expensive process that require the health sector to plan well in one time for the all endemic places in the country.

1.9.1 The approach of the study for *Taenia solium* cysticercosis in Iringa rural

Digital health education was chosen in this study to demonstrate its usefulness and applicability in the control of *T. solium* cysticercosis. This kind of education method can be used as a role model in the control of zoonoses.

A baseline cross-section study was conducted in Izazi, Migoli and Mlowa wards to assess practices which could be promoting the parasite transmission in the study area. The first visitation in April to May, 2018 during the end of a rainy season was for collection of households' data and pig blood samples. Questionnaire and observational checklist were the tools used by researchers in collection of household information. A respondent had to provide information requested by a researcher based on questionnaire upon visitation. A survey technique was in quasi controlled field trial with pre- and post-intervention assessment for porcine cysticercosis and the associated household practices applied in the studied wards. Collected information considered socio-cultural practices and life style related to *Taenia solium* life cycle, the household pig management, sanitation and hygiene practices. Questionnaire was filled in parallel with pig blood sampling upon a household visit.

Immediately after baseline study, a digital health intervention was made in Migoli and Izazi wards. The intervention involved a door-to-door video show of animations carrying educational messages on *T. solium* cysticercosis and taeniosis. Tablets used for a video show were then left in ward offices in the intervention wards for voluntary learning through surfing. Furthermore, free internet access was provided to the designated ward offices to provide unsupervised community access to online health education using smartphone they own or the project tablets. This digital health intervention was conducted as pilot study under non-Discriminating Access for Digital Inclusion (DigI) project that aimed to offer digital health education to digitally divided communities in Tanzania.

Post-intervention assessment on porcine cysticercosis and associated household practices was then conducted 25 months after full intervention installation. This second visitation with the same data collection and sampling procedures as previously in baseline, was conducted in July, 2021 during dry season. The collected blood later analysed using an enzyme-linked immunosorbent assay (ELISA), to detect for *Taenia solium* cysticercosis prevalence.

In that same period of data collection was another cross-sectional study, involved 78 public service health offices, in the 26 regions of the Tanzania mainland. This study based to investigate the adoption of digital health technology in health information, health learning and in management of health issues. The questionnaire filled with responses received by face-to-face respondents reply upon researcher visitation, or in an electronically filled the distributed questionnaire through email in places where researchers couldn't afford to reach. This survey aimed to receive information concerning experiences on the use of digital health. All the information data were received through KoBo collect toolbox installed in android devices from which the organization of data was aided.

1.9.2 Study Rationale

T. solium emanated diseases are among the neglected tropical diseases (Ngowi *et al.,* 2019) causing serious impact to human health and wealth. The larva form of a worm (cyst) that develops in animal and human tissues cause health problems, economic and social loses. A developed cyst in nervous system (neurocysticercosis) may result into severe headache or blindness or paralysis or convulsions and or epileptic seizures to a victim (Winkler, 2012). A person with neurocysticercosis of any mentioned condition suffers a significant life quality reduction, and cannot work normally. This patient ends with economic retardation and may be stigmatized by family or community members (WHO, 2021). Due to unawareness of the community on the epidemiology of the diseases emanated by *T. solium* worm, the situation is progressing in endemic areas.

Public health education aided with digital technology is required in considering for a quick and friendly approach in strategies to overcome the *T. solium* taeniosis and cysticercosis effects, especially in endemic areas. This study aimed to emphasize policy and decisions of ICT use in public health education, in diseases control and in providing health services to communities in Tanzania. Education creates community awareness and it sensitizes police makers to plan and consider for diseases control.

Digital health education is the best strategy seem to reach wider community for short time in control of zoonoses and other unhealthy conditions (Holst *et al*., 2021; Ren *et al*., 2017), hence it will save in strategies of controlling this *Taenia solium* worm. Thus, it is imperatively important to understand the suitability of digital health education application in public health education for *Taenia solium* and other zoonoses control in Tanzania towards attaining a Sustainable Development Goal 3 of the SDG's 2030 (To ensure healthy lives and promote well-being for all at all ages).

1.10 Study Objectives

1.10.1 Overall Objective

This study was established with the overall objective of assessing the epidemiology and application of digital health education in controlling *Taenia solium* cysticercosis in remote communities in Iringa region, Tanzania

11.10.2. Specific Objectives

i. To investigate the determinants on implementation and adoption of digital health information/education in Tanzania.
ii. To assess socio-cultural practises associated with *Taenia solium* taeniosis and cysticercosis transmission in endemic area
iii. To determine the effect of digital health education intervention on porcine cysticercosis prevalence and related practices in Iringa region, Tanzania.

CHAPTER TWO

PAPER 1: Socio-cultural practices related to Taenia solium taeniosis and cysticercosis epidemiology in endemic areas in Iringa District Council, Tanzania

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Socio-cultural practices related to *Taenia solium* taeniosis and cysticercosis epidemiology in endemic areas

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SUMMARY

Socio-cultural settings and lifestyles of communities in *Taenia solium* taeniosis/cysticercosis (TSTC) in endemic areas influence significantly the epidemiology of the disease. This study investigated the community perceptions and practices influencing the occurrence and endemicity of TSTC. A cross-sectional survey focusing on pig-keeping households was carried out in three wards of Iringa District Council as a representative of other TSTC endemic areas. Questionnaire and observation checklists were employed for data collection. Eighty-seven (99%) of the 88 surveyed households had pit latrines, and 84(95%) of the households were found using their latrines. These latrines varied from good to a very good quality according to subjective qualitative scores. About 294 (85%) pigs were enclosed and 52(15%) were free roaming. The results indicated poor adherence to routine pig inspection at sales (50% inspection) and less pork inspection at slaughter (50% uninspected). Furthermore, there were no authorized centres for slaughter and sales. Health Officers and farmers were comfortable with the boiling form and home prepared pork (>90%). Health Officers perceived deep-frying and roasting of pork as inappropriate preparation methods. Generally, the social cultural practices and life style in the study area promoted the endemicity of *Taenia solium* life cycle. A strategy for surveillance on socio-cultural practices in the community is important during planning for TSTC control. This community needs sustainable health education on TSTC diseases control.

Keywords: *Perception, pig, public-hygiene, risk factors, taeniosis/cysticercosis*

INTRODUCTION

The epidemiology of infectious diseases such as *Taenia solium* Taeniasis Cysticercosis (TSTC), which is easily preventable, is associated with community ignorance and poverty (Ayim, 2011; Wang *et al.*, 2016). Public illiteracy on the source and spreading mechanisms of infectious agents make the diseases endemic in certain regions (Ayim, 2011).

The cultural values, believes, and practices also promote the replication of the agents of the diseases and automatically expose individuals to the risks of infection (Aung and Spelman, 2016).

Proper public health education can positively modify social-cultural activities and lifestyle and reduce the risks of infection (Solhi *et al.*, 2017). *Taenia solium* worm is an infectious agent of taeniosis and cysticercosis, which are endemic in Iringa region (Ngowi *et al.*, 2019; Yohana *et al.*, 2013). Humans acquire *Taenia solium* (adult worm) by inadvertent ingestion of cysticerci in raw or undercooked infected pork. The ingested cysticerci develop to adult worms that live in small intestines (Symeonidou *et al.*, 2018), the condition, which is called taeniosis.

Taenia solium cysticercosis condition refers to the occurrence of pork tapeworm cysts in the tissues of the intermediate host. Pigs are infected by ingesting eggs released by the adult tapeworms normally through human faeces (Flisser *et al.*, 2004). The normal intermediate host for the worm is the pig; however, humans can also be infected if they ingest the eggs of the parasite mostly through oral-faecal- route. Once the eggs are ingested, they hatch into hexacanth embryos in the gastrointestinal tract. The embryos invade through the interstitial wall to the bloodstreams and migrate to multiple tissues, especially to the striated muscles and the central nervous system where they mature into cysticerci (Symeonidou *et al.*, 2018). The infection by adult tapeworm and/or larval form is referred to as *Taenia solium* taeniosis/cysticercosis (TSTC) respectively.

Taenia solium cysticercosis in human is associated with neurological symptoms as a result of infection by the larval form of the parasite in the brain and spinal cord (neurocysticercosis) (Del Brutto, 2012; Winkler, 2012). *Taenia solium* cysticercosis is the main cause of epilepsy in low-income countries (Blocher *et al.*, 2011).

Taenia solium cysticercosis is a zoonotic condition that causes a substantial burden in human beings such as acquired epilepsy, headache, reduced visual acuity, and other manifestations (Pal *et al.*, 2000; Winkler, 2012). *Taenia solium* cysticercosis is further related to disability leading to a loss of productivity (Mwang'onde *et al.*, 2014). The parasite in pigs, porcine cysticercosis, decreases the value of pork within the farmer's formal marketing system, hence provides poor returns in the pork industry (Mkupasi *et al.*, 2013). Given the nature of the spreading of the worm, TSTC endemic communities are mostly associated with poverty and illiteracy (Gweba *et al.*, 2010).

The life cycle of *Taenia solium* involves the development stages crossing between human and pig hosts, through undercooked meats and oral-faecal route (Galán-Puchades and Fuentes, 2013). This means that along with the illiteracy and poverty, the community practices involving public hygiene and pig husbandry systems play important roles in the epidemiology of the TSTC. Limiting pigs from accessing human faeces and avoiding eating pork with viable worm cysts are basic practical ways of breaking the continuity of the parasite (Ngowi *et al.*, 2017; Samorek-Pieróg *et al.*, 2018). Adhering to basic public health principles including proper use of toilet/latrine and hands washing after toilet and before eating is equally important. Achieving the outlined basics optimally depends on community customs adjustments and literacy levels (Gabriël *et al.*, 2016). Some traditional practices including lack of and/or failure of using toilets/latrines, and the manner in which people manage pigs, pose risks for contracting TSTC (Mwang'onde, 2019). Providing proper education is known to contribute positively to the community perceptions and practices towards prevention of such conditions (Kungu *et al.*, 2017; Ngowi *et al.*, 2017).

Communities vary significantly regarding their ways of life, and hence the provision of proper education requires understanding of the basics for a given society (Kimbi *et al.*, 2015). To control TSTC, a given community has to be oriented towards the importance and mechanisms of getting quality toilets/latrines and of using them properly. According to the World Health Organization (WHO, 2020), a good quality toilet, in addition to ensuring lack of access of wastes, should be clean and safe to encourage usage and prevent entry of non-human beings such as livestock (e.g. pigs).

Likewise, farmers have to understand the importance of pig housing to provide comfortable environments for pigs. To educate society on a particular disease, a trainer has to understand a given society perception towards the disease in question, its epidemiology, and control (Ngowi *et al.*, 2017).

Understanding the local community practices is important in providing education on TSTC control (Johansen *et al.*, 2014; Ngowi *et al.*, 2011). There are limited publications on current socio-cultural practices that promote TSTC diseases in the studied area. It has been reported that training resulted to the adoption of good practices known to reduce the diseases risks (Ngowi *et al*., 2008). This study addressed the present socio-cultural practices related to the TSTC epidemiology in the context of the application of digital health education.

MATERIAL AND METHODS

Study area

The study was conducted in three wards (Izazi, Migoli, and Mlowa) in Iringa District Council, Iringa region in Southern Highlands of Tanzania (Figure 1). The area has the prevalence of TSTC of up to 33.3percent (Ngowi *et al.*, 2019; Yohana *et al.*, 2013). Based on the prevalence of the disease, the area was targeted for digital health education program with free internet access for communities to learn on the prevention and control of TSTC.

Due to limited resources, Izazi and Migoli Wards were selected for this digital health education piloting. Mlowa Ward was used as control. This program was implemented by the installation of the internet connectivity at the Ward Executive Offices (WEO).

The offices were provided with tablets for internet connection and access to the health education materials, which were created by the study team and uploaded in the local server at the Izazi and Migoli Wards. This was not done for Mlowa Ward (The control ward).

As adopted from key informant's report, traditionally Mlowa, like Izazi and Migoli, raises pigs. Also according to literature, Mlowa is among the endemic area for *Taenia solium* (Yohana *et al.,* 2013).

Being in the same geographical location with Izazi and Migoli, Mlowa was taken as a control, as this Ward was not targeted for internet connectivity and digital health information.

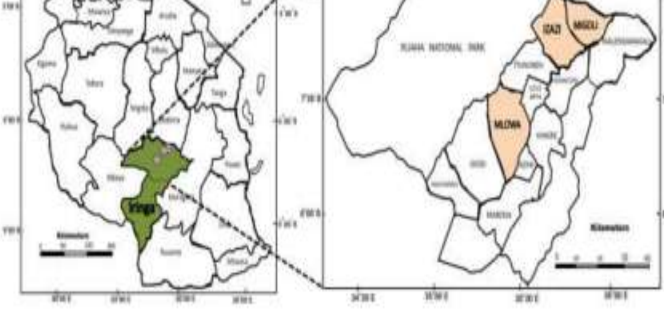

Figure 1: A sketch map of Iringa Rural Districts, southern Highlands of Tanzania, showing the location of the three wards covered in the study.

Study design and data collection

This was a cross-sectional study; a list of households keeping pigs (at least one pig) was made in each ward with the help of ward and village leaders. The studied households were selected from the list and these were visited once for data collection. About 423 households were known to keep pigs in the three wards. Since this socio-cultural study was planned to be carried out with the study of porcine cysticercosis prevalence, pigs sample size was calculated. The pig sample size was estimated using the formula: $n = Z^2PQ/L^2$ (Martin et al., 1987) where: n is the number of pigs to be examined and Z is the score for confidence level. P is a known or estimated prevalence of the factor in the study area, Q is 1-P, and L is the acceptable estimation error. A confidence level of 95 percent and an estimation error of 5 percent were considered. Previously published prevalence of 32 percent (Maganira et al., 2019) was applied for the calculation of pigs sample size. The estimated sample size for pigs from the calculation was 334 ($n = 1.96^2 \times 0.32 (1-0.32)/ (0.05)^2$).

It was learned from the ward officials that pig keepers had an average of four pigs per household. According to the average number of pigs kept by households in the study area, the maximum of 100 households were aimed for the study. All households keeping pigs in the list were equally considered for their participation in the study. However, based on pig eligibility as in the selection criteria and the household willingness to participate in the study, 88 household heads (33 from Migoli, 14 from Izazi, and 41 from Mlowa) participated in the study. Pregnant and lactating pigs were excluded from the study whereas piglets above two month of age and clinically health pigs were included.

Selection of farmers was based on those households, which were keeping pigs. The non-pig keepers were investigated in a parallel study on digital health education on human cysticercosis (Radovanovic *et al*., 2020).

Questionnaires were used to gather information. The respondents (household heads or adult representatives) were asked to provide information regarding pig rearing systems and experiences, sanitation and hygiene, pig slaughtering, and meat preparations. The local government leaders were interviewed on village pig slaughtering and inspection activities, community pork eating behaviours, and general community understanding on the taeniosis and cysticercosis. Information on the presence and quality of the physical structures was supplemented through direct observation.

The observation study used a checklist with quality parameters described in Farmer's Hand Book on Pig Production (FAO 2009), in good practices for biosecurity in the pig sector (FAO 2010) and in a review of sanitation and hygiene in Tanzania, 2013.

Latrines and pigpen conditions were assessed by subjectively scoring ranging from 1 to 4 very poor to poor, and 7 to 10 good to very good. The quality of latrines was assessed by qualitative score numbered from 1 to 10 to rank latrines from very poor to very good respectively (Supporting Table 1). The same qualitative score was used for pig pens grading with numbers ranging from 1 to 10 referring to very poor to very good respectively (Supporting Table 2).

Kobo Collect (Kobo Collect v.1.27.3-3) downloaded freely from Google Play Store and installed on Android tablets was used for formulation of questionnaires and data collection.

Questionnaires results were supplemented with direct observation during visits to the households. The observation involved making a checklist on the presence of pigpen and latrine, and then scoring each for quality. This observation study was used to complement information collected from household heads, and from examining pig pen and latrine qualities according to subjective scores.

All participants signed a consent form after being briefed on the aim of the study and confidentiality terms. The consent forms were approved by the Tanzania National Institute for Medical Research (Ref. NIMR/HQ/R.8a/Vol.IX/2947). Permission to carry out the study was granted by Sokoine University of Agriculture (SUA) and the respective local government authorities (Ref. FA.255/265/01/PART 'C/72).

Data analysis

Data were imported from the KoBoCollect toolbox into Microsoft Excel Window 10 for cleaning and analysis. Thereafter, the data were transferred to a program for analysis in IBM Statistical Package for Social Sciences (SPSS) version 20 of the year 2011, Armonk in New York. A descriptive statistic was carried out to determine the frequencies and percentages of variables.

RESULTS

Eighty-eight households and 346 pigs from nine villages in the three wards of Iringa District Council were investigated. Nine government officers namely, three Ward Executive Officers, two Agricultural Extension Officers, and four Village Chairpersons were interviewed. In addition, 97 respondents were interviewed (Table 1).

Table 1: Distribution of the respondents and number of pigs in the villages and wards involved in the study

Ward	Village	Number of respondents	Number of pigs
Izazi	Izazi	3	10
	Makuka	4	22
	Mnadani	10	38
Mlowa	Mlowa	2	14
	Malinzanga	41	98
Migoli	Makatapora	10	49
	Mbweleli	5	8
	Migoli	13	58
	Mtera	9	49

Hygiene factors associated with TSTC risk

The results indicated that 87 out of 88 (99%) households owned pit latrine, one household (1%) had no latrine in the premises. As for the households with latrines, 95 percent were regularly using their latrines. The regular use was identified by a clear path towards it, the smelling, and/or remains of urine or water on latrine floor. Having unclear path towards latrine and/or lack of other mentioned features indicated irregular or lack of usage used. Alternatively, the presence of human deposits on the surrounding bushes was the evidence of irregular use of latrine. The average score for latrine qualities was 7, which was interpreted as good start for quality. The majority of households had latrines ranging from good to very good latrines (Supporting Table 2). None of the households had latrines fixed with hand washing facilities of running water. Empty hand washing facilities were fixed near each visited latrine for demonstration purpose during the inspection.

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Table 2: Distribution of the latrine conditions concerning subjective score

Score	Interpretation	Households n (%)
1-2	Very poor	1 (1)
3-4	Poor	8 (9)
5-6	Fair	24 (28)
7-8	Good	23 (26)
9-10	Very good	32 (36)

Pig husbandry and slaughter risk factors

During the time of visit, 15 percent of the households were keeping pigs for the first time and for less than six months period. Also among the studied households, 17 percent raised outdoor pigs or did not restrict pigs from free roaming at all. Fifteen percent (15%) out of these households confined their pigs during the night.

However, 83 percent of the households reported to restrict pigs from free roaming, 50 percent were found to be keeping free roaming pigs, since they only kept adult pigs indoor while allowing piglets to roam around outdoor, and one (1%) household among them tethered animals (not shown). Eighty-three percent of pig keepers had pig pens and the remaining 17 percent of pig keepers had no any physical structure for sheltering their animals. Tethering was more practised as a temporal option following the damage to pigpens while waiting for renovation/reconstruction.

Pig pen conditions were graded, and on average, 33 percent of pigpens were graded as fair (Table 3).

Table 3. Summary of pig husbandry practices associated with TSTC risk

Parameter		% of households
Kept pigs for more than 6 months		85
Confine pigs in pig pens		83
Let pigs roam in day time only		15
Let pigs roam all the time		2
Let piglets roam in day time (adult indoor)		50
Pig pens used were old		86
Pig pens condition	Very poor	4
	Poor	20
	Fair	33
	Good	27
	Very good	16

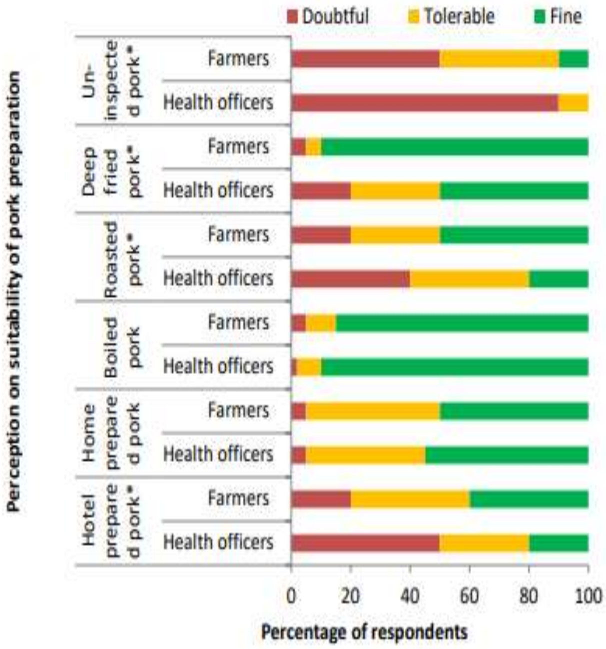

Figure 2: Perceptions from Health Officers and farmers on pig meat handling and pork preparation. Most health officers were in doubt with uninspected, hotel prepared, roasted and deep fried pork as indicated by *.

There were no formal/official slaughter points for pigs in the studied villages. Ninety percent of pigs were slaughtered at homesteads and 10 percent at groceries, which are also not legally authorised as pig slaughtering centres. Forty five percent of pork was eaten in the groceries, accompanied with beer and the rest was taken for preparation in the homesteads to be consumed by family members. Seventy-five percent of the pork in groceries was estimated to be deep-fried while the rest were open fire-roasted or boiled (Figure 2). Health Officers were concerned about the environment of pork preparation, cooking methods, and consumption of the uninspected pork. Through questionnaire interview, respondents were required to estimate in range the percentage of pork consumption rate. However, farmers were not informed on the risks associated with handling of the pigs and pork trading related to TSTC (Figure 2). Pig keepers were selling live pigs to both rural and urban traders. Eighty (80%) and 50 percent of sold live pigs and of the locally slaughtered pigs respectively were not inspected. The Animal Health and Public Health Officers reported to have been informed on the mandatory pig trading protocol that recommends animals and meat inspection and permission by the authorized meat inspectors.

DISCUSSION

This study investigated socio-cultural practices based on pig management, hygiene, and sanitation in different wards of Iringa District representing TSTC endemic areas (Table 1). Owning and using a latrine was a common phenomenon in the studied area and most of the latrines were in good condition (Table 2 and Supporting Table 1). In addition, only one percent (1%) did not have latrines compared to twelve percent (12%) of the households previously reported not to have latrines (Yohana *et al.* 2013).

However, all visited latrines had empty hand washing facilities which appeared to be installed for demonstration purpose during public hygiene inspections. Some latrines were irregularly used as they were surrounded by bushes and unclear paths and some appeared to have been constructed recently as they had no fresh deposit in the pits.

Furthermore, it was revealed through direct conversations with respondents that almost each household had a latrine in response to a recently launched government and NGO's campaign on the use of latrines for sanitary environment. However, some household members were not using the latrine because of their taboos. Examples of the taboos include one whereby "the household head is *not supposed* to share a latrine with the in-laws" (Séverine Thys *et al.*, 2015).

Other reasons discouraging the use of latrines includes poorly maintained latrines, prompting people especially people with limited mobility and children to use the alternative (Asfaw *et al.,* 2016) including nearby bushes. This was evidenced with prevalent human deposits observed in bushes near the homesteads. Improper use of sanitary latrine facility (Komba *et al.*, 2013) and open ground defecation expose the community to the risk of TSTC infection. Better quality latrines provide higher chances for being used and avoid open defecation (Kumwenda *et al.*, 2017; Odagiri *et al.*, 2017). Good floor, wall, and roofing are important for sanitation and protection against non-human entrance (including pigs) hence minimizing the spread of TSTC (Thys *et al.*, 2015). Toilets availability and proper use of them break the cycle of TSTC in the community (Carabin and Traoré, 2014).

Evaluation of management and marketing practices revealed a significant proportion of households kept their pigs under free roaming condition with an excuse of exercising them and finding nutritional supplements (Table 3); similar results were reported by Yohana *et al.*, (2013) and other studies across sub-Saharan and other regions in Africa (Edia-Asuke *et al.*, 2014; Gabriël *et al.*, 2016; Pondja *et al.*, 2010).

In addition to the reasons already described, other reason for higher proportion of free roaming of pigs were previously linked to poorly constructed pig pens that allow easy escape of pigs from their confinements (Maganira *et al.*, 2018) and (Supporting Table 2). The predominance of poor pig pens made with wooden walls had limited animal space; earth floors caused physical stress to pigs prompting their escape from shelters (Kimbi *et al.*, 2015). According to Maziku *et al.* (2017), limited pig supplements and lack of pig housing and feeding skills are indicators of poor or no planned budget for pigs, and that is contributed by farmer's ignorance or poverty (Motsa'a *et al.*, 2018).

The study also found no official or formal slaughter slab/points in the studied area that would facilitate pork inspection. Furthermore, it was revealed 10% of the respondents had the perception that uninspected pork was not threat whereas as large proportion of farmers were least informed on the importance of pig and pork inspection (Figure 2). Pork preparation methods were not considered as one of the factors causing TSTC in the studied community, a similar finding was revealed in a study by Thomas *et al.*, (2017).

The home slaughter of pigs with limited veterinary supervision (Cook *et al.*, 2017; Hrynick *et al.*, 2019), is an indication that the community is at risk of *Taenia solium* infection (Mokoele *et al.*, 2015). Pork preparation by open fire roasting and deep-frying, unless done with extra care, would likely fail to kill the cysts hence putting consumers health at risk (Meester *et al.*, 2019). However, undercooked pork is consumed in some places in Tanzania (Maridadi *et al.*, 2011; Mwanjali *et al.*, 2013).

Consuming pork in local bars with alcohol increases the chances of eating undercooked meat. Drunkenness may erode people's ability of waiting for the meat to cook and for tasting the quality of good cooked pork.

Lastly, this study revealed that both social and cultural practices may be contributing to the TSTC endemicity in the studied area. The findings in this study emphasises the need for community health education as previously advocated (Ngowi *et al.*, 2011) with emphasis on importance of veterinary and animal health professionals and services (Sithole *et al.*, 2020), construction and use of latrines, construction of slaughter slabs and improved pig management with readily available resources as suggested by Kamage *et al.* (2014). In addition, sustainable training on pig feeding and good pig housing can improve pig management practices (Komba *et al.*, 2013) and minimises free roaming pigs.

A change of socio-cultural practises is important for the TSTC control and that can be achieved through continuous leaning of an individual on a subject and changes one's mind-set (Johansen *et al.*, 2017). Similarly, previous studies revealed that sustainable health education could bring success on TSTC control (Ngowi et al., 2011). However, the long-term outcome of health education in different social-cultural practices remain a subject of further investigation

Although the study was conducted in a relatively limited geographical area among several TSTC endemic regions that might have slightly different social-cultural practices, the findings are useful and applicable to a wide range of communities with similar settings as reported from different areas within and outside Tanzania.

CONFLICT OF INTEREST

Authors do not have any conflict of interest.

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SUPPORTING INFORMATION

Supporting Table 1: The latrine condition scores

Score	Condition	Elaboration
1-2	Very poor	No door (open doors), Earth-damp floors, Floor have see-through holes, Short walls (less than 1.5 m), Walls have see-through spaces, No roof
3-4	Poor	No lockable doors (have a cloth to protect view), Earth-damp floors, Short walls (less than 1.5 m), No roof
5-6	Fair	Have lockable doors, Earth but neat floors, high walls (more than 1.5 m), have a roof but cannot protect leakage from rainwater
7-8	Good	Have lockable door with a stopper, Earth but neat floors, high tight strong walls (more than 1.5 m), have a roof that protects rain
9-10	Very good	Have lockable doors with a stopper, concrete neat floors, high tight strong walls (more than 1.5 m), have a roof that protects rain, pit-hole have a cover, toilet in clean condition, have hand washing facilities

Supporting Table 2: Pig-pen condition scores

Score	Condition	Elaboration
1-2	Very poor	Unsteady woody stick walls, Earth-soggy floors, no feeders, the pen in dirty condition with heaped manure inside, no doors
3-4	Poor	Unsteady woody stick walls, Earth-soggy floors, broken dirty feeders, the pen in a dirty condition, no doors
5-6	Fair	Wood sticks walls, Earth floors, dirty feeders, and the pen in a dirty condition. Have a lockable entrances
7-8	Good	Wood timber or brick walls, wood timber raised floors, clean feeders. Have lockable doors/entrances
9-10	Very good	Wood timber or brick walls, full protection from sun/rain, concrete or wood timber raised floors, clean steady feeders, floor and walls clean. Have lockable doors/entrances

CHAPTER THREE

PAPER II: Porcine Cysticercosis Sero-prevalence and Factors Associated with its Occurrence in Southern Highlands, Tanzania

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Porcine Cysticercosis Sero-prevalence and Factors Associated with its Occurrence in Southern Highlands, Tanzania

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ABSTRACT

Porcine cysticercosis is endemic in Tanzania, especially in the Southern Highlands, Central areas and Northern Highlands regions of the country. It is a condition that reduces pork quality and suitability for human consumption and hence affecting public health and the pig industry. The prevalence and possible associated factors for porcine cysticercosis occurrence were investigated to assist in the planning for sustainable control measures. This study was conducted in three wards of Iringa region, southern Tanzania. A blood sample was collected from 346 pigs in 88 households and analysed using an enzyme-linked immunosorbent assay (ELISA), to detect *Taenia solium* antigens (Ag). A questionnaire administered to farmers and an observational checklist tool assisted the researcher in collecting household information on pig management, sanitation and hygiene practices. On average, 22.3 ± 3.44 per cent of pigs was seropositive for porcine cysticercosis in the three wards, and 53.4 per cent of the surveyed households had at least one seropositive pig. Statistically, porcine cysticercosis was associated with the scavenging pig rearing method (OR=2.426; $p\leq0.05$) and poor quality pig housing (OR=1.75; $p\leq0.05$). This means that scavenging pigs and those living in poor-quality pens had two times higher chances of being infected. Having more than half studied pig units with positive case(s) indicates limited inputs in pig feeding and sheltering thus exposing them to infection vulnerability. The poor-quality pens allowed pigs to escape and/or scavenge on *T. solium* eggs contaminated environment. Training and sensitising on improved pig management using locally available resources is

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essential. Also emphasising regular latrine use, hygiene and sanitation practices can support control.

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Introduction

Pigs, whose population is estimated to be around 2 million, are kept in most parts of Tanzania, mostly under small-scale production or as a household farmyard activity [24]. It has been estimated that 22.4 per cent of livestock-keeping households in both rural and urban areas keep pigs [16]. Pig farming contributes significantly to rural livelihood and is an important source of protein, consumed in the form of pork [1]. Globally, pig production has shown an increasing trend in low-income and middle-income countries and was estimated to reach 60 per cent of the world's pig production by 2020 [42]. However, the pig business encounters various constraints including diseases that limit the expected outputs and expectations of farmers [23]. Porcine cysticercosis hinders pig production by reducing meat quality and creating fear of pork consumption [25]. The cysts in pork destroy pork's wholesomeness and good appearance and put consumers at risk of tapeworm infestation upon ingesting viable cysts in raw or undercooked meat. The viable cysts develop into worms in the human small intestine. Therefore, the infested humans and people living in the same household become vulnerable to cysticercosis, since human tapeworm carriers will shed eggs that may contaminate the environment including food and water. Accidentally, the ingestion of eggs in contaminated food and/or water exposes eggs to penetrating human intestinal mucosa to develop cysts in body tissues.

The causative agent of porcine cysticercosis is *Taenia solium*, a zoonotic parasite which also causes taeniosis and cysticercosis in humans [39]. Humans are definitive hosts, harbouring the adult forms of a parasite in their intestines, whereas pigs are intermediate hosts, harbouring the larval forms (cysts) in muscles and other body tissues [34]. The infection of humans by the larval form is possible through ingestion of *T. solium* eggs from the contaminated environment. The eggs are deposited in the environment by human tapeworm carrier(s), who previously consumed pork with viable cyst(s). Once larvae lodge in the central nervous system, they cause neurocysticercosis [39], which is the cause of up to 30 per cent of epilepsy cases in humans in endemic areas [38]. Porcine cysticercosis is among the poverty-related diseases; it affects farmers who allocate limited resource for pigs, while aiming at earning for household subsistence hence pigs are promoted to scavenge for food where they become exposed to infection. Pigs are infected when feeding on *T. solium* eggs contaminated environment. The disease is common in low-income and middle-income countries with sub-standard pig rearing systems, which promote fewer inputs and allow pigs to roam for their needs, hence they become vulnerable to infestation [2].

In Tanzania, porcine cysticercosis seroprevalence ranges from 1.5 to 33.3 per cent, varying by regional and rearing systems and depending with pig keeping traditional settings [30]. The most famous pig-keeping system is the free-roaming which exposes pigs to feeding on the human faecal contaminated environment. The environment is contaminated with pork tapeworm eggs by humans carrying the adult form of the parasite through indiscriminate defecation [20]. This is among the practices that make allow the high persistent prevalence of porcine cysticercosis in the Southern Highlands zone of Tanzania [30]. The Southern Highlands zone that covers Njombe, Iringa, Mbeya, Songwe and Ruvuma regions, together contributes about 54 per cent of pig production in the country [16]. In general, porcine cysticercosis can be reduced through multiple interventions: Regular animal and meat inspection, deworming of the infected cases, sanitation and good pig husbandry [12]. However, many pig-keeping communities inadequately abide by the given recommendations due to different reasons including lack of knowledge and ignorance. Several studies in Tanzania associate porcine cysticercosis with husbandry practices involving: Free-roaming pig rearing, drinking water from rivers and ponds and feeding pigs with contaminated food residues, among other factors [30]. Different programs have been continuously implemented in different parts of the country to reduce and eventually eradicate the disease.

Among the leading efforts in Tanzania for managing *T. solium* is education, which is focused on enabling farmers to use improved pig housing made from locally available resources, improve pig feeding by preparing the feeds and feeding animals from locally known and well-treated available resources, and also environmental hygiene and sanitation [5,18,30]. Strategically, education is more focused on the endemic communities which are practising free-roaming pig management, human open defecation and poor sanitation and hygiene [29,33]. In embracing the growing information technology, digitally-based education has increasingly been adopted in addition to conventional paper-based and face-to-face methods. Digital health education has been found to hasten knowledge transfer and effective disease control in public health education [31]. The Vicious Worm Educational Tool (VWET) is an example of the digital health education material, which was found effective in training the health and agricultural professionals in the control of *T. solium* in Mbeya region, Tanzania [18].

Monitoring the effectiveness of different methods employed in the efforts of reducing the occurrence of porcine cysticercosis, is an important evaluation step in guiding for improvement and further development. For instance, the effectiveness of digital health education on *T. solium* control in imparting knowledge and stimulating positive change in the community was investigated in a pilot study in Iringa District [9]. The program reported improving community knowledge of good practices in pig management, sanitation and hygiene towards the control of the *T. solium* parasite [10]. The current study establishes the baseline regarding porcine cysticercosis prevalence and farmers' practices towards control of porcine cysticercosis in the context of testing a digital health education tool on *T. solium* cysticercosis/taeniois.

Materials and methods

Study area

The study was carried out in Iringa District (7^0 46′ 23.1384" S and 35^0 41′ 56.8320" E) in the Southern Highlands of Tanzania. The district occupies 20,576 km^2 at 1600-2700 m above sea level with average temperatures falling below 15°C in cold seasons and with rainfall of up to 704 mm per year. The wet season is from November to May and peaks in January [40]. The estimated population by 2012 was 254,032 [28]. Pigs are predominantly kept under small-scale farming, which contributes to about 14.5 per cent of the pig population in Tanzania [28]. The porcine cysticercosis prevalence estimated by lingual palpation in the area was 7.5 per cent by 2013 [41]. This study was conducted as part of the research activities in an innovation project called Non-Discriminating access for Digital Inclusion (the Digi-project), and carried out in nine villages in three wards (Izazi, Migoli and Mlowa). A digital health education intervention, developed by a team of Tanzanian and international experts, with a multi- and interdisciplinary approach (Holst *et al.*, 2021a) was proposed and piloted to help control the disease in the community. The community was provided with free internet access to a digital health education platform that offered educational content for porcine cysticercosis control [9]. Izazi and Migoli wards were selected as interventions, while Mlowa Ward served as a control.

Sampling design

In a cross-sectional study design, samples were gathered between March and May of 2019. The number of pigs to be examined was given as "n," and the formula used to estimate the sample size was, therefore, $n = Z^2PQ/L^2$ [22]. "P" was a known or estimated prevalence of the factor in the study area, "Q" was 1-P, a proportion free of the factor and "L" was an acceptable estimation error [22]. The value of "Z" in this study was 1.96, calculated at a 95 per cent confidence level. The value of "P" was the estimated cysticercosis-infected pigs in a population (33% or 0.33) and "Q" was the proportion of pigs not infected with cysticercosis (1-0.33). The value of "L" was 5 per cent or 0.05. According to the computation, 339 pigs in total were needed, even though the study was able to collect a sample of 346 suitable pigs from the 88 households that were the subject of the study. On average, the studied pigs in Izazi and Migoli were five pigs per household and three pigs per household in Mlowa ward.

With information from ward officers that one household keeps approximately four pigs on average, a random sample of 100 pig-keeping households was selected. The selection was randomized from a list of 423 known pig-keeping households obtained from the ward office. Upon being informed, 88 out of the 100 selected households agreed to participate in the study and 12 did not participate due to lack of time ($n = 7$) or unavailability when visited or traced by phone call ($n = 5$).

Data collection

A structured questionnaire that was produced in English, translated to Kiswahili, and then presented as a face-to-face interview guide to respondents in the study households, was pretested by ten experts from Sokoine University of Agriculture. Then from the pretest amendments, households were visited once for the interview that followed with pig blood sampling. In each household, the interviewee was the family head or an adult representative. The basic collected information included: duration and experience in pig rearing, reasons for adopting the pig rearing system and the purpose of pig keeping. Upon permission from the household head or representative, the status of the latrine and pig pen was assessed for the basics as described on quality parameters [6]. The latrine and pig pen quality was scored according to a scaled evaluation chart.

Pig blood sampling

Before sampling, a brief animal history, including animal age and the likelihood of being in gestation for females was gathered from the respondents by using a checklist tool. Then blood samples were taken from all adult pigs, not in gestation and piglets above 2 months of age (weaned). Piglets less than 2 months of age pose difficulty in blood collection due to small blood vessels, but also they have a low chance of having a detectable cyst infestation, as cysts develop in 10 to 12 weeks after infection [32]. Gestating sows were avoided to reduce the chance of stress, which may have adverse results on the pregnancy. A pig was restrained using a pig snare and about 5 ml of blood was collected through the external jugular vein into a plain vacutainer tube as recommended by Swindle, [35]. The collected blood sample was immediately stored in a cool box in an upright position. Samples were then transported to a mini-laboratory at Migoli Ward Dispensary for centrifugation and serum harvest. The harvested serum samples were kept in a 2ml cryogenic tube per pig and temporarily stored at -20°C in Migoli, before they were transported to Sokoine University of Agriculture for further storage and analysis.

Ethical consideration and consent to participate

This research was approved by Sokoine University of Agriculture (Ref. No. SUA/ADM/R.1/8/316) and the Tanzania National Institute for Medical Research (Ref. No. NIMR/HQ/R.8a/Vol. IX/2947). Participants verbally consented to participate after being informed of the purpose and scope of the study. For confidentiality and data protection, an identification number was assigned to each household instead of names. Permission to carry out the study was also provided by the district, ward and village government authorities of Iringa District Council (Ref. No. FA.255/265/01/PART 'C;/72).

Data analysis

Each completed questionnaire transcript was assigned an identification code and its data, together with the related pig samples data were entered into a Microsoft Excel spreadsheet.

To get pig sample data, the frozen serum samples were thawed at room temperature for 30 min. and analyzed for *T. solium* antigens using a commercial Enzyme-Linked Immunosorbent Assay (ELISA) kit (Dorny *et al.*, 2004). The pre-treated control and serum samples were added to the B158C11A10 monoclonal antibody-coated plate wells, which were then incubated. The positive samples were detected by absorbance read at the presented intense blue colour that turned yellow with 0.5M H_2SO_4. The circulating cysticerci antigen (excretory-secretory products glycoprotein) in the serum were bound to B158C11A10 monoclonal antibody (IgG isotype)-coated in plate wells. The bound-in wells of the kit form an antigen-antibody complex. The complexes become detected with specific peroxidase-conjugated B60H8A4 monoclonal antibodies that are added with a coloured chromogen solution (containing tetramethylbenzidine and hydrogen peroxidase) to bind the complex. Antigen index was calculated using optic density read at an absorbance of 450nm. Then antigen index values $\leq$0.8 and values $\geq$ 1.3 were deemed positive and negative, respectively, while values in between the two were considered doubtful and re-analyzed.

The frequency and distribution of cysticercosis positive samples were generated in the Microsoft Excel spreadsheet program, which was then incorporated with the questionnaire collected data. The association between disease prevalence and household factors was analysed using regression analysis in the Statistical Package for Social Sciences (SPSS) version 20 (Armonk, New York).

Results

Studied households and pig populations

According to Table 1, the distribution of respondents in the studied households among the three wards was 17, 38 and 45 per cent for Izazi, Migoli and Mlowa, respectively. The proportion of males and females among the respondents was 68.5 and 31.8 per cent respectively. Out of the surveyed households, 75 (85.2%) of them had pig pens while 13 (14.8%) households were practising free-roaming pig keeping.

The total number of pigs sampled from the three wards was 346, distributed as 70 (20%), 164 (47%), and 112 (33%) from Izazi, Migoli and Mlowa Wards, respectively. Taking care of the inclusion criteria that pigs for sampling were required to be at the age of above two months and non-gravid for females, 65 per cent of the sampled pigs were males and that13.9 per cent were pigs left to scavenge in the daytime and the rest were kept in pig pens.

Pig houses and human sanitation facilities

In all the households, there was at least a single pig pen used to confine the pigs either in the daytime or both day and night. Good as well as poor quality pig houses were observed in the study area. Poor quality pens were the ones characterized by weak walls, rough and wet muddy floors, but also lacking good drinkers, shade and enough space to accommodate the pigs. Overall, 168 (48.6%) pigs were kept in pig pens that qualified to be of good quality. Comparatively, Migoli Ward had a higher proportion (56.7%) of pigs kept in good-quality pig pens when compared to the other two wards, whereby 35.7 and 44.6 per cent of pigs for Izazi and Mlowa, respectively were kept in good-quality pig pens ($p \leq 0.05$). Of the pig pens, 84 per cent were old, meaning they were built five or more years ago, the rest were new pig pens. None of the pigs in Izazi was kept in new pig pens; the proportion was significantly lower ($p = 0.0233$) compared to the other wards, which were

Table 1
Studied households' respondents and pig populations

Respondent particulars	Gender		Ward of residence			Has the household had a pig pen?	
Number (n=88)	Male	Female	Izazi	Migoli	Mlowa	Yes	No
Percentage (%)	68.5	31.8	17.0	37.5	45.5	85.2	14.8
Animals particulars	**Animal sex**		**Animals from**			**Animal housed (day time)**	
Number (n=346)	Males	Females	Izazi	Migoli	Mlowa	Indoor	Scavenging
Percentage (%)	65	35	20.2	47.4	32.4	86.1	13.9

Table 2
Surveyed households and porcine cysticercosis status among three wards

Particular		Ward			X^2 analysis (p-value)
		Izazi	Migoli	Mlowa	
Number of households surveyed		15	33	40	-
Number of pigs sampled		70	164	112	-
The average number of pigs per household		5	5	3	-
Number of pigs in daytime					
	Indoor	49	142	107	< 0.0001*
	Scavenging (outdoor)	21	22	5	
Number of pigs kept in					
	Good quality pen	25	93	50	0.0079*
	Poor quality pen	45	71	62	
Number of pigs kept in					
	New pig pens	0	17	15	0.0233*
	Old pig pens	70	147	97	
Seropositive pig n (%)		18 (26)	35 (21)	24 (21)	0.7380
Households with at least one seropositive pig n (%)		11 (73.3)	16 (48.5)	20 (50.0)	0.2344

Table 3
Pig situations associated with porcine cysticercosis seropositivity

Pigs situation	Percentage seropositive (n = 77)	Odds ratio (Range)	p-value
Housing system			
Confined (n = 311)	20.6	2.43 (1.20 - 5.30)	0.026*
Scavenging (n = 35)	37.1		
Piggen Quality kept in			
Good (n = 168)	18.5	1.75 (1.02 - 2.99)	0.042*
Poor (n = 178)	25.8		
Kept with farming experience			
>6 months (n = 324)	22.2	0.87 (0.47 - 3.91)	0.956
<6 months (n = 22)	22.7		

* indicates significant difference between situations

10.4 and 13.4 per cent in Migoli and Mlowa Wards respectively. Free-roaming pigs were observed around some households, including the one that reported raising their pigs in confinement during the daytime. It was also observed that latrines without closable doors entertained roaming pigs to scavenge. In most families, hand washing facilities made of locally available water containers were installed at latrine entrances. However, a notable four household latrines and almost all, 98 per cent of hand washing facilities indicated not being used regularly.

Sero-prevalence of Porcine Cysticercosis

The results in Table 2 indicate that 13.9 per cent of the pigs were kept under the scavenging system in the daytime and 86.1 per cent were full-time confined. In Izazi, 30 per cent of the sampled pigs lived by scavenging in the daytime, which is a significantly higher proportion ($p < 0.0001$) than the ones for pigs kept that way in Migoli (13.4%) and Mlowa (4.5%). About 77 (22.3%) out of the 346 tested pigs were seropositive for cysticercosis infection and 53.4 per cent of the household had at least one pig that tested positive. In both the seroprevalence status and the presence of at least one positive pig in a household, there were no significant differences between the three wards at a 95 per cent confidence level.

Prevalence of Porcine Cysticercosis in relation to pig raising practices

Among the 77 seropositive, 18 were scavenging in the daytime and inclosed in pens at night (Table 3) and 59 were full-time confined. The proportion of seropositivity among scavenging pigs was 37.5 per cent as compared to 19.7 per cent among the confined pigs. The comparative risk of testing positive was therefore 2.43 times higher in scavenging pigs than in confined pigs. The difference in the risk of infection between the scavenging and the confining pigs, was significant ($p = 0.026$) when the Odds Ratio was calculated. Similarly, pigs kept in low-quality pens had a higher risk of infection compared to pigs raised in good-quality pens ($p=0.042$). The relative experience of the farmers in keeping pigs did not pose a significant risk of pigs testing positive for cysticercosis.

Discussion

The results of this study showed that porcine cysticercosis sero-prevalence was within the previously reported range in the endemic regions of the southern highlands of Tanzania [30]. In 2013, the disease was reported to have a 7.5 per cent prevalence by lingual palpation method (Yoana *et al.*, 2013), which is a less sensitive examination method compared to ELISA used in the current study. The reported 22.3 per cent of seroprevalence gives a clue that the disease is still endemic in the studied areas, comparable to the previously reported status in Mbeya and Ruvuma regions [3,33]. The endemic state indicates access of pigs to *T. solium* eggs from human faeces which is common in communities where improper use or lack of toilets is prevalent and pigs are allowed to scavenge or are raised in poor-quality pens [4]. Few farmers were reported to raise their pigs in a free-range system. However, pig houses in many households are poorly made, indicating that pigs kept indoors might still get a chance of escaping and roaming and hence increasing their vulnerability to infection. The household infection rate is greater than the overall prevalence, with more than half (53.4%) of the households with at least one pig infected. This is probably because pigs do not contract the infection from another infected pig directly.

Generally, sociocultural practices and lifestyles have been identified as key factors for *T. solium* epidemiology [13]. The reported and observed free-roaming pigs in the study area represents the community practice that increases the chance of pig infection [17,33]. The high infection rate among pigs is also suggestive of a high human infection rate [34,39]. The environment lacking sanitation and regular use of latrine exposes free-roaming pigs to *T. solium* eggs from infected human faeces [8].

Raising pigs in the scavenging system is among the characteristics of small-scale pig farming in some parts of Tanzania and is mostly perpetrated by low budget allocation due to low investment capital [14]. In addition, small-scale pig farming is mostly practised by low-income and illiterate families who may also fail to accommodate good quality latrine costs and often practice open defecation in the bushes [15,36]. It has been reported by the UN Social and Economic Council that only 15 per cent of the people in rural areas of Tanzania use improved sanitation facilities and up to 8 per cent practice open defecation [37]. The situation is propagated by illiteracy, age factors, rurality and poverty [21] and remains among the important factors in addressing the persistent and spread of porcine cysticercosis and human taeniosis.

Controlling porcine cysticercosis and human taeniosis can be achieved if the community is educated and enabled to practice good pig husbandry and human sanitation practices [26,27,29]. This study reports a moderate prevalence of porcine cysticercosis. However, when weighed against previous and recent studies [19,33], the reported prevalence and infection rate suggest the disease is persistent. The notable prevalence and infection rate and the suggestive persistent trend of porcine cysticercosis in the area are probably dependent on the observed pig rearing and human sanitation practices. Being one of the countries with the lowest levels of access to sanitation, Tanzania, through the government and non-government organs has engaged in extensive national sanitation and hygiene programs that have shown promising results in the targeted regions [7]. Advocating for the installation of improved sanitation facilities should go hand in hand with campaigning on the importance of their proper use. The presence of non-used sanitation facilities in this study was evidenced by latrines with no faecal matter in the pits, while some had dry floors with widespread cobwebs in containment and no clear footpath.

The findings of this study suggest that strong educational efforts should be directed toward pig farmers. Strategic health education on pig management, safety pork consumption, sanitation and hygiene is necessary for the control of *T. solium* and other hygiene and food-borne diseases. Pieces of training and sensitization on proper latrine use can promote latrine ownership and regular use. Digital health education is suggested to be included in knowledge dissemination due to the demonstrated efficacyin knowledge uptake in recent trials [10,18].

Conclusion and recommendation

Over half of the studied pig keeping household units were prevalent for porcine cysticercosis. This indicates that they may practice poor pig management which exposes them to infection. The study also demonstrates pigs to be raised poorly in terms of feeding and good sheltering which exposes them to infection vulnerability. The studied poor-quality pens allowed pigs to escape from total confinement, and the free-roaming pigs were infected with *T. solium* eggs through feeding in a contaminated environment. The studied communities need training and sensitization on improved pig management using locally available resources. Regular latrine use, hygiene and sanitation practices are essential in emphasizing and supporting disease control. Further studies are recommended to establish ways of incorporating the proper use of improved sanitation facilities in the cultural practices and mindsets of rural communities. Digital health education tools may represent an innovative way to share appropriate and tailored knowledge with affected communities.

Study limitations

The Ag-ELISA test for porcine cysticercosis was reported to be only 82.7 per cent sensitive and 86.3 per cent specific [11]. In pigs, the assay test may cross-react with *Taenia hydatigena* and *Taenia asiatica* if the pig is infected with these *Taenia* species although the latter has not been reported in Tanzania. The exclusion of pigs in gestation and piglets may have slightly affected randomization in sampling.

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Authors' contributions

FK performed all research activities: conception and design of the study, manuscript development and response to reviewers' comments. BJM moderated the idea conceptualization, supervision and manuscript revision. CH moderated the structured questionnaire and observation checklist. BN and FS were the fieldwork technical facilitators and provide inputs on research material and revised the manuscript. JN and AW improved the research idea, provided research material and manuscript revision and HN performed all supervision works and manuscript revisions.

Declaration of Competing Interest

The authors declared no competing interests. All authors have been approved for the final article submission.

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CHAPTER FOUR

PAPER III: Effects of a Digital Intervention for Public Health Education on Porcine Cysticercosis Prevalence and the Associated Household Practises, Iringa-Tanzania

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neurocysticercosis that reduces life quality [6,7], and it affects the pig industry by disrupting pork quality, hence reducing income from pig business while creating a threat to public health [8,9].

Tanzania is one of the African countries highly affected by *T. solium* cysticercosis in humans and pigs. The disease is endemic in many regions of the country, including the northern, central and southern highlands [10,11]. Different intervention strategies have been applied to control *T. solium*, with health education suggested as an important component in any control strategy for *T. solium* infections [12–14]. Digital technology has been suggested as a quicker and more convenient means of delivering health education to the public to enhance the control of *T. solium* cysticercosis [15–17]. The technology has improved the knowledge and altitude of the awareness of the control of *T. solium* cysticercosis [4], though the intervention effect based on actual practices for disease management is lacking.

A project named "Non-discriminating Access for Digital Inclusion (the DIGI project)" in Tanzania, funded by the Norwegian Research Council, developed health education messages for *T. solium* infection control and disseminated them to selected pilot communities in southern Tanzania, through showing videos and the provision of free internet access. The implemented program allowed the local communities (individually or in groups) to learn the epidemiology, prevention and control of *T. solium* infections. This study aimed at assessing the effects of the digital health intervention on the prevalence of *T. solium* cysticercosis in pigs and favourable practices for the control of the infection.

2. Materials and Methods

2.1. Study Area

This study was conducted in three wards, namely Izazi, Migoli and Mlowa, involving nine villages. The study sites are within the Iringa District in the southern highlands of Tanzania. In 2012, the Iringa District was estimated to have 254,032 people [18], and the pig population was estimated to be 35,065 out of the total 241,829 pigs accounted for in the Iringa region [18], which is among the southern highland regions producing pigs in Tanzania. The district is located between 7° 05′ and 36° 32′ south and 33° 47′–36° 32′ east with an area of 20,576 km^2. The Iringa District lies at an altitude of 475 meters above sea level with high peaks of 2981 meters above sea level. Rainfall reaches up to 704 mm per year, and the cold season's temperature falls below 15 °C. The wet season occurs from November to May with a peak in January [19]. The district predominantly produces pigs on a small scale, and contributes about 15 per cent of the pig population in Tanzania [18]. Although the pig production industry is known to improve livelihoods [20], the industry has been affected by porcine cysticercosis [9]. The present study was conducted from April 2019 to July 2021. It is important to note in this study that the study site had sanitation campaigns in the year 2020, which emphasized the construction and use of latrines using sanitary methods among households. In addition, in the same year, district and village leaders enforced by-laws which insisted on indoor pig-keeping. In addition, the COVID-19 pandemic emerged in Tanzania around February 2020, which stimulated sanitation (especially handwashing) that was highly emphasized.

2.2. Study Design

This was a quasi-field trial with pre-intervention and post-assessment of porcine cysticercosis and related household practices. The study involved a baseline assessment of the prevalence of porcine cysticercosis, pig-keeping style and pig pen quality and the latrine quality assessment, followed by a digital health intervention (started immediately after the baseline to 25 months) and finally a follow-up survey similar to the baseline study (25 months after the intervention). Pig-keeping style was defined as poor for scavenging or tethering yearly and good for confinement all year. Poor pig pen quality was defined as pens that cannot support total animal confinement and animal welfare, while good pig pens were those that can support total animal confinement and animal welfare all year. In addition, latrine quality was defined as poor when it discouraged use and had an unrestricted entrance, but was defined as good when it encouraged use and had a restricted non-human entrance. The digital health intervention assessment was for the evaluation of the intervention effect. Post-intervention data were collected in July 2021.

2.3. Sample Size and Sampling

The sample size for pigs was calculated using the formula $n = Z^2PQ/L^2$ [21], where "n" is the required sample size, "P" is the known or estimated prevalence of the desired factor (in this case porcine cysticercosis), "Q" is 1-P, which is a proportion free of the factor, and "L" represented acceptable estimation error. "Z" is the z-score for a confidence level, which was 1.96, as we preferred a 95 per cent confidence level. Consequently, "L" was 5 per cent. Based on previous studies in neighbouring districts of Mbozi and Mbeya, "P" was estimated at 33 per cent [22]. Thus, 339 pigs were required for the study. About 346 pigs were examined from 88 households at baseline. During the post-intervention assessment, a total of 298 pigs from 70 households who continued keeping pigs underwent examination.

2.4. Data Collection

Biodata and a brief history were collected for each study pig, including the likelihood of the female pig is pregnant. An approximately 5 mL blood sample was collected through the external jugular vein into a plain vacutainer tube [23] and allowed to clot. The clotted blood samples were centrifuged at 2000 revolutions per minute (rpm) for 3 min. Each serum sample was kept in a 2 mL cryogenic tube and stored at −20°C before analysis. Piglets younger than two months and sows with detectable pregnancy were excluded to reduce chances of stress which could have adverse health effects. Using a commercial Enzyme-Linked Immunosorbent Assay (ELISA) kit [24] as per the manufacturer's (apDia bvba, Raadsherenstraat 3, 2300 Turnhout, Belgium) instruction, the seropositivity status of each pig was obtained.

Parallel to pig sampling was the observational study that aimed at assessing household practices related to pig management, sanitation and hygiene. Pig-keeping style and pig pen and latrine qualities were examined to determine good or poor practices. A checklist of targeted factors guided the observational study. Interviews and observational data were collected in Kobo toolbox software installed on Android tablets.

2.5. The Digital Health Literacy Intervention

The digital health literacy intervention consisted of two phases. The first phase was from April to May/June 2019, soon after baseline data collection. This phase involved research assistants showing a video to some randomly selected household members of the intervention wards (Izazi and Migoli). The video consisted of animated health messages on *T. solium* taeniasis/cysticercosis. The tablets with the video were left in the ward offices for more voluntary learning in the villages. The second phase was from November 2019 to September 2020, which involved the provision of free information and internet access in an InfoSpot (a centre with free wireless access to a health platform and the internet). In the InfoSpot, the community had unsupervised access to health education in the form of texts, pictures, animations and quizzes. Viewers were expected to access the educational content using personal smartphones or the DIGI project tablets available in the InfoSpots and ward offices in the intervention wards.

2.6. Intervention Allocation

Izazi and Migoli Wards were assigned to the intervention, while Mlowa Ward served as a control because of its isolated location, which was considered favourable to reduce chances of information communication and contamination.

2.7. Post-Intervention Data Collection

The post-intervention data were collected from the same households examined during the baseline still keeping pigs. The same data collection procedures as those used in the baseline study were used during the post-intervention study.

2.8. Data Analysis

Data were entered into a Microsoft Excel spreadsheet and analysed in STATA 15 to assess the effect of the digital health intervention on porcine cysticercosis prevalence and the three household practices: pig-keeping style, the quality of a constructed pig pen and the quality of a household latrine. This analysis involved only households that participated in both the baseline and the post-intervention studies, hereby referred to as "full participants". To avoid the effect of clustering at the household level, although several pigs were examined in some households based on availability, the intervention effect was analysed at the household level by considering a household positive if it had at least one infected pig at the visitation time. First, McNemar's Chi-Square tests were used to see if, within a treatment group (intervention or control) there was any significant difference in the prevalence of at least one infected pig in a household between the baseline and post-intervention periods. Therefore, baseline and post-intervention data within a group were considered as paired since the same households were examined between the two periods. However, a different pig population was most likely examined post-intervention because of the long time difference between the two periods (approximately 25 months), in which most baseline pigs would have been sold. Thus, the presence of at least one infected pig in a household was considered a household factor. McNemar's Chi-Square test was computed in STATA 15 using the command *mcc*. To analyse the effect of the intervention on the studied variables, the intervention and control households were considered independent. Therefore, the STATA command *prtest* was used to analyse the effect of the digital health intervention on the prevalence of at least one case of porcine cysticercosis in the household. In addition, the data at the pig level were analysed using the Wilcoxon signed-rank test for within-treatment group changes from baseline and Wilcoxon rank-sum test for between-treatment group differences (intervention effects). Pig-keeping style, pig pen quality and latrine quality were the analysed household practices. Although the practices were rated into three levels, good, fair and poor (or similar terms), in the analysis of the intervention effect, all variables were dichotomised into good or poor by merging the poor and fair into poor. The intervention effects on these factors were analysed using the same statistical procedures used in analysing the intervention effect on porcine cysticercosis at the household level described above.

3. Results

3.1. General Results

This study included 88 households during the baseline (48 intervention and 40 control). At the post-intervention assessment, 18 households (16 intervention and 2 control) could not be followed up because they were no longer keeping pigs. Therefore, 70 households (32 intervention and 38 control) participated in both assessments, and hence, they were analysed for the intervention effect. The baseline prevalence of porcine cysticercosis and its associated risk factors have been reported elsewhere [25].

3.2. The Effect of Digital Health Literacy Intervention on The Prevalence of Porcine Cysticercosis

The difference in the pig-level prevalence of porcine cysticercosis between the intervention and control groups is shown in Table 1. There was no significant difference in the pig-level prevalence of porcine cysticercosis between the baseline and post-intervention periods in the intervention group, despite a slight decrease during the post-intervention period ($p = 0.365$). On the other hand, there was a significant decrease in the pig-level prevalence of porcine cysticercosis during the post-intervention period in the control group ($p = 0.026$). The non-parametric analysis of the pig-level data using the Wilcoxon signed-rank test for within-treatment group changes from baseline and Wilcoxon rank-sum test for between-treatment group differences did not find any statistical significance (p = 0.6988, 0.1175 and 0.5184, respectively).

Table 1. Effect of the digital health literacy intervention on porcine cysticercosis prevalence at pig level in Iringa Rural District, Tanzania, 2019–2021.

Ward	Group	Baseline Study			Post-Intervention Study			Difference	Statistical Significance
		Tested	+ve	Prev. (%)	Tested	+ve	Prev. (%)	Post interv. and Baseline	*p*-Value
Izazi	intervention	56	12	21.4	69	10	14.5	−6.9	0.311
Migoli	intervention	89	18	20.2	110	20	18.2	−2.0	0.715
Izazi and Migoli	intervention	145	30	20.7	179	30	16.8	−3.9	0.365
Mlowa	control	114	26	22.8	119	14	11.8	−11.0	0.026

Having found no significant difference in the prevalence of porcine cysticercosis between the two intervention wards (Izazi and Migoli), in the subsequent analysis, the two wards were analysed in combination. Although the percentage of households with at least one positive case increased from 50 to 53.1 per cent in the intervention group, this increase was not statistically significant (p = 0.7963, n =32). Similarly, the decrease in the percentage of households with at least one infected pig from 39.5 to 28.9 per cent in the control group was not statistically significant (p = 0.3938, n = 38) (Table 2).

Table 2. Effect of a digital health literacy intervention on the prevalence of at least one case of porcine cysticercosis in a household in Iringa Rural District, Tanzania, 2019–2021.

Group	Households Examined (a)	Households Changing from Positive to Negative After Intervention (b)	Households Changing from Negative to Positive After Intervention (c)	Net Change in Status After Intervention (d = c − b)	Percentage Net Change in Status After Intervention (d/a × 100)	Difference in Change Between Control and Intervention in % (and 95% CI)	Significance of The Change in Status Between Groups (*p* Value)
Control	38	13	9	4	10.5	7.4 (−4.1, 18.9)	0.231
Intervention	32	7	8	1	3.1		

This analysis found no statistical difference that could be attributed to the intervention (p = 0.2310), as while some households changed from disease to no disease status in both groups, a reasonable number of households changed from no disease to disease status, making it difficult to rule out the role of chance.

3.3. *Effect of The Digital Health Literacy Intervention on Household Practices Related to Porcine Cysticercosis*

Intervention effects on a change from baseline levels of the pig-keeping style, pig pen quality and latrine quality are shown in Table 3. The within-treatment group comparison between the baseline and post-intervention periods using McNemar's Chi-Square test found a significant change from scavenging/tethering to confinement of pigs in both the intervention and control households (p = 0.000 in both). There were no significant differences between the baseline and post-intervention periods on pig pen quality (emphp = 0.263 and 1.000, respectively) or latrine quality, in either of the treatment groups (p = 0.146 and 0.064, respectively). The comparison between groups revealed a significant change in good practices of keeping pigs under confinement and constructing good-quality pig pens attributable to the intervention (p = 0.026 and 0.025, respectively).

Table 3. Effect of the digital health literacy intervention on household pig-keeping style, pig pen quality and latrine quality in Iringa Rural District, Tanzania, 2019–2021.

Group	Households Examined (a)	Households Changing from Poor to Good Practice After Intervention (b)	Households Changing from Good to Poor Practice After Intervention (c)	Net Change in Status After Intervention (d = c − b)	Percentage Net Change in Status After Intervention (d/a × 100)	Difference in Change Between Control and Intervention in % (and 95% CI)	Significance of the Change in Status Between Groups (*p* Value)
	Pig-keeping style						
Control	38	29	1	28	73.7	20.1 (3.7, 36.4)	0.026
Intervention	32	30	0	30	93.8		
	Pig pen quality						
Control	38	10	9	1	2.6	16.2 (16.7, 30.6)	0.025
Intervention	32	13	7	6	18.8		
	Latrine quality						
Control	38	7	17	10	26.3	7.5 (−27.0, 11.9)	0.453
Intervention	32	3	9	6	18.8		

4. Discussion

This study has, for the first time, evaluated the effect of a digital health literacy intervention on the prevalence of porcine cysticercosis and three associated actual practices in an endemic setting in Tanzania. A study by [4] reported improved knowledge and attitudes towards the control of porcine cysticercosis through digital health education in Tanzania. Such kind of education has not been found to predict the intervention effect on pig management practices and with no disease magnitude. This pilot study has shown promising results towards the use of digital technology to enhance the dissemination of health education messages to reduce endemic diseases, particularly neglected tropical diseases in sub-Saharan Africa, as the intervention improved some key practices necessary for the control of *T. solium* infections.

The digital health literacy intervention on *T. solium* infection control caused significant improvement in confinement and animal welfare, as well as a marked increase in pig confinement. These are important measures to prevent pigs from acquiring infections from contaminated environments. This positive finding suggests that knowledge has influenced practices positively. A study by [12] found no significant improvement in pig confinement approximately 10–12 months following a community-based face-to-face health education intervention, despite improvement in knowledge and attitudes. The authors deduced that the time was too short to observe any change in practices based on the Diffusion of Innovation Theory [26]. The remarkable improvement in pig house quality and pig confinement observed in the present study could be because of the longer duration of 25 months post-intervention compared to the previous study [12]. It could also be attributed to the easiness, and the strength in conveying digitally enabled health messages and animations used to educate the community on practising good pig husbandly for porcine cysticercosis control. The findings of this study are consistent with a similar study in Mozambique, which revealed changes to good pig-keeping style and construction of good-quality pig pens through education [27].

The digital health literacy intervention did not improve the quality of household latrines. This suggests that some behaviour changes may need more time to allow knowledge synthesis to practical outcomes [28,29], as they may be tied to cultural norms, making them difficult to change within a short time. Studies elsewhere have indicated that changes in health management practices in communities require regular education and the provision of enabling skills for the implementation of essential public health measures [30]. Skills and/or guidance in constructing a pig pen were not provided in the current education program, which could have a large effect on the quality of the construction of pig pens in the study area.

The digital health literacy intervention did not have a significant effect on the prevalence of porcine cysticercosis. The lack of any effect from the intervention could partly be attributed to the lack of improvement in household latrine quality. Despite increased confinement of pigs observed during our snapshot visit to the households, such pigs may still be at risk of infection due to poor latrines and confinement is not permanent practice. It was reported that some farmers do release their pigs to access field crop leftovers post-harvest, especially during the dry season [31]. This may allow pigs to access human faecal material, which may sometimes contain *T. solium* eggs. The general decline in porcine cysticercosis prevalence post-intervention in both the intervention and control households observed in this study implies that the decline cannot be related to the intervention. Still, rather it could be a result of other factors that occurred in the study areas, which may include sanitation campaigns carried out in the year 2020 that emphasised the construction and use of latrines using sanitary methods among households. In addition, in the same year, district and village leaders enforced by-laws that insist on indoor pig-keeping. Another factor was the COVID-19 pandemic that emerged in Tanzania in February 2020, in which sanitation (especially hand washing) was highly emphasised. In Burkina Faso and Tanzania, porcine cysticercosis has been reported as more prevalent in free-roaming than among confined pigs, especially during cold weather or the rainy season [31,32]. Pigs scavenging on farm leftovers, practised during the dry season, likely exposed the pigs to porcine cysticercosis infection that becomes detectable two to three months later, a period falling in the following rainy season. This could account for possible factors that led to a higher prevalence of porcine cysticercosis at baseline (end of rainy season) compared to the post-intervention period (dry season). Presence of tall grasses and bushes after rainy season create convenient environment away from home for open defecation [33], hence posing a risk to roaming and even confined pigs feeding on cut grass. Grown shrubby and shade trees provide cool weather conditions for pig habitation far away from their homes [34], widening the pigs' chances of coming into contact with *T. solium* eggs in contaminated environments. Running water in the rainy season increases the chances of environmental contamination by dispersing materials, including worm eggs, from contaminated environments. However, the decline in the prevalence post-intervention in both the intervention and control wards was not statistically significant. The pig producers were not restricted to selling or slaughtering their pigs, and the fact that the post-intervention sampling was conducted two years from the time of the baseline study makes it likely that the pigs examined during the post-intervention were different from the ones examined during the baseline, thus possibly reflecting new cases (incidents) of porcine cysticercosis.

5. Conclusions

This study revealed a significant improvement in pig pen quality and increased pig confinement attributable to the digital health literacy intervention in Izazi and Migoli Wards of the Iringa District of southern Tanzania. This is an important step forward towards the control of *T. solium* infections. The intervention did not improve the quality of household latrines, nor did it reduce the prevalence of porcine cysticercosis. This may be explained by the two factors being interwoven and that more time is needed to see changes resulting from an education intervention. The authors recommend the digital health literacy intervention as a strategy for wider and sustainable dissemination of educational messages for the control of *T. solium* infections and other public health problems. Sustainability of the digital health intervention remains a challenge to solve, possibly between the public sector (such as the ministry of health) and private sector, in particular mobile phone operators, to enable poor rural communities to afford the costs associated with internet access.

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CHAPTER FIVE

MANUSCRIPT 1: Determinants for Adoption of Digital Health Information Exchange on Diseases Control in Tanzania

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Determinants for Adoption of Digital Health Information Exchange on Diseases Control in Tanzania

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ABSTRACT

Digital health information for education and health services save less time and minimal cost in the diseases surveillance and diseases management. Exploring factors for adoption of digital health information exchange is important in strategizing optimum utilization of digital health innovations for public health.

An online cross-sectional survey was carried out using Google Chrome platform in randomly selected public health offices from 26 regions of Tanzania mainland. The use of mobile phone and internet for digital health information and the determinants for adoption of digital health information exchange were gathered through questionnaire.

Among the 210 respondents (110 men, 100 women) asked for participation, 123 agreed to be interviewed (64 men, 59 women). Of which 60 were the health professional workers and 63 the other professional workers. The majority (93) were from urban or peri-urban, while 30 were from rural areas. The study revealed mobile phone as digital devices and internet were used in health information search (90.2 %). Females (93.2 %) were proportionally slightly more internet users than males (87.5 %), although it was not statistically significant. Health workers (98.3%) preferred internet, SMS and phone calls in health information and services. Using digital health information was associated with individual primary occupation, availability of digital health information materials, affordability of internet use, preference on internet, SMS and phone call in health information exchange and the staying in areas with reliable electricity ($p<0.05$).

Tanzanians are aware of and ready for adoption of digital health information exchange. Health workers prefer digital health technology in health sectors. However mobile digital tools and internet save in accessing health information and solving health challenges, remote villages are limited with digital health technologies and reliable electricity for healthy lives. Therefore, it is wealth to bridge the digitally divided communities in Tanzania for the best control of zoonoses and other communicable diseases.
Key words: Surveillance, adoption, digital, health, internet, ICT

1.0 Introduction

The promotion of digital health services worldwide (Kreps, 2014) and use of mobile phone applications (apps) such as Telemedicine and Afya data, relieve countries from health tensions (deRiel *et al.*, 2017) as they serve less time and minimal cost in the surveillance and management of diseases (Falzon *et al.*, 2016; Karimuribo *et al.*, 2017). Digital services make health information and medical consultation easier (The World Bank, 2016). In Tanzania, digital health innovations are motivated in harnessing health information exchange (Kajirunga and Kalegele, 2015) and smooth health services (MOHSW, 2013). Innovation motivation is in parallel with the facilitation of electrical power and network connections through government projects, NGO’s and agencies. The Rural Energy Agency (REA) supports rural electrification to power villages while mobile phone business operations are working hard to connect the country (Mibei *et al.*, 2017).

Over 45% of the adulthood population in Tanzania uses mobile phone internet and about 82% go online via mobile phones (TCRA, 2018). Internet is literary used for communication and education purposes, and little in business (Sedoyeka, 2016). Government workers reported depending solely on mobile and internet-based facilities for effective jobs performance (TCRA, 2018). Physicians and veterinarians also use information communication technology (ICT) and mobile phones in communicating health issues and on awareness creation. Thus, ICT and mobile phones are important in the control of zoonoses and outbreaks of other infectious diseases (Rweyemamu *et al.*, 2013). However, to make the technology practical and useful, the country's policies, political will and efficiency in mobile and internet-based tools are equally important for smoothing digital health information services (Akhlaq *et al.*, 2016). Communicating health issues using mobile and internet-based tools is becoming powerful when users realize that privacy and security are maintained (Eden *et al.*, 2016). Although sometimes restrictions such as password restricted digital health messages for security, require endorsement that may filter users who are critically in need of the information to solve health issues (Ngalyuka, 2013). Apart from restriction, digital health information also requires a reliable power supply in facilitating mobile and internet digital utilization.

In developing countries, digital divide impairs digital health information exchange (Pick and Sarkar, 2015) and it is attributed with unequal network connections and power supply. Effective network connections and power supply in urban areas create more urban digital users and vice versa for rural remote (Gillwald, 2018). The financial situation also divide digital users (Mibei *et al.*, 2017). Young and old aged people who may be financially unstable, are limited to digital mobile and internet preferences in communication and interaction (McGrath, 2012; Olaitan, 2015). For that case, youth and elderly majority miss digital health information benefits because of no financial allocation for digital spend.

This study reports the determinants for adoption of digital health information exchange in Tanzania societies whose majority are rural dwellers. The goal is to provide insights for country policy makers on digital health opportunities optimization and on bridging digital divide to fit in the Sustainable Development Goal 3 of the SDG's 2030 (To ensure healthy lives and promote well-being for all at all ages).

2.0 Methodology

2.1 Study area

The study involved all 26 regions of the Tanzania mainland.

2.2 Study design

The study was conducted in a cross-sectional survey design. Participants were engaged once to provide information through either questionnaire or phone call interview.

2.3 Participants and sample size

Participants were selected from public servant offices including regional, district and ward medical and animal health offices. Using google search, offices were identified and the snowball technique used to gather addresses of respondents were able to be reached though phone call in each region. Three offices were randomly selected among the listed office addresses. At least three participant names were planned to be interviewed from each targeted office. The individuals were consulted through phone call and asked for the willingness to participate in the study. The sample size was determined according to the assertion by Bailey (1994). Therefore, in each of the 8 zones of Tanzania, three regions were identified and from each region, ten to fifteen respondents were contacted. A total of 210 individuals were engaged as respondents.

2.4 Data collection

Data were collected using a structured questionnaire or phone call interview, literature review and official reports. The questions targeted information on the use of mobile phone or other internet-enabled digital tools for casual and official health information exchange. Interested information included “having a conventional cell phone and/or smartphone”, “easy access to a computer or related digital mobile device such as tablet”, “internet use and health information search” and “using email in accessing, sending and receiving messages”.

Prior to the interview, the questionnaire was sent to respondents through email or WhatsApp phone application for familiarization, and the interview was carried at least one day after the respondents received the questionnaire. The interview took an average of 10 minutes per respondent and data were collected in KoboCollect application installed in android devices. The questionnaire was also sent through email to 98 participants who were previously contacted and agreed to participate in the study, and they were asked to fill and send back their response by replying to the email in the given time (two months). The emailed data were also fed into KoboCollect toolbox.

2.5 Data processing and analysis

Cleared data from Kobo collect toolbox were exported to Microsoft Excel for a descriptive statistical analysis. Logistic regression models were run in IBM Statistical Package for Social Sciences version 20 (Armonk, New York). The analysis determined an association between digital health information search or exchange and variables, such as residence location, availability and accessibility of digital mobile tool, sex, age, occupation, perception and preference in information search.

3.0 Results

3.1 Participants socio-demographic characteristics

The determinants for adoption of digital health information exchange were studied from 123 respondents belonging to 26 regions in the listed zones of Tanzania (Table 1). Males 52.0 % were slightly more than the female percent. Respondents' age ranged between 26 and 55 years. Health professional workers occupied 48.9% in the study population; the rest were other professional workers. The study was dominated by 75.6% urban and peri-urban dwellers while the remaining percent were the respondents from rural areas. Rural respondents from digital signal limited places were physically visited for questionnaire filling. Smartphones were owned by majority respondents (77.3%) in studied areas of urban, peri-urban and rural, and only few (22.7%) had conversional cell phones.

Table 3.1: Respondents from different zones in Tanzania mainland (n=123)

Zones	**Sex**			**Age**		**Profession**		**Residence**		**Respondents**
	Female	Male	25-35	36-45	46-55	Health workers	Other workers	Urban & Peri-urban	Rural	**Total**
East	13	20	10	12	11	19	14	31	2	33
West	10	5	5	7	3	7	8	13	2	15
North	6	3	3	4	2	5	4	8	1	9
North-east	7	6	4	6	3	4	9	12	1	13
Lake zone	8	4	5	5	2	5	7	12	0	12
South	4	4	3	4	1	4	4	3	5	8
S. highlands	8	20	13	7	8	13	15	9	19	28
Central	3	2	2	2	1	3	2	5	0	5
Total	**59**	**64**	**45**	**47**	**31**	**60**	**63**	**93**	**30**	**123**

Key: Other workers included professions who are not health workers

3.2 Searching health education information and services using mobile phone and internet-enabled tools

Table 2 shows frequency of use of internet for health information search by age, sex, geographical location and occupation as reported by respondents. Majority were used to digital health information search (90.2%) whether on regular basis or rarely. Very few respondents (9.8%) had never searched for digital health information. Females (93.2 %) were proportionally more digital health information users compared to males (87.5 %). The digital health information use or searches was mostly practised in urban and peri-urban by all age groups (Table 2). Seventy percent health workers suggested digital health messages were efficient, reliable and stable and majority (98.3%) preferred internet-based applications such as WhatsApp, SMS and phone calls in communicating health issues and providing services. These health workers (83.3%) reported to have digital health learning materials available at their working places. The digital health information users (77.2%) reported to spend their money willingly in digital health information search.

Table 3.2: Digital health information search by respondents (n=123)

Category		Never	Rarely	Regular
Sex	Male n(%)	8(12.5)	30(46.9)	26(40.6)
	Female n(%)	4(6.8)	24(40.7)	31(52.5)
Age	Up to 35 yr. n(%)	3(6.7)	18(40.0)	24(53.3)
	36-45 yr. n(%)	5(10.6)	20(42.6)	22(46.8)
	Above 45yr. n(%)	4(12.9)	16(51.6)	11(35.5)
Location	Urban &peri-urban n(%)	7(7.5)	43(46.2)	43(46.2)
	Village n(%)	5(16.7)	11(36.7)	14(46.7)
Occupation	Health workers n(%)	2(3.3)	24(40.0)	34(56.7)
	Other workers n(%)	10(15.9)	30(47.6)	23(36.5)

3.3 Factors associated with the use of digital health information exchange

A binary logistic regression model was built to analyse for factors influencing adoption of digital health information exchange. The model showed that using digital health information exchange was significantly associated with individual primary occupation, availability of digital health information materials, the affordability of internet use, the preference of using internet based applications or web pages, SMS and phone call in health information exchange and the staying in areas with reliable electricity ($p<0.05$). Personal age was also slightly associated with digital health information exchange; youth were less used to digital health information exchange compared to middle age and elderly people (Table 3). Males in this study appeared less used to digital health information search and use compared to females (OR = 0.267). People who sometimes or always search the health information and those preferring crosschecking for validity of the digitally sourced health information are used to digital health information (OR = 1.517). Living in urban or peri-urban is automatically favouring the use of digital health information exchange (OR = 3.354). Also, the attractiveness of the digital health messages (OR = 7.389) and the easiness of using digital tools (OR = 1.422) promotes for digital health information exchange.

Table 3.3: Factors influencing the use of Digital Health Information Exchange

DHI USES	Coef.	St.Err.	p-value	Unadjusted Odds ratio	[95% Conf. Interval]	Sig
Location: (1)	0	.	.	1	.	
Urban/peri-urban	1.21	1.112	.276	3.354	-0.969 to 3.388	
Sex: (1)	0	.	.	1	.	
Male	-1.322	.936	.158	0.267	-3.156 to 0.512	
Age: (1)	0	.	.	1	.	
36-45yrs	.432	1.066	.685	1.540	-1.658 to 2.522	
Above 45yrs	2.316	1.195	.053	10.135	-0.027 to 4.659	*
Occupation: (1)	0	.	.	1	.	
Other workers	-3.715	1.212	.002	0.024	-6.091 to -1.339	***
DHI materials: (1)	0	.	.	1	.	
Are available	7.187	2.13	.001	1322.131	3.012 to 11.362	***
Internet for DHI: (1)	0	.	.	1	.	
Is affordable	5.183	1.876	.006	178.217	1.505 to 8.86	***
DHI airtime & phone call:	0	.	.	1	.	
Is preferred	4.663	2.012	.02	105.954	0.72 to 8.606	**
Gathering DHI: (1)	0	.	.	1	.	
Always	4.286	3.408	.209	72.675	-2.394 to 10.965	
Sometimes	2.434	3.215	.449	11.404	-3.867 to 8.735	
DHI information: (1)	0	.	.	1	.	
Is not accurate	-.649	.986	.51	0.523	-2.581 to 1.284	
For validity DHI: (1)	0	.	.	1	.	
Crosscheck	.417	.982	.671	1.517	-1.508 to 2.343	
Area electricity: (1)	0	.	.	1	.	
Is reliable	2.367	1.421	.096	10.665	-0.418 to 5.153	*
Stay in house with: (1)	0	.	.	1	.	
Reliable electricity	-2.655	1.347	.049	0.0703	-5.294 to -0.016	**
DHI messages: (1)	0	.	.	1	.	
Are attractive	2	1.223	.102	7.389	-0.398 to 4.398	
Digital tools use: (1)	0	.	.	1	.	
Are easy to use	.352	1.157	.761	1.422	-1.915 to 2.618	
Constant	-18.811	7.33	.01	6.77E09	-33.178 to -4.444	**

4.0 Discussion

The use of digital health information exchange in this study was associated with individual primary occupation, availability of digital health information materials, the affordability of internet use, the preference of using internet-based mobile phone applications, SMS and phone call and the staying in areas with reliable electricity.

Based on daily duties, health workers prefer searching for digital health information, to perform better their work activities. They use digital health information exchange for health threats detection and for offering proper diagnosis on any existing and or emerging diseases, which is the best role of digital use for health (Falzon et al., 2016; Karimuribo et al., 2017). The availability of digital health information materials enhances people an easy access and hence preference in learning and solving health challenges. Health workers in this study (human and animal health professionals), suggested that the digital health information exchange was efficient, reliable and stable in their working places. Digital health technology helps during reporting, aiding in quick diseases diagnosis and on health decision making. The digital health messages helps on quick reporting of disease outbreaks from rural remote (Monaghesh and Hajizadeh, 2020) and the internet, SMS and phone calls facilitate health messages delivering. Based on the importance of digital health information, the studied health workers had digital health learning materials available at their working places.

Populations affected with health challenges usually prefer digital health information to improve the situation (Sherman et al., 2020) and the health stakeholder's working performance. But digital illiteracy usually affects the optimum utilization of digital health information. Lacking digital technical skills creates the situation of missing digital health information opportunities and becoming digitally filtered (Mercader and Gairín, 2020). The digital illiterate candidate can fail to perform common digital involving activities such as typing, emailing, short message services (SMS) and use of electronic books. Therefore, digital skill is necessary for opting for digital health information exchange. The digital illiterates usually tend to spend less or no time in learning for digital health and other digital skills (Sanda and Kurfi, 2013). Traditionally African females especially from village areas spend much of their daytime in domestic chores, agriculture and other income-generating activities (Mohan et al., 2020), hence they have less or no time allocated for digital application. In this study females had digital tools and they appeared to use them for digital health information exchange. It was suggested that females do have high motives for health-related information search and they enjoy in searching for digital health information (Bidmon & Terlutter, 2015) when they encounter an opportunity.

Well-structured digital infrastructure in studied urban and peri-urban areas was supporting its utilization. Mobile networks and internet services are widely covered in Tanzania, although internet is mainly accessed in urban and peri-urban areas with various connectivity frameworks (Yonah, 2017). Living in internet located places attract possession of mobile digital tools such as smart phone, tablets and computer, in optimizing for internet and network opportunities (TCRA, 2018). Telecommunication agencies are investing in urban and peri-urban areas of densely populated and of reliable infrastructure in support for businesses (GSMA, 2018). Low densely populated rural areas are limited with network connection facilities due to high installation cost, hence weak internet signal strength (Pazi, 2019).

Prepared digital verbal messages that involve listening and or visualizing suggested the preferred and attractive digital health information for health learning and information exchange. Phone call-based messages or video programmes and or television was reported the best and widely used in communicating important issues, including health issues (Pazi, 2019). This justifies why smartphones are owned more than conversional cell phones, even in villages with limited internet (Pazi, 2019). Smartphones facilitate visual aid and quick information exchange, the opportunity that conventional cell phones miss. Video show, digital verbal messages and or pictures attract users, including digital illiterates who easily can learn through pictures and listening to the health messages. A well designed digital health information program may attract majority, including males who traditionally rarely visit physicians or health care units for consultation (Muheirwe and Nuhu, 2019). The digital health information search may save in place of physical visits to health care units on health challenges.

According to this study, youths were less using the digital health information exchange when compared to middle aged and elderly. Although youth prefer digital information search, they are only limited to income source for spending on mobile and internet digital services (Doyle *et al*., 2021) and they are also less challenged with health issues. Possession of mobile digital tool makes a potential power of becoming connected, but with limited air time for network and internet, digital communication and services become impossible. The low-income earners who could not afford to save from spending for basic needs, they face difficulties in spending for digital information search, which is of relatively high cost for them (Tayo*et al.,* 2015). Middle aged people mostly use digital information and services in their daily working with wealth and health issues. They are also financially stable, hence they can easily afford for digital health information exchange. As according to Niehaves and Plattfaut (2014), elderly people usually become interested in digital information search only in seeking for job-related or income-generating opportunities. Although in some cases, elderly people withdraw digital use for health reasons that include physical age-related changes, such as visual acuity, colour perception, glare susceptibility and hearing problems (Chiu and Liu, 2017). Sometimes elderly people tend to feel of no time and money to spend on cell phones and internet learning or socialization (Scott Kruse et al., 2018). In this study, elderly people preferred using digital health information exchange. Digital health adoption can be attained if the perceived costs and benefits are identified to guide community in spending their time and wealth searching for digital health information.

Limitations in this study included; the difficult to reach respondents in rural areas were network and internet was problem. Opinions concerning digital health education from different people of different geographical zones tend to vary due to cultural and geographical variations.

5.0 Conclusion

- The adoption of digital health information exchange was associated with the primary occupation related to daily searching for health information, the availability of digital health information materials, the affordability of internet use and the preference of using internet, SMS and phone call in health-related information.
- Reliability of electricity favors digital health information exchange and majority adult Tanzanians especially females are frontiers in digital health information use. Most people are regularly searching the digital health information; also living in urban or peri-urban in well-established digital infrastructures favors the use of digital health information exchange.
- The surveyed results indicate that Tanzanians are aware of the importance of digital health information exchange, and they are used in learning and being informed the health challenges and diseases control. Health workers are positively considering the digital health to be good technology for use in country health systems in improving public health services.
- Mobile digital tools and internet was found to be important in accessing for health information, solving health challenges and in communicating with expertise on health issues.
- Therefore; public health sector is advised to support in establishment of the mobile phone digital health technologies in all places including remote villages. The availability of digital tools is potential in the control of existing and emerging individual and public health challenges. Also, pictorial animations and voice messages were suggested the best presentation in conveying health information and in educating

public health issues especially to digital illiterates. Electrification and internet connectivity were found to be the basic requirements for sustainability of digital health information exchange and in attaining the healthy lives and promotion of well-being for all at all ages.

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CHAPTER SIX

6.0 GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6.1 General Discussion

Taenia solium cysticercosis, being a neglected tropical disease, should not be underestimated due to its fatal effects on the community. It is still prevalent in pigs kept by smallholder farmers in many parts of the country, as in this study has been demonstrated in Iringa District Council (*Kajuna et al*., 2022), which is situated in the southern highlands zone. Despite the different control interventions that have been piloted, such as those discussed in Ngowi *et al*. (2019) and Kabululu *et al*. (2020), the disease continues to persist. Community health education interventions is promising in improving disease awareness and reducing disease prevalence, as discussed in Ngowi *et al*. (2008), Mwidunda et al. (2015), Ngowi *et al*. (2017), and Hobbs *et al*. (2019). Therefore, community health education is suggested for sustainable control of the disease. Digital health education has been considered for the sustainability of health education to communities, as highlighted in Ertel *et al*. (2015), Karimuribo *et al*. (2017), Muroff *et al*. (2017), and Holst *et al*. (2021). Digital health education at the studied community aimed to test its effectiveness, but also to understand the community's behavior towards the use of digital health information and services. This kind of health education was able to improve practises of pig confinement and improved pigpen (Kajuna *et al*., 2023)

The studied community showed a preference for digital health information exchange when it comes to learning and solving health problems. This preference is in line with findings from other studies conducted in Tanzania and other countries, which report that residents prefer to use digital health services (Busagala and Kawono, 2015; Manteghinejad and Javanmard, 2021). Technology in healthcare provides a user-friendly environment where health information can be easily accessed from anywhere, making it the first option for managing health issues at the individual, family, and national levels. Digital health cannot be neglected in the management of public health in the country. Health workers and those who surf for health information on a day-to-day basis reported using digital health services. The availability of digital health materials and tools facilitates their usage. Health workers use digital health to improve their knowledge and skills in handling health cases, and they are obligated to use technology to simplify their work. Majority of Tanzanians, especially females, in the study are digital health information users. Those living in urban or peri-urban areas have well-established infrastructures, mobile digital tools, and internet access, which make it easy to access health services and information to solve health challenges.

Continuous innovations in digital health technology have led to opportunities for quick disease diagnosis and reporting health information from remote villages to central decision-makers (Falzon *et al*., 2016; Karimuribo *et al*., 2017). As a result, the installation of digital infrastructure is critical important. Unfortunately, remote communities in the study area have irregular access to digital signals, while others are digitally divided, even though they possess conventional cell phones and smartphones and are eager to benefit from digital technology. In areas lacking network and internet, the possession of conventional cell phones and smartphones alerts decision-makers to consider infrastructure installation to allow technology penetration and application.

Individual primary occupation is associated with searching for digital health information. It appears that less-educated people are less encouraged to use the technology (Mohan *et al.*, 2020). Properly searching for available digital health information is also a challenge for laymen who require particular health information. Furthermore, searching for digital information is related to individual economics. Although network and internet prices are sometimes affordable through special bundles for social media and internet (Sedoyeka, 2016), the majority of people cannot afford to use them. Additionally, digital users are limited by the insufficient power supply in some areas, traditional living styles, age group, gender, and daily activities (Mohan *et al*., 2020; Doyle *et al*., 2021). The traditional way of living also affects the use of digital health information and changing behavior towards improving community health during disease control for public health.

Assimilating knowledge to change practices is associated with cultural heritage and may take a long time to show its effects. The 25-month duration of the study was not sufficient for the community to change their traditional practices that have been in place for several years. These unchanged traditional practices are known to propagate diseases of public health importance, including *T. solium* cysticercosis (Pondja *et al*., 2010; Kajuna *et al*., 2020).

The epidemiology of *T. solium* cysticercosis in this study was perpetuated by the socio-cultural lifestyle of the community. Unrestricted latrines entrance that allow for scavenging pigs to access human faeces, and limited water for hand washing as routine sanitary practices encourage the dispersal of *T. solium* eggs. The unrestricted latrines entrance allow pigs to become infected with the cysticercoids, perpetuating the life cycle of *T. solium* cysticercosis. To combat this, the community needs training on proper sanitation practices, construction of good latrines using locally available materials, and using them properly. Training and sensitization on advantages of proper construction and use of sanitary latrines are essential. The sustainable such digital health education intervention to this community and other endemic communities for the control of *T. solium* is important. It can transform the poor practices based on hygiene and sanitation which exposed individuals to risks of infection, the good practices will be encouraged as it has been revealed on pig management practises for rescuing individuals from being infected.

The study revealed that free-roaming pigs or those raised with less confinement indicate farmers are lacking knowledge about the benefits of total pig confinement, which outweighs the traditional way of raising pigs. This type of pig management is risky and perpetuates the *Taenia solium* life cycle, making the community vulnerable to TSC infection. Pigs are coprophages and can be exposed to *T. solium* eggs by consuming faeces from human tapeworm carriers who defecate openly. They can also become infected from the environment contaminated with the eggs by any means.

Consuming uninspected pork and practicing backyard pig slaughter without proper inspection impairs pork safety, and consumers may encounter worm infection from the infected pork. Although this study showed a decrease in the prevalence of *T. solium* cysticercosis in pigs post-intervention, various factors need to be considered for a constant decline within the intervention and control sites. The sampling period weather could be one of the factors, as the baseline was near the end of the rainy season while the post-intervention was conducted during the dry season. Additionally, unlimited restrictions to pig business during the study period could have affected the results since surveyed households kept selling and buying pigs from outside the study community. For this reason, different pig litters could have been examined on baseline and post-intervention in the same household.

As suggested, health education can improve practices towards the control of *T. solium* cysticercosis. In this study, digital health education was able to improve pig confinement and the quality of pigpens witnessed during the post-intervention study visit. The digital intervention was found to contribute to the improvement of pig confinement for a period of 25 months, although there was an insignificant decrease in porcine cysticercosis prevalence in both the intervention and control areas. Improving pig confinement supports the idea that digital health should be regarded as one of the important strategies in disseminating knowledge aimed at controlling *T. solium* and other public health diseases in wider communities, and for sustainability.

Digital health intervention was used as a new technology strategy for controlling the disease, and its impact on disease prevalence and practices that put the study community at risk of infection was investigated. The intervention was found to improve pig confinement in the community, although other factors could have contributed synergistically, such as the reinforcement of bylaws requiring pigs to be kept indoors by village leaders. Practices involving latrine construction and use remained unchanged after the intervention, although knowledge improvement was reported among individuals (Holst et al., 2021).

The sustainability of this digital health education is important in providing community awareness of the occurrence of the disease and how to control it, and in transforming especially the young generation from risky practices to good practices for control. The fact that the majority of people in the study community have smartphones and access to the internet is a strength in promoting the use of digital health. This study's findings revealed the same as previous studies that Tanzanians prefer surfing digital health information for learning and solving health problems (Busagala and Kawono, 2013). Therefore, digital health should be considered an important strategy for sustainable control of *T. solium*-related diseases and other zoonoses of a similar category. However, challenges to digital health information gathering should never be underestimated.

The limited knowledge in using the internet, SMS, and/or phone calls, and the poor economic status of individuals were mentioned as major challenges to digital health information gathering in this study and elsewhere (Mibei *et al*., 2017; Cummins and Schuller, 2020). The studied remote communities in Tanzania mainland hardly practice digital health services due to constraints such as electricity, network, and internet access. Also, the marginalized rural communities fail to afford the costs associated with the necessary hardware and internet access. Hence, the applicability of digital health in such communities requires public and private sector

partnership to make it work. Therefore, in planning to improve public health, the digitally divided communities should also be considered. Working with the mentioned and other speculated challenges towards digital health will facilitate the sustainability of digital health services and hence the maintenance of public health in the country.
Limitations in this study included: The difficult reach of digitally divided respondent for their views, the only husband as head of the family was responsible provide household information on socio-cultural practices. Few animals eligible for sampling per households and some households participated at baseline were no longer eligible hence they were omitted in the study post intervention.

6.2 Conclusions

The persistent presence of seropositive pigs in Iringa District Council suggests that the life cycle of *T. solium* worms is being encouraged and that the socio-cultural lifestyle of the community is favorable to this. The lack of restrictions at the entrance of latrines and the limited hand washing after using the toilet, despite education interventions, indicates a negligence in the safe and sanitary use of latrines. This implies that the community has not been sufficiently transformed to practice sanitation, construct proper latrines with locally available materials, and use them appropriately. The uncomfortable latrines discourage people from using them, leading to open defecation in bushes, which is an important way for *T. solium* eggs to be dispersed into the environment. The fact that pigs are allowed to roam freely or are raised in weak confinement indicates that farmers are less informed about the benefits of keeping pigs under total confinement.

In Tanzania, remote communities on the mainland are not widely practicing digital health services due to constraints such as lack of electricity, network coverage, and internet access. In addition, marginalized rural communities cannot afford the costs associated with necessary hardware and internet access. Therefore, public and private sector partnerships are required to make digital health services applicable in such communities.

In planning to improve public health, it is important to consider digitally divided communities. Tanzanians prefer digital health services for learning and tackling health problems, but the availability, accessibility, and affordability of digital resources and internet connection tend to impede their use. The use of digital health services is also associated with primary occupation, availability of digital health materials, affordability, and preference for internet, SMS, and phone call in health information search, as well as staying in areas with reliable electric power.

6.3 Recommendations

Communities in endemic areas for *T. solium* require close and regular follow-up health education on the epidemiology and control of the disease. Digital health education can be well-designed to reach the majority of all age groups in the community and has the potential for community health education.

The digital health education intervention has shown to promise in promoting pig confinement, indicating its potential for use in local and wider areas for control diseases of public health importance. However, public and private partnerships are necessary to address limitations in accessing digital information and services, and investment in digital health services and businesses is needed.

The persistent *T. solium* infections in Iringa District Council calls for the implementation of more effective digital health education intervention strategies to protect the public health and livelihoods of communities. Control strategies should consider the aggregation nature of *T. solium* infections, such as placing special focus on indirect transmission methods.

Training good pig management practices is critical for improving the situation, and digital health interventions can be incorporated during knowledge dissemination for the control of *T. solium* and other public health diseases in wider communities to ensure sustainability. Additionally, surveillance of socio-cultural practices in communities and sustainable health education are mandatory considerations in planning for TSC control.

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APPENDICES

Appendix 1: ELISA Test Procedure

The apDia Cysticercosis Antigen (Ag) ELISA is an Enzyme Immunoassay for the qualitative determination of viable metacestodes (cysticerci) of *Taenia* spp. in human and porcine serum samples.

PRINCIPLE OF THE CYSTICERCOSIS AG ELISA

The pretreated controls and samples are added to the B158C11A10 monoclonal antibody-coated wells. During this incubation step circulating antigen from viable cysticerci are bound specifically to the wells. After removal of the unbound serum proteins by a washing procedure, the antigen-antibody complex in each well is detected with specific peroxidase-conjugated B60H8A4 monoclonal antibodies. After removal of the unbound conjugate, the strips are incubated with a chromogen solution containing tetramethylbenzidin and hydrogen peroxide: a blue colour develops in proportion to the amount of immune complex bound to the wells of the strips. The enzymatic reaction is stopped by the addition of 0.5M H_2SO_4 and the absorbance values at 450 nm are determined.

ASSAY PROCEDURE

General Remarks:

1. Use a separate disposable tip for each sample transfer to avoid cross-contamination.
2. All reagents must be allowed to come to room temperature before use. All reagents must be mixed without foaming.
3. Once the assay has been started, all steps should be completed without interruption.

Reconstitution of the Reagents

Washing Solution: dilute 125 ml of concentrated Washing Solution (**5**) to 2500 ml with distilled water. Reconstituted solution can be stored at least 1 month, store at 2 – 8 °C.

At higher temperatures, the concentrated Washing Solution (**5**) may appear cloudy without affecting its performance. Upon dilution, the solution will be clear.

Washing procedure

1. One cycle is done as follows:
   - Add 300 µl of diluted Washing Solution to all wells of the microtiterplate.
   - Remove Washing Solution immediately from the wells by inverting the microtiterplate and tapping dry on absorbent paper.

2. An automatic microtiterplate washer may be used but this will require adaptation of the washing procedure. If necessary, increase the number of cycles and include a soak time after each wash cycle based on the OD values of the negative and positive controls.

Pre-treatment of samples/controls for in duplo determination

For CSF specimens the pre-treatment step described in this chapter may be skipped. The positive control however must be pre-treated with TCA.

1. Add 150 µl TCA Solution (8) and 150 µl sample/control in an Eppendorf Tube®.
2. Mix immediately by vortexing.
3. Incubate for 5 to 20 minutes at room temperature.
4. Mix again by vortexing.
5. Centrifuge the tubes for 5 to 9 minutes at 12000g.
6. While centrifuging, prepare for each sample an Eppendorf Tube® containing 150 µl Neutralisation Buffer (**9**).
7. Neutralise mixture by adding 150 µl of the supernatant into the Eppendorf Tubes® with the same volume of Neutralisation Buffer (**9**). Mix by vortexing

Remark: this results in a final dilution of ¼ of the samples/controls.

Pre-treatment of samples/controls for single determination

For CSF specimens the pre-treatment step described in this chapter may be skipped. The positive control however must be pre-treated with TCA.

1. Add 60 µl TCA Solution (**8**) and 60 µl sample/control in an

Eppendorf Tube®.

2. Mix immediately by vortexing.
3. Incubate for 5 to 20 minutes at room temperature.
4. Mix again by vortexing.
5. Centrifuge the tubes for 5 to 9 minutes at 12000g.
6. While centrifuging, prepare for each sample an Eppendorf Tube® containing 60 µ l Neutralisation Buffer (9).
7. Neutralise mixture by adding 60 µl of the supernatant into the Eppendorf Tubes® with the same volume of Neutralisation Buffer (9). Mix by vortexing.

Remark: this results in a final dilution of ¼ of the samples/controls.

Assay Procedure

1. Take the necessary amount of test strips (**1**) and return non-used strips in the sachet. In each run 1 negative control (**2**) and 1 positive control (**3**) should be included.
2. Add 100 µl of the pre-treated samples/controls to each well. Determine the samples preferably in duplo. Seal strips securely with a microplate sealer.
3. Incubate for 15 minutes at 37°C while shaking at 700-800 rpm.
4. After incubation, wash the microtiterstrips with 300 µL of Washing Solution (5), apply 5 cycles. Change Washing Solution for each cycle. Finally empty the microtiterstrips and remove excess fluid by blotting the inverted strips on absorbent paper.
5. Add 100 µl of Conjugate Solution (4) to the wells. Seal strips securely with a microplate sealer.
6. Incubate for 15 minutes at 37°C while shaking at 700-800 rpm.
7. After incubation, wash the microtiterstrips 5 times with 300 µL of Washing Solution (5) as described in step 4.
8. Add 100 µl of Chromogen Solution (6) to each well. Seal strips securely with microplate sealer.
9. Incubate for 15 minutes at room temperature. Avoid light exposure during this step.
10. After incubation, add 50 µl of Stopping Solution (7) and read OD at 450 nm with reference wavelength 600-650 nm in a microplate

reader within 15 minutes after stopping.

RESULTS

Cut-off calculation and calculation of Ag Index <u>for human specimens</u>

- Mean ODneg is used to calculate the cut-off by multiplying its value by 2:

Cut-off value = mean ODneg x 2

- The antigen index (Ag Index) of each sample is calculated by dividing the OD value of the sample (ODsample) by the cut-off value:

Cut-off calculation and calculation of Ag Index <u>for porcine specimens</u>

- Mean ODneg is used to calculate the cut-off by multiplying its value by 3,5:

Cut-off value = mean ODneg x 3,5

- The antigen index (Ag Index) of each sample is calculated by dividing the OD value of the sample (ODsample) by the cut-off value:

Interpretation of the results for detection of cysticercosis antigen in human and porcine specimens

A positive reaction corresponds to an Ag Index above or equal to 1.3

A negative reaction corresponds to an Ag Index below or equal to 0.8.

A grey-zone between Ag Index 0.8 and 1.3 has to be considered. Samples inside this “grey-zone” should be considered as doubtful and should be retested, preferably using a freshly drawn blood sample, alternatively, additional diagnostic methods should be used.

Negative result: Ag Index ≤ 0.8 Positive result: Ag Index ≥ 1.3
Doubtful result: 0.8 < Ag Index < 1.3

EXPECTED VALUES

Example of typical O.D. values for the Negative Control and Positive Control:

NC	0.027
PC	2.890

PERFORMANCE

Diagnostic and Analytical Sensitivity

Serum samples from 100 Peruvian patients diagnosed for cysticercosis, have been tested in the apDia Cysticercosis Ag ELISA. In this group, 94 patients tested positive. Based on imaging data and other clinical data, the 6 patients with the negative test result could be subdivided in 3 groups: 2 patients had no living cysts, 2 patients had 1 living cyst and 2 patients had 2 living cysts in the brain. All patients infected with at least 3 living cysts were tested positive.

In a study on infected animals, a panel of 31 animals infected with viable cysticerci of *Taenia* spp. were tested, all samples gave a positive result in the Cysticercosis Ag ELISA from apDia.

Specificity

Human serum samples of 20 patients negative for cysticercosis, originating from a non-endemic area in Peru, were tested in the apDia Cysticercosis Ag ELISA. In this area, other parasitosis cases are very prevalent. All samples were tested negative.

300 negative human samples from Belgian blood donors were analysed in the apDia Cysticercosis antigen ELISA. None of the 300 samples tested repeatedly positive while 2 samples gave a positive result in the first run resulting in a specificity of 99.3%.

300 negative porcine samples were analysed in the apDia

Cysticercosis antigen ELISA. None of the 300 samples tested repeatedly positive while 1 sample gave a positive result in the first run resulting in a specificity of 99.6%.

TEST VALIDITY

- The individual absorbance value (optical density OD) of the positive control (ODpos) must be above 1.000.
- The average OD of the negative control (ODneg) must be lower than 0.100.
- If one of these specifications is not met, the results should be considered invalid and the series of tests should be repeated.

LIMITATIONS OF THE ASSAY

Strict adherence to the protocol and recommended equipment is necessary to obtain reliable test results. Accurate sample and reagent pipetting and timing of washing and incubation should be respected.

- As with all *in vitro* diagnostic tests, a definitive clinical diagnosis should not be made based only on the results of a single test. A complete evaluation by a physician is needed for a final diagnosis.
- The assay detects viable cysticerci, it does not detect degenerated or calcified cysticerci.
- The sensitivity of the assay decreases when the number of viable cysticerci is low.

Appendix 2: Consent form

INVITATION TO PARTICIPATE IN A RESEARCH PROJECT

FREE ACCESS TO DIGITAL HEALTH INFORMATION IN TANZANIA

This study is part of the project *Non-discriminating access for digital inclusion* (Digi), an innovation project funded by the Norwegian Government and the Norwegian Research Council. The purpose of this study is to investigate your knowledge related to HIV/AIDS, Tuberculosis (TB) and *Taenia solium* cysticercosis/taeniosis (TSCT). The University of Oslo (UiO), Norway, is responsible for the study together with the National Institute for Medical Research (NIMR) in Dar es Salaam and Sokoine University of Agriculture in Morogoro. Only the PIs from UiO and NIMR will have access to your personal information. This particular project is a PhD-project. Your household has been selected at random to take part in the study.

WHAT DOES PARTICIPATION IN THE PROJECT IMPLY?

The data collection includes a survey with questionnaires. The questions will concern your knowledge of the HIV/AIDS, TB and TSCT. Our research staff will collect your answers with small computers. After the first questions, we will offer you detailed information of the diseases through films at the small computers. After the films, we will ask you ask you the same questions again. The same films will be available, free of charge in the Wi-Fi spot in the village. You can decide yourself whether or not you want to make use of that information. We will come back and ask the same questions again after 3, 6 and 12 months. After 12 months the data collection period is over.

Your name, sex, age, education, mobile number, village and GPS coordinates will be collected. The data will be made de-identified and kept at a server at the Services for sensitive data (TSD) at the University of Oslo, Norway. This means your name and background information is stored separately from the rest of the collected data, and is only known to a selected group of researchers. As a participant in this study, you have the right to send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority (contact details under approvals) related to the handling of your personal information. Your consent to participation is the legal foundation for processing personal data, meaning that without your consent we cannot process your personal data.

POSSIBLE BENEFITS AND EXPECTED DISADVANTAGES OF TAKING PART

The expected benefits of participating in this study is increase in your health knowledge. This increase in health knowledge can help protect you and your family from the above-mentioned diseases. Increased health knowledge can also lead to earlier treatment for people with a disease, meaning that a possible benefit of taking part in this study is not only improvement of your own health, but even improvement of community health, i.e. health of the people surrounding you.

The expected disadvantages to participate are few or none. However, you are encouraged to contact the researchers if you need follow-up after your participation in this study.

VOLUNTARY PARTICIPATION AND THE POSSIBLITY TO WITHDRAW CONSENT (OPT-OUT)

Participation in the study is entirely voluntary. If you wish to take part, you will need to check the box(es) and sign the informed consent on the last page. You can, at any given time, without prior notice and without any reasons withdraw your consent. This will not have any repercussions on any future treatment or contact with health workers. If you decide to withdraw your participation in the project, you can demand that your questionnaire answers will be deleted, unless however, the data have already been analysed or used in scientific publications. If at a later point you wish to withdraw consent or have questions regarding the project, you can contact

- Dr. Bernard Ngowi, National Institute for Medical Research, Muhimbili Medical Research Centre, Tanzania, Kalenga Street, P.O. Box 3436 Dar es Salaam, Tanzania. Tel: +255 763918181. E-mail: b_ngowi@yahoo.co.uk
- National Health Research Ethics Committee (NatHREC) of the National Institute for Medical Research Tanzania, 2448 Ocean Road, P.O. Box 9653, Dar es Salaam, Tanzania. Tel: +255 22 2121400. Fax: 255 22 2121360. Website: www.nimr.or.tz
- Christine Holst, tel +47 4823 4044, Christine.holst@medisin.uio.no

WHAT WILL HAPPEN TO YOUR INFORMATION?

The information that is recorded about your knowledge will only be used within the overall research project Digi. You have the right to access the recorded information about you and the right to stipulate that any error in the information that is recorded, is corrected. All information will be processed and used without your name, address or personal identification number, or any other information that is directly identifiable to you. The de-identified data from the surveys will be uploaded to a secure platform at the Services for sensitive data (TSD) in Norway. The Project Manager has the responsibility for the daily operations/running of the Research Project and that any information about you will be handled in a secure manner. After the project is over, your personal information will be deleted. The project will end in September 2020.

APPROVAL

The Project is approved by the Norwegian Centre for Research Data, ref 59643 / 3 / EPA,
Contact: The Data Protection Official for Research at NSD - Norwegian Centre for Research Data AS.
email: personvernombudet@nsd.no, Telephone +47 55 58 21 17

Ethical approval from the National Institute for Medical Research (NIMR), Tanzania, has been granted with the reference number NIMR/HQ/R.8a/Vol IX/2947. The study is registered in ClinicalTrials.gov ID: NCT03808597. Permission to conduct this study was given by COSTECH.

CONSENT FOR THE MINOR - PARTICIPATING IN THE RESEARCH PROJECT

I have received and understood information about the project *FREE ACCESS TO DIGITAL HEALTH INFORMATION IN TANZANIA*, and have been given the opportunity to ask questions. I give consent:

☐ to participate in the survey

I give consent for my personal data to be processed until the end date of the project, in September 2020.

City/Town and date   Participant's signature

Participants name (in BLOCK LETTERS)

I confirm that I have given information about the research project.

Place and date   Signature

Role in the research project

Section only for those who cannot read and / or write:

Thumb print under:

Witness to sign for those who cannot read and write:

______________ ____

Appendix 3: Checklist used and Questionnaire forms

Observation Study and Pig Sampling Data

A. Observation study Data

1. Household ID; . Names: …………………………………………………
2. Presence of household latrine, Yes No
3. Appearance of latrine, 1-10: Poor (1), Excellent (10)
4. Presence of pigpen Yes No
5. Appearance of pigpen, 1-10: Poor (1), Excellent (10)
6. Number of pigs in a drift

B. Pig Sampling information and Data

7. Pig ID
8. Pig Age (months)
9. Pig sex Male Female
10. Pig demeanor. 1-5: Alert (1), dull (5)
11. Date blood sampled

Questionnaire on Pig Rearing, Sanitation and Hygiene

C. Respondent Information

12. Names:……………………………….. Occupation: ………………………………
13. Ward: …………………………….……. Village: …………………………………..

D. Household Practices on Pig Rearing

14. Experiences in keeping pigs: More than six month, Less than six months
15. When do you feed pigs? ………………………………………………………....

16. What do you feed pigs?
    ....
17. Regular activities performed to your animals: **Deworming**,
    ○ Yes, ○ No.; **Teeth creeping,** ○ Yes, ○ No.; **Castration,**
    ○ Yes, ○ No.
18. Pig sales: ○ Live animal, ○ Slaughter and sell pork, ○ Live and Slaughter animal
19. Where do pigs slaughtered? ○ Homestead, ○ at organized common slaughter slab
20. Are the pigs or pork inspected at slaughter? ○ Yes, ○ No,
    ○ Sometimes
21. What is your perception on suitability of uninspected pork preparations for consumption?
    - Deep fried pork; ○ Doubtful, ○ Tolerable, ○ Fin
    - Roasted pork; ○ Doubtful, ○ Tolerable, ○ Fine
    - Boiled pork; ○ Doubtful, ○ Tolerable, ○ Fine

E. Sanitary and Hygiene Practices

22. How regular do you wash hands after latrine? ○ Always,
    ○ Sometimes, ○ Not at all
23. Are your children under 5 years using latrines? ○ Yes, ○ No. If No, who is helping them……………………………………
24. Is there a latrine at the village local bars? ○ Yes, ○ No.
25. Is there a latrine at local market places? ○ Yes, ○ No,
26. Where do you source your domestic use water
    ………………………………

Thank you for your time to respond this questionnaire.

Digital Health Use Questionnaire

F. Respondent's particulars

1. Name*
2. Sex* Male Female
3. Age* 15-25, 26-35, 36-45, 46-55, above 56
4. Village/ward, district and region you live*
5. Primary occupation* Student, Crop farmer, Livestock keeper, Health worker, Vet/Livestock officer, Other
6. Time you spend at your current occupation* <1 year, 1-5 years, >5 years

G. Digital Health Accessibility and Availability (Describe the proportion of respondents who have and/or who can access digital-based information).

7. What do you own among the following?*

Smart phone/ipad, Computer, Cellphone, Radio

8. What can you access freely among the following?*

Smart phone/ipad, Computer, Cellphone, Radio

9. Is internet available in your locality?* Yes No
10. Is internet available at your workplace?* Yes No
11. Are the digital health information learning materials available at your home?* Yes No
12. Are the digital health information learning materials available at your working place?* Yes No

H. Legal validity (Respondents views on digital health information as legally valid)

13. Do you think the official health information be communicated by digital means?* Yes No
14. Do you think all health-related information be communicated by digital means?* Yes No
15. Would you take with similar seriousness the health information with legal implications, whether received in hard form or through digital communication?* Yes No
16. Does communicating health information through digital means reduce privacy?* Yes No

I. Efficiency (how quick and capable digital ways can transfer correct information)

17. Does it take shorter time to transfer health information through digital means as compared to any other means?*
    Yes No

18. How many times do you visit internet to get health information?*
    Never, Sometimes, in average of once in a month, Sometimes, in average of once in a week, At least once in a day, more than once in a day

19. With digital means what percent of recipients receive full message of information in day one?* <50%, 50-75%, >75%

20. If you are responsible to send health information, is it necessary to send it in additional with hard copy, after sending it through digital means?* Yes, No

J. Reliability (to know how respondents think on the accuracy of digitally sourced information)

Please select your opinion on each item based on scale 1-5: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree.

21. Information I get from digital based sources is accurate* . I find it necessary to crosscheck with other sources the digitally sourced information* . I can solely depend on digital tools to obtain new information* .

K. Stability/consistency (respondent's thoughts on digital sourced information)

Please select your opinion on each item based on scale 1-5: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree.

22. Un-altered message is received by different recipients from same source through internet* . No inconsistency for digital sourced health information* . "Lost-websites" usually happen when one returns to a site visited earlier*

L. Individual attitudes and perception (person opinion on digital based health information)

Please select your opinion on each item based on scale 1-5: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree.

23. I prefer using internet, SMS and phone call (air-time) as source of health information* . Internet and air-time (for SMS and phone call) are currently my best source of information* . I prefer my subordinate sending me digital

information than paper format* . I can opt to spend money for searching health information from the internet than buying hard-copy books* .

M. Individual attitudes and perception (person opinion on digital based health information)

24. How frequently do you use digital tools for health information gathering? Not at all, I did only once, Sometimes, Always

N. Technical and infrastructural capacity

Please select your opinion on each item based on scale 1-5: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree.

25. There is availability of digital technology education programs for public at my village/ ward* . There is a reliable electricity at my village/ward* . I have good knowledge on computer use such as typing and other functions* .

O. Individual attitudes and perception (person opinion on digital based health information)

26. Do you stay in a house that connected with national grid electricity or solar power electricity?* Yes No
27. Do you have an email address?* Yes No
28. Do you think costs of getting information through digital devices are lower than getting the same in printed materials?* Yes No

29. Do you afford internet charges whenever you want to get health information online?* Yes No

P. Usability

Please select your opinion on each item based on scale 1-5: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree.

30. Most digital based health messages are well designed to attract users* . Most digital tools are easy to use* . I prefer typing over hand-writing when preparing documents* . I am a frequent user of social network programs like Facebook, WhatsApp and Instagram*

Q. Usability in touch with social media

31. Which of the following social media do you have an active account?* Facebook, WhatsApp, Instagram, Twitter, None of the above, All of the above

Kuhusu Tasnifu hii

Tegu wa nguruwe ni mnyoo unaoambukizwa kati ya binadamu na nguruwe. Binadamu huambukizwa mnyoo mpevu tumboni kwa kula nyama ya nguruwe yenye maambukizi katika hatua ya funza/lava. Wakati nguruwe na binadamu tena huambukizwa kwa kula chakula au kunywa maji yaliyochafuliwa kwa kinyesi cha binadamu chenye mayai ya mnyoo mpevu. Maambukizi ya funza/lava wa mnyoo husababisha unyanyapaa, huathiri afya na uchumi kuanzia mtu mmojammoja, familia hata taifa. Mwaka 2019 utafiti ulionesha maambukizi ya tegu wa nguruwe yalikuwa wastani wa asilimia 21.4 (Izazi), 20.2 (Migoli) na 22.8 (Mlowa) Iringa-Tanzania. Takribani miaka miwili baada ya elimu ya kidijitali kuhusu udhibiti wa tegu wa nguruwe na binadamu, tathmini ilionesha maambukizi yalikuwepo, lakini jamii ilizingatia ujenzi wa mabanda na ufugaji bora wa nguruwe kama njia ya kujikinga na maambukizi. Jamii iliaswa kuhakikisha kinyesi cha binadamu kinatumbukizwa ndani ya tundu la choo moja kwa moja, kuepusha kisifikiwe na nguruwe au kuchafua maji, mimea/vyakula kwenye mazingira.