International Journal of Medical Informatics 172 (2023) 105018

Contents lists available at ScienceDirect

International Journal of Medical Informatics

journal homepage: www.elsevier.com/locate/ijmedinf

Acceptability and applicability of biometric iris scanning for the identification and follow up of highly mobile research participants living in fishing communities along the shores of Lake Victoria in Kenya, Tanzania, and Uganda

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A R T I C L E I N F O

Keywords:
East Africa
Fishing communities
Lake Victoria
Acceptability
Iris scanning
Biometric identification

A B S T R A C T

Background: Recruitment and retention of participants in research studies conducted in fishing communities remain a challenge because of population mobility. Reliable and acceptable methods for identifying and tracking participants taking part in HIV prevention and treatment research are needed. The study aims to assess the acceptability, and technical feasibility of iris scans as a biometric identification method for research participants in fishing communities.
Methods: This was a cross-sectional study conducted in eight fishing communities in Kenya, Tanzania, and Uganda, with follow-up after one month in a randomly selected subset of participants. All consenting participants had their iris scanned and then responded to the survey.
Results: 1,199 participants were recruited. The median age was 33 [Interquartile range (IQR) 24–42] years; 56% were women. The overall acceptability of iris scanning was 99%, and the success rate was 98%. Eighty one percent (n = 949) had a successful scan on first attempt, 116 (10%) on second and 113 (9%) after more than two attempts. A month later, 30% (n = 341) of participants were followed up. The acceptability of repeat iris scanning was 99% (n = 340). All participants who accepted repeat iris scanning had successful scans, with 307 (90%) scans succeeding on first attempt; 25 (7%) on second attempt, and 8 (2%) after several attempts. The main reason for refusing iris scanning was fear of possible side effects of the scan on the eyes or body.
Conclusion: The acceptability and applicability of biometric iris scan as a technique for unique identification of research participants is high in fishing communities. However, successful use of the iris scanning technology in research will require education regarding the safety of the procedure.

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https://doi.org/10.1016/j.ijmedinf.2023.105018
Received 24 October 2022; Received in revised form 31 January 2023; Accepted 3 February 2023

1. Introduction

Populations residing in fishing communities (FCs) around Lake Victoria are disproportionately affected by HIV infection and are highly mobile [1–4]. About three million people resident in these communities (FCs) on the shores of Lake Victoria depend either directly or indirectly on fishing activities [5]. The people are known to move between different FCs and are often absent for days, weeks and sometimes months, but usually return to their home communities. This kind of mobility often includes short and medium duration movements between the neighbouring countries around the lake [6]. Such populations could greatly benefit from research studies aiming to evaluate novel HIV prevention and care strategies. However, evidence shows that high mobility negatively impacts the recruitment, retention and follow up of participants in research and health programs [7,8]. Furthermore, conventional participant identification methods such as the use of names, date of birth, and identification (ID) numbers are often unreliable and inaccurate [9–12]. National identification numbers are particularly challenging for fishing populations who cross national borders as it is unclear which country ID one would use and not everybody has a national ID. These personal identifiers are also associated with multiple registrations as one person may have multiple IDs, or one ID may be associated with multiple individuals or there may be incomplete registration [9]. Similarly, use of identifiers such as names, has been associated with confusion since names can be very similar in some communities. Names and national IDs have also been associated with confidentiality concerns, and are a common barrier to accessing HIV testing and prevention services [13,14]. Therefore, studies are needed to identify reliable, acceptable methods that facilitate recruitment and retention of highly mobile populations in HIV prevention and treatment research studies. Biometric technologies such as iris scanning may overcome the limitations of the traditional methods of identification at follow up in research and health programmes.

The patterns of the human iris are a unique, permanent, and universal "biometric signature" that does not change during a person's lifespan [15–18]. A human iris is always stable, irrespective of age [18]. Even genetically similar people have entirely different irises; thus, iris scanning recognition avoids misidentification even among identical twins [16,19,20]. This is in contrast to identification strategies based on fingerprint structure—the most widespread biometric method of identification, which varies during childhood and only becomes stable as an individual grows older [20,21]. Iris-based biometric system studies have shown better performance, sensitivity and accuracy compared to fingerprint biometric recognition [17,22]. Thus, the use of iris scan technology can substantially increase reliability of study findings in settings where the population is highly mobile [3,11,12].

Despite its reliability, the use of iris scanning in both research and routine health care services has sometimes raised worries and misconceptions among both patients and study participants including safety concerns and anxiety about the physical effects that intense light exposure during biometric scanning could have on eyes [22,23]. There is little information about the acceptability of iris scan technology among residents of fishing communities and similar key populations that have become a focus of HIV vaccination and other prevention research interventions. We assessed acceptability, and technical feasibility of iris scanning technology as a biometric identification method for research participants in fishing communities along the shores of Lake Victoria in Kenya, Tanzania, and Uganda.

2. Methods

2.1. Study design and settings

The study is part of on-going multisite research investigating several aspects of women's mobility in fishing communities around Lake Victoria in Kenya, Tanzania, and Uganda. This collaborative research project is being implemented by investigators from the partners of the Lake Victoria Consortium for Health Research (LVCHR). LVCHR members include: i) Kenya Medical Research Institute (KEMRI); ii) Mwanza Intervention Trials Unit (MITU) in Tanzania; iii) UVRI-IAVI HIV Vaccine Program (UVRI/IAVI); and iv) the Medical Research Council/Uganda Virus Research Institute & London School of Hygiene and Tropical Medicine (MRC/UVRI & LSHTM) Uganda Research Unit [24].

We conducted a multisite observational study involving an initial cross-sectional survey and a follow-up survey one month later of a randomly selected subset of about 30% of participants enrolled at each study site. The study was conducted in eight fishing communities, two for each of the four-participating institution between February and September 2021. For the purpose of this study, a fishing community was defined as a community situated along the shores of Lake Victoria consisting of one or more landing sites on either the mainland or an island with the main economic activity focusing on fishing and fishing-related work. The communities have been assigned letters, to provide confidentiality, in this paper A and B in Kenya; C and D in Tanzania; and E, F, G and H in Uganda (Fig. 1). The communities were selected based on proximity to the location of each partner institution, previous participation in mobility studies [1–4,7,25,26], a population of at least 1000 people, and high HIV prevalence (≥25%) [1–4,7].

The study population comprised participants aged 15 years or older, who had lived in the fishing communities for at least six months (Fig. 1).

2.2. Study procedures

Description of the device/system: We used BMT-20 camera binoculars type dual iris imager (*CMITech America Inc.* San Jose, CA, USA). The device consists of a portable binocular iris recognition camera connectable to computer via Universal Serial Bus (USB) (Fig. 2). The device scans both iris and (when connected to internet-enabled computer) transmits encrypted templates and inputted data to a database on a central server via Global System for Mobile. Records on the database are viewable via a password-secured website.

The device privacy protections included the following: when a new participant is enrolled, an encrypted biometric template is created from their iris scan and a randomly assigned 12-digit number is drawn from a pool of 90 billion numbers. On subsequent visits, the identity of the participant is verified when their template is matched, and the system returns the original 12-digit unique identifier. The system operator uses the pseudonymous identifier within their ecosystem to positively ID the participant. No personal data were saved or transmitted to the cloud server. Only an image of both iris and barcoded identification number generated by the software were stored in the server in encrypted form and retrieved on subsequent scan to identify the individual.

2.3. Data collection

Community leaders in the fishing community helped in mobilizing the study participants. A biometric station (camera, laptop, internet WiFi dongle, tablet for data collection) was set up in each fishing community. Each station was managed by two staff members trained in the use of biometric station equipment. Residents aged 15 years and above, living in the fishing community and interested in taking part in the study were given detailed information about the study and the iris scanning system before providing informed consent for participation.

Data collection proceeded in two steps during the cross-sectional survey. All participants who consented to both iris scanning and interview, underwent iris scanning procedure, before responding to an interviewer-administered structured questionnaire. The questionnaire was designed to capture the following information: i) Socio-demographic information (sex, age, education level, place of residence, marital status, number of children and income level; ii) experiences and concerns about iris scanning and whether the participant would recommend iris scanning to someone else; iii) Chronic diseases

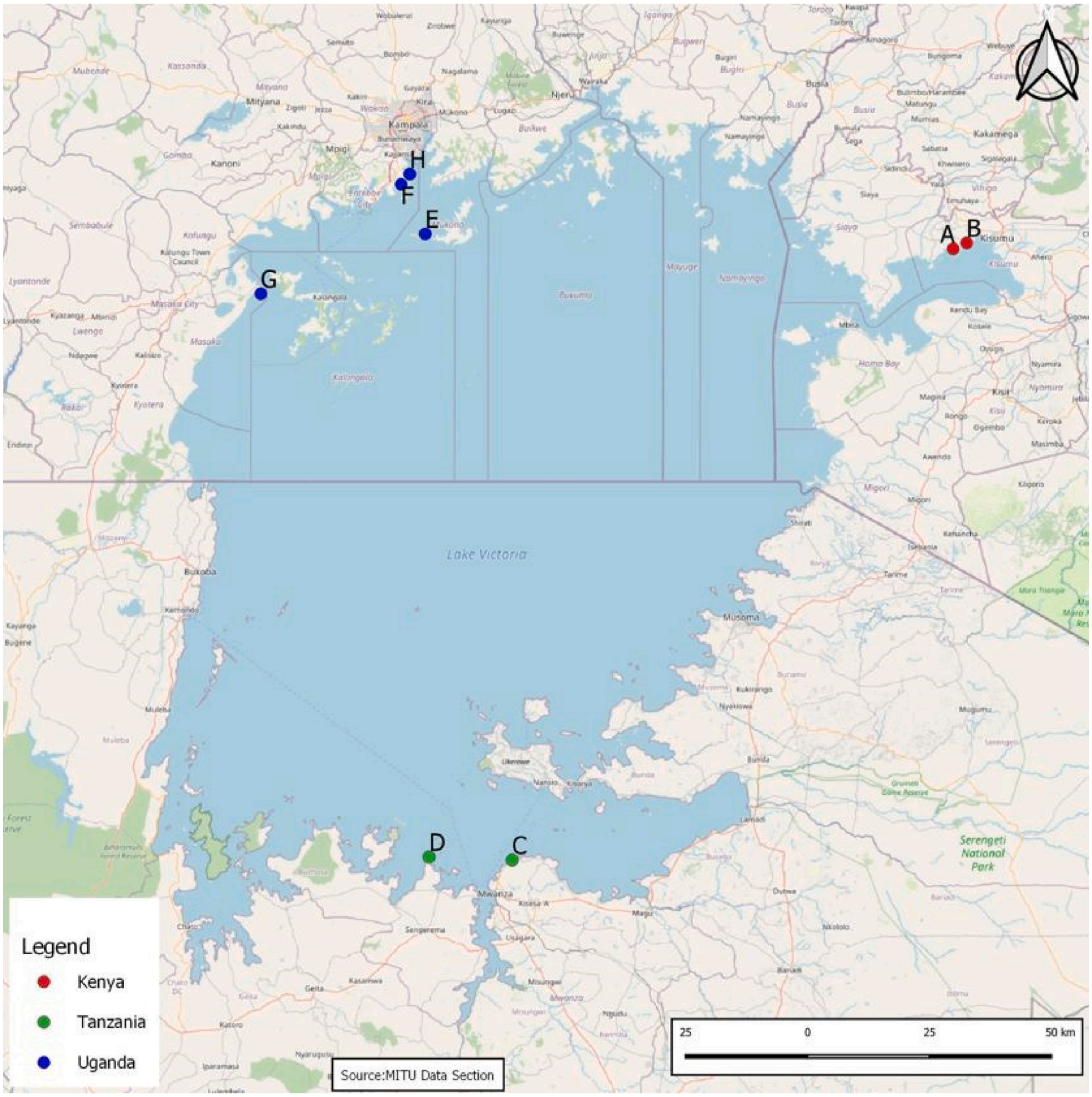

Fig. 1. Map showing study sites in Kenya, Tanzania, and Uganda.

Fig 2. Iris scanners (BMT-20 camera).

and service utilization. The questionnaire was developed in English and translated into the local languages of Dholuo, Kiswahili and Luganda used in Kenya, Tanzania, and Uganda, respectively.

Feasibility was assessed using the system performance as measured by the hardware failure, internet failure, camera failure or laptop malfunction. Acceptability was defined as the number of participants agreeing to iris scanning as a proportion of all the individuals approached.

The follow up study was conducted one month after enrolment in a randomly selected subset comprising 30% of participants enrolled at each site. Participants selected for follow-up were contacted by phone to schedule their re-scanning and a follow up interview. Before administering the questionnaire, participants were requested to participate in iris re-scanning to confirm their identity. The follow up questionnaire covered the same topics as at baseline.

2.4. Statistical analysis

Data were directly entered into questionnaires on tablets programmed in Open Data Kit (ODK) for Tanzania and Ugandan sites and in CSEntry for the Kenyan site. Both data capture applications had inbuilt consistency and validity checks. Further data validation was done at each study site and the final datasets merged into one. Data queries were resolved by checking source documents. Data were then transferred to STATA version 16 (StataCorp, TX, USA) for analysis. A descriptive analysis of participants' demographics was conducted by study site and overall. Median age and interquartile ranges were calculated. The frequency and percentage of participants with each level of the categorical variables were calculated and presented by site and overall. The number of participants accepting iris scanning, and the number of attempts at scanning were summarised using proportions to represent iris scan acceptability, and successful scanning outcome, respectively. Successful scanning outcome was defined as obtaining a successful initial iris scan and correctly identifying participants during follow-up. Acceptability and outcomes of iris scanning were compared for the subset of participants with follow-up data to examine any changes.

2.5. Ethical considerations

Ethics approvals were obtained from the following institutional and national ethics committees: KEMRI Scientific and Ethics Review Unit in Kenya (SERU# 3593); the National Health Research Ethical Committee (NatHREC #: MR/53/100/637 & 659) in Tanzania; the UVRI Research Ethics committee (UVRI REC# 605), the Uganda National Council for Science and Technology (UNCST SS#: 4470) and the LSHTM ethics committee (LSHTM#: 22,449 and 22639). Detailed study information was shared with every study participant before they were invited to take part in the study. Study procedures were only implemented after obtaining written informed consent from the participants.

3. Results

3.1. Demographics

Overall, we recruited 1199 out of 1200 individuals invited to participate in the study; 150 participants in each of seven communities in Kenya and Uganda and 149 participants in one community in Tanzania. The overall median age of participants was 33 (IQR, 24–42) years, with the median ages ranging from 28 to 36 years in participating sites (Table 1). Overall, most study participants were women (56%), had primary level education (58%), and were married or cohabiting (63%). The majority of people across all sites were Christians, comprising Catholics (35%), Protestants (21%) and Pentecostal/Evangelicals (24%). Overall, 15% of the participants reported that they were living with HIV with HIV prevalence ranging from 3% to 24% across sites.

3.2. Acceptability and success rates of iris scanning

Iris scanning was found to be acceptable by 1193 out of 1199 (99%) study participants (Table 2). The acceptability of iris scanning was 100% in the fishing communities in Kenya. Two (<1%) participants in Tanzania and four (1%) in Uganda declined iris scanning. Out of the six participants who declined iris scanning, two said they feared the medical effects of the scan on the eyes or body, scanning of iris failed for one participant with albinism, one participant refused because of a pre-existing eye problem while the other two did not provide reasons for refusal. All iris scan refusals were in people between the ages of 25 and 44 years.

The overall success rate for iris scanning was 99% (1178/1193) with successful iris scanning reported in 95–100% of cases across the sites (Table 2). Overall, 949 (81%) participants had a successful scan on first attempt, 116 (10%) on second attempt and 113 (9%) after three or more attempts. There were 56 (5%) participants who reported that they had challenges while undergoing iris scanning. The problems encountered by the study participants included repeated attempts due to poor internet connection (n = 22), pain in the eye due to prior eye injury and albinism (n = 10). teary eyes due to the camera's flickering light (n = 9), and lengthy iris scanning process due to failure of the scanner to detect one iris (n = 2).

Table 1
Characteristics of participants in a survey to assess acceptability of iris scans among residents in Lake Victoria fishing communities in Kenya, Tanzania, and Uganda.

Characteristic	Tanzania (MITU) (n = 300)	Kenya (KEMRI) (n = 300)	Uganda (MUL) (n = 300)	Uganda (UVRI/ IAVI) (n = 299)	Total (N = 1,199)
	n (%)	n (%)	n (%)	n (%)	n (%)
Median age (IQR)	36 (27–45.5)	34 (25–43)	34 (27.5–40)	28 (21–37)	33 (24–42)
Sex					
Male	150(50)	121(40)	140(47)	120(40)	531(44)
Female	150(50)	179(60)	160(53)	179(60)	668(56)
Religion					
Catholic	126(42)	32(11)	100(33)	163(55)	421(35)
Protestant	51(17)	80(27)	60(20)	57(19)	248(21)
Pentecostal	30(10)	128(43)	70(23)	55(18)	283(24)
Muslim	39(13)	1(0)	47(16)	14(5)	101(8)
Other	54(18)	59(20)	23(8)	10(3)	146(12)
Education					
None	40(13)	21(7)	29(10)	18(6)	108(9)
Primary	192(64)	165(55)	160(53)	182(61)	699(58)
Secondary	63(21)	91(30)	101(34)	97(32)	352(29)
Tertiary	5(2)	23(8)	10(3)	2(1)	40(3)
Marital status					
Married/ cohabiting	192(64)	201(67)	216(72)	152(51)	761(63)
Separated/ divorced	26(9)	10(3)	39(13)	56(19)	131(11)
Widowed	15(5)	29(10)	9(3)	11(4)	64(5)
Single/never married	67(22)	60(20)	36(12)	80(27)	243(20)
HIV positive	9(3)	44(15)	44(15)	71(24)	168(14)

3.3. Repeat survey and iris scan

The median age of 341 participants selected for follow-up iris scanning was 34 (IQR 25–41) years; 234 (69%) were female. Characteristics of selected participants were similar to those of all participants recruited during initial scanning (Table 3). The acceptability of repeat iris scanning among the participants was 99% with 340 out of the 341 participants accepting to undergo repeat iris scanning (Table 3). The reason for the refusal was fear that repeated iris scanning may affect the eyes.

All the 340 participants who accepted iris scanning had successful scans, with 307 (90%) scans succeeding on the first attempt; 25 (7%) on second attempt and 8 (2%) after three or more attempts. Only 2 (1%) participants reported that they experienced pain in the eyes while undergoing iris scans. The proportion of participants who reported that they would recommend iris scanning for identifying people in healthcare or research was 99% during follow up compared to 96% in the initial iris scanning. The proportion that reported that it was very easy to undergo iris scanning during follow up was 77% compared to 67% during the initial scan.

4. Discussion

We conducted a multisite observational study to examine the acceptability of biometric iris scan for potential use in identifying participants enrolled in research studies. Our study showed high (99%) acceptability for both initial iris scan and the repeat scan one month after enrolment among participants in fishing communities around Lake Victoria. High rates of biometric iris scan acceptability have been reported previously in different populations in low- and middle-income settings including health care providers enrolled in vaccine trials (99%), patients attending HIV care clinics (98%), and genetics studies (100%) [22,23,27]. Our findings confirm that acceptability of iris scanning for biometric identification remains high in the community in the research context where participation is voluntary and not linked to

Table 2
Baseline acceptability and outcomes of iris scanning among residents in Lake Victoria fishing communities in Kenya, Tanzania, and Uganda.

	Tanzania (MITU)	Kenya (KEMRI)	Uganda (MUL)	Uganda (UVRI/ IAVI)	Total
Accepted iris scanning					
Yes	298(99)	300 (100)	296(99)	299 (100)	1193 (99)
No	2(1)	0(0)	4(1)	0(0)	6(1)
Outcome of iris scanning*					
Successful	298(100)	285(95)	296 (100)	299 (100)	1178 (99)
Unsuccessful	0(0)	15(5)	0(0)	0(0)	15(1)
Number of iris scan attempts†					
One	257(86)	254(85)	196(65)	242(81)	949 (81)
Two	15(5)	22(7)	47(16)	32(11)	116 (10)
Three or more	26(9)	9(3)	53(18)	25(8)	113 (9)
Ease of iris scanning for participant*					
Very easy	195(65)	266(89)	214(71)	133(44)	808 (67)
Easy	96(32)	17(6)	60(20)	148(49)	321 (27)
Somewhat easy	6(2)	1(0)	14(5)	11(4)	32(3)
Not easy	1(0)	16(5)	8(3)	7(2)	32(3)
Experienced problems during iris scan*‡					
No	281(94)	–	280(93)	276(92)	837 (93)
Yes	17(6)	–	16(5)	23(8)	56(6)
Would recommend iris scan it to other people? *					
No	26(9)	9(3)	8(3)	4(1)	47(4)
Yes	272(91)	291(97)	288(96)	295(99)	1146 (96)

*Denominator is the number of participants who accepted iris scan.
† Denominator is the number of participants who had successful iris scan.
‡Data on problems experienced while undertaking iris scan were not reported in one site.

Table 3
Acceptability and outcomes of repeat iris scanning among residents in Lake Victoria fishing communities in Kenya, Tanzania, and Uganda.

	Tanzania (MITU)	Kenya (KEMRI)	Uganda (MUL)	Uganda (UVRI/ IAVI)	Total
Median age (IQR)	37 (26–46)	35 (28–40)	35 (27–41)	30 (21–37)	34 (25–41)
Sex					
Male	32(45)	30(33)	45(50)	0(0)	107(31)
Female	39(55)	60(67)	45(50)	90(100)	234(69)
Accepted iris scanning					
No	0(0)	0(0)	0(0)	0(0)	0(0)
Yes	71(100)	90(100)	89(99)	90(100)	340 (100)
Outcome of iris scanning*					
Successful*	71(100)	90(100)	89(99)	90(100)	340 (100)
unsuccessful	0(0)	0(0)	0(0)	0(0)	0(0)
Number of iris scan attempts†					
One	71(100)	69(77)	80(89)	87(97)	307(90)
Two	0(0)	15(17)	9(10)	1(1)	25(7)
Three or more	0(0)	6(7)	0(0)	2(2)	8(2)
Ease of iris scanning for participant*					
Very easy	67(94)	79(88)	75(83)	42(47)	263(77)
Easy	4(6)	10(11)	14(16)	46(51)	74(22)
Somewhat easy	0(0)	1(1)	0(0)	0(0)	1(0)
Not easy	0(0)	0(0)	0(0)	2(2)	2(1)
Experienced problems during iris scan*‡					
No	71(100)	–	89(100)	88(98)	248(73)
Yes	0(0)	–	0(0)	2(2)	2(1)
Would recommend iris scan to other people*					
No	4(6)	0(0)	0(0)	0(0)	4(1)
Yes	67(94)	90(100)	89(100)	90(100)	336(99)

*Denominator is the number of participants who accepted iris scan.
†Data on challenges while undertaking iris scan were not reported in one site.

either health services or other government services from which participants draw direct benefits. Availability of a reliable and accurate unique participant identification method ensures validity of findings from longitudinal studies. It also helps to overcome the limitations of conventionally used methods of participant identification. These limitations include multiple registration, breach in confidentiality associated with use of names and inaccuracies or errors arising during documentation or verification of personal identifiers [9–12,14]. Similarly, the high acceptability rates for return visits aligns with findings in previous studies [22,23], and corroborates the self-reported satisfaction with the initial iris biometric scan in our study participants. Despite the high acceptability, it is noteworthy that the levels of awareness and prior use of biometric iris technologies in most populations remain low and participants express general safety concerns and anxiety about the physical effects biometric scanning could have on eyes [23]. Other reasons for hesitancy in accepting biometric iris identification include privacy and confidentiality concerns among patients and misconceptions about iris scanning [22,23]. Such concerns and additional considerations around adoption of new technologies need to be addressed to ensure successful use of biometric iris identification [23].

Apart from high acceptability, the outcomes of biometric iris scanning – obtaining a successful initial iris scan and correctly identifying participants during revisits – also had high success rates demonstrating the applicability of iris scanning under field conditions [28]. These high success rates were achieved using simple low-cost technology, operated by field staff with basic training on handling of biometric devices. Our observations strengthen the case for deployment of biometric identification using iris scans in field studies in resource constrained settings.

Most iris scans were successful on first attempt although multiple attempts at iris identification were common – in 19% and 10% of participants at baseline and follow-up respectively. There are known causes of iris biometric identification failures for example degradation of biometric performance, defined as an increase in the false non-match rate with increasing time between acquisition of enrolment and verification of images [29]; improper head positioning or device settings and operation, and cataract surgery or medications that affect the texture of the iris [30–32]. The increased success rates with multiple attempts and the short period between acquisition of enrolment image and verification revisit implies that poor head positioning, and incorrect operation of devices were more likely explanations of biometric scan failures.

The use of multiple study sites and the resulting high rates of successful follow up across sites are key strengths of this study. Some limitations are worth highlighting. First, the overwhelmingly high acceptability of iris scan observed in this study means that we have limited power to examine factors associated with non-acceptability of this procedure in this population. It is possible that sceptics did not come forth for enrolment, and we were unable to collect data on community members prior to conducting informed consent for the study. Such information would help to identify barriers to iris scanning and contribute valuable information for future planning. Second, our findings have greater external validity compared to those from studies conducted within healthcare settings. Fishing communities differ significantly from the general population in terms of degree of urbanization, and other health and socioeconomic indices that could potentially limit the generalizability of our findings. However, some of these differences that characterise fishing communities e.g. urbanisation have been shown not to impact acceptability of biometric iris identification in other studies. They were however differences in reasons for refusal of the Iris scan with the fishing community showing more concern for possible effects of scan to health compared to the general population study [22].

The high rates of successful follow up among participants in this study is a key strength that allowed exploration of additional information on the impact of initial scanning experience on future acceptability in an area where no biometric studies have been undertaken. Our study did not explore in detail the possible causes of difficulties with identification resulting in multiple attempts or actual identification. Although actual identification failures were rare in our study. Future studies can examine the reasons for identification failures.

5. Conclusion

The acceptability and applicability of biometric iris scan as a technique for precise identification and follow up of research participants is high in fishing communities in the shores of Lake Victoria. This technique may be very useful for longitudinal research studies to address the many health problems that exist in these communities. Although our study provides considerable evidence of acceptability and technical feasibility of using this technique in research in resource-constrained settings, successful use of these technologies in this context will require careful consideration of the potential barriers to adoption including low awareness, misconceptions, and safety concerns.

Authors contributions

Conception and design of the study: EO, ZK, JS, SK, BO, PF, HG, MP, FK, EB, PK, WK; study implementation: EO, ZK, BO, GN, SN, AS; statistical analysis PA, RH; Writing original draft: EO, PA; Critical revision of the manuscript for important intellectual content; SK, HG, JS, MP, EB, GN, ZK, SN, BO, UB, RH, BO, ER, PF, FK, AS, MK. All authors read and approved the final manuscript.

Declaration of Competing Interest

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

Acknowledgements

We acknowledge the Leadership and support of partner members of the Lake Victoria consortium for Health Research. Particular gratitude is made to; Jan De Bont, Anatoli Kamali, and William Kidega; the IAVI leadership who supported funding of this work. We are thankful to the study field team members; Edmund Kisanga, Derick Deogratias, John Luwayi, Bernard Dajo, Catherine Makokha, George Ochieng, Seth Owino, Esther Awino, Joseph Ssembatya, Geofrey Basalirwa, Mathias Wambuzi, Henry Kaloma, Patricia Mulungi, Marion Namuleme, Tom Wambi and Joel Odenyo for their invaluable effort in implementing the field work. More importantly, we thank all study participants for agreeing to provide information for the study.

Funding

The study was funded by IAVI with the support from other donors, including United States Agency for International development (USAID) [Grant No USAID_AID_16_0000_32]. The full list of IAVI donors is available at http://www.iavi.org. The contents of this manuscript are the responsibility of its authors and do not necessarily reflect the views of USAID or the US Government. The funder had no role in the conduct of the study and the publication of its findings.

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