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BIOMETRICS & KEY POPULATIONS

Biometrics: acceptability and feasibility when working with key populations

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Acceptability and Feasibility of Biometric Identification Systems in the Delivery of Health Services to Key Populations: a Narrative Review

Thesis

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Abstract

Introduction

Key populations are disproportionately burdened by HIV infections and addressing their health needs is a public health priority. Improving patient identification systems is recognized as a strategy to improve the delivery of health services. Biometric technologies offer solutions to various limitations of current identification systems. However, the implementation of biometrics identification systems (BIS) in the provision of health services raises concerns and questions among stakeholders. This review aims to contribute to improving health service delivery to key populations and provide insight into the applicability of BIS in healthcare by surveying the current state of knowledge regarding the acceptability and feasibility of BIS in the provision of health services to key populations, with an emphasis on low- and middle income countries.

Methods

A systematic search was performed in January 2016 of the PubMed, EMBASE, and Web of Science databases in order to identify relevant studies. After a selection process, 13 studies were included in the review. These studies were analysed inductively and deductively to find relevant themes and concepts.

Results

Biometrics are employed in varying healthcare contexts, such as tuberculosis treatment, HIV prevention and counselling, and antiretroviral therapy, but only four explicitly targeted key populations. The majority of the included studies was performed in Sub Saharan Africa and in Asia. All studies concerned fingerprint scanners, mainly due to their ease of use, affordability, individuality, and efficiency. The findings suggest that fingerprint scanning is acceptable among various populations. However, several concerns regarding privacy and security of data were identified. The findings indicate that by addressing such concerns through careful explanation of the system and adapting the system to the needs of users, the acceptability can be increased substantially. Experiences with the technology were largely positive and included reduced time required per participant, little need for training, and in some cases increased regard by patients.

Discussion

The findings of this review suggest that fingerprint-based BIS are largely acceptable and feasible, and can have a positive impact on health service delivery. However, further qualitative studies are required to investigate what determines the acceptability in varying health contexts and among different target populations. Privacy and data security remain much debated aspects of biometric identification, but the findings of this review suggest that service providers can implement a range of measures to improve security and enhance the privacy of service users. In order to improve the delivery of health services, BIS can be tailored to the needs of its end users and to the context in which they are implemented.

List of abbreviations

AIDS	Acquired immunodeficiency syndrome
BIS	Biometric identification system
FPR	Fingerprint reader
FSW	Female sex worker
GSM	Global system for mobile communications
HIC	High income countries
HIV	Human immunodeficiency virus
IDU	Injecting drug user
KP	Key populations
LIC	Low income countries
LMIC	Low and middle income countries
MIC	Middle income countries
MSM	Men who have sex with men
PC	Personal computer
PWID	People who inject drugs
PWUD	People who use drugs
SMS	Short message service
STI	Sexually transmitted infections
TB	Tuberculosis
TP	Transgender people
WHO	World Health Organization

Table of Contents

1. Introduction

Although the global number of AIDS-related deaths is dropping, HIV epidemics remain a major public health issue. It is well known that the burden of HIV is disproportionately high among key populations, such as people who use drugs (PWUD), sex workers (SWs) and men who have sex with men (MSM) (2, 3). Risk behaviours that are more common among key populations, such as needle-sharing and unprotected sex, lead to increased risk of HIV infection (4). Consequently, key populations need to have access to adequate health services (2). However, people from key populations face many social and legal barriers, including stigmatization and discrimination, which challenge their engagement in healthcare (5). As a result, access to and uptake of health services among key populations remains low and HIV incidence continues to be high (2, 6).

Improving the delivery of health services to key populations is widely recognized as a priority in the response to both concentrated and general HIV epidemics. Prior studies indicate that HIV infections in key populations have a substantial impact on the dynamics of general HIV epidemics (2, 3, 6). In 2014, the WHO published guidelines on HIV prevention, diagnosis, treatment and care for all key populations (2). In order to maximize impact, the WHO stresses that HIV-related services should be integrated where possible, and should be made “accessible, acceptable, affordable, and equitable” (2). In addition to expanding the coverage of health services for key populations, increasing the efficiency and effectiveness of the available health services to deliver care to key populations is crucial in reducing the burden of HIV (7).

Implementation of effective patient identification systems is identified as a strategy to enhance the delivery of health services. Accurate patient identification is crucial for ensuring that healthcare services are delivered to the right people and that health outcomes are improved (1). Misidentification of patients or participants can lead to a range of medical mistakes, such as erroneous medication administration (8). Furthermore, inadequate identification systems can result in fraudulent claims of healthcare and other forms of service abuse (9). As a consequence of patient misidentification, valuable resources are wasted and health outcomes are suboptimal (9). Therefore, improving patient identification systems can increase the effectiveness and efficiency of health care delivery.

Current patient identification systems in low- and middle income countries (LMIC) generally lack rigidity and can obstruct the uptake of health services. In most countries, patients are identified through conventional identifiers such as identity cards or name and date of birth (10). However, in some LMIC, such methods can present a variety of problems. For example, patients may not have a set address, may be illiterate and/or provide different spellings of their name, and may not know their exact date of birth (11). Furthermore, although many LMIC have established national identity systems, these perform variably and have been shown to exclude disadvantaged parts of the population (12). Furthermore, in the context of HIV-related health services, using names or other personal identifiers can raise privacy issues due to stigmatization and other socio-structural factors (1, 13). As a result, conventional patient identification systems are inadequate in conforming patient identities and can be a barrier to essential health services, especially for key populations.

Biometric identification systems (BIS) are gaining interest as innovative technological alternatives to conventional patient identification methods. BIS identify people through the recognition of physiological biometrics, such as fingerprint and ear shape, or behavioural biometrics, such as gait and eye movement (14). Currently, most BIS create templates of biometric features using pattern recognition algorithms, which can be stored in a database or compared with previously stored templates (15). The key principles are that biometric traits are to a large extent universal and unique per individual, consistent over time and cannot be lost or forgotten like identity cards and passwords (16). As such, biometric technologies support secure and reliable means of registering and identifying patients (17).

Several developments make biometric technologies increasingly relevant in healthcare settings in LMIC. First of all, through technological developments, biometric technologies are increasingly easy to use, accurate, affordable and mobile (17). Secondly, many LMIC are undergoing infrastructural improvements, making electricity and internet increasingly available, even in poorer areas (18). Thirdly, devices that can operate the identification systems, such as computers and tablets, are increasingly ubiquitous (19). Finally, there is an increasing amount of open-source software platforms that support BIS (10, 15). Together, these developments pave the way for the implementation of new technological solutions such as BIS to enhance patient identification in the provision of health services.

However, as the WHO stresses in the guidelines on essential HIV interventions, health services should be made “accessible, acceptable, affordable, and equitable” for key populations (2). Prior studies into consumers’ perspectives on biometric systems in general indicate that biometrics are often negatively associated with government control and that concerns regarding privacy and data security are common (20, 21). Given the sensitivity of health information and the socio-structural barriers that key populations face, health services implementing biometric technologies for patient identification should take into account the needs of key populations. However, knowledge of the acceptability of BIS among key populations is scattered and few studies have reviewed the feasibility of BIS in healthcare contexts. Therefore, this literature review aims to contribute to improving health service delivery to key populations and provide insight into the applicability of BIS by surveying the current state of knowledge regarding the acceptability and feasibility of BIS in the provision of health services to key populations, with an emphasis on LMIC.

1.1 Research question

What is the current state of knowledge regarding the acceptability and feasibility of biometric identification systems in the provision of health services to key populations?

2. Methods

2.1 Key concepts

The current study reviewed knowledge on the acceptability and feasibility of biometric identification systems (BIS) in health services for key populations, with an emphasis on LMIC. For the purpose of this review, acceptability was defined quantitatively as the extent to which BIS are tolerated by service users and qualitatively as the views and beliefs of service users regarding the use of BIS. Feasibility refers to those aspects that influence the extent to which BIS are operationally viable in the delivery of health services. In this review, BIS can be understood as systems that employ technology to identify patients based on biometric features. Several characteristics of BIS were included in this review; type of biometrics, hardware, software, and costs. Health services are considered “all services dealing with the diagnosis and treatment of disease, or the promotion, maintenance and restoration of health” as defined by the WHO (2). In the current study, the WHO’s definition of key populations was used, which states that key populations are “groups who, due to specific higher-risk behaviours, are at increased risk of HIV irrespective of the epidemic type or local context. Also, they often have legal and social issues related to their behaviours that increase their vulnerability to HIV” (2). Five main groups of key populations are described by the WHO; people who inject drugs (PWID), sex workers (SW), men who have sex with men (MSM), people in prisons and other closed settings, and transgender people (2). This study largely follows the WHO’s definition of key populations, except that instead of looking at PWID, this study also includes other people who use drugs (PWUD) as a key population. For the purpose of this study, the classification of low-, middle-, and high income countries (LIC, MIC, HIC) was adopted from the World Bank in February 2016.

2.2 Search strategy

In January 2016, systematic searches were performed of three scientific databases to identify relevant studies; PubMed, Embase, and Web of Science. This review is restricted to studies published since 2005 in order to exclude studies that concern outdated technologies, which would have provided substantially different experiences. Preliminary searches were performed in order to become familiar with the language used to describe the key concepts. Subsequently, search syntaxes were built for each database using the identified key terms and synonyms - Appendix A includes an overview of the final syntaxes that were used. The terms acceptability and feasibility were not included in the systematic searches, because studies can investigate these without explicitly stating so. The bibliographies of articles were searched manually to find additional earlier publications, which is often termed backward snowballing. Where possible, citation indices were searched using Web of Science and Google Scholar of relevant studies in order to find more recent publications - forward snowballing. Furthermore, the Global Health Library was consulted to search for studies from LMIC, but no additional studies were found.

2.3 Inclusion and exclusion criteria

This review included studies that were written in English or Dutch, were published since 2005, and used qualitative and/or quantitative methods to investigate the acceptability and/or feasibility of BIS in the provision of health services. Studies that reported implementation of a BIS in health services, but did not include any findings on its acceptability or feasibility were excluded. Peer-reviewed articles were preferred, but grey literature were included as well. However, reviews were excluded. No restrictions were placed on the study design and the type of health service or intervention. Although key populations were the focal point of this review, other study populations were included due to the limited amount of published studies. Similarly, there was a preference for studies performed in LMIC, but studies from HIC were included as well when they concerned any of the five key populations. Furthermore, since the review concerns technological systems that are sold commercially, studies that indicated having conflicting interests were excluded.

2.4 Study selection

The search strategy resulted in the identification of 226 studies after 41 duplicates were removed. The title and abstract of the 226 studies were screened for relevance, which led to the removal of 178 studies. Subsequently, 46 studies were read in full in order to assess their eligibility based on the in- and exclusion criteria. Of the 46 studies, 18 did not use a BIS, 9 did neither include data on the acceptability nor on the feasibility of the BIS, three studies were not written in English or Dutch, and three studies were not available. As such, 13 studies were included in the review.

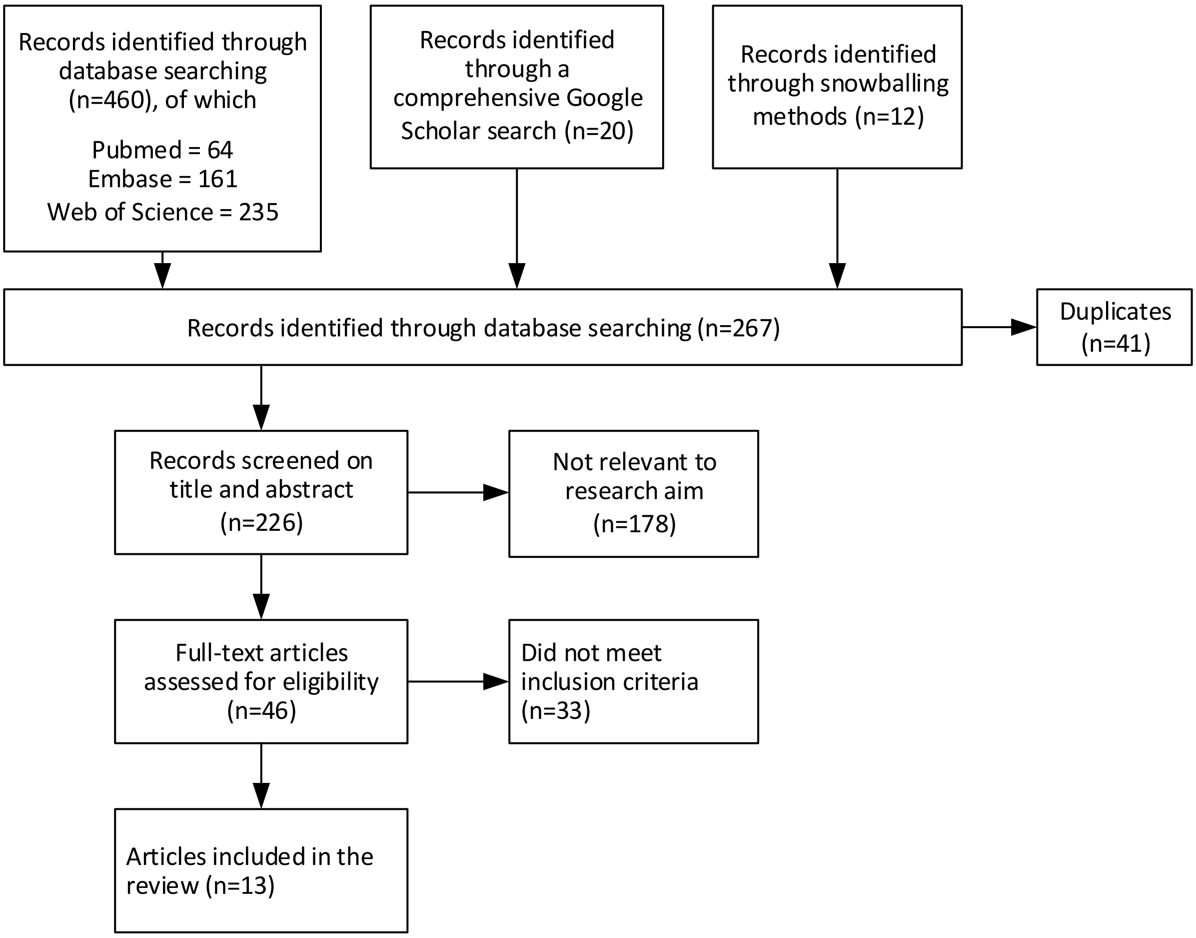

Figure 1. Flow chart of study search and selection

2.5 Data extraction and analysis

The included articles were analysed for relevant data, which were extracted by means of coding schemes. General characteristics of the included studies and the investigated BIS were summarized in excel sheets. Collected data regarding the acceptability and feasibility of biometric technology were analysed inductively to identify relevant concepts. During the coding process, the articles were read and reread carefully to minimize the possibility of missing relevant data. Based on the main concepts that were found, themes were developed to structure the data. The study findings were summarized and grouped under the corresponding themes. Subsequently, the data were double-checked to ensure that the findings reported in the review corresponded with the original articles.

3. Results

3.1 Study characteristics

The systematic search resulted in the selection of 13 studies. An overview of the study characteristics is shown in Table 1. Three non-peer-reviewed articles were included in the review, two conference papers on BIS in India and one letter to the editors of the Journal of Acquired Immune Deficiency Syndromes (JAIDS), which reports on the acceptability of fingerprint identification in HIV-related services in Los Angeles (22-24). Two of the included studies concerned a BIS, called 'eCompliance', but since they applied the system in different settings in India and Uganda, they were both included in the review (23, 25). Furthermore, two studies implemented BIS to prevent co-enrolment in clinical trials (26, 27). Although it could be argued that these studies therefore do not concern health services as defined by the WHO, both reported on the acceptability and feasibility of BIS in context of health and were included in the review due to their perceived relevance.

Four studies were explicitly aimed at key populations; two included MSM (24, 28), and two included female sex workers (FSW) (1, 22). Ten studies targeted specific diseases; four studies focused on tuberculosis (TB) (22, 23, 25, 29), five studies concerned HIV/AIDS (1, 24, 26, 28, 30). Two studies had no specific target groups (11, 27) and one study used biometrics in the surveillance of mobile pastoralists (31). Most of the studies (92%) took place in LMIC, of which four (31%) in LIC (25, 30-32) and eight (61%) in MIC (1, 11, 22, 23, 26-29). The majority of the studies took place in Sub-Saharan Africa (61%) and in Asia (31%), of which three were performed in India (22, 23, 29). Seven pilot studies (54%) were included in the review. Other studies were mainly observational (38%) (four cross-sectional and one retrospective cohort study) and one study (8%) was a case-control, as shown in Table 1.

Eight studies investigated the use of biometrics in the context of health services described as essential in the WHO guidelines for key populations (69%); four in HIV testing and counselling (HTC) services (1, 22, 24, 28), one in the provision of antiretroviral therapy (ART) (30), four in the prevention, diagnosis and treatment of TB (22, 23, 25, 29), and one in a condom program (22). Other applications of fingerprint biometrics included health demographics and surveillance (11, 31) and the prevention of misclassification and co-enrolment in clinical trials (26, 27). A study by Verbeke et al. in Rwanda discussed the pilot of a BIS in the nation's largest public hospital, the University Central Hospital of Kigali (32). However, since the article makes no further mention of the exact context in which the BIS was tested within the hospital, it is unclear what types of services and users the BIS supported.

Table 1 Study characteristics

No.	Author and year	Setting (urban / rural)	Type of biometrics	Stationary / mobile	Type of health service	Study design	Sample size	Age	Target populations (%)	Type of facilities
1	Batra et al. (2012) (23)	India (urban)	Fingerprint	Both	Prevention, diagnosis and treatment of tuberculosis (TB)	Qualitative and quantitative cross-sectional	>1400	n/a	TB patients (100%)	TB treatment centers
2	Bhatnagar et al. (2012) (29)	India (urban)	Fingerprint	Stationary	Prevention, diagnosis and treatment of TB	Qualitative cross-sectional	35	n/a	TB patients (100%)	TB treatment centers
3	Cohen et al. (2012) (24)	USA (urban)	Fingerprint	n/a	HIV testing and counselling	Qualitative cross-sectional	147	n/a	MSM (94%)	STD & HIV clinic
4	Harichund et al. (2013) (26)	South Africa (n/a)	Fingerprint	Stationary	HIV prevention research	Pilot study	+/- 21,728	n/a	n/a	Clinical research site
5	Okall et al. (2014) (28)	Kenya (urban)	Fingerprint	n/a	HIV testing and counselling	Qualitative cross-sectional	51	18-34	MSM (100%)	Public hospital
6	Paik et al. (2010) (22)	India (Urban)	Fingerprint	Both	HIV testing and counselling	Pilot study	550	n/a	FSW (52%), TB patients (48%)	Women's health clinic & TB treatment centers
7	Serwaa-Bonsu et al. (2010) (11)	South Africa (rural)	Fingerprint	Stationary	Health surveillance	Retrospective cohort study	19,176	All ages	n/a	Health and demographic surveillance sites
8	Snidal et al. (2015) (25)	Uganda (rural)	Fingerprint	Both	Prevention, diagnosis and treatment of TB	Case-control study	142	>18	TB patients (100%)	TB treatment centers
9	The SonLa Study Group (2007) (27)	Vietnam (rural)	Fingerprint	Stationary	Cholera vaccine research	Pilot study	153	18-41 (m=23)	n/a	Nursing school
10	Verbeke et al. (2013) (32)	Rwanda (rural)	Fingerprint	n/a	unspecified	Pilot study	342	n/a	n/a	Public hospital
11	Wall et al. (2015) (1)	Zambia (urban & rural)	Fingerprint	Both	HIV testing and counselling	Pilot study	153	>18	FSW (100%)	HIV clinic & women's support clinic
12	Weibel et al. (2008) (31)	Chad (rural)	Fingerprint	Mobile	Health surveillance	Pilot study	933	>12	Mobile pastoralists	n/a (only field surveillance)
13	Yu et al. (2005) (30)	Malawi (urban)	Fingerprint	Stationary	Antiretroviral therapy	Pilot study	1100	n/a	AIDS patients (100%)	ART clinic

3.2 Characteristics of the BIS

All of the included studies concerned the application of fingerprint biometrics in delivering health care. One study (22) mentioned having initially considered the use of voice recognition technology in TB clinics, but switched to fingerprinting due to issues with background noise, fear of contagion and the inability to automate the registration process. Most commonly cited reasons for choosing fingerprint biometrics as opposed to alternative biometric technologies include its ease of use (46%), affordability (38%), individuality (38%), efficiency (31%), portability (15%), accuracy (15%), and security (15%).

In most studies, the fingerprint readers were attached to a stationary PC or a laptop, although two studies (1, 11) used tablets instead. Of the eight studies that described the fingerprint readers (FPRs) that were used, all made use of optical FPRs, as opposed to capacitive, ultrasonic, or thermal FPRs (1, 11, 22, 25, 27, 29, 31, 32). However, none of the studies elaborated on the choice for optical FPRs. Seven studies described the software that was used. In four of the studies, the software was developed specifically for associated health programme (1, 23, 25, 26). One of these studies indicated that they set up a contract with a commercial company, which designed the system, and provided on-site support and training sessions (1). However, no details are provided of the contract's costs. Three studies reported using generic database management software, such as Microsoft Access (22, 31) and the open-source OpenMRS (11).

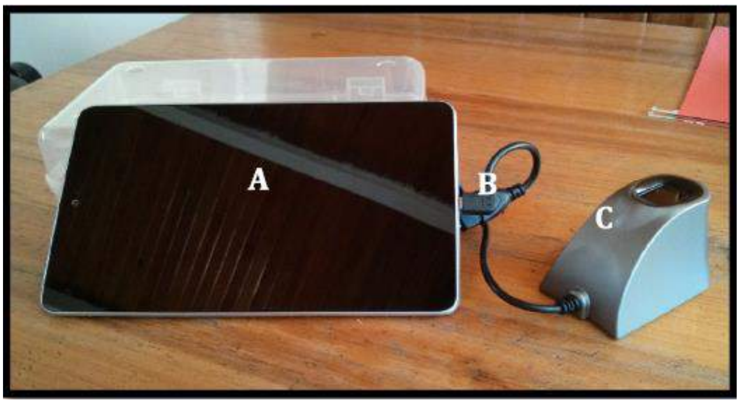

Figure 2. Three components of a BIS used in Zambia by Wall et al. in 2015; A) Tablet, B) USB connector C) FPR (1)

Figure 3. Interface of the BIS used by Wall et al. (1)

Table 2 Characteristicsof the BIS

Author and year	Type of biometrics	Stationary / mobile	Hardware	Software	Total costs
Batra et al. (2012) (23)	Fingerprint	Both	Fingerprint reader Computer GSM modem	n/a	n/a
Bhatnagar et al. (2012) (29)	Fingerprint	Stationary	Digital Persona U.are.U 4500 fingerprint reader Computer GSM modem	Windows Steady State Unspecified antivirus	n/a
Harichund et al. (2013) (26)	Fingerprint	Stationary	Computer Fingerprint reader	Biometric Co-enrolment Prevention System (BCEPS)	+/- $2000 for a computer and a fingerprint reader $0.71 annually per active record for system maintenance
Paik et al. (2010) (22)	Fingerprint	Both	Asus Eee PC 1005HA ($360) Digital Persona U.are.U4500 ($100) Nokia 1650 ($30) SMS Plan (<$4/year)	Smscountry.com subscription for receiving and archiving Microsoft Access	$490 for the hardware; $144/year for SMS system;
Serwaa-Bonsu et al. (2010) (11)	Fingerprint	Stationary	Secugen Hamster Plus ($80) and IV ($100) MorphoSmart CBM Windows XP Tablet	Microsoft Vista SQL Server database Windows Mobile 6.0 OpenMRS	n/a
Snidal et al. (2015) (25)	Fingerprint	Both	Asus Eee PC model ($200); Digital Persona U.are.U 4500 fingerprint reader ($70)	eCompliance ($0) Unspecified antivirus	$770 Hardware ($270) 2-day training ($500)
The SonLa Study Group (2007) (27)	Fingerprint	Stationary	Laptop Optical fingerprint scanner	n/a	n/a
Verbeke et al. (2013) (32)	Fingerprint	n/a	Microsoft Fingerprint Reader (<$50)	n/a	n/a
Wall et al. (2015) (1)	Fingerprint	Both	Portable single-finger multi-spectral imaging sensor Google Nexus 7 tablet	Unspecified, but provided and maintained by a commercial company	n/a
Weibel et al. (2008) (31)	Fingerprint	Mobile	IBM notebook W32 fingerprint scanner (Microsoft) Two Sunbag L solar panels Portable fuel generator	Desktop Identity (Griaule Biometrics) Microsoft Access 2002	n/a
Yu et al. (2005) (30)	Fingerprint	Stationary	Fingerprint reader Computer	n/a	$2000 for a single room clinic

3.3 Acceptability

Out of the 13 included studies, 11 reported on the acceptability of fingerprint-based BIS among participants, which are summarized in Table 3. Both qualitative and quantitative measures of acceptability were included. A study by Serwaa-Bonsu et al. employed fingerprinting to link records from health and demographic surveillance systems (HDSS) with those of health facilities in South Africa, aiming to improve knowledge of population health (11). At one of the HDSS sites, the Africa Centre in the KwaZulu-Natal province, where a fingerprint-based BIS had been used since 2007 for electronic health records, none of the 17,031 participants refused to take part. When they employed fingerprinting during a community-based surveillance in the north-eastern Mpumalanga province, Serwaa-Bonsu et al. found that around 2% of the 2,145 participants refused to provide a fingerprint (11). A study by Snidal et al. in Uganda found that none of the participants refused to provide a fingerprint for taking part in a TB treatment adherence study (25). Conversely, one study reported a 100% enrolment rate in a BIS used in a clinical trial for cholera vaccines in Vietnam (27), which suggests that no refusals were encountered.

Two studies conducted surveys to measure the acceptability of BIS in HIV-related services among MSM. In Kenya, Okall et al. found that 49 of the 51 participants answered “yes” to the question of whether fingerprinting was acceptable in context of HIV testing and counselling for MSM (28). A study was also focused on MSM (94% of the participants) and found that 72% of the participants believed that it was “very likely” or “likely” that they would provide their fingerprint in an HIV clinic (24).

Five studies reported qualitative observations of fingerprinting acceptability among participants. Two studies report that high levels of acceptability were observed by the health workers, stating that “patients had no trouble providing fingerprints” (23) and that “hardly any refusal was observed” (31). A study performed by Paik et al. in India, which employed fingerprinting in TB clinics as well as women’s support centres, found that there was high acceptance among TB patients receiving TB treatment in four clinics in urban areas of South Delhi, who were “not hesitant to give their fingerprint”. However, Paik et al. also found that FSW coming to women’s support centres “were much more hesitant to provide fingerprints” (22).

Exploring the acceptability of fingerprinting among FSWs in Zambia, Wall et al. (1) found that the level of acceptance was strongly affected by the context in which it took place. During a pilot study in which FSWs were approached in the field - i.e. on the street, in bars -, about half refused to participate. Conversely, among the FSWs that were fingerprinted at the clinic, only 2% refused. After the pilot, the researchers organized focus group discussions with FSWs to discuss the acceptability of the BIS and the factors that influenced it. Furthermore, a survey was developed based on the results of the discussions. The findings of the survey indicated that most of the FSWs would like to be fingerprinted in the clinic (47%) or at home (30%), whereas some would prefer a bar/club (9%), mobile units in the field (8%), or on the street (4%). Furthermore, results of the survey indicated that the presence of a Queen Mother – an older

FSW who is respected and trusted -, the presence of another FSW that has been fingerprinted before, and the use of incentives would increase the acceptability of the BIS. Furthermore, many FSWs would prefer providing fingerprints in the morning hours (62%) over the afternoon (22%) or the evening (16%) (1). These findings indicate that by adopting the BIS to the needs of the end users, the acceptability of the BIS can be increased.

The study performed by Bhatnagar et al. (29) was unique in that it interviewed 23 TB patients on their views of the implemented fingerprint scanners. Overall, they found that "about half of patients (52%) expressed positive feelings for the biometrics […] while the remaining patients did not offer an opinion". As Bhatnagar et al. are first to point out, these results may be biased due to participants' fear of giving a negative or 'wrong' answer, especially given the medical context, the pronounced social hierarchy in India and the fact that the included patients were from slum communities. Finally, one study performed in a public hospital in Rwanda reported that "patient acceptance of fingerprint enrolment appeared to be low", mainly due to privacy concerns (32). Participants worried that by providing their fingerprint to the hospital, which was government-owned, their information could be linked to other governmental institutions. As a result, there was little support for the BIS and the project was ended.

Table 3 Level of acceptability

No.	Author and year	Target population	Type of data	Reported acceptability
1	Batra et al. (2012) (23)	TB patients (100%)	Qualitative; observation	"patients had no trouble providing fingerprints"
2	Bhatnagar et al. (2012) (29)	TB patients (100%)	Qualitative; patient perception	"About half of patients (52%) expressed positive feelings for the biometrics, saying that it was "good", while the remaining patients did not offer an opinion"
3	Cohen et al. (2012) (24)	MSM (94%)	Quantitative; 5-point Likert scale	72%
4	Harichund et al. (2013) (26)	n/a	n/a	n/a
5	Okall et al. (2014) (28)	MSM (100%)	Quantitative; yes/no	96%
6	Paik et al. (2010) (22)	FSW (52%), TB patients (48%)	Qualitative; observation	"[TB] patients are not hesitant to give their fingerprint" "[FSW] were much more hesitant to provide fingerprints"
7	Serwaa-Bonsu et al. (2010) (11)	n/a	Rate of refusal (%)	0% and 2%
8	Snidal et al. (2015) (25)	TB patients (100%)	Qualitative; observation	No refusal was reported
9	The SonLa Study Group (2007) (27)	n/a	Enrolment (%)	100%
10	Verbeke et al. (2013) (32)	n/a	Qualitative; observation	"Patient acceptance of fingerprint enrolment appeared to be low"
11	Wall et al. (2015) (1)	FSW (100%)	Rate of refusal (%)	2%
12	Weibel et al. (2008) (31)	Mobile pastoralists	Qualitative; observation	"Hardly any refusal was observed"
13	Yu et al. (2005) (30)	AIDS patients (100%)	n/a	n/a

3.4 Feasibility

Of the included studies, 11 had implemented fingerprinting technologies in practice. The key findings with regard to the reported feasibility in the studies are summarized in Table 4. Four main aspects could be distinguished in the findings that were reported; implementation requirements, practicality, reliability, and security.

Implementation requirements

With regard to the implementation requirements, the majority of studies reported that with some training, ranging from less than one hour (27) to multiple training sessions (29), staff was able to operate the systems. Few studies encountered technological issues during implementation; two reported that several updates had to be performed (11, 25) and one study stated that the system had to be redesigned in order to synchronize devices automatically (22).

Furthermore, two studies indicated that some test runs were required to determine the optimal sensitivity of the scanner (1, 32). As Wall et al. explain, it is possible to change the receiver operating characteristics (ROC), which define the extent to which the scanned fingerprint has to match the stored fingerprint in order to be accepted (1). When the threshold is set high, there is less chance of a false match where one person's fingerprint being recognized as another's, which is expressed as the false matching ratio (FMR) or the false acceptance ratio (FAR). At the same time, a high threshold means that the false rejection ratio (FRR) is greater, which would require participants to re-scan their fingerprint until there is a match.

Practicality

Several practical issues were encountered in the studies that had implemented fingerprint technologies. A recurring problem was that participants were difficult to enrol, either due to scars and cuts on their fingertips (11, 31, 32), indistinct fingertips (26), or decorations such as henna tattoos (31). For example, the study by Weibel et al. in Chad concerned nomadic groups, who mostly held agricultural occupations and worked with their hands a lot. As a result, many of them had scars and cuts on their hands, and at the same time it was common for them to have cultural henna tattoos, which meant that more than 10% of the participants could not be enrolled (31).

Various studies reported on issues with the hard- and software that were used. The majority of these problems related to the hardware, such as device crashes (1), USB connectivity issues (1), physical damage (29), and power issues (1, 29, 31). One study in a TB treatment centre in India reported that some of the staff members used the computers for purposes other than work (i.e. entertainment), which led to problems with viruses that rendered the system unusable (29). To solve this issue, Windows Steady State software was installed to prevent changes in the system and staff was instructed to use the devices for work only.

From the included studies, some practical benefits associated with the use of fingerprint technology could be identified. Four studies indicated that by using fingerprints, the time required to register participants could be reduced (22, 25, 27, 30). As Yu et al. describe, the time taken for new patients in an ART clinic in Malawi was reduced from around 10.3 minutes to roughly 9.2 minutes, and for follow-up visits from around 6.1 to approximately 3.4 minutes (30). However, one study reported that after registering more than 280 patients, fingerprint recognition times slowed from "near instantaneous" to over 15 seconds, causing frustration among staff and patients (22).

Several studies pointed out that fingerprint technology is practical, because it can be used without having to rely on stable internet connections. Since internet networks are not yet reliable in many areas, GSM networks were used in four studies to store and communicate data. In these studies, a GSM modem was connected to the operating device - i.e. computer or tablet - or was integrated into the device, which could upload templates of registered fingerprints and data regarding patient compliance (22, 23, 25, 29). For example, the eCompliance program is designed to increase treatment adherence among TB patients and has been implemented in India and Uganda (23, 25). Upon enrolment, an attendance log is created for a participant, which is coupled to a unique code and fingerprint template. The BIS used in eCompliance can keep track of the treatment adherence, by scanning participants' fingerprints during each follow-up visit. The information gathered on the terminal can be sent automatically to a secure server through text messages. In the messages, only attendance data is included and no personal information to safeguard the participant's privacy. As such, the data can be updated continuously to ensure that the involved health workers are aware of which patients have received their treatment (23, 25).

Reliability

Eight studies reported findings on the reliability of the BIS that were used, as shown in Table 4. None of the studies reported that the BIS were unreliable, although several studies took measures to increase the reliability of the fingerprint readers. For example, Bhatnagar et al. registered two fingerprints per participant, so if one didn't work, the other could be used as well (29). To increase the reliability of the system, Paik et al. made each participant scan their finger four times to create a reliable template (22). Several studies indicated that they encountered problems with false rejection of participants, but the problems could often be resolved by re-scanning a fingerprint one or two times (1, 27). Overall, these findings indicate that fingerprint-based BIS are reliable to a large extent.

Security

Ensuring the security of the hardware and the collected data was reported as a key aspect in the feasibility of BIS in healthcare. Four studies indicated that the BIS were protected by only allowing designated staff to handle the system and requiring them to log in using passwords and/or biometrics (1, 22, 25, 26). Furthermore, three studies explained that data stored in the databases was encrypted (23, 25, 27). One study that collected fingerprints of FSWs in Zambia using tablets described that software was installed, which could track the devices and clear data remotely if the devices were stolen (1). These findings show that there are various ways in which data collected in the BIS can be secured.

Table 4 Main aspects related to the feasibility of fingerprint identification systems

		Low income countries				Middle income countries	
Study		Snidal et al., 2015 [#]	Verbeke et al., 2013 [#]	Weibel et al., 2008 [#]	Yu et al., 2005 [#]	Batra et al., 2012 [#]	Bhatnagar et al., 2012 [#]
Feasibility	Implementation	Four major software updates were necessary; Four training sessions over two days	Some trial-and-error testing was required to find optimal sensitivity settings for the fingerprint scanner	n/a	n/a	n/a	Multiple training sessions required; On-site help was offered during implementation
	Practicality	Easy to operate for those unfamiliar with computers; New registration in <10 minutes; Registration of a supervised dose in <1 minute	Patients needed assistance during enrollment, causing queues; Many agricultural workers could not be enrolled due to cuts and lesions	10.1% patients could not be enrolled due to henna or cuts and lesions; Cleaning fingertips and scanner with ethanol helped enrolling; Fuel generator was necessary to power the devices on clouded days	Time required per patient was reduced by approximately 1 minute; Personnel required to maintain operational was reduced from 9 to 6	Does not require internet connection; Attendance data is automatically stored; Automatic reminders are sent in cases of a missed dose	Various challenges; power surges, physical damage & computer viruses due to misuse for entertainment;
	Reliability	>99.5% accuracy	FRR = 1:342 FAR = <1:300,000	n/a	n/a	n/a	Two fingerprints were registered for each participant to increase the reliability
	Security	Health care workers can only access patient information by providing their own biometric fingerprints; Biometric information stored in the system is encrypted and cannot be exported	n/a	n/a	n/a	Private data is kept only on a secure server that has undergone an independent SAS 70 audit; Biometric data is stored in the terminals only in binary form	n/a

Table 4 Continued

Study	Middle income countries Harichund et al., 2013 [#]	Paik et al., 2010 [#]	Serwaa-Bonsu et al., 2010 [#]	The SonLa Study Group, 2007 [#]	Wall et al., 2015 [#]
Implementation	No challenges in learning how to use the program;	System had to be redesigned to synchronize across terminals in order to accommodate for HCWs working simultaneously in the field and the clinic.	Implementing new scanners required system updating to solve device and software incompatibilities	Required no specific skills to operate: local collaborators were able to operate the system after less than one hour of training or practice;	A half day training, covering workflows, troubleshooting of common problems and how to approach clients during recruitment; Some test runs were performed to determine the optimal sensitivity of the fingerprint reader
Practicality	Difficulties enrolling smokers with indistinct fingerprints or participants with dry hands; Communication challenges in network administration, due to outsourcing; Adaptable to any research environment	Data management can be performed off-line; Internet is only required to connect to the SMS server; Registration of >280 people significantly slowed registration and recognition times from near-instantaneous to about 15s, frustrating some of the patients and HCWs	Direct sunlight hinders successful fingerprint scanning; Scars and cuts (+/- 5% of people) limited the ability to scan multiple fingers	Required little physical space; Fingerprint reader could be powered through the laptop battery; Participant registration required 5 – 50 seconds (mean=6); In some cases, scanner and/or fingertip had to be wiped before successful enrolment	GSM network was not always stable, but the data could be cached automatically; Some driver issues and device crashes were encountered and solved; Staff members sometimes forgot to charge the devices
Reliability	"External evaluation […] found that the system was accurate"	For each participant, one finger was scanned four times to create a reliable template	Lower enrolment rates among children <3 years +/- 2% failure to enroll due to technical problems	5% false rejection upon first try, 0% on second or third; No false acceptance detected	FRR: 1/1000 FAR: <1/10,000
Security	The biometric co-enrolment prevention system was password protected and only staff designated by the principal investigator were given access; Operating staff were required to login using their fingerprints	New registrations and other changes in data only possible when the clinic counsellor has provided their fingerprint in the last hour; Attempts to register a new counsellor trigger an SMS alert to existing counsellors	n/a	Only templates of the fingerprints were stored in the database, so no distinctive features could be retrieved	Devices were kept in a locked location at night; Each device had software for real-time tracking and clearing if stolen; Record database was password-secured

4. Discussion

The aim of this study was to survey the current state of knowledge regarding the acceptability and feasibility of biometric identification systems in the provision of health care to key populations. A systematic search identified 13 studies that were included in the review. The studies were performed in varying healthcare contexts, with different target populations, and mostly in LMIC. Clearly, the context of a study plays a major role in the reported experiences with biometric technologies and parties interested in implementing BIS should always take their specific context into account. The findings of this review can be used to inform stakeholders who are interested in or involved in the implementation of biometric technologies for patient identification.

4.1 Main findings

All of the included studies concerned the application of biometric fingerprinting technologies for patient identification. Findings of the included studies suggest that fingerprint-based identification systems are largely acceptable, feasible, and have a positive impact on healthcare delivery. Fingerprint-based systems were most commonly used because of their ease of use, low costs, individuality, mobility, and efficiency. Several problems with hard- and software were described with regard to the implementation and daily use of the BIS, but the findings suggest that these could be solved within reasonable time. In most studies, some training was required to familiarize the staff with the system, although multiple studies specifically commented on the ease of use. The findings indicate that fingerprint-based BIS are to a large extent reliable and secure, and that a variety of additional measures can be implemented to enhance security of data and hardware. Together, these findings suggest that fingerprint-based BIS are to a large extent feasible for implementation in various healthcare contexts

The majority of the included studies reported high levels of acceptability, but varying parameters of acceptability were used. Few studies directly measured the level of acceptability among participants, whereas many used indirect measures, such as enrolment rates. As such, many of the reported levels of acceptability are based on assumptions that when patients enrol in health programs using biometrics, they perceive the technology as acceptable. However, the included studies were performed in healthcare contexts and with disadvantaged populations, who generally have limited access to healthcare. Therefore, it can be argued that the results of the studies are prone to bias, since the participants might have been motivated by fear of exclusion from health services, or wanting to 'please' the healthcare providers / involved researchers. Nevertheless, the findings provide support for further investigation of the application of BIS in healthcare contexts, even with key populations.

4.2 Privacy

In the debate on biometric technologies, privacy remains one of the most discussed topics. On the one hand, biometric technologies are often regarded as privacy-invading and remain controversial among many stakeholders (20). On the other hand, there are groups that believe privacy can be improved by using biometric technologies (REF). In the literature on biometrics and privacy, several main privacy risks associated with biometric identification are discussed. Often recurring is the fear for an Orwellian society, where biometrics are used for surveillance, especially by governments and without people knowing – "Big Brother is watching you" (33). This fear was also one of the main reasons a fingerprint-based BIS used in a government-owned hospital in Rwanda was not accepted by many patients (32).

However, although the fear for state control or unknown parties being able to link private information through biometrics is valid, it is uncalled for in the majority of healthcare applications for several reasons (34). As Woodward explains, BIS generally store computer-generated templates of features, as opposed to actual biometrics, which are coupled to a unique identifying code in order to increase efficiency and accuracy (35). Furthermore, in healthcare contexts, BIS often use small decentralized databases, which was also found in the included studies, because the size of the database correlates with the time required for the identification of service users (17, 22). Since each database creates unique identifying codes and there is a wide range of different software used by the systems that apply varying algorithms to create templates, it is highly unlikely that participant information could be linked across organizations, unless the system is specifically designed to do so (14, 15, 36). As such, implementing a BIS can contribute to patient privacy and confidentiality.

Some of the included studies indicated that by using biometrics for identification purposes, as opposed to verification, participant privacy can be improved. Biometric verification entails that biometric technologies are used to verify that a person is who they claim to be, and therefore requires someone to claim an identity, for example by stating their name or showing a document (16). When an identity is claimed, the system can match the corresponding entry in a database with the biometric data that is provided. In contrast, biometric identification refers to the process of recognizing a person's biometrics, within a certain database (14). As such, biometric identification does not necessitate anyone to claim an identity and can thus enhance privacy, especially for those dealing with stigma.

In this review, few concerns with regard to privacy and the use of biometrics were found. A possible explanation for the is that worries expressed by participants were simply not registered by the operating staff members. Another explanation could be that participants feared that expressing such worries could exclude them from obtaining care or put them in disfavour with the health workers. It is also possible that any concerns were appropriately addressed beforehand by careful explanation of the purpose and use of the technology by the staff. Finally, it is also possible that the participants did not have any privacy concerns with regard to the use of BIS in health service delivery. Nevertheless, future studies into the acceptability of BIS in healthcare contexts should consider their design and ensure that patients can freely express their feeling towards the technology, for example by explicitly offering an alternative system for identification.

4.2 Security

Another central topic in the debate on biometric technologies is the security of the data that is stored. Especially in context of health information, ensuring the security of data is widely regarded as an essential factor in the acceptability of BIS (16, 17, 37, 38). In most countries, biometric data security standards are currently defined by more general legal guidelines on data and information security (38). The findings of this review indicate that there are a variety of measures that service providers can take to enhance the security of their system, such as login protection, encryption, and the use of tracking and clearing software. Furthermore, in certain applications, such as attendance tracking, the BIS can be set up not to store any private or personal information, further enhancing the confidentiality and security of the system. However, several studies also reported that measures were required to ensure the security of the devices that were used against theft or damage, indicating that careful consideration of the system's safety is necessary before and after implementation. Together, these findings suggest that biometric technologies can be implemented in various healthcare contexts with a reasonable level of security, as long as the providers take sufficient measures.

4.3 Strengths and weaknesses of this review

It should be noted that this review was performed by a single researcher, as opposed to multiple, as is common for systematic reviews. As a result, there has been limited discussion with regard to interpretations of the data and there is the possibility of interpretation bias. However, careful reading and rereading of the included studies and double-checking of the findings with the original data was performed to improve the validity of the results. The findings may have been further strengthened by assessing the quality of the included study, for example by using the PRISMA standard that is often used in systematic reviews.

Further limitations of this study concern the amount and type of studies that were included in the review. Although the aim was to investigate the acceptability of BIS in the provision of health services to key populations, only four studies were found that targeted key populations. Since these studies were also performed in different contexts, the ability to generalize the findings is limited. Furthermore, since most studies were performed in Sub-Saharan Africa and Asia, there is a possibility that the findings suffer from geographical bias. This bias may have been amplified by the choice for only including English written studies as opposed to for example including French and/or Spanish written, which are dominant languages in many parts of the world where HIV is still a major public health issue.

4.4 Recommendations

First and foremost, it is recommended that any parties interested in the implementation of BIS in the context of healthcare carefully consider the needs of the service users, specifically if those include key populations, to ensure that health services are accessible and acceptable to its users. The findings of this review indicate that BIS can provide valuable contributions to the delivery of health services, but at the same time various concerns are identified among the end users that need to be addressed. Especially in settings where key populations still suffer from serious socio-structural barriers, and where their behaviours may be criminalized, it is essential that their safety is ensured. Therefore, health programs should carefully assess the context and the end users in order to adapt the intended BIS to the situation. As the findings of this review indicate, the technology used in BIS is flexible in its application and allows providers to add various functions that can contribute to addressing the identified needs and concerns of service users.

When a BIS is to be implemented, it is recommended that the participants receive careful explanations of the system's functionality and purpose in order to increase its acceptability. Furthermore, to ensure that participants can make informed decisions, they should be provided with information regarding the health program and the BIS. An essential aspect of the end user's decision to participate or not is the context in which it is made. As Mordini and Ottolini argue, patients who need access to healthcare never really can provide free consent (8). However, by ensuring participants that they will be able to receive care regardless of their participation, and by always offering alternative identification systems for those who do not want to be registered in the BIS, health service providers can compensate for such effects.

Finally, there are still many unanswered questions regarding the acceptability and feasibility of BIS in the delivery of health services, especially among key populations. In future research, qualitative methods can be employed to explore the perceptions of service users and to investigate in depth those factors that determine the levels of acceptability. Furthermore, quantitative studies can contribute to creating more generalizable knowledge of the levels of acceptance among different population groups. Additionally, organizations interested in the application of BIS in health services would benefit from design studies that can show in detail how BIS can be tailored to different healthcare settings, while ensuring security of data and protecting confidentiality and privacy. Another important aspect that requires more attention in further studies is the complex legal framework for biometric technologies, specifically with regard to privacy and human rights. Although biometric identification systems are not without flaws, the findings of this study show that they can contribute to delivering health services in complicated settings and should not be disregarded as inherently unacceptable.

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7. Appendix A

7.1 Search syntaxes

PubMed 21-01-2016 (64)

1: biometric identification system* OR biometric technolog* OR (“biometric”[tiab] AND (“identification”[tiab] OR “authentication”[tiab] OR “registration”[tiab] OR “enrolment”[tiab])) OR fingerprinting[tiab] OR “Dermatoglyphics”[Mesh] OR dermatoglyphics[tiab] OR (("fingerprint"[tiab] OR "iris"[tiab] OR "retina"[tiab] OR "voice"[tiab] OR "palm vein"[tiab]) AND ("registration"[tiab] OR "scanner"[tiab] OR "scanning"[tiab] OR "identification"[tiab] OR "enrolment"[tiab] OR "recognition"[tiab])) OR “hand geometry”[tiab]

2: “Drug Users”[Mesh] OR drug user*[tiab] OR “people who use drugs”[tiab] OR “PWUD”[tiab] OR “people who inject drugs”[tiab] “PWID”[tiab] OR “PUD”[tiab] OR “Sex Workers”[Mesh] OR sex worker*[tiab] OR prostitut*[tiab] OR FSW[tiab] OR MSW[tiab] OR TSW[tiab] OR “Homeless Persons”[Mesh] OR homeless person*[tiab] OR “Homosexuality, Male”[Mesh] OR “men who have sex with men”[tiab] OR “MSM”[tiab] OR key population*[tiab] OR hidden population*[tiab] OR stigmatized population*[tiab] OR high risk population*[tiab] OR “hard to reach”[tiab] OR “hard-to-reach”[tiab]

3: “Harm Reduction”[Mesh] OR “harm reduction services”[tiab] OR "Opiate Substitution Treatment"[Mesh] OR “Opioid substitution”[tiab] OR “opiate substitution”[tiab] OR “HIV testing”[tiab] OR “HIV counselling”[tiab] OR “antiretroviral therapy”[tiab] OR condom program*[tiab] OR needle and syringe program*[tiab] OR needle exchange program* OR "Needle-Exchange Programs"[Mesh]

4: #1 AND (#2 OR #3)

Web of Science 21-01-16 (235)

1: TS=Biometric identification system* OR TS=dermatoglyphics OR TS=Biometr* OR TS=(Biometric* NEAR/2 (Identification OR authentication OR enrolment OR registration)) OR TS=((fingerprint OR iris OR voice OR retina OR face OR facial OR "palm vein") NEAR/5 (scanner OR scanning OR identification OR registration OR enrolment OR recognition)) OR TS=hand geometry

2: TS=drug user* OR TS=”people who use drugs” OR TS=”PWUD” OR TS=”people who inject drugs” OR TS=”PWID” OR TS=”injecting drug users” OR TS=”IDU” OR TS=”PUD” OR TS="sex work*" OR TS=prostitut* OR TS="homeless persons" OR TS=homeless* OR TS=((hidden OR key OR stigmatized OR hard-to-reach) AND population*) OR TS="men who have sex with men" OR TS="MSM"

3: TS=”harm reduction” OR TS=”opiate substitution” OR TS=”opioid substitution” OR TS=”HIV testing” OR TS=”HIV counselling” OR TS=”antiretroviral therapy” OR TS=”condom program*” OR TS=”needle exchange program*” OR TS=”needle and syringe program*”

4: #1 AND (#2 OR #3)

Embase 21-01-2016 (161)

1: biometr*:ab,ti OR 'biometry'/exp OR 'biometry' OR 'dermatoglyphics'/exp OR 'dermatoglyphics' OR dermatoglyphics:ab,ti OR ('fingerprint' OR 'voice' OR 'iris' OR 'retina' OR 'palm vein' OR 'face' OR 'facial') NEAR/2 ('identification' OR enrolment OR 'registration' OR 'scanner' OR 'scanning' OR 'recognition') OR 'hand geometry'

2: (drug NEAR/2 user*):ab,ti OR 'people who use drugs':ab,ti OR 'pwud':ab,ti OR 'pud':ab,ti OR 'injecting drug user':ab,ti OR 'idu':ab,ti OR 'people who inject drugs':ab,ti OR 'pwid':ab,ti OR 'prostitution'/exp OR prostitut*:ab,ti OR (sex NEAR/1 work*):ab,ti OR 'homeless persons':ab,ti OR (('high risk' OR stigmatized OR hidden) NEXT/2 population*):ab,ti OR (key NEXT/1 population*):ab,ti OR ('high risk' NEXT/2 group*):ab,ti OR 'men who have sex with men'/exp OR 'men who have sex with men':ab,ti OR 'msm':ab,ti

3: 'harm reduction':ab,ti OR 'opiate substitution therapy'/exp OR 'opioid substitution':ab,ti OR 'opiate substitution':ab,ti OR 'HIV test'/exp OR ‘HIV testing and counselling’:ab,ti OR 'antiretroviral therapy':ab,ti OR ‘antiretroviral treatment’:ab,ti OR (condom NEXT/4 program*) OR (needle NEXT/2 exchange NEXT/2 program*):ab,ti OR (needle NEXT/2 syringe NEXT/2 program*):ab,ti

4: #1 AND (#2 OR #3)