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An Exploration of Opportunities for Quantified-Self Technology in Diabetes Self-Care: A Systematic Literature Review

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Background and Purpose: To avoid the adoption of quantified-self technologies for diabetic self-care by trial and error, this study investigated quantified-self opportunities. The premise of the study was that the adoption of quantified-self technologies should be preceded by knowledge of the opportunities that are provided by the technology. In this respect, the research search question was, 'What are the opportunities for the use of quantified self technology in the management of diabetes in developing countries?'.
Methods: A systematic literature analysis was carried out to answer the research question. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed to select articles from four databases, which are PubMed, ProQuest, Web of Science and Science Direct. A total of 50 peer-reviewed journal and conference articles published between 2018 and 2024 were analysed.
Results: Literature analysis uncovered four opportunities for using quantified-self technologies in the management of diabetes. Opportunities include monitoring, adherence, reduced cost, and data collection and sharing.
Conclusions: The identified opportunities are informative and empower diabetic patients with knowledge that helps them with decision making prior to the adoption of quantified-self technologies for diabetic self-care. The results of this study are equally applicable to the adoption of any other technology, as it is important that the opportunities brought by a technology should be known before its adoption.

Keywords: diabetes, quantified-self technology, self-care, self-tracking, personalised treatment

1 Introduction

Diabetes is acknowledged as a chronic disease that is influenced by one's lifestyle and requires strict adherence to self-care practices [1]. Adherence requires strict self-management of routines that include diet, physical activities, medication, and blood glucose monitoring [2]. Keeping up with self-care routines is difficult due to several reasons, for example, pressure at work, life, or amnesia. Until now, research has confirmed that adherence to self-care routines has a significant impact on reducing diabetes attacks and emergency admissions in hospitals [3] [4]. Ellahham [3] confirmed that the self-management of diabetes can be improved by using artificial intelligence (AI) technologies that can help monitor the disease, of which quantified-self is one of those capabilities.

The term quantified-self refers to individuals who participate in the self-monitoring of various types of biological, physical, behavioural, or environmental data, which is perceived as a natural phenomenon because people always collect data about themselves [4]. Research has found that quantified-self technologies can collect data that includes eating habits, physical activity, taking medicine, sleeping patterns, and monitoring diseases [5][6]. Data collection is facilitated by quantified-self gadgets that include wristwatches, smartphones and other wearable digital devices [2][7][8].

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Although the literature has shown that the use of quantified-self tools is substantial in improving self-care for chronic diseases, its adoption in developing countries is not well-documented [9][10]. Mutunhu et al. [9] argued that to strengthen the adoption of self-monitoring technologies in developing countries, it is important that opportunities to use technology in the management of diabetes are identified and shared. Opportunities are prospects/situations brought about by quantified-self technologies that enable diabetic people to self-manage their ailments. Therefore, this study employed a systematic literature analysis to explore the opportunities of quantified-self technologies in the management of diabetes for the benefit of patients in developing countries. To this end, the premise of the study was that the adoption of quantified-self technologies should be preceded by knowledge of the opportunities that are provided by the technology. The premise was translated into the following research question, which is investigated this study, 'What are the opportunities for the use of quantified-self technology in the management of diabetes in developing countries?'. The results of this study are informative, uncovering quantified-self technology opportunities that citizens of developing countries need to know to integrate and benefit from quantified-self technology in the management of diabetes.

The remainder of this paper is organised as follows, Section 2 presents the background studies on quantified-self technology and identifies the gap in knowledge, Section 3 presents the methods, Section 4 presents the results, Section 5 presents the discussion, and Section 6 the conclusion of the study.

2 Quantified-Self Technology Background

This study reviewed fifteen peer-reviewed systematic literature analysis published articles on quantified-self technology adoption [10][11][12][13][14][7][15][16][17][18][19][20][9][21][22]. The analysis found that the first article on quantified-self technologies was published in 1990 [12], however, Kelly and Wolf are attributed to have founded the quantified-self phenomenon in 2007 [4]. Although the analysis found varied results from the articles, most investigated the adoption of quantified-self technologies within the health and well-being of individual people, and patients under health care practitioners. Concerning well-being, many articles investigated applications of quantified-self in tracking sports, daily activities, diet, and sleeping patterns [7][15]. For studies that applied quantified-self technology in health, it was found that it can be used to enforce adherence to medication, diet, and monitoring blood glucose levels [12].

The analysed studies revealed motivations for using quantified-self technology [14][13][15][22]. Jiang and Cameron [13] identified motivations as behaviour change, compliance, improved health, rewards, and self-efficacy. In addition, quantified-self technology was found to be helpful in goal-setting [21][19][20].

Three papers focused on the design of quantified-self applications [11][18] [14]. Lentferink [11] found that a well-designed quantified-self application should be usable, persuasive, and provide affordance. Regarding design, Epstein et al. [14] found that self-tracking applications should be designed to change behaviour and encourage social connection between users.

Two papers discussed the ethics of using quantified-self applications [14][10]. The papers discussed issues of identity protection and data sharing with friends/ family through social media. It was revealed that if quantified-self data end up in the wrong hands, it may be misused against the person. In that respect, both studies recommended that the design of quantified-self applications should consider issues of privacy, security, and ethics.

Future research is recommended to focus on ethics [23][14], attitudes, barriers [7][23], social-cultural contexts [23][10], theoretical frameworks [23][14][13] and opportunities for quantified-self in diabetes self-care [9][21][24]. This study builds on Mutunhu et al. [9], and is backed by a gap in knowledge identified from an analysis of theoretical underpinnings of quantified-self studies. Of the 50 studies analysed in this study, 14 articles presented in Table 1 had underpinning theories. An analysis of the constructs of the underpinning theories uncovered that none had a construct that explicitly focused on identifying opportunities brought by technology. This indicates that the studies that were analysed in this study did not investigate the opportunities of quantified-self technologies in the self-care of diabetes. Based on the identified gap in knowledge, this study investigated the opportunities offered by quantified-self technology in diabetes self-care.

 J Health Inform Afr. 2024;11(2):17-30. DOI: 10.12856/JHIA-2024-v11-i2-481

Table 1. Quantified-self technology studies with theoretical underpinnings

Theory	Constructs	Studies that adopted the theory
Cognitive-affective-social-motivational model	• perceived usefulness • perceived ease of use • Effectiveness • feelings • social images	[25]
Unified Theory of Technology Acceptance and Use of Technology (UTAUT)	• performance expectancy • effort expectancy • social influence • facilitating conditions • gender • age • experience • voluntariness of use • behavioural intention • use behaviour	[26] [27][28][29]
Unified Theory of Technology Acceptance and Use of Technology 2 (UTAUT2)	• performance expectancy • effort expectancy • social influence • facilitating • hedonic motivation • price value • Habit • Age • Gender • experience • behavioural intention • use behaviour	[30][31]
Extended Valence Theory (EVT)	• utilitarian value • perceived risk • perceived return • trust • intention to purchase	[16]
Self Determination Theory (SDT)	• autonomy • competence • relatedness • Intrinsic motivation • Extrinsic motivation	[32]
Cognitive Motivation Relational Theory	• cognitive appraisal • emotional response • behavioral reactions • individual factors	[33]
Social Cognitive Theory	• personal factors • behaviour • environment • Reciprocal Determinism • Behavioural Capability • Observational Learning • Reinforcements • Expectations • Self-efficacy	[34] [35]

 J Health Inform Afr. 2024;11(2):17-30. DOI: 10.12856/JHIA-2024-v11-i2-481

Revised TAM model; Diffusion of Innovation; Self Efficacy; Social Exchange Theory	• perceived usefulness • perceived ease of use • Embedded Technology Self-Efficacy • Gender • Age • Perceived Risk • Privacy Concerns	[36]
Technology Acceptance Model; Health Information Technology Acceptance Model; Mobile Application Rating Scale	• Engagement • Functionality • aesthetics • information quality • Perceived ease of use • Perceived usefulness • Perceived disease threat	[37]

3 METHODS

This systematic review used the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol [38]. Adhering to PRISMA, the research systematically identified, selected, screened, examined and summarised published research articles on the opportunities provided by quantified-self technology in the management of diabetes.

3.1 Data Sources and Search Strategy

A comprehensive search was carried out in the year 2024 across the following five databases that host peer-reviewed articles: PubMed, ProQuest, Science Direct, and Web of Science. The search strategy encompassed variations and synonyms of keywords: "quantified self" and "diabetes".

(("lifelog" OR "life-log" OR “self-monitor*” OR “self monitor*” OR “self-track*” OR “self track*” OR “quantified self” OR “quantified-self” OR “self quantif*” OR “self-quantif*”) AND "diabet*")

However, due to the syntax discrepancies, the constructed search term was altered to align with the requirements of each database.

3.2 Inclusion and exclusion criteria

The inclusion and exclusion criteria are delineated in Textbox 1. To further strengthen the article search's overall comprehensiveness, citation chaining was done.

INCLUSION CRITERIA
- Studies published between 2018 and 2024.
- Research articles disseminated in the English language.
- Full text articles.
- Research findings published in a peer-reviewed scholarly journal and conference proceedings.

EXCLUSION CRITERIA
- Commentary pieces, editorials, and grey literature
- Studies on quantified-self technology but not focused on healthcare
- Studies not discussion quantified-self technology opportunities in healthcare
- Research using non-human primary empirical subjects, like goods, services, or marketplaces
- Non-peer-reviewed studies that include unpublished manuscripts, conference abstracts, and studies not undergoing rigorous peer review

Textbox 1: Inclusion/exclusion Criteria

 J Health Inform Afr. 2024;11(2):17-30. DOI: 10.12856/JHIA-2024-v11-i2-481

3.3 Screening

A total of 2831 articles were selected from the four databases, 41 articles from PubMed, 32 articles from Science Direct, 1589 articles from ProQuest, and 1169 articles from Web of Science. A total of 762 duplicates were eliminated, and, furthermore, 1724 were excluded because they did not meet the inclusion criteria. The abstracts, keywords, and conclusions of the remaining 345 articles were analysed, and 248 articles were excluded. There were 97 articles that met the inclusion criteria and were analysed by two researchers. The two researchers read through the 97 articles thoroughly and agreed that 47 articles did not meet the inclusion criteria. The remaining 50 articles were fully analysed by the researchers.

4 RESULTS

The results of the article selection are presented in a PRISMA flow chart in Figure 1. The flow diagram shows the selection process and the number of articles searched per database.

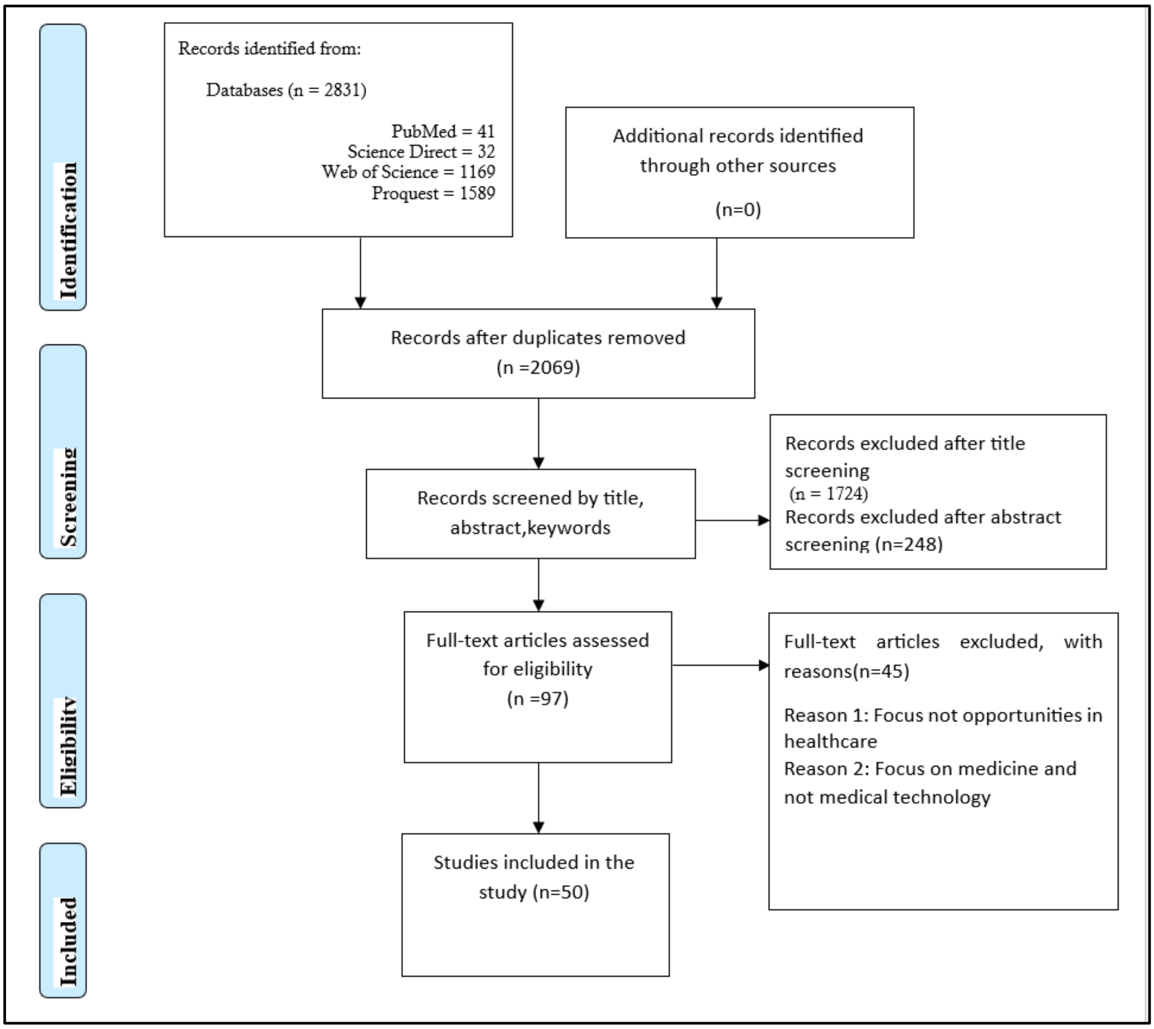


Figure 1. PRISMA 2020 flow diagram

4.1 Reviewed Articles

Table 2 provides a summary of 50 articles that were reviewed in this study. It identifies the opportunities for quantified-self technology in healthcare and gives a list of references. Table 2: Quantified-self technology opportunities

 J Health Inform Afr. 2024;11(2):17-30. DOI: 10.12856/JHIA-2024-v11-i2-481

Table 2. Quantified-self technology opportunities

OPPORTUNITY (Main theme)	SUB OPPORTUNITY (Sub-theme)	REFERENCES
Monitoring	Chronic disease monitoring	[28] [39] [40] [41] [42][43] [44] [45] [46] [47] [48][37] [49] [31] [50] [51] [6] [52] [53] [54] [55] [56] [57] [52] [58] [37] [59] [60]
	Disease tracking	[61] [32] [62] [48] [15] [2] [52] [62] [63]
	Monitoring treatment	[42] [31] [55] [63] [52] [64] [65] [48]
	Monitoring of physical activities and exercise	[24] [33] [61][48] [61]
Adherence	Reminders to take medication	[52] [55] [44] [59] [28] [50] [66] [51] [62] [37]
	Medical refill reminders	[26] [56] [42] [67] [68] [69]
Data Collecting and Sharing	Personalised Feedback	[52] [53] [33] [59] [57] [29] [68] [64] [2] [35] [64] [57] [35]
	Trend analysis of the disease	[69] [65] [47] [44] [59] [60] [50] [6] [56] [54] [64]
	Disease prediction analysis	[2] [41] [35] [29] [55] [56] [64]
	Patient-Physician data sharing	[67] [52] [62] [49] [69] [70]
Cost reduction	Reduced hospitalisation/visits to the clinic	[29] [49] [40] [26] [70] [67]
	Reduced healthcare care cost	[63] [71] [48] [49] [60] [30] [15] [55] [6] [56] [34] [25] [32]

4.2 Year of publication

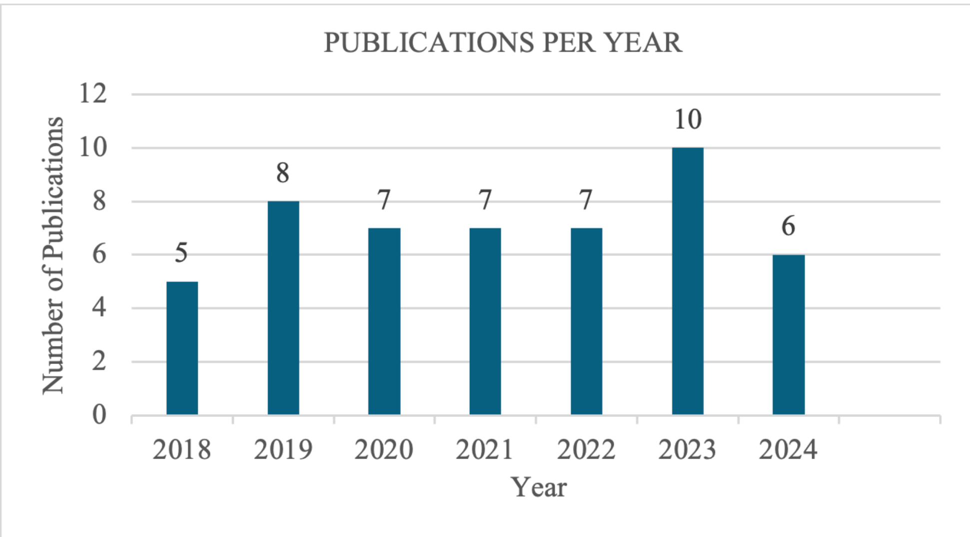


Figure 2 : Publications per Year

Figure 2 shows the annual publication trends of the analysed quantified-self articles. There appears to be a gradual peak in publications from 2018 (5) articles to 2023 (10) articles per year, showing a growing trend in quantified-self research. Although there is a general growth, some negative growths were observed between some of the years. Fluctuations could be due to that research on the quantified-self is still new and has not reached equilibrium. The lower number of publications in the year 2024 (6) could be because the year is now halfway (June), and more papers could not have been published.

4.3 Country where research was conducted

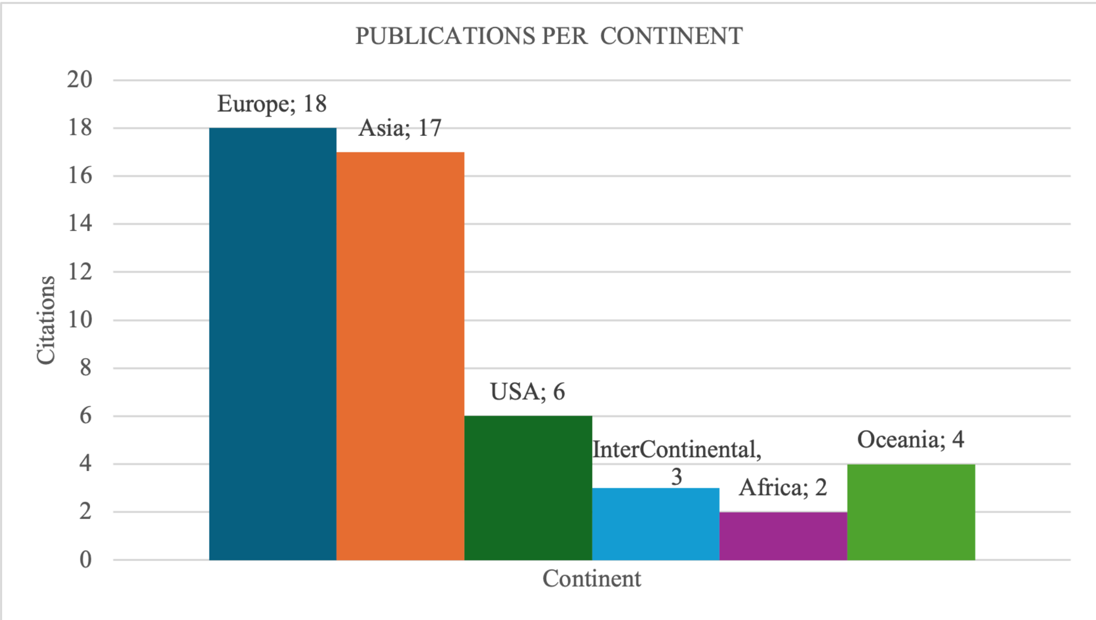


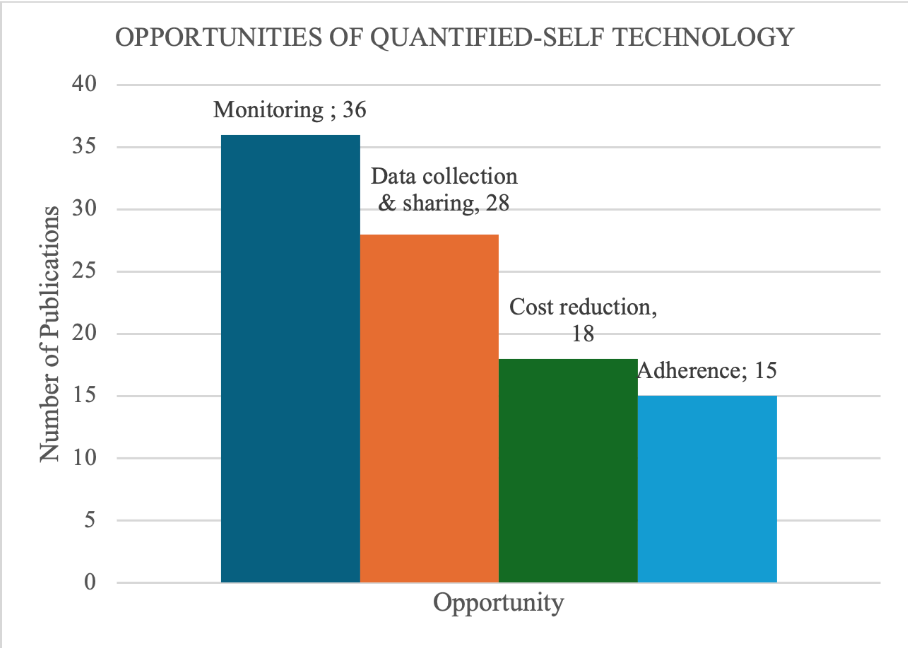
Figure 3. Frequency of Publications per Continent

Figure 3 shows that most of the publications are from Europe and Asia, with 18 and 17 publications, respectively. The two continents seem to be leading the research on quantified-self with over 80% of the total publications. There is low representation from the USA, Africa, and Oceania, with 6, 2, and 4 publications, respectively. There were four publications classified as inter-continental showing collaboration among academics from different continents.

4.4 Opportunities for Quantified-Self Technology

Opportunities for the use of quantified-self technology in the management of diabetes are depicted in Figure 4. The graph shows the four main opportunities that were identified from the literature analysis, monitoring, data collection & sharing, cost reduction, and adherence. The opportunity that was mentioned in most articles was monitoring, appearing in 36 articles, and the opportunity with the least appearances was adherence, featuring in 15 articles.

 J Health Inform Afr. 2024;11(2):17-30. DOI: 10.12856/JHIA-2024-v11-i2-481



Figurw 4. Opportunities of quantified-self technology

5 Discussion

This section discusses quantified-self technology opportunities and relates them to practical use cases of diabetic self-care management. This section answers the research question investigated in this study 'What are the opportunities for the use of quantified-self technology in the management of diabetes in developing countries?'. The opportunities identified from the systematic literature analysis are monitoring, adherence, reduced cost, and data collection and sharing. These opportunities are now discussed.

5.1 Monitoring

Quantified-self technology allows people with diabetes to monitor a wide range of health parameters, including blood sugar levels, blood pressure, exercise, diet, cholesterol, and stress [59]. Physiological monitoring provides information on glucose level fluctuations, which facilitates timely interventions if abnormalities are observed [48][52]. Various studies have shown the importance of quantified-self technology as an enhancer of self-care among diabetic patients tracking their ailments [44][45][40][61]. For example, in a case study of a self-tracking diabetic patient [61], the patient stabilised the blood sugar level by following a strict self-tracking routine involving diet and exercise. In a study carried out in New Zealand [42], quantified-self technologies were reported to have provided positive results in glucose monitoring, leading to improved health behaviours. In another study carried out in Sweden, quantified-self technologies provided positive results in monitoring motor symptoms, stress levels, dietary habits, and sleep [52]. Furthermore, studies carried out in Germany [34] and the Netherlands [62] found that using quantified-self technologies for fitness tracking was significant in improving physical fitness and glycaemic control compared to non-users. These case studies supported that quantified-self technologies can provide an opportunity for physiological monitoring in diabetic patients.

5.2 Adherence

There is a complex interplay of factors that affect the adherence to the taking of chronic medications by diabetic patients [73] [74]. Two factors that negatively affect adherence are forgetfulness and time management, which can lead to mortality [72]. Time management is complicated in situations where patients are required to take multiple drugs at different intervals [56]. To overcome the challenges of forgetfulness and time management, which are prevalent in young and old people, some research in health informatics has shown that implementing quantified-self based reminders can provide lasting solutions [26][42][44][68][67]. In addition, quantified-self technologies can track medication intake, dosages, and schedules helping patients to adhere. Ajana [71] claimed that quantified-self technologies can remind users through alarms to take medication, exercise, or increase their water intake. Furthermore, some studies [44][68] confirmed that improved adherence positively improves morbidity, lifestyle, and enhances the autonomy of young and old people. However, a study from India reported that self-tracking technologies were perceived as confusing and costly due to the requirement of frequent blood glucose measurements, leading to non-adherence [50]. In this regard, a study conducted in China [66] called for the implementation of quantified-self technology adoption awareness campaigns as a way to overcome nonadherence to chronic medications.

5.3 Collecting and Sharing Data

Accurate treatment of diabetes requires intensive data collection and analysis, which requires accurate capture, transmission, and interpretation of quality data [73]. In the realm of electronic health, quantified-self technology has been considered as a technology that can facilitate self-assessment [33], trend analysis [17], predictive analysis [64][74] and data sharing [2][22].

Quantified-self technology has the potential to increase health self-awareness in diabetic patients by accurately gathering and analysing physiological data [33]. Through the captured data, patients can receive feedback on their health status, recommendations, and alerts based on their needs [2][7]. In the case of autism management [64], patient data was found to be significant in analysing patterns associated with specific behavioural triggers. If disease patterns are understood in diabetic patients, they empower individuals to make informed self-care decisions, proactively adjust dietary and lifestyle habits, and seek medical assistance immediately when necessary [64] [2] [7]. In line with the findings, there are studies [59] [41] that emphasise that effective management of diabetes necessitates an understanding of how activities and daily routines are proportionally aligned with fluctuations in diabetes. Furthermore, quantified-self technologies allow diabetic patients to share data remotely with physicians, family, peers, or supportive communities[2] [22].

Quantified-self technology redefines patient-physician communication by integrating data from self-monitoring devices [64]. Data provide physicians with comprehensive information on patient health status, facilitating more informed treatment decisions, timely modification of treatment regimens, and ultimately improved diabetes management results [60] [52].

Socially, quantified-self technology can facilitate emotional support for elderly patients, allowing them to participate in virtual communities, exchange experiences, and receive encouragement from peers or caregivers [31]. Online networks provide valuable peer support, allowing people to share insights, pose questions, and learn from others on their diabetes management journey. This alleviates feelings of isolation and improves general well-being, which are crucial aspects of healing [6].

5.4 Reduced costs

Quantified-self technology can improve diabetes management by tracking conditions that lead to diabetes such as diet, physical activity, body weight and other physiological factors [17][64][74]. The literature has provided significant results supporting the notion that quantified-self technologies can provide feedback and recommendations on physiology, diet, and activities that help people lead healthy lives [2] [7]. By having a healthy lifestyle, diabetics can manage conditions that cause diabetic attacks, which means they will not be admitted to hospitals regularly, which in turn reduces hospital bills and associated costs [48] [60]. There are case studies that showed that quantified self-care reduces hospitalisation costs [49] and oral medication costs [61] in diabetic patients. Furthermore, there is research [75][76] that revealed that the adoption of quantified-self technologies is supported by company wellness programs and health insurance, which provides incentives for wearable quantified-self gadgets and insurance discounts. Consistently, there are studies [71] [34] that found that quantified-self technologies encourage healthy living by rewarding those who achieve personalised goals. Rewards provided by quantified-self technology were recognised for persuading users to achieve goals, for example, running several kilometers per day [61][48]. Therefore, the

 J Health Inform Afr. 2024;11(2):17-30. DOI: 10.12856/JHIA-2024-v11-i2-481

incentives and rewards provided for using quantified-self technologies potentially reduce medical costs in the long run.

Quantified-self technology provides an opportunity for telehealth through a variety of applications that enable the collection of self-tracking data, texting, and video conferencing [77]. Telehealth provides remote services such as online consultation, monitoring, and mentoring, which cost less than having a face-to-face medical consultation [78]. Additionally, quantified-self technology facilitates the capture of personal data, for example, heart rate, blood pressure, and glucose test, whose results can be shared remotely and help with remote consultation [79][80]. Data capture by the patient costs less than tests performed in a laboratory.

6 Conclusions

The premise of this study was that the adoption of any technology should be preceded by knowledge of the opportunities that the technology being adopted provides. The premise was contextualised to the adoption of quantified-self technologies in the self-care of diabetes. The research question of the study was 'What are the opportunities for the use of quantified-self technology in the management of diabetes in developing countries?'. The systematic analysis of the literature uncovered four opportunities in which quantified-self technology can be used in the management of diabetes. The opportunities are monitoring, adherence, reduced cost, and data collection and sharing. The identified opportunities are valuable because having prior knowledge before adopting quantified-self technology enables a person to determine if the technology will satisfy their needs. Furthermore, the opportunities are beneficial to citizens of third-world countries who usually adopt technologies with insufficient knowledge of the opportunities that they can benefit from.

This systematic literature analysis study was limited by the number of articles that were analysed. Due to constrained human capacity and time, a larger sample of articles could not be reached. However, quantified-self is a new research field and the contribution made in this study will theoretically contribute to the body of knowledge and practically influence the adoption of quantified-self technologies in diabetic self-care.

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