REVIEW ARTICLE

EXPLORING TECHNOLOGY DOMAINS FOR DIABETES CARE AND MANAGEMENT UNDER PANDEMIC: A PRELIMINARY SCOPING REVIEW

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ABSTRACT

OBJECTIVE:

Technology innovation emerged in diabetic care and management during COVID-19. To tackle emerging opportunities, this scoping review aims to analyze current technology used for diabetic care by employing WHO technology initiatives to reveal technology use potentials for future research and development.

MATERIALS AND METHODS:

We conducted a review following PRISMA. We initiated a search of related terms for peer-reviewed publications in PubMed and Web of Science, including those themed in diabetic care and management and published in English.

RESULTS:

We reviewed 42 articles following the guidance of WHO technology conceptualization, including mHealth (12%), eHealth (76%), and dHealth (12%). These initiatives are used to reveal six areas of technology utilization for diabetes care during the pandemic, including (1) social media; (2) sensor; (3) teleconference; (4) virtual care; (5) artificial intelligence; and (6) data mining.

DISCUSSION:

Based on the identified dimensions related to technology and health, we presented seven diabetes-related health events and their associations with technologies. Implications such as technology's association with diabetes disease progression, technology diagramming for interdisciplinary collaboration, and technology features for health outcomes provide direction for future research and development.

CONCLUSION:

This review illustrates current technology utilization in diabetes care during the pandemic. It also uncovers innovation opportunities across technology and diabetic healthcare domains and provides direction for future pursuits in academia and practice.

KEYWORDS

diabetes, Covid-19, mobile health, electronic health, digital health, mHealth, eHealth, WHO

INTRODUCTION

Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2, or commonly known as COVID-19) has direct and indirect repercussions on regular operations in medicine and healthcare for individuals with chronic diseases. Diabetes has been highlighted as an important one requiring clinical attention [1] because patients with diabetes are more susceptible to pandemic risks than non-diabetic individuals, making it more challenging to control, manage, and provide services and care for diabetes [2].

With diabetes being a chronic condition requiring continuous healthcare services, technology provides potential solutions to address the changes demonstrated in primary care visits during the pandemic. Additionally, diabetic care during the pandemic initiated unprecedented technological innovation opportunities as showcased by the values presented in novel technology development and use [3]. To mitigate the risk of pathogen exposure, apps use and platforms during the pandemic increased when compared with their use before the pandemic [4, 5]. As a result, the use of technology as a response to pandemic outbreaks provides an opportunity to deploy state-of-the-art tools for tackling new challenges across two disciplines of technology and diabetic healthcare [6].

However, there is limited research regarding how the two disciplines relate, which may hinder innovators seeking cross-disciplinary collaboration. The COVID-19 pandemic offers new technological use opportunities [7]. COVID-19 provides a context for health informatics to explore innovation opportunities [8], but current research focuses on disaggregated use cases [9], [10] and does not show connections across domains under two disciplines of technology and diabetic healthcare. It remains unclear how technology developments resonate with digital development trends. This inspires us to analyze and integrate technology use inspired by WHO initiatives mHealth, eHealth, and dHealth, which have identified innovation in settings of chronic illness [11].

The mHealth domain encompasses the use of mobile or wireless technologies for healthcare service [12]. The domain of eHealth embraces a broader scope than mHealth, primarily encompassing the use of information and communications technologies, including health care services, health surveillance, health literature, and health education, knowledge and research [12]. The dHealth domain refers to latest technology realms. The digital health expands the concept of eHealth to include digital consumers, with a wider range of smart and connected devices, including data mining and artificial intelligence, etc. [12].

While WHO initiatives offer valuable perspectives to examine technology, however, there lacks official document specifying their distinctions. Based on major technology uses in included literature, we refined mHealth, eHealth, and dHealth scopes for the purpose of study: The mHealth refers to technology primarily built on platforms for users to socially interact such as social media. In contrast, dHealth refers to the most recent types of technology, including artificial intelligence, and data mining, etc. The eHealth relates to technology types not encompassed by the preceding two. Hence our goal is to unveil: What categories of technology are utilized for diabetic care and management during a pandemic? Which contexts of diabetic care and administration utilize the technologies?

MATERIALS AND METHODS

STUDY DESIGN

This scoping review was reported following the Joanna Briggs Institute (JBI) Manual for Evidence Synthesis in Scoping Reviews [13], which provides a rigorous framework in the planning, development, study selection, and management of results to ensure that the search and report in a systematic fashion to support a field of research, identify the types of available evidence in a given field, identify and analyze knowledge gaps, identify key characteristics or factors related to a concept, and clarify the conceptual boundaries of a topic [13, 14]. To this, we conducted this review within our re-defined WHO initiatives to conceptualize technology with components of mHealth, eHealth, and dHealth [15].

INCLUSION AND EXCLUSION CRITERIA

This scoping review focused on (1) original research articles published in peer-reviewed publications, case reports, or conference proceedings applying technologies to diabetes management; (2) articles published in or after 2020, the year when COVID-19 appeared worldwide; and (3) articles written in English. We excluded articles that broadly discussed COVID-19 disease severity in diabetic patients without focusing on diabetes care and management and that discussed diabetes along with other chronic diseases (e.g., hypertension) management.

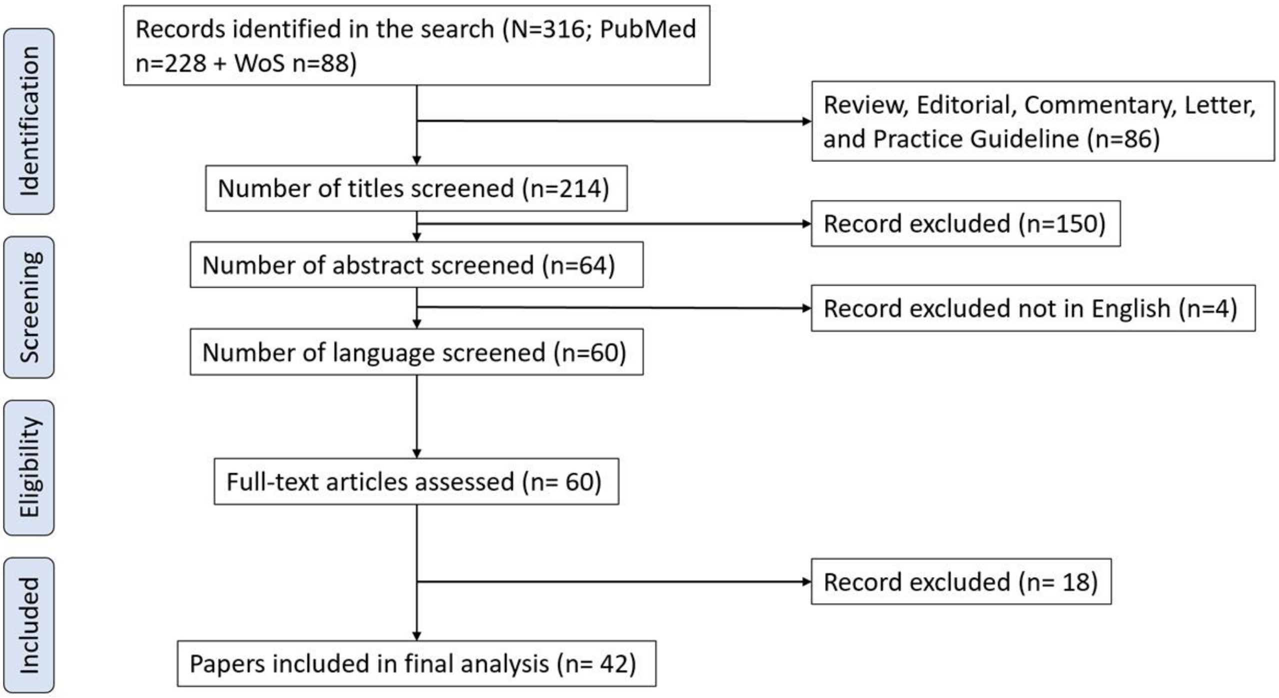
Identification and Selection of Evidence

We searched for peer-reviewed publications on PubMed and Web of Science (WoS) databases. Searches were refined to only include peer-reviewed articles published in English between January 2020 and April 2022. Based on Medical Subject Headings (US National Library of Medicine. Medical Subject Headings (MeSH, https://meshb.nlm.nih.gov/search) and literature browsing, we identified three groups of search terms to retrieve relevant articles meeting the eligibility criteria: (1) disease-related terms [e.g., diabetes mellitus, diabetes, diabetic], (2) technology-related terms [e.g., Internet-of-Thing, Sensor Internet-of-Thing, Blockchain, ledger, wireless, 5G, Zoom, Skype, WhatsApp, Facebook messenger, cell phone, Artificial Intelligence, machine learning, virtual], and (3) COVID-19-related terms (e.g., COVID-19, Severe acute respiratory syndrome coronavirus 2, SARS-CoV-2).

SEARCH OUTCOMES

Our initial search yielded 316 publications. After removing the review, editorial, commentary, letter, and practical guideline publications, 214 unique publications were identified. Of the 214 publications whose titles and abstracts were screened by two researchers (MYC and YSL) for relevance to the study purpose; 64 were identified as eligible for full-text review. Nevertheless, four of the 64 publications were excluded for its publication in a language other than English. After the full-text reviews, 18 additional publications were excluded because diabetes care was not their primary focus. Eventually, 42 publications were identified and included in the final synthesis. A flow diagram for the scoping review process adapted from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement was reported in (Figure 1) [13].

FIGURE 1. FLOW DIAGRAM FOR THE SCOPING REVIEW PROCESS ADAPTED FROM THE PRISMA STATEMENT BY MOHER AND COLLEAGUES (2015)



ADDITIONAL SEARCHING

The reference lists of those 42 identified publications were hand-searched to identify additional publications which were relevant but not been identified from the first-round literature search.

DATA EXTRACTION

Data was extracted by two reviewers (MYC and YSL) working together on the 42 included publications. Data was extracted into a Microsoft Excel spreadsheet to allow for easy comparison between the outcomes from the extracted studies. Extracted data included author, year of published, study period, location of research, study design, technology factors, health impacts, and diabetes care-related health events (Table 1). (See the appendix)

RESULTS

We investigated the links between the main technological conceptualization components of mHealth, eHealth, and dHealth to find insights from the literature. Within the 3 technology domains, the 39 evaluated publications indicated six technological categories: social media, sensor, teleconference, virtual care, data mining, and artificial intelligence. Seven diabetes care-related events are categorized under technological conceptualization by the American Diabetes Association clinical practice guidelines [16] (Figure 2).

FIGURE 2. TECHNOLOGY INNOVATION DIAGRAM: DIABETES-RELATED HEALTH EVENTS, RE-DEFINED WHO TECHNOLOGY CONCEPTUALIZATION, AND THEIR CONNECTIONS

Table 1 contains WHO technology conceptualization and diabetes care-related health events-reviewed literature. In the following, we describe these findings by domains: mHealth, eHealth, and dHealth.

MHEALTH

Twelve percent of mHealth diabetics care and management used social media.

SOCIAL MEDIA

Social media (n=5) was the sole technology or devices under mHealth employed in diabetes care and management (Table 1) [17, 18, 19, 20, 21], including popular providers Facebook, WhatsApp, TikTok, WeChat, and LINE, etc. mHealth technology was employed in diabetes education, lifestyle change (diet and exercise), and glucose control (Table 1 and Figure 2). Three papers employed social media for diabetes education [17, 18, 20], while one used WhatsApp for diabetes education and glucose management. One article used mHealth for lifestyle change (exercise) and diabetes management [19]. One research employed this technology for dietary behavior change curriculum [21]. Asia has the most studies (n=3; 60%) [18, 19, 20], followed by North America (n=1; 20%) [21] and the Middle East (n=1; 20%) [17].

EHEALTH

eHealth generally incorporates pandemic-related diabetes care using information or communication technology. The research we conducted found sensor, teleconference, and virtual care eHealth technologies. Teleconferences are online communication technologies as chatrooms or multi-media conferences. We defined virtual care as situations using other technology features in a teleconference. eHealth is the most applied domain, including sensor, teleconference, and virtual care. It had been used in 32 COVID-19 pandemic investigations (76%) (Figure 2).

SENSOR

Ten studies used sensor technologies [6, 22, 23, 24, 25, 26, 27, 28, 29, 30] (Table 1). Sensor technology in eHealth was employed for various diabetes care purposes. Glucose management (n=7), including continuous glucose monitoring [23, 24, 25, 26, 27, 30] and gestational diabetes management [28], was the most common application of this technology. The hybrid closed loop system or insulin pump is another diabetic care in eHealth. One study integrated eHealth for insulin treatment [29], whereas the other three used it also for glucose management [24, 25, 26]. Two (18.2%) studies used sensors for diabetic retinopathy and visual care [6, 22]. Queiroz photographed retinas with smartphone platform. Only one research used eHealth for lifestyle changes, including diet and exercise, showing that glucose control in people with diabetes requires more technology than lifestyle change. In prior studies, mHealth and eHealth are both used for diabetes education. Only one study indicated using eHealth in health education (Table 1 and Figure 2).

North America and Europe had the most studies (n=6; 60%) [6, 23, 25, 26, 28, 30], followed by South America (n=2; 20%) [22, 24], the Middle East (n=1; 10%) [29], and Asia (n=1; 10%) [27].

Nomenclature for similar or related technologies is inconsistent throughout reviewed literature. Thus, for the purpose of this research, the term teleconference refers to videotelephony primary used for conversation purposes. The term virtual care, on the other hand, pertains to scenarios in which videotelephony is used for purposes beyond conversation or in conjunction with other technology devices. Two categories are analyzed:

TELECONFERENCE

All seven studies used phone, Zoom Video, Videoconference, or Facetime for pandemic teleconferences. Three diabetes education, diet, and glucose control studies used Zoom Video consultations [31, 32, 33] (Table 1 and Figure 2). In glucose management (n=4) and insulin administration (n=2), three papers used implanted phone interviews or consultations [33, 34, 35]. Another research only mentioned online foot care consultation [36]. The Middle East (n=3; 43%) [31, 33, 35], North America (n=3; 43%) [32, 34], and Asia (n=1; 14%) [36] were the most studied regions.

VIRTUAL CARE

Fifteen eHealth studies have used virtual care technology (Table 1) [37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49]. Diabetes care uses virtual care most. In virtual care, diabetes treatment included virtual health education (n=4), glucose management (n=12), insulin treatment (n=6), eye health (n=1), foot health (n=2), and exercise (n=1). One study used an insulin pump [39]. Two studies developed diabetes care protocols [40, 42], two used apps [44, 50], five discussed continuous glucose monitoring [45, 46, 47, 48, 49], one examined photocoagulation [41], and one described a hybrid closed loop [43]. Lifestyle changes in diet did not employ virtual care. Teleconference and virtual care, despite their technology application differences, were the most used eHealth technologies for diabetes care health events (Figure 2).

Three studies were from Asia (n=3, 20%) [40, 41, 47], three from Europe (n=3, 20%) [39, 45, 51], two from the Middle East (n=2, 13%) [42, 43], four from North America (n=6, 40%) [46, 48, 49, 50], and one from South America (n=1, 6%) [44].

DHEALTH

Data mining and artificial intelligence are identified in following articles:

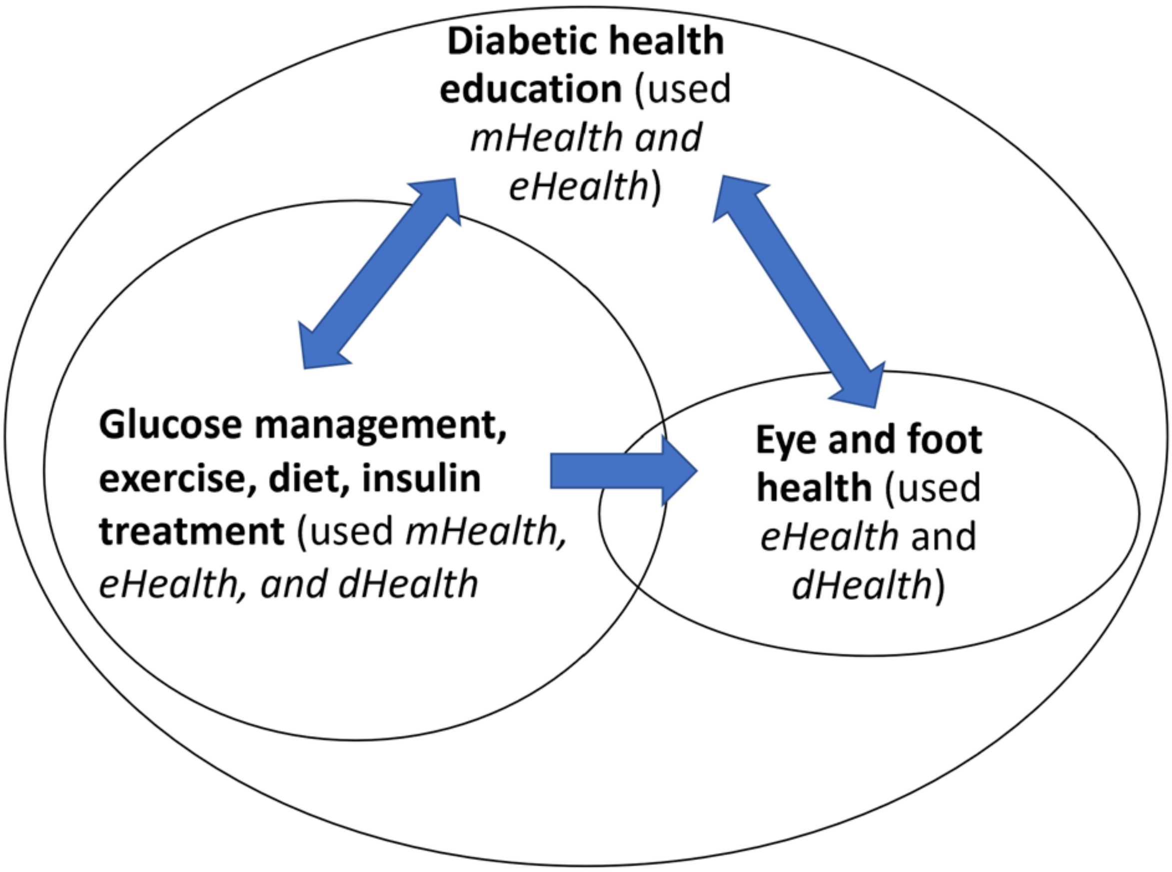
Artificial Intelligence /Data Mining

During COVID-19, only foot health, glucose management, and insulin treatment used dHealth (12%) (Table 1 and Figure 2). Three of the 42 diabetic foot care dHealth research employed artificial intelligence [18, 36] and data mining [52]. Kong's study calculated diabetic ulcer wound size with artificial intelligence algorithm evaluating foot lesion images for phenotype development [36]. Data mining focuses on improving diabetic ulcer triage. In gestational DM, artificial intelligence adjusted insulin administration by blood sugar level [53]. Another study used artificial intelligence to improve HbA1c data, which is essential for diabetes care [54]. Only glucose management, as a diabetes care-related event, is used in all three WHO technology domains (Figure 2). Most studies were from North America (n=3) [18, 52, 54], Asia (n=1) [36], and Europe (n=1) [53].

SUMMARY OF TECHNOLOGY USE

Technology use is found to associate with diabetes progress: Diabetes education, glucose management, exercise, diet, and insulin treatment used mHealth and eHealth technology. dHealth was mostly utilized for diabetes management, eye care, and foot care. Health education is crucial for diabetes management and lifestyle change (e.g., glucose management, exercise, food, and insulin administration). The concepts of health education and diabetic foot and eye care are associated (represented by bidirectional arrows). Diabetic eye and foot care need comprehensive health education, while health education playing a crucial role in promoting and facilitating proper care for individuals with diabetes, particularly in the context of eye and foot health. Untreated diabetes can be causally associated with most diabetic eye and foot complications (represented by uni-directional arrows) [55]. Proper management and control of diabetes are crucial in preventing these complications. Technology in eHealth domain was used in eye and foot care (Figure 3).

FIGURE 3. RELATION BETWEEN DIABETES DISEASE PROGRESSION AND WHO INITIATIVES



DISCUSSION

The discoveries from our literature review are supported by our analysis based on WHO technology initiatives. We identified six fields of technologies, including social media, sensor, teleconference, virtual care, data mining, and artificial Intelligence. While analyzing the literature, we built a taxonomy of technologies used for diabetic care during the pandemic based on technology conceptualization. More specifically, mHealth, eHealth, and dHealth are found to correspond to distinct technology fields: mHealth (12%) involves social media, eHealth (76%) includes teleconference and virtual care, and dHealth (12%) involves data mining and artificial intelligence.

In addition, by examining the contexts or situations in which technologies are used for diabetic care during the pandemic, we identified seven types of diabetic care-related health events, including education, lifestyle change (diet and exercise), glucose management, insulin treatment, eye health, and foot health. These events are found to associate with certain components for technology use: mHealth and eHealth are used for education glucose management, lifestyle (exercise/ diet) change, and insulin treatment, while eHealth and dHealth are used for eye and foot health.

We unveiled the relationship among mHealth, eHealth, and dHealth, along with six technology fields and seven contexts or situations in which technologies are used for diabetic care during the pandemic, namely diabetic care-related health events. With the complexity of diabetic care and management in pandemic, these events define areas valuable to innovators across two disciplines of technology and diabetic healthcare, making it easier to identify congruous opportunities for investing collaborative efforts [7].

TECHNOLOGY VALUE FOR HEALTH IMPACT

The integration of technology in diabetic care-related health events has revolutionized the safety, effectiveness, and efficiency of diabetes care compared to traditional modes, resulting in significant health impacts [26, 47, 62]. Technology also reduced the need for in-person visit and has overcome the transportation barriers for patients in healthcare resource-limited areas [26, 46, 49]. Saving time on transportation allows patients to better manage diabetes at their places [25, 53]. In addition, the integration of technology in diabetic care-related health events can have positive health impacts. Based on our finding from this review, we have summarized the following health impacts associated with diabetes: (1) promoting patient engagement, (2) remote monitoring capabilities, (3) reducing healthcare providers' workload, (4) improving timeliness of intervention, (5) data-driven decision-making, and (6) contributing to better health outcomes for individuals with diabetes. The use of mHealth has been found to enhance patient engagement in managing diabetes. Patients can access comprehensive educational resources on exercise and glucose management through this technology [17]. Healthcare providers are able to remotely monitor patients' illness through eHealth and dHealth, including TIR, diet consultation, eye care, and foot care [16, 22, 23, 24, 25, 26, 28, 32, 36]. The implementation of eHealth and dHealth, such as patients' health education on diet, exercise, glucose management, and insulin treatment, mainly aims to reduce healthcare providers' workload [27, 53]. Both eHealth and dHealth enhanced the flow of information between patients and healthcare providers as well [27, 33, 36, 53, 63]. A study revealed the value of eHealth on diabetic associated health impact was to improve timeliness of intervention to support people with diabetes to successfully manage their glucose and illness [31]. There are also studies that found data-driven decision-making to be benefited by the use of eHealth and dHealth [36, 50, 54]. The use of teleconference and virtual visits of eHealth has contributed to better health outcomes in diabetic patients, making technology a significant factor in healthcare during the pandemic [26]. As technology continues to evolve and become more integrated into healthcare systems, it has the potential to significantly improve diabetes management.

IMPLICATIONS

Diagramming Technology Innovation for Interdisciplinary Collaboration

Our research reveals the connections across knowledge domains in technology and diabetic healthcare, as illustrated with three rings: inner, middle, and outer (Figure 2). The inner ring depicts WHO technology conceptualizations, including mHealth, eHealth, and dHealth. The middle ring specifies major technology fields, including social media, sensor, teleconference, virtual care, data mining, and artificial intelligence. The outer ring shows two meanings: technical settings and diabetes care events from medical or health viewpoints.

The diagram links professional disciplines with respective specialized knowledge, competency, and vocation. This image depicts several knowledge or skill disciplines by closeness, size for relationship valuable for future cooperation. From the inner rings outward, this graphic shows how technology conceptualization may emphasize for diverse use settings, or care events. When read from outside rings inward, this figure shows how health events may use specific professional technologies while alluding to WHO's policy and development initiatives.

Refined Connections from Health Events to Technologies

We found more technology-diabetic healthcare links. Glucose control encompassed the most eHealth, mHealth, and dHealth technologies, from social media to artificial intelligence. Diabetes patients must maintain their blood glucose levels during the epidemic. Smartphone-connected continuous glucose monitoring managed glucose. These wearable technologies assist diabetics manage their condition in real time [56, 57]. Continuous glucose monitoring was used before the epidemic but expanded throughout it [57]. In some studies, insulin treatment by hybrid closed loop was used along with CGM in either eHealth or dHealth to stabilize patients' blood glucose levels during the pandemic. Both diabetes care-related events (glucose management and insulin treatment) used sensor, teleconference, virtual care, and artificial intelligence technologies. This reflected the complexity of these care events for diabetes patients and healthcare providers. The virtual educational sessions helped to maintain this effectiveness [42]. A study found that 86% of diabetes patients are interested in virtual clinics. In addition, more than 56% of diabetes patients are prepared for every visit to be in the virtual format [58]. The suspension of face-to-face clinic visits significantly impacted glucose level maintenance among diabetes patients. Healthcare providers have been making efforts to find a feasible way to provide quality care comparable to traditional face-to-face visits. Virtual care technology is an alternative way to provide health care to diabetes patients.

We found that foot care utilized both eHealth and dHealth, including artificial intelligence technology. On the other hand, we found that eye care used only eHealth. In this systematic review, we did not find the use of sensor technology for diabetes complications such as kidney disease, skin complications, hearing loss, and neuropathy.

Technology Features for Health Outcomes

When technology is used for health intervention, features such as alert messages [58] and user data uploading [59] can have impacts on population's health outcome. Unfortunately, included literature discussed interventions with technology features considered as a whole, and failed to separately analyze how each feature affects efficacy. While technological intervention improves health outcomes, related findings suggest that future study may focus on specific qualities like simplicity or ease of use [31]. Other topics include: (1) how end-users assess the usefulness of a design feature [59], (2) how adding new features may improve users' experiences [44], and (3) how merging features into new platforms helps produce a new healthcare solution [41]. IT developers can utilize this research to create and build novel tools for various user scenarios.

Our scoping review is limited to literature within PubMed and Web of Science access and is not as inclusive as a systematic review. Other databases might be incorporated for more comprehensive topics [60].

CONCLUSION

Diabetes care during the COVID-19 pandemic presented an unprecedented opportunity to use technology. To illustrate this unknown landscape, our research reviewed and analyzed extant research and delineated the technologies used in various settings. Relevant factors meaningful for technology innovation were discovered such as technology factors, health impacts, and diabetes care-related health events.

Inspired by WHO initiatives of technology conceptualization—mHealth, eHealth, and dHealth, our research aims to uncover domains and their mutual connections for promoting opportunities. Three components were found to associate with certain diabetes care-related health events and disease progression. With our findings and diagramming considered, implications for future research and development were suggested. Findings help academia and professionals chart knowledge domains for building future collaborative endeavors.

COMPETING INTERESTS

The authors declare no competing interests.

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None.

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APPENDIX

TABLE 1. SUMMARY OF INCLUDED STUDIES

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
mHealth						
Social media	Odeh, 2020 [17]	March 17 to May 24, 2020	Jordan	1. T1D patients received information regarding COVID-19 and diabetes from physicians via WhatsApp and Facebook for T1D care 2. Patients contacted the medical team through telemedicine by phone calls and/or WhatsApp	Using technologies to provide guidance and support for T1D patients during lockdown was possible	Diabetes education + glucose management
	Kong, 2021 [18]	Not specified	China	Evaluate the diabetes-related videos in TikTok	The overall video quality for diabetes management is averagely acceptable	Diabetes education

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
	Kang, 2021 [19]	May to August 2020	China	1. The WeChat app was used to send DM health education knowledge videos and to investigate the management of blood glucose, blood pressure, body mass index (BMI), time in range (TIR), and incidence of hypoglycemia in the intervention group 2. Traditional medical treatment was used in the control group 3. Tracking physical activity	Remote management can increase TIR without increasing the risk of hypoglycemia Remote management also improves patients' self-management during the pandemic	Glucose management + exercise
	Leong, 2021 [20]	July 2020 to January 2021	Taiwan	Usual care + Taipei Medical UniversitLINE Oriented Video Education (TMU-LOVE) for T2D patients	The social media-based program effectively enhanced the knowledge, attitudes, and self-care activities of T2D patients	Diabetes education

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
	Sharma, 2021 [21]	June to November 2020	USA	Videos about A Prescription for Healthy Living (APHL) culinary medicine curriculum to change dietary and cooking behavior among T2D patients in lockdown	The virtually implemented culinary medicine curriculums improved health outcomes among low-income patients with T2D	Diet
EHealth						
Sensor	Queiroz, 2020 [22]	February 6 to March 14, 2020	Brazil	A smartphone-based (Eyer, Phelcom Technologies, and EyerCloud platform) technology was used to take the retinal images of T2D patients	A handheld device such as a smartphone is feasible and has the potential to increase coverage of DR screening in underserved areas	Eye health
	van der Linden, 2021 [23]	January 6 to June 14, 2020	USA	Used G6 rtCGM System (Dexcom, Inc., San Diego, CA)	The CGM provided adequate glycemic control during the COVID-19 pandemic	Glucose management

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
	Khurana, 2021 [6]	August 30, 2017 to January 12, 2018	USA	Provide a series of letters on the phone screen to the patient one at a time, progressively decreasing the size. The patient identifies the correct letter by selecting the corresponding matching letter shown in large typeface at the bottom of the mobile application (Correlation of Paxos Checkup Mobile App to Standard in Office Visual Assessment)	The study yielded a strong agreement between the Checkup group and standard in-office procedures for assessing near-corrected visual acuity	Eye health
	Gomez, 2021 [24]	March to July 2020	Colombia	Use a hybrid closed loop (HCL) system in managing disease for T1D	HCL systems allow T1D patients to improve TIR, TBR, and glycemic variability	Glucose management + insulin treatment
	Hakonen, 2022 [25]	March 18 to May 13, 2020	Finland	Use CGM or insulin pumps to monitor the TIR	The use of CGM is more effective to control blood glucose in TIR among T1D children during the lockdown	Glucose management + insulin treatment

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
	Choudhary, 2022 [26]	March 15, 2019 to March 14, 2020	USA	Use CGM to monitor the TIR	The use of CGM is more effective to control blood glucose in TIR among T1D children during the lockdown	Glucose management + insulin treatment
	Jiang, 2022 [27]	September 2020 to March 2021	Singapore	Smartphone app for diabetes health education, self-management for blood sugar, diet, and exercise (a nurse-led smartphone-based self-management program)	The use of technology effectively reduced nurses' workload by delegating tasks to individuals through self-management strategies. This enabled nurses to increase contact time with patients, and individuals to take the onus of their disease through increased self-efficacy, facilitated by technology	Diabetes education + glucose management + diet + exercise

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
	El Moazen, 2021 [28]	March to June 2020	Austria	Use DiabCare mobile app to remotely monitor glycemic levels among GDM pregnant women	The benefits of remote monitoring to support conventional therapy cannot be dismissed, especially in times of the pandemic	Glucose management
	Magliah, 2021 [29]	June 21 to June 23, 2020	Saudi Arabia	Use of insulin pump therapy during lockdown	Two-thirds of T1D patients reported difficulty obtaining at least one variety of insulin pump supplies. Most patients indicated no change in adherence to insulin pump behaviors	Insulin treatment
	Evin, 2020 [30]	In 2020	Turkey	Use CareLink or FreeStyle LibreLink to monitor the CGM of eight T1D patients	Most T1D patients had less variation (coefficient of variation < 36%) in blood sugar level by using CGM	Glucose management

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
	Al-Moteri, 2021 [31]	July 2020	Saudi Arabia	Zoom Video to interview the diabetes management experiences	The findings could be used to devise interventions and instructions to support people with diabetes to successfully manage their illness during such crises or any public emergencies	Glucose management
Teleconference	Lee, 2021 [32]	December 2019 to August 2020	USA	Telemedicine via Zoom, Videoconference, FaceTime, etc.	Zoom was the most popular video platform followed by Videoconference Telemedicine continued the maintenance of T1D care during the pandemic	Diabetes education + diet
	Alguwaihes, 2021 [33]	April 26 to May 7, 2020	Saudi Arabia	Patients reported benefits from virtual communication with physicians by phone and Zoom	Maintaining two-way virtual communication channels between physicians and their	Glucose management

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
					T1D patients should be encouraged	
	Steinhardt, 2021 [34]	May to June 2020	USA	Phone interview about self-management of diabetes during COVID-19	Qualitative findings guided the appropriate implementation of technology for the study, which facilitated a successful restart. High retention of participants through the study transition provides evidence that participants are invested in learning how to manage their diabetes despite the challenges and distractions imposed by COVID-19	Glucose management

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
	Magliah, 2021 [35]	January 23 to February 10, 2021	Saudi Arabia	Virtual phone visit	T1D patients are satisfied with the virtual phone visits during COVID and have a high interest in continuing their use of virtual visits in the future	Insulin treatment
	Kavitha, 2020 [36]	Not specified	India	Online consultation was used in the management of diabetic foot disease Use of telepodiatry in the management of diabetic foot disease in low-risk subjects	Telemedicine is an adequate screening tool for diagnosing and managing low-risk subjects with diabetic foot problems and enables a triaging system for deciding on hospital visits and hospitalization	Foot care
	Fung, 2020 [61]	March to May 2020	Canada	Virtual and phone-mediated conferences are implemented for clinical visits	Usability of virtual and phone visits are recognized, and are hoped to be kept used in the future	Education + Glucose management + Insulin Treatment

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
Virtual care	Schiller, 2021 [37]	March and June 2021	Israel	Virtual care is used to accommodate Type 1 diabetic patients' needs as a result of the pandemic lockdown	About half of the T1D patients are interested in continuing their use of telemedicine care in the future, validating the benefits of using virtual care for diabetic care.	Education+ Glucose management + Insulin Treatment
	Aubert, 2022 [38]	March to Nov 2020	US	Virtual visits are used for US veterans.	Favorable virtual care results for T2D care with higher-risk concerns from the pandemic among veterans aged 65 and up. Physical-visit comparable applicability for future use was demonstrated.	Glucose management

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
	Forde, 2022 [39]	November to December 2020	UK	Diabetes care is delivered remotely primarily in two modalities during the pandemic: phone or video consultation, for starting insulin pumps.	Training effectiveness was evaluated—the number of new starts and renewals of pumps after warrantee expiration is reduced.	Insulin treatment
	Rastogi, 2021 [40]	March 2020 to September 2020	India	Virtual care is incorporated into healthcare-providing protocols, facilitating efficient triage for foot care and limb salvage services. Service includes clinical history, online examination and assessment of foot wounds, home-based wound care, and more. Additionally, real-time messaging enables the medical provider to grade the lesion, categorize the risk, and provide homecare modes.	Virtual care teleconsultation provides similar ulcer and limb outcomes to traditional physical face-to-face foot care settings, validating the effectiveness of virtual care for diabetic foot ulcers. Also, virtual communication makes it possible to provide continuing service for patients with uncomplicated	Foot health

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
					DFU or who are at risk of DFU.	
	Chen, 2021 [41]	October 2019 to July 2020.	China	Online 5G-based laser photocoagulation was used to successfully treat diabetic retinopathy. A teleophthalmology platform is used for conducting telelaser planning and intervention with laser-based remote computer control.	Teleophthalmology is developed and used based on an online platform treating diabetic retinopathy without delay.	Eye health
	Al-Sofiani, 2021 [42]	Unspecified	Saudi Arabia	A protocol of a Diabetes Telemedicine Clinic is depicted, using technology or digital tools readily available to most patients and clinics.	The use of telemedicine helps to maintain good glucose control during the pandemic and virtual educational sessions are helpful to maintain effectiveness and satisfaction.	Diabetes education + glucose management + insulin treatment

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
	Petrovski, 2021 [43]	Not specified	Qatar	Using a hybrid closed loop (HCL) system in managing disease for T1D teenagers and Skype for a weekly meeting	Patients and healthcare providers reported high satisfaction with virtual care	Glucose management + insulin treatment
	Leon-Vargas, 2021 [44]	3 months in 2021	Colombia	Using a free App (Tidepool) and Mobile to monitor and manage the disease	Users agreed the use of Tidepool achieved better disease management and communication with the healthcare team	Glucose management + insulin treatment
	Parise, 2020 [45]	March 10 to June 3, 2020	Italy	Two virtual visits by phone were conducted CGM was used to monitor the TIR	Virtual visits allow the persistence and improvement of glycemic control.	Glucose management
	Grag, 2020 [46]	In 2020	USA	Zoom, e-mail, and telephone calls were used to manage new-onset T1D CGM with Dexcom G6 sensor was used	Telemedicine showed feasibility and effectiveness in new-onset diabetes education and insulin dosage management.	Diabetes education + Glucose management + Insulin treatment

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
	Lian, 2021 [47]	April 7 to June 1, 2020	Singapore	Phone consultations were used for moderate-risk patients; diabetes education videos were made available CGM was used to monitor the blood sugar level	Virtual health applications were found to be safe, effective, and efficient to replace current in-person visits.	Diabetes education + Glucose management
	Jones, 2020 [48]	January 2020 to April 2020	USA	Teleconference by phone to monitor the TIR	Transitioning to virtual care models does not limit the glycemic outcomes of inpatient diabetes care and should be employed to reduce patient and provider exposure in the setting of COVID-19.	Glucose management

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
	Carlson, 2021 [49]	Not specified	USA	Investigated the experience of using remote monitoring of CGM	The use of telemedicine and remote monitoring of CGM and insulin data enabled healthcare providers to assess glycemic control and make therapy adjustments without the potential hazards and patient burden of in-person clinic visits.	Glucose management
	Hernandez-Jimenez, 2021 [62]	June to November 2020	Mexico	Virtual intervention is introduced for self-care, metabolic, and emotional parameters	Virtual care program is proven effective, offering a feasible solution the management of diabetic patients during COVID-19.	glucose management+ foot health + exercise
	Underwood 2022 [63]	Unspecified	USA	CGM is employed	Virtual care helps efficiently manage CGM users, leading to improved clinical	Glucose Management

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
					workflow, decisions, and health outcomes.	
DHealth						
Artificial intelligence	Grossman, 2021 [54]	Unspecified	USA	AI helps improve diabetic patients' long-term health through CGM via hemoglobin A1c (HbA1c) monitoring disruption during Covid-19. Despite HbA1c data absence, CGM is used to estimate HbA1c via AI assistance.	AI techniques including machine learning and linear regression models are developed for improved approximation by reducing HbA1c estimation error in comparison with the current protocol, providing values of clinical trials remotely under Covid constraints.	Glucose management
	Kong, 2021 [50]	June 2020 to January 2021	Canada	AI-powered machine-imaging technology is employed to focus on the wound and determine its	This AI algorithm replaces the traditional manual "ruler-and-paper-	Foot health

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
				accurate area size by using s smartphone camera.	based" diagnosis while reducing the time and effort needed to make a physical visit.	
	Kavitha, 2020 [36]	Unspecified	India	AI helps assess diabetic patients' foot health by analyzing foot lesion images from diabetic patients for developing clinical phenotypes.	Design of typical tele-visit workflows which help streamline the diagnosis and treatment of diabetic foot health	Foot health
	Albert, 2020 [53]	March 31 to May 14, 2020	Spain	Using App (SineDie) with AI to adjust diet and insulin treatment by blood sugar level in gestational diabetes mellitus	Prevent unnecessary hospital visits, maintain the best quality health care, and reduce clinicians' workload	Insulin treatment
Data mining	Schmidt, 2020 [52]	March 2020 to the end of May 2020	USA	Data mining helps in the development of strategies to improve the triage process to manage risks for diabetic foot ulcer care. Data are collected and traced from diabetes patients with foot ulcer care needs.	Data mining outputs help build a risk stratification, which helps prevent deadly complications related to Covid-19 or late-stage diabetic foot exacerbation. This	Foot health

WHO technology conceptualization domains and corresponding fields of technology used for diabetes care and management	Author, Year	Study period	Location	Technology factors	Health impacts	Diabetes care-related health events
					strategy also helps avoid additional risks for inpatients, especially those who are from high-risk populations.	